FreeBSD 使用手册

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修訂：47472
2015-10-01 由 delphij.
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摘要

歡迎使用FreeBSD！本使用手冊涵蓋範圍包括了 FreeBSD 8.4-RELEASE、FreeBSD 9.3-RELEASE 和 FreeBSD 10.3-RELEASE 的安裝和日常使用。 這份使用手冊是很多人的集體創作，而且仍然『持續不斷』的進行中。 許多章節仍未完成，已完成的部份也有些需要更新。 如果您有興趣協助本計畫的話，請寄 e-mail 到 FreeBSD documentation project 郵遞論壇。 在 FreeBSD 網站 可以找到這份文件的最新版本(舊版文件可從 `http://docs.FreeBSD.org/doc/` 取得)，也可以從 FreeBSD FTP 伺服器 或是眾多 mirror 站臺 下載不同格式的資料。 如果比較偏好實體書面資料，那可以在 FreeBSD Mall 購買。 此外，也可以在 使用手冊 中搜尋資料。

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序

給讀者的話

若您是第一次接觸 FreeBSD 的新手，可以在本書第一部分找到 FreeBSD 的安裝方法，同時會逐步介紹 UNIX® 的基礎概念與一些常用、共通的東西。而閱讀這部分並不難，只需要您有探索的精神和接受新概念。

讀完這些之後，手冊中的第二部分花很長篇幅介紹的各種廣泛主題，相當值得系統管理者去注意。 在閱讀這些章節的內容時所需要的背景知識，都註釋在該章的大綱裡面，若不熟的話，可在閱讀前先預習一番。

延伸閱讀方面，可參閱 附錄 B, 參考文獻。

第三版的主要修訂

您目前看到的這本手冊第三版是 FreeBSD 文件計劃的成員歷時兩年完成的心血之作。 新版的主要修訂部分，如下：

- 章 11, 設定與效能調校(Tuning), 設定與效能調校(Tuning)，該章節針對新內容作更新，比如： ACPI 電源管理、cron、以及其他更多的 kernel tuning 選項說明內容。
- 章 13, 系統安全, 系統安全篇，該章節增加了虛擬私人網路(VPN)、檔案系統的存取控制(ACL)，以及安全公告(Security Advisories)的內容。
- 章 15, Mandatory Access Control, 集權式存取控制(MAC)是本版所增加的章節。本章介紹：什麼是 MAC 機制？以及如何運用它來使您的 FreeBSD 系統更安全。
- 章 17, 儲存設備篇, 儲存設備篇，新增了像是：USB 隨身碟、檔案系統快照(snapshot)、檔案系統配額(quota) 、檔案及網路的備援檔案系統、以及如何對硬碟分割區作加密等詳解。
- 章 26, PPP and SLIPPPP 及 SLIP 一章中增加了故障排除的說明。
- 章 27, 電子郵件電子郵件一章中新增有關如何使用其它的 MTA 程式、SMTP 認証、UUCP、fecthmail、procmail 的運用以及其它進階專題。
- 章 28, 網路伺服器, 網路伺服器篇，是新版中全新的一章。這一章介紹了如何架設 Apache HTTP 伺服器、FTPd，以及用於支援 Microsoft Windows client 的 Samba 伺服器。其中有些段落來自原先的章 30, 網路進階練功房進階網路應用一章。
- 章 30, 網路進階練功房進階網路應用一章新增有關在 FreeBSD 中使用藍芽設備、安裝無線網路以及使用 ATM(Asynchronous Transfer Mode) 網路的介紹。
- 增加了一份詞彙表(Glossary)，用以說明全書中出現的術語。
- 重新美編書中所列的圖表。

第二版的主要修訂

本手冊的第二版是 FreeBSD 文件計劃的成員歷時兩年完成的心血之作。第二版包含了如下的主要變動：

- 增加完整的目錄索引。
- 所有的 ASCII 圖表均改成圖檔格式的圖表。

- 每個章節均加入概述，以便快速的瀏覽該章節內容摘要、讀者所欲了解的部分。
- 內容架構重新組織成三大部分：“開始使用 FreeBSD”，“系統管理”，and “附錄”。
- 章 3, UNIX 基礎概念(“UNIX® 基礎概念篇”)新增了 processes, daemons 和 signals 的介紹。
- 章 4, 軟體套件管理篇：Packages 及 Ports 機制 (“軟體套件管理篇”)新增了介紹如何管理 binary package 套件的資訊。
- 章 5, X Window 視窗系統 (“X Window 視窗系統篇”) 經過全面改寫，著重於在 XFree86™ 4.X 上的流行 x11-wm，像是： KDE 和 GNOME 。
- 章 12, FreeBSD 開機流程篇 (“FreeBSD 開機流程篇”)更新相關內容。
- 章 17, 儲存設備篇 (“儲存設備篇(Storage)”) 分別以兩個章節 “Disks” 與 “Backups” 來撰寫。我們認為這樣子會比單一章節來得容易瞭解。還有關於 RAID(包含硬體、軟體RAID) 的段落也新增上去了。
- 章 25, Serial Communications(“Serial 通訊篇”)架構重新改寫，並更新至 FreeBSD 4.X/5.X 的內容。
- 章 26, PPP and SLIP (“PPP 及 SLIP”)有相當程度的更新。
- 章 30, 網路進階練功房(“進階網路應用篇”)加入許多新內容。
- 章 27, 電子郵件 (“電子郵件篇”)大量新增了設定 sendmail 的介紹。
- 章 10, Linux® 二進位檔的相容性 (“Linux® 相容篇”) 增加許多有關安裝 Oracle® 及 SAP® R/3® 的介紹。
- 此外，第二版還新加章節，以介紹下列專題：
  - 章 11, 設定與效能調校(Tuning), 設定與效能調校(Tuning)。
  - 章 7, 多媒體影音娛樂(Multimedia), 多媒體影音娛樂(Multimedia)。

本書架構

本書主要分為五大部分，第一部份『開始使用』：介紹 FreeBSD 的安裝、基本操作。 讀者可根據自己的程度，循序或者跳過一些熟悉的主題來閱讀； 第二部分『常用操作』：介紹 FreeBSD 常用功能，這部分可以不按順序來讀。 每章前面都會有概述，概述會描述本章節涵蓋的內容和讀者應該已知的， 這主要是讓讀者可以挑喜歡的章節閱讀； 第三部分『系統管理』：介紹 FreeBSD 老手所感興趣的各種專題部分； 第四部分『網路通訊』：則包括網路和各式 Server 專題；而第五部分『附錄』：是各種有關 FreeBSD 的資源。

章 1, 簡介, 簡介篇
: 向新手介紹 FreeBSD。該篇說明了 FreeBSD 計劃的歷史、目標和開發模式。

章 3, UNIX 基礎概念, UNIX® 基礎概念篇
: Covers the basic commands and functionality of the FreeBSD operating system. If you are familiar with Linux® or another flavor of UNIX® then you can probably skip this chapter.

章 4, 軟體套件管理篇：Packages 及 Ports 機制, 軟體套件管理篇
: Covers the installation of third-party software with both FreeBSD's innovative “Ports Collection” and standard binary packages.

章 5, X Window 視窗系統, X Window 視窗系統篇
: Describes the X Window System in general and using X11 on FreeBSD in particular. Also describes common desktop environments such as KDE and GNOME.

章 6, 桌面環境應用程式, Desktop Applications
: Lists some common desktop applications, such as web browsers and productivity suites, and describes how to install them on FreeBSD.

章 7, 多媒體影音娛樂(Multimedia), Multimedia
Shows how to set up sound and video playback support for your system. Also describes some sample audio and video applications.

章 8, 設定 FreeBSD Kernel, Configuring the FreeBSD Kernel
Explains why you might need to configure a new kernel and provides detailed instructions for configuring, building, and installing a custom kernel.

章 9, 列印, 列印篇
Describes managing printers on FreeBSD, including information about banner pages, printer accounting, and initial setup.

章 10, Linux® 二進位檔的相容性, Linux® Binary Compatibility
Describes the Linux® compatibility features of FreeBSD. Also provides detailed installation instructions for many popular Linux® applications such as Oracle®, SAP® R/3®, and Mathematica®.

章 11, 設定與效能調校(Tuning)
Describes the parameters available for system administrators to tune a FreeBSD system for optimum performance. Also describes the various configuration files used in FreeBSD and where to find them.

章 12, FreeBSD 開機流程篇
Describes the FreeBSD boot process and explains how to control this process with configuration options.

章 13, 系統安全
Describes many different tools available to help keep your FreeBSD system secure, including Kerberos, IPsec and OpenSSH.

章 14, Jails
Describes the jails framework, and the improvements of jails over the traditional chroot support of FreeBSD.

章 15, Mandatory Access Control
Explains what Mandatory Access Control (MAC) is and how this mechanism can be used to secure a FreeBSD system.

章 16, Security Event Auditing
Describes what FreeBSD Event Auditing is, how it can be installed, configured, and how audit trails can be inspected or monitored.

章 17, 儲存設備篇
Describes how to manage storage media and filesystems with FreeBSD. This includes physical disks, RAID arrays, optical and tape media, memory-backed disks, and network filesystems.

章 18, GEOM: Modular Disk Transformation Framework
Describes what the GEOM framework in FreeBSD is and how to configure various supported RAID levels.

章 20, Other File Systems
Examines support of non-native file systems in FreeBSD, like the Z File System from Sun™.

章 21, Virtualization(虛擬機器)
Describes what virtualization systems offer, and how they can be used with FreeBSD.

章 22, 語系設定 - I18N/L10N 用法與設定
Describes how to use FreeBSD in languages other than English. Covers both system and application level localization.

章 23, 更新、升級 FreeBSD
Explains the differences between FreeBSD-STABLE, FreeBSD-CURRENT, and FreeBSD releases. Describes which users would benefit from tracking a development system and outlines that process. Covers the methods users may take to update their system to the latest security release.

章 24, DTrace
Describes how to configure and use the DTrace tool from Sun™ in FreeBSD. Dynamic tracing can help locate performance issues, by performing real time system analysis.

章 25, Serial Communications, Serial Communications
Explains how to connect terminals and modems to your FreeBSD system for both dial in and dial out connections.

章 26, PPP and SLIP, PPP and SLIP
Describes how to use PPP, SLIP, or PPP over Ethernet to connect to remote systems with FreeBSD.

章 27, 電子郵件, Electronic Mail
Explains the different components of an email server and dives into simple configuration topics for the most popular mail server software: sendmail.

章 28, 網路伺服器, Network Servers
Provides detailed instructions and example configuration files to set up your FreeBSD machine as a network filesystem server, domain name server, network information system server, or time synchronization server.

章 29, 防火牆, Firewalls
Explains the philosophy behind software-based firewalls and provides detailed information about the configuration of the different firewalls available for FreeBSD.

章 30, 網路進階練功房, Advanced Networking
Describes many networking topics, including sharing an Internet connection with other computers on your LAN, advanced routing topics, wireless networking, bluetooth, ATM, IPv6, and much more.

附錄 A, 取得 FreeBSD 的方式, Obtaining FreeBSD
Lists different sources for obtaining FreeBSD media on CDROM or DVD as well as different sites on the Internet that allow you to download and install FreeBSD.

附錄 B, 參考文獻, Bibliography
This book touches on many different subjects that may leave you hungry for a more detailed explanation. The bibliography lists many excellent books that are referenced in the text.

附錄 C, 網際網路上的資源, Resources on the Internet
Describes the many forums available for FreeBSD users to post questions and engage in technical conversations about FreeBSD.

附錄 D, PGP Keys, PGP Keys
Lists the PGP fingerprints of several FreeBSD Developers.

本書的編排體裁

為方便閱讀本書，以下是一些本書所遵循的編排體裁：

文字編排體裁

斜體字(Italic)
斜體字型(Italic) 用於：檔名、目錄、網址(URL)、 強調語氣、以及第一次提及的技術詞彙。

`###(Monospace)`
`###(Monospace)` 用於： 錯誤訊息、指令、環境變數、port 名稱、主機名稱(hostname)、帳號、群組、設備(device)名稱、變數、 程式碼等。

粗體字型(Bold)
以粗體字表示：應用程式、命令、按鍵。

使用者輸入

鍵盤輸入以 粗體字(Bold) 表示，以便與一般文字做區隔。 組合鍵是指同時按下一些按鍵，我們以 `+' 來表示連接，像是：

Ctrl+Alt+Del

也就是說，一起按 Ctrl 鍵、 Alt 鍵，以及 Del 鍵。

若要逐一按鍵，那麼會以逗號(,)來表示，像是：

Ctrl+X, Ctrl+S

也就是說：先同時按下 Ctrl 與 X 鍵， 然後放開後再同時按 Ctrl 與 S 鍵。

舉個實例

下面例子以 `E:\>` 為開頭的代表 MS-DOS® 指令部分。 若沒有特殊情況的話，這些指令應該是在 Microsoft® Windows® 環境的 “命令提示字元(Command Prompt)” 內執行。

```
E:\> tools\fdimage floppies\kern.flp A:
```

例子若是先以 `#` 為開頭再接指令的話，就是指在 FreeBSD 中以 root 權限來下命令。 你可以先以 `root` 登入系統並下指令，或是以你自己的帳號登入，並使用 su(1) 來取得 root 權限。

```
# dd if=kern.flp of=/dev/fd0
```

例子若是先以 `%` 為開頭再接指令的話，就是指在 FreeBSD 中以一般帳號來下命令即可。 除非有提到其他用法，否則都是預設為 C-shell(csh/tcsh) 語法，用來設定環境變數以及下其他指令的意思。

```
% top
```

致謝

您所看到的這本書是經過數百個分散在世界各地的人所努力而來的結果。 無論他們只是糾正一些錯誤或提交完整的章節，所有的點滴貢獻都是非常寶貴有用的。

也有一些公司透過提供資金讓作者專注於撰稿、提供出版資金等模式來支持文件的寫作。 其中，BSDi（之後併入 Wind River Systems) 資助 FreeBSD 文件計劃成員來專職改善這本書直到 2000 年 3 月第一版的出版。(ISBN 1-57176-241-8) Wind River Systems 同時資助其他作者來對輸出架構做很多改進，以及給文章增加一些附加章節。這項工作結束於 2001 年 11 月第二版。(ISBN 1-57176-303-1) 在 2003-2004 兩年中，FreeBSD Mall 把報酬支付給改進這本手冊以使第三版印刷版本能夠出版的志工。

部 I. 開始使用 FreeBSD

這部份是提供給初次使用 FreeBSD 的使用者和系統管理者。 這些章節包括：

- 介紹 FreeBSD 給您。
- 在安裝過程給您指引。
- 教您 UNIX® 的基礎及原理。
- 展示給您看如何安裝豐富的 FreeBSD 的應用軟體
- 向您介紹 X， UNIX® 的視窗系統以及詳細的桌面環境設定，讓您更有生產力。

我們試著儘可能的讓這段文字的參考連結數目降到最低，讓您在讀使用手冊的這部份時可以不太需要常常前後翻頁。

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章 1. 簡介

Restructured, reorganized, and parts rewritten by Jim Mock.

1.1. 概述

非常感謝您對 FreeBSD 感興趣！以下章節涵蓋 FreeBSD 計劃的各方面：比如它的歷史、目標、開發模式等等。

讀完這章，您將了解：

- FreeBSD 與其他 OS 之間的關係；
- FreeBSD 計劃的歷史源流；
- FreeBSD 計劃的目標；
- FreeBSD open-source 開發模式的基礎概念；
- 當然囉，還有 “FreeBSD” 這名字的由來。

1.2. Welcome to FreeBSD!

FreeBSD 是一個從 4.4BSD-Lite 衍生出而能在以 Intel (x86 and Itanium®), AMD64, Alpha™, Sun UltraSPARC® 為基礎的電腦上執行的作業系統。同時，移植到其他平台的工作也在進行中。 對於本計劃歷史的介紹，請看 FreeBSD 歷史源流， 對於 FreeBSD 的最新版本介紹，請看 current release 。若打算對於 FreeBSD 計劃有所貢獻的話(像是程式碼硬體設備、基金)， 請看 如何對 FreeBSD 有貢獻。

1.2.1. FreeBSD 能做什麼？

FreeBSD 提供給你許多先進功能。這些功能包括：

- 動態優先權調整的『先佔式多工』能夠確保，即使在系統負擔很重的情況下， 程式執行平順並且應用程式與使用者公平地共享資源。
- 『多人共用(multi-user)』代表著許多人可以同時使用一個 FreeBSD 系統來處理各自的事務。 系統的硬體周邊(如印表機及磁帶機)也可以讓所有的使用者適當地分享。 也可以針對各別使用者或一群使用者的系統資源，予以設限， 以保護系統不致被過度使用。
- 好用的『TCP/IP 網路功能』可支援許多業界標準，比如：SCTP、DHCP、NFS、NIS、PPP、SLIP、IPSec、IPv6 的支援，也就是說 FreeBSD 可以容易地跟其他作業系統透過網路共同運作，或是當作企業的伺服器用途 ，例如提供遠端檔案共享(NFS)及電子郵件(email)等服務， 或是讓您的企業連上網際網路(Internet)並提供 WWW、FTP、 路由(routing)、及防火牆(firewall、security)等必備服務。
- 『記憶體保護(Memory protection)』能確保程式(或是使用者)不會互相干擾， 即使任何程式有不正常的運作，都不會影響其他程式的執行。
- FreeBSD 是『32位元(32-bit)』的作業系統 (在 Alpha、Itanium®、 AMD64 及 UltraSPARC® 上則是『64位元(64-bit)』) — 打從一開始便是這樣設計的。
-

業界標準的『X Window 系統』(X11R7)可以在常見的便宜 VGA 顯示卡/螢幕， 提供了圖形化的使用者介面(GUI)，並且包括了完整的原始程式碼。

-

- 數以萬計的立即可以執行的應用程式，這些都可透過 FreeBSD 的『ports』及『packages』軟體管理機制來取得。 不再需要費心到網路上到處搜尋所需要的軟體。

- 此外，網路上尚有可非常容易移植的數以萬計應用程式。 FreeBSD 的原始程式碼與許多常見的商業版 UNIX® 系統都相容， 所以大部分的程式都只需要很少的修改(或根本不用修改)，就可以編譯執行。

- 需要時才置換(demand paged) virtual memory 及 “merged VM/buffer cache” 的設計， 這點在系統中有用去大量記憶體的程式執行時，仍然有不錯的效率表現。

- 支援 CPU 的對稱多工處理(SMP)：可以支援多 CPU 的電腦系統。

-

- 整個系統都有『原始程式碼』， 這讓你對作業環境擁有最完全的掌握度。 既然能擁有完全開放的系統，何苦被特定封閉軟體所約束，任廠商擺佈呢？

- 廣泛且豐富的『線上文件』。

- 當然囉，還不止如此！

FreeBSD 系統乃是基於美國加州大學柏克萊分校的電腦系統研究群(Computer Systems Research Group 也就是 CSRG) 所發行的 4.4BSD-Lite，以及基於 BSD 系統開發的優良傳統。 除了由 CSRG 所提供的高品質的成果，為了提供可處理真正具負荷的工作， FreeBSD 計劃也投入了數千小時以上的細部調整， 以能獲得最好的執行效率以及系統的穩定度。 正當許多商業上的巨人正努力地希望能提供效能及穩定時， FreeBSD 已經具備這樣的特質 -- 就是現在！

FreeBSD 的運用範圍無限，其實完全限制在你的想像力上。 從軟體的開發到工廠自動化，或是人造衛星上面的天線的方位角度的遠端控制； 這些功能若可以用商用的 Unix 產品來達成，那麼極有可能使用 FreeBSD 也能辦到！ FreeBSD 也受益於來自於全球各研究中心及大學所開發的數千個高品質的軟體 ，這些通常只需要花費很少的費用或根本就是免費的。 當然也有商業軟體，而且出現的數目是與日俱增。

由於每個人都可以取得 FreeBSD 的原始程式碼， 這個系統可以被調整而能執行任何原本完全無法想像的功能或計劃， 而對於從各廠商取得的作業系統通常沒有辦法這樣地被修改。 以下提供一些人們使用 FreeBSD 的例子：

- 網路服務： FreeBSD 內建强勁的網路功能使它成為網路服務(如下例)的理想平台：

  - 檔案伺服器(FTP servers)

  - 全球資訊網伺服器(WWW servers) (標準的或更安全的 [SSL] 連線)

  - IPv4 及 IPv6 routing

  -

  - 電子郵件伺服器(Electronic Mail servers)

  - 網路新聞伺服器(USENET News) 或是電子佈告欄系統(BBS)

  - 還有更多...

有了 FreeBSD，您可以容易地先用便宜的 386 PC， 再逐步升級您的機器到四個 CPU 的 Xeon 並使用磁碟陣列(RAID)來滿足您企業運用上的需求。

- 教育： 若您是資工相關領域的學生，再也沒有比使用 FreeBSD 能學到更多作業系統、計算機結構、及網路的方法了。 另外如果你想利用電腦來處理一些其他的 工作，還有一些如 CAD、 數學運算以及圖形處理軟體等可以免費地取得使用。
- 研究：有了完整的原始程式碼，FreeBSD 是研究作業系統及電腦科學的極佳環境。 具有免費且自由取得特性的 FreeBSD 也使得一個分置兩地的合作計劃，不必擔心版權及系統開放性的問題， 而能自在的交流。
-
-
- 軟體開發： 基本安裝的 FreeBSD 就包含了完整的程式開發工具，如 GNU C/C++ 編譯器及除錯器。

你可以經由燒錄 CD-ROM、DVD 或是從 FTP 站上抓回 FreeBSD -- 包括立即可執行的系統以及系統的完整程式碼。 詳情請參閱 附錄 A, 取得 FreeBSD 的方式 取得 FreeBSD。

1.2.2. 誰在用 FreeBSD？

許多 Internet 上的大型網站都是以 FreeBSD 作為它的作業系統，例如：

- Yahoo!
- Apache
- Blue Mountain Arts
- Pair Networks
- Sony Japan
- Netcraft
- Weathernews
- Supervalu
- TELEHOUSE America
- Sophos Anti-Virus
- JMA Wired

以及許多其他的網站。

1.3. 關於 FreeBSD 計劃

接下來講的是 FreeBSD 計劃的背景，包含歷史源流的簡介、計劃的目標，以及開發的模式。

1.3.1. FreeBSD 歷史源流的簡介

Contributed by Jordan Hubbard.

FreeBSD 計畫的想法是在 1993 年初所形成的， 那是源自於維護一組 『非官方 386BSD 的 patchkit(修正工具)』計劃的三個協調維護人 Nate Williams，Rod Grimes 和我(Jordan Hubbard)。

我們最初的目標是做出一份 386BSD 綜合修正的 snapshot 版，以便修正當時一堆 patchkit 都不容易解決的問題。有些人可能還記得早期的計劃名稱叫做 “386BSD 0.5” 或 “386BSD Interim” 就是這個原因。

386BSD 是 Bill Jolitz 的作業系統，在當時就已有約一年的分裂討論。 當該修正工具 (patchkit) 日漸龐雜得令人不舒服，我們無異議地同意要作一些事了， 並決定提供一份臨時性的 “淨化版(cleanup)” 來幫助 Bill。 然而，由於 Bill Jolitz 忽然決定取消其對該計劃的認可，且沒有明確指出未來的打算， 所以該計劃便突然面臨斷炊危機。

不久我們便決定在即使沒有 Bill 的支持下，讓該計劃仍然繼續下去， 最後我們採用 David Greenman 丟銅板決定的名字，也就是『FreeBSD』。 在詢問了當時的一些使用者意見之後，就開始決定了最初的目標， 當該計劃開始實施一切就要成真時，一切就變得更清楚了。 我跟 Walnut Creek CD-ROM 討論發行 CD-ROM 這樣子不便上網的人就可以用比較簡單的方式取得 FreeBSD。 Walnut Creek CD-ROM 不只贊成以 CD-ROM 來發行 FreeBSD 的想法，同時提供了一台機器以及快速的網際網路的頻寬。 如果不是 Walnut Creek CD-ROM 幾乎是空前的信任這個剛開始還是完全默默無聞的計劃， 那麼很可能 FreeBSD 不會如此快速的成長到今日這樣的規模。

第一張以 CD-ROM（及網路）發行的 FreeBSD 1.0 是在 1993 年十二月。 該版本是基於由 U.C. Berkeley 以磁帶方式發行的 4.3BSD-Lite (“Net/2”)以及許多來自於 386BSD 和自由軟體基金會的軟體。對於第一次發行而言還算成功， 我們又接著於 1994 年 5 月發行了相當成功的 FreeBSD 1.1。

然而此後不久，另一個意外的風暴在 Novell 和 U.C. Berkeley 關於 Berkeley Net/2 磁帶之法律地位的訴訟確定之後形成。 U.C. Berkeley 接受大部份的 Net/2 的程式碼都是『侵佔來的』且是屬於 Novell 的財產 -- 事實上是當時不久前從 AT&T 取得的。 Berkeley 得到的是 Novell 對於 4.4BSD-Lite 的『祝福』，最後當 4.4BSD-Lite 終於發行之後，便不再是侵佔行為。 而所有現有 Net/2 使用者都被強烈建議更換新版本，這包括了 FreeBSD。 於是，我們被要求於 1994 年 6 月底前停止散佈基於 Net/2 的產品。在此前提之下，本計劃被允許在期限以前作最後一次發行，也就是 FreeBSD 1.1.5.1。

FreeBSD 便開始了這宛如『重新發明輪子』的艱鉅工作 -- 從全新的且不完整的 4.4BSD-Lite 重新整合。 這個 “Lite” 版本是不完整的，因為 Berkeley 的 CSRG 已經刪除了大量在建立一個可以開機執行的系統所需要的程式碼（基於若干法律上的要求），且該版本在 Intel 平台的移植是非常不完整的。 直到 1994 年 11 月本計劃才完成了這個轉移， 同時在該年 12 月底以 CD-ROM 以及網路的形式發行了 FreeBSD 2.0。 雖然該份版本在當時有點匆促粗糙，但仍是富有意義的成功。 隨之於 1995 年 6 月又發行了更容易安裝，更好的 FreeBSD 2.0.5。

我們在 1996 年 8 月發行了 FreeBSD 2.1.5，在 ISP 和商業團體中非常流行。 隨後， 2.1-STABLE 分支的另一個版本應運而生，它就是在 1997 年 2 月發行 FreeBSD 2.1.7.1 ，同時也是 2.1-STABLE 分支的最後版。之後此分支便進入維護狀態， 僅僅提供安全性的加强和其他嚴重錯誤修補的維護(RELENG_2_1_0)。

1996 年 11 月 FreeBSD 2.2 從開發主軸分支 (“-CURRENT”) 出來成為 RELENG_2_2 分支。它的第一個完整版(2.2.1)於 1997 年 4 月發行。 2.2 分支的延續版本在 97 年夏秋之間發行的，其最後版是在 1998 年 11 月發行的 2.2.8 版。 第一個正式的 3.0 版本在 1998 年 10 月發行，亦即宣告 2.2 分支的落幕。

1999/01/20 日再度分支，這產生了 4.0-CURRENT 以及 3.X-STABLE 兩個分支。 3.X-STABLE 方面，3.1 發行於 1999/02/15，3.2 發行於1999/05/15，3.3 發行於 1999/09/16， 3.4 發行於 1999/12/20，3.5 發行於 2000/06/24 ，接下來幾天後發佈了一些的修補檔(對 Kerberos 安全性方面的修正)，就升級至 3.5.1 ，這是 3.X 分支最後一個發行版本。

在 2000/03/13 又有了一個新的分支， 也就是 4.X-STABLE 。這個分支之後發佈了許多的發行版本： 4.0-RELEASE 在 2000 年 3 月發行， 而最後的 4.11-RELEASE 則在 2005 年 1 月發行。4–STABLE 分支的支援會持續到 2007/01/31 ，但主要焦點在於安全方面的漏洞、臭蟲及其他嚴重問題的修補。

期待已久的 5.0-RELEASE 在 2003/01/19 正式發行。這是將近開發三年的巔峰之作，同時 也開始加强多顆 CPU(SMPng)的支援、kernel thread(KSE) 的支援、檔案系統採用 UFS2 以及支援 snapshot 等， 並支援

UltraSPARC® 和 ia64 平台、支援藍芽、32 bit 的 PCMCIA 等。之後於 2003 年 6 月發行了 5.1。 而 -CURRENT 這個發展主軸分支的最後 5.X 版本是在 2004 年 2 月正式發行的 5.2.1-RELEASE，在 5.X 系列進入 -STABLE (RELENG_5分支)之後，–CURRENT 就轉移為 6.X 系列。

RELENG_5 分支於 2004 年 8 月正式開跑，之後是 5.3-RELEASE ，它是 5-STABLE 分支的第一個發行版本。 最後的 5.5-RELEASE 是在 2006 年 5 月發行的，在此之後 RELENG_5 分支不再繼續。

RELENG_6 分支於 2005 年 7 月開跑，而 6.X 分支的第一個 release(6.0-RELEASE) 是在 2005 年 11 月出的。 最新的 9.3-RELEASE 是在 2006 年 5 月 發行。 當然囉，RELENG_6 分支還將有後續的發行版。

RELENG_7 分支於 2007 年 10 月開跑，最新的 10.3-RELEASE 是在 2006 年 5 月 發行。 RELENG_7 分支還將有後續的發行版。

目前，長期的開發計畫繼續在 8.X-CURRENT (trunk) 分支中進行，而 8.X 的 CD-ROM（當然，也可以用網路抓）snapshot 版本可以在 FreeBSD snapshot server 取得。

1.3.2. FreeBSD 計劃的目標

Contributed by Jordan Hubbard.

FreeBSD 計劃的目標在於提供可作任意用途的軟體而不附帶任何限制條文。 我們之中許多人對程式碼（以及計畫本身）都有非常大的投入， 因此，當然不介意偶爾有一些資金上的補償，但我們並沒打算堅決地要求得到這類資助。 我們認為我們的首要『使命(mission)』是為任何人提供程式碼， 不管他們打算用這些程式碼做什麼， 因為這樣程式碼將能夠被更廣泛地使用，從而發揮其價值。 我認為這是自由軟體最基本的，同時也是我們所倡導的一個目標。

我們程式碼樹中，有若干是以 GNU GPL 或者 LGPL 發佈的那些程式碼帶有少許的附加限制，還好只是强制性的要求開放程式碼而不是別的。 由於使用 GPL 的軟體在商業用途上會增加若干複雜性，因此，如果可以選擇的話， 我們會比較喜歡使用限制相對更寬鬆的 BSD 版權來發佈軟體。

1.3.3. FreeBSD 的開發模式

Contributed by Satoshi Asami.

FreeBSD 的開發是一個非常開放且具彈性的過程，就像從 貢獻者名單 所看到的，是由全世界成千上萬的貢獻者發展起來的。 FreeBSD 的開發基礎架構允許數以百計的開發者透過網際網路協同工作。 我們也經常關注著那些對我們的計畫感興趣的新開發者和新的創意， 那些有興趣更進一步參與計劃的人只需要在 FreeBSD technical discussions 郵遞論壇 連繫我們。 FreeBSD announcements 郵遞論壇 對那些希望了解我們進度的人也是相當有用的。

無論是單獨開發者或者封閉式的團隊合作，多瞭解 FreeBSD 計劃和它的開發過程會是不錯的：

The SVN and CVS repository

> 過去數年來 FreeBSD 的中央 source tree 一直是以 CVS (Concurrent Versions System) 來維護的， 它是個自由軟體，可用來做為版本控制，一裝完 FreeBSD 內就有附了。 然而在 2008 年 6 月起， FreeBSD 版本控制系統改用 SVN(Subversion)。 這切換動作我們認為是有必要，因為 CVS 先天的技術限制，導致 source tree 以及歷史版本數量不斷快速擴張。 因此，主要的 repository 目前是採用 SVN ，而 client 端的工具像是 CVSup、 csup 都是以舊式的 CVS 架構為基礎，仍可以繼續正常運作 —— 此乃因 SVN repository 有 backport 回 CVS 才可以繼續讓 client 端相容。 目前，就只有中央 source tree 是採 SVN 版本控制方式。 而文件、網頁、 Ports 這些 repository 仍持續使用 CVS 版本控制方式。 而主要的 CVS repository 是位於美國加州 Santa Clara 的某台機器上， 然後再 mirror 到世界上其他的許多機器上。 SVN tree 內有兩個主分支： -CURRENT 以及 -STABLE ，這些都可輕鬆複製到自己機器上。 詳情請參閱 更新你的 source tree 一節。

The committers list

> 所謂的 committers 指的是對 CVS tree 有 write 權限， 並依不同授權部分，而有不同權限可修改 FreeBSD source。 (“committer” 這詞源自 cvs(1) 中的 commit 指令，該指令是用來把新的修改提交給 CVS

repository。）而提交修改給 committer 們檢查的最好方式，就是用 send-pr(1) 指令。 若提交 PR 的流程系統上有壅塞現象的話， 也可以改用寄信方式，寄信到 FreeBSD committer's 郵遞論壇 即可。

The FreeBSD core team

如果把 FreeBSD 看成是一家公司的話， FreeBSD core team 就相當於『董事會(board of directors)』。 core team 的主要職責在於確保此計劃有良好的架構，以朝著正確的方向發展。 此外，邀請熱血且負責的軟體開發者加入 committers 行列， 以在若干成員離去時得以補充新血。 目前的 core team 是在 2008 年 7 月 committers 候選人中選出來的，每兩年會舉辦一次選舉。

有些 core team 成員還負責某些特定範圍， 也就是說他們必須盡量確保一些子系統的穩定、效能。 關於 FreeBSD 開發者們以及各自責任範圍，請參閱 貢獻者名單 。

注意

core team 大部分成員加入 FreeBSD 開發都是志工性質而已， 並未從本計劃中獲得任何薪酬，所以不該把 “commitment” 誤解為 “guaranteed support” 才對。 剛前面所講的『董事會』可能是不恰當的類推，或許我們應該說： 他們是一群自願放棄原本的優渥生活、個人其他領域成就， 而選擇投入 FreeBSD 開發的熱血有為者才對！

其他的貢獻者

最後一點，但這點絕非最不重要的， 最大的開發者團隊就是持續為我們提供回饋以及錯誤修正的使用者自己。 與 FreeBSD 非核心開發者互動的主要方式，便是透過訂閱 FreeBSD technical discussions 郵遞論壇 來進行溝通，這方面可參考，請參閱 附錄 C, 網際網路上的資源 以瞭解各式不同的 FreeBSD 郵遞論壇(mailing lists)。

FreeBSD 貢獻者名單 相當長且不斷成長中， 只要有貢獻就會被列入其中， 要不要立即考慮貢獻 FreeBSD 一些回饋呢？

然而，提供原始碼並非為這個計劃做貢獻的唯一方式； 還需要大家投入的完整工作列表、說明，請參閱 FreeBSD 官網。

簡單的說，我們的開發模式就像是一組沒有拘束的同心圓。 這種集中開發模式是以 給使用者方便 為主，同時讓他們能很容易地共同維護軟體，而不會把潛在的貢獻者排除在外！ 我們的目標是提供含有大量一致性的 應用軟體(ports/packages) ，以便讓使用者輕鬆安裝、使用的作業系統 —— 而這開發模式相當符合此一目標。

我們對於那些想要加入 FreeBSD 開發者的期待是： 請保持如同前人一樣的投入，以確保繼續成功！

1.3.4. 最新的 FreeBSD 發行版本

FreeBSD 是免費使用且帶有完整原始程式碼的以 4.4BSD-Lite 為基礎的系統，可以在 Intel i386™, i486™, Pentium®, Pentium® Pro, Celeron®, Pentium® II, Pentium® III, Pentium® 4（或者相容型號）, Xeon™, DEC Alpha™ 和 Sun UltraSPARC® 為基礎的電腦上執行的作業系統。 它主要以加州大學巴爾克利分校 的 CSRG 研究小組的軟體為基礎，並加入了 NetBSD、OpenBSD、386BSD 以及自由軟體基金會的一些東西。

自從 1994 年末，我們發佈了 FreeBSD 2.0 之後，系統的執行效率、 功能、穩定性都有了令人注目的提升。 最大的改變就是我們將記憶體與檔案系統的 cache 機制結合在一起。 這不只使得系統的表現變得更好，並且使得 FreeBSD 系統最少的記憶體需求減少到 5 MB。 其它的改進包括完整的 NIS client and server 功能支援，支援 transaction TCP、PPP 撥接連線、整合的 DHCP 支援、 SCSI 子系統的改進、ISDN 的支援，ATM、FDDI 以及乙太網路（Ethernet、包括 100 Mbit 和 Gigabit) 的支援，提升了最新的 Adaptec 控制卡驅動程式的改善，以及數以千計的 bug 修正。

除了最基本的系統軟體，FreeBSD 還提供了廣受歡迎的套件軟體管理機制： Ports Collection。 到本書付印時，已有超過 24,000 個 ports，這範疇涵蓋從 http(WWW) 伺服器到遊戲、程式語言、編輯器以及您能想到的幾乎所有的東西。 完整的 Ports Collection 需要約 500 MB 的硬碟空間，除了 port 基本架構檔案外，都只儲存與該 port 軟體的原始碼有『須要變更』的部份。 如此一來，我們可以更容易更新這些 ports，也大量的減少如舊的 1.0 版 Ports Collection 對於硬碟空間的需求。 要安裝一個 port 的話，只需要進入該 port 的目錄，輸入 `make install` ，這樣子系統就會幫你裝好了。 您要編譯的每個程式的完整原始程式， 都可從 FTP 或 CD-ROM 中獲得，所以您只需準備足夠的硬碟空間來編譯你要的 port 軟體。 幾乎每一個 port 都有已事先編譯好的 “package”以方便安裝， 如果不想從編譯 port 的人，只要用個簡單指令 (`pkg_add`)就可以安裝。 有關 packages 和 ports 的細節，可以參閱 章 4, 軟體套件管理篇：Packages 及 Ports 機制。

FreeBSD 主機的 `/usr/share/doc` 目錄下找到許多有用的文件， 來幫助您安裝、使用 FreeBSD。 也可以使用下面的網址，以瀏覽器來翻閱本機上安裝的手冊：

FreeBSD 使用手冊
    `/usr/share/doc/handbook/index.html`

FreeBSD 常見問答集
    `/usr/share/doc/faq/index.html`

此外，可在下列網址找到最新版（也是更新最頻繁的版本）：`http://www.FreeBSD.org/` 。

章 2. 安裝 FreeBSD 9.X 和更新的版本

Restructured, reorganized, and parts rewritten by Jim Mock.
Updated for bsdinstall by Gavin Atkinson 且 Warren Block.
Updated for root-on-ZFS by Allan Jude.

2.1. 概述

自從 FreeBSD 9.0-RELEASE開始，FreeBSD 提供一個易用，文字介面的安裝程式 bsdinstall。 本章描述如何用 bsdinstall來安裝 FreeBSD。

一般來說，本章所寫的安裝說明是針對i386™ 和 AMD64 架構。如果可以用於其他平台，將會列表說明。 安裝程式和本章所敘述的內容可能會有些微差異，所以請將本章視為通用的指引，而不是完全照著來做。

注意

喜歡用圖形化安裝程式安裝 FreeBSD 的使用者， 可能會對 pc-sysinstall有興趣，這是PC-BSD計畫所使用的。 他可以用來安裝圖形化桌面 (PC-BSD) 或是命令列版本的 FreeBSD。 細節請參考 PC-BSD 使用者 Handbook (http://wiki.pcbsd.org/index.php/PC-BSD%C2%AE_Users_Handbook/10.1)。

讀完這章，您將了解：

- 最低的硬體需求和 FreeBSD 支援的架構。
- 如何建立 FreeBSD 的安裝媒體。
- 如何開始執行 bsdinstall。
- bsdinstall會詢問的問題，問題代表的意思，以及如何回答。
- 安裝失敗時如何做故障排除。
- 如何在正式安裝前使用 live 版本的 FreeBSD。

在開始閱讀這章之前，您需要：

- 閱讀即將安裝的 FreeBSD 版本所附帶的硬體支援清單，並核對系統的硬體是否有支援。

2.2. 最低硬體需求

安裝 FreeBSD 的硬體需求隨 FreeBSD 的版本和硬體架構而不同。 FreeBSD發行版支援的硬體架構和裝置列在硬體支援清單的檔案裡。 這個檔案通常名為 HARDWARE.TXT ，位於發行媒體的根目錄。 支援硬體清單的副本也可以在FreeBSD 網站 (http://www.FreeBSD.org/releases/index.html)的發行資訊頁面找到。

FreeBSD 最小安裝需要至少 64 MB 的 RAM 和 1.5 GB 的可用硬碟空間 但是這真的是 最 最小，幾乎沒有剩下多餘的空間。 較實際的安裝，不用圖形化環境最少需要 4 GB ，如果要用圖形化介面至少要有 8 GB 以上。 第三方應用程式需要更多空間。建議增加 It is recommended to increase RAM 和硬碟空間以應付應用程式的需求和未來可能儲存的資料量。

每一種架構的處理器需求概述如下：

amd64
有兩類處理器可以跑 amd64。 第一類是 AMD64 處理器，包括 AMD Athlon™64 和 AMD Opteron™ 處理器。

第二類包括那些使用 Intel® EM64T 架構的處理器。 這些包括除了Sossaman以外的所有多核心 Intel® Xeon™ 處理器。 單核心 Intel® Xeon™ 處理器 Nocona, Irwindale, Potomac, 和 Cranford，Intel® Core™ 2 (非 Core Duo) 和更新的處理器，所有的 Intel® Pentium® D 處理器， 和某些 Intel® Pentium® 4s 與使用Prescott核心的 Celeron Ds 。

單處理器 (UP) 和對稱多處理器 (SMP)的設定都有支援。

i386
幾乎所有有浮點運算裝置的 i386 相容處理器都有支援。所有 Intel® 486或是更新的處理器也有支援。

如果 CPUs 有支援，FreeBSD 會利用實體位址延伸 有開啓 PAE 支援的核心會偵測超過 4 GB 的記憶體，讓他能被系統使用。 這項功能為 FreeBSD 的驅動程式與部分功能帶來一些限制，詳情請見 pae(4)。

ia64
目前支援的處理器是 Itanium® 和 Itanium® 2。支援的晶片組包括 HP zx1， Intel® 460GX 和 Intel® E8870。 單處理器 (UP) 和對稱多處理器 (SMP)的設定都有支援。

pc98
NEC PC-9801/9821 系列幾乎所有 i386 相容處理器包括 80486， Pentium®， Pentium® Pro 和 Pentium® II 都有支援。 所有 AMD, Cyrix, IBM, and IDT 的i386 相容處理器都有支援。 相容NEC PC-9801 的EPSON PC-386/486/586 系列都有支援。 NEC FC-9801/9821 and NEC SV-98 系列也有支援。

高解析度模式並不支援。NEC PC-98XA/XL/RL/XL^2 和 NEC PC-H98 系列只支援正常 (PC-9801 相容) 模式。 FreeBSD 對稱多處理器 SMP 相關特色並不支援。 PC-H98， SV-H98 和FC-H98 新延伸標準架構 (NESA) 匯流排不支援。

powerpc
所有內建USB的 New World ROM Apple® Mac® 系統都有支援。 SMP 在多 CPUs的機器都有支援。

32位元的核心只能使用前 2 GB的RAM。

sparc64
FreeBSD/sparc64 支援的系統列在 FreeBSD/sparc64 計劃 (http://www.freebsd.org/platforms/sparc.html).

所有超過一個處理器的系統都有支援SMP。需要專用的磁碟系統，因為此時無法和其他作業系統共用磁碟。

2.3. 安裝前的工作

一旦確定系統符合安裝 FreeBSD 的最低硬體需求，就可以下載安裝檔案並準備安裝的媒體。 做這些之前，先檢查以下核對清單的項目是否準備好了：

1. 備份重要資料

   安裝任何作業系統前， 總是 要先備份所有重要資料。 不要儲存備份在即將安裝的系統上。改為將資料儲存在可移除磁碟，像是 USB 隨身碟，網路上的另一個系統或是線上備份服務上。 開始安裝前，要測試備份，確定它含有所有需要的檔案。 一旦安裝程式格式化系統的磁碟，所有儲存在上面的資料都會遺失。

2. 決定 FreeBSD 安裝在哪裡

   如果 FreeBSD 是唯一要安裝的作業系統，這個步驟可以略過。 但是假如 FreeBSD 將和其他作業系統分享磁碟空間的話，要決定 FreeBSD 要安裝在哪個磁碟或是哪個分割區。

在 i386 和 amd64 平台，磁碟可以使用兩種分割區配置之一來分割成多個分割區。 傳統的主開機紀錄 (MBR) 有一個分割區表定義最多到 主分割區。 因為歷史性的理由， FreeBSD稱這些主分割區為 slices。 其中一個主分割區可以分成一個 延伸分割區 ，他包含多個 邏輯分割區。 GUID 分割區表 (GPT) 是較新和較簡單的分割磁碟的方法 一般GPT 實作允許每個磁碟最多達128個分割區，減少使用邏輯分割區的需要。

警告

一些比較舊的作業系統，像是 Windows® XP , 和 GPT 分割區配置並不相容。 如果 FreeBSD 將和這樣的作業系統共享一個磁碟，那就需要用 MBR 分割。

FreeBSD 開機啓動程式需要主分割區或是 GPT 分割區。 如果所有的主分割區或 GPT 分割區都已使用，必須釋放其中一個分割區讓 FreeBSD 使用。 如果要建立一個分割區而不刪除原有的資料， 可以使用磁碟分割工具來縮小現有的分割區， 並使用多出的空間來建立新分割區。

各種自由的和商業化的磁碟分割工具列於 http://en.wikipedia.org/wiki/List_of_disk_partitioning_software。 GParted Live (http://gparted.sourceforge.net/livecd.php) 是包含分割編輯工具GParted的自由的 live CD。 GParted 也包含在許多 Linux live CD 套件裡。

警告

當正確地使用，磁碟分割工具可以安全地建立空間讓新的分割區使用。 因為有可能會誤選已經存在的分割區，所以在修改磁碟分割區前， 一定要備份重要資料，並確認備份的完整性。

包含不同作業系統的磁碟分割區可以讓一台電腦安裝多重作業系統。 另一種作法是使用虛擬機器 (章 21, Virtualization (虛擬機器))，可以讓多重作業系統同時間執行而不需要改變任何磁碟分割區。

3. 收集網路資訊

有些 FreeBSD 安裝方法為了下載安裝檔案需要網路連線。 在系統安裝之後，安裝程式將會讓您設定系統的網路介面。

如果網路有 DHCP 伺服器，可以自動設定網路。 如果沒有 DHCP ， 需要從區域網路管理者或是網際網路服務商取得以下系統的網路資訊：

1. IP 位址
2. 子網路遮罩
3. 預設閘道器 IP 位址
4. 網路的網域名稱
5. 網路 DNS 伺服器 IP 位址

4. 檢查 FreeBSD 勘誤表

儘管 FreeBSD Project 努力確保每個 FreeBSD 發行版能夠儘可能地穩定，錯誤偶爾還是會悄悄出現。 有極小的機會錯誤會影響安裝過程。 當這些問題被發現並修正後，會被紀錄在 FreeBSD 網站的 FreeBSD 勘誤表 (http://www.freebsd.org/releases/10.3R/errata.html)。 安裝前要檢查勘誤表，確保沒有會影響到安裝的問題。

所有發行版的資訊和勘誤表可以在 FreeBSD 網站的發行資訊找到 (http://www.freebsd.org/releases/index.html)。

2.3.1. 準備安裝的媒體

The FreeBSD installer is not an application that can be run from within another operating system. Instead, download a FreeBSD installation file, burn it to the media associated with its file type and size (CD, DVD, or USB), and boot the system to install from the inserted media.

FreeBSD installation files are available at www.freebsd.org/where.html#download. Each installation file's name includes the release version of FreeBSD, the architecture, and the type of file. For example, to install FreeBSD 10.0 on an amd64 system from a DVD, download `FreeBSD-10.0-RELEASE-amd64-dvd1.iso` , burn this file to a DVD, and boot the system with the DVD inserted.

Several file types are available, though not all file types are available for all architectures. The possible file types are:

- `-bootonly.iso` : This is the smallest installation file as it only contains the installer. A working Internet connection is required during installation as the installer will download the files it needs to complete the FreeBSD installation. This file should be burned to a CD using a CD burning application.
- `-disc1.iso` : This file contains all of the files needed to install FreeBSD, its source, and the Ports Collection. It should be burned to a CD using a CD burning application.
- `-dvd1.iso` : This file contains all of the files needed to install FreeBSD, its source, and the Ports Collection. It also contains a set of popular binary packages for installing a window manager and some applications so that a complete system can be installed from media without requiring a connection to the Internet. This file should be burned to a DVD using a DVD burning application.
- `-memstick.img` : This file contains all of the files needed to install FreeBSD, its source, and the Ports Collection. It should be burned to a USB stick using the instructions below.

Also download `CHECKSUM.SHA256` from the same directory as the image file and use it to check the image file's integrity by calculating a checksum. FreeBSD provides sha256(1) for this, while other operating systems have similar programs. Compare the calculated checksum with the one shown in `CHECKSUM.SHA256` . The checksums must match exactly. If the checksums do not match, the file is corrupt and should be downloaded again.

2.3.1.1. 將印象檔寫入USB

The `*.img` file is an image of the complete contents of a memory stick. It cannot be copied to the target device as a file. Several applications are available for writing the `*.img` to a USB stick. This section describes two of these utilities.

重要

Before proceeding, back up any important data on the USB stick. This procedure will erase the existing data on the stick.

過程 2.1. 使用 dd 指令來寫入印象檔

警告

This example uses `/dev/da0` as the target device where the image will be written. Be very careful that the correct device is used as this command will destroy the existing data on the specified target device.

- The dd(1) command-line utility is available on BSD, Linux®, and Mac OS® systems. To burn the image using `dd`, insert the USB stick and determine its device name. Then, specify the name of the downloaded installation file and the device name for the USB stick. This example burns the amd64 installation image to the first USB device on an existing FreeBSD system.

  ```
  # dd if=FreeBSD-10.0-RELEASE-amd64-memstick.img   of=/dev/da0 bs=64k
  ```

  If this command fails, verify that the USB stick is not mounted and that the device name is for the disk, not a partition. Some operating systems might require this command to be run with sudo(8). Systems like Linux® might buffer writes. To force all writes to complete, use sync(8).

過程 2.2. 使用Windows® 來寫入映象檔

警告

要確保提供正確的磁碟機代號，因為磁碟上的資料會被覆蓋和摧毀。

1. 取得Image Writer for Windows®

   Image Writer for Windows® 是一個免費的應用程式，可以正確地將映像檔寫入隨身碟。 從 `https://launchpad.net/win32-image-writer/` 下載，並解壓縮到一個資料夾。

2. 用 Image Writer 寫入映象檔

   雙擊 Win32DiskImager icon 啓動程式。 確認 `Device` 顯示的磁碟機代號是隨身碟的磁碟機代號。 按下資料夾 icon 選擇要寫入隨身碟的映像檔。 按下 [Save] 按鈕確定映像檔名。 確認所有東西都正確，隨身碟的資料夾並沒有在其他視窗開啓。 所有東西準備好後，按下 [Write] 將映像檔寫入隨身碟。

您現在可以開始安裝 FreeBSD 。

2.4. 開始安裝

重要

By default, the installation will not make any changes to the disk(s) before the following message:

```
Your changes will now be written to disk.  If you
have chosen to overwrite existing data, it will
be PERMANENTLY ERASED. Are you sure you want to
commit your changes?
```

> The install can be exited at any time prior to this warning. If there is a concern that something is incorrectly configured, just turn the computer off before this point and no changes will be made to the system's disks.

This section describes how to boot the system from the installation media which was prepared using the instructions in 節 2.3.1, “準備安裝的媒體”. When using a bootable USB stick, plug in the USB stick before turning on the computer. When booting from CD or DVD, turn on the computer and insert the media at the first opportunity. How to configure the system to boot from the inserted media depends upon the architecture.

2.4.1. Booting on i386™ and amd64

These architectures provide a BIOS menu for selecting the boot device. Depending upon the installation media being used, select the CD/DVD or USB device as the first boot device. Most systems also provide a key for selecting the boot device during startup without having to enter the BIOS. Typically, the key is either F10, F11, F12, or Escape.

If the computer loads the existing operating system instead of the FreeBSD installer, then either:

1. The installation media was not inserted early enough in the boot process. Leave the media inserted and try restarting the computer.

2. The BIOS changes were incorrect or not saved. Double-check that the right boot device is selected as the first boot device.

3. This system is too old to support booting from the chosen media. In this case, the Plop Boot Manager (http://www.plop.at/en/bootmanager.html) can be used to boot the system from the selected media.

2.4.2. Booting on PowerPC®

On most machines, holding C on the keyboard during boot will boot from the CD. Otherwise, hold Command+Option+O+F, or Windows+Alt+O+F on non-Apple® keyboards. At the `0 >` prompt, enter

```
boot cd:,\ppc\loader cd:0
```

2.4.3. Booting on Sparc64®

Most Sparc64® systems are set up to boot automatically from disk. To install FreeBSD from a CD requires a break into the PROM.

To do this, reboot the system and wait until the boot message appears. The message depends on the model, but should look something like this:

```
Sun Blade 100 (UltraSPARC-IIe), Keyboard Present
Copyright 1998-2001 Sun Microsystems, Inc.  All rights reserved.
OpenBoot 4.2, 128 MB memory installed, Serial #51090132.
Ethernet address 0:3:ba:b:92:d4, Host ID: 830b92d4.
```

If the system proceeds to boot from disk at this point, press L1+A or Stop+A on the keyboard, or send a BREAK over the serial console. When using tip or cu, `~#` will issue a BREAK. The PROM prompt will be `ok` on systems with one CPU and `ok {0}` on SMP systems, where the digit indicates the number of the active CPU.

At this point, place the CD into the drive and type `boot cdrom` from the PROM prompt.

2.4.4. FreeBSD 開機選單

Once the system boots from the installation media, a menu similar to the following will be displayed:

圖形 2.1. FreeBSD 開機管理程式選單

By default, the menu will wait ten seconds for user input before booting into the FreeBSD installer or, if FreeBSD is already installed, before booting into FreeBSD. To pause the boot timer in order to review the selections, press Space. To select an option, press its highlighted number, character, or key. The following options are available.

- `Boot Multi User` : This will continue the FreeBSD boot process. If the boot timer has been paused, press 1, upper- or lower-case B, or Enter.
- `Boot Single User` : This mode can be used to fix an existing FreeBSD installation as described in 節 12.6.2, “Single-User Mode”. Press 2 or the upper- or lower-case S to enter this mode.
- `Escape to loader prompt` : This will boot the system into a repair prompt that contains a limited number of low-level commands. This prompt is described in 節 12.3.3, “Stage Three, `/boot/loader`”. Press 3 or Esc to boot into this prompt.
- `Reboot` : Reboots the system.
- `Configure Boot Options` : Opens the menu shown in, and described under, 圖形 2.2, “FreeBSD 開機選項選單” .

圖形 2.2. FreeBSD 開機選項選單

The boot options menu is divided into two sections. The first section can be used to either return to the main boot menu or to reset any toggled options back to their defaults.

The next section is used to toggle the available options to `On` or `Off` by pressing the option's highlighted number or character. The system will always boot using the settings for these options until they are modified. Several options can be toggled using this menu:

- `ACPI Support`: If the system hangs during boot, try toggling this option to `Off`.
- `Safe Mode`: If the system still hangs during boot even with `ACPI Support` set to `Off`, try setting this option to `On`.
- `Single User`: Toggle this option to `On` to fix an existing FreeBSD installation as described in 節 12.6.2, "Single-User Mode". Once the problem is fixed, set it back to `Off`.
- `Verbose`: Toggle this option to `On` to see more detailed messages during the boot process. This can be useful when troubleshooting a piece of hardware.

After making the needed selections, press 1 or Backspace to return to the main boot menu, then press Enter to continue booting into FreeBSD. A series of boot messages will appear as FreeBSD carries out its hardware device probes and loads the installation program. Once the boot is complete, the welcome menu shown in 圖形 2.3, "歡迎選單" will be displayed.

圖形 2.3. 歡迎選單

Press Enter to select the default of [Install] to enter the installer. The rest of this chapter describes how to use this installer. Otherwise, use the right or left arrows or the colorized letter to select the desired menu item. The [Shell] can be used to access a FreeBSD shell in order to use command line utilities to prepare the disks before installation. The [Live CD] option can be used to try out FreeBSD before installing it. The live version is described in 節 2.10, "使用 Live CD".

提示

To review the boot messages, including the hardware device probe, press the upper- or lower-case S and then Enter to access a shell. At the shell prompt, type `more /var/run/dmesg.boot` and use the space bar to scroll through the messages. When finished, type `exit` to return to the welcome menu.

2.5. 使用 bsdinstall

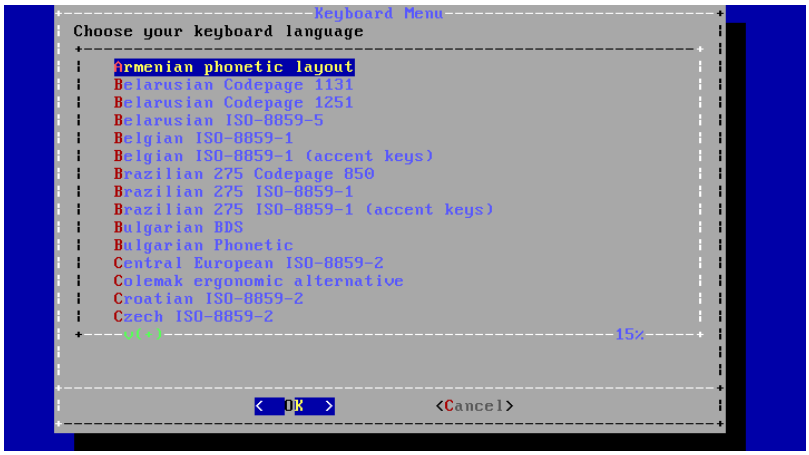
This section shows the order of the bsdinstall menus and the type of information that will be asked before the system is installed. Use the arrow keys to highlight a menu option, then Space to select or deselect that menu item. When finished, press Enter to save the selection and move onto the next screen.

2.5.1. Selecting the Keymap Menu

Depending on the system console being used, bsdinstall may initially display the menu shown in 圖形 2.4, “Keymap Selection”.

圖形 2.4. Keymap Selection

To configure the keyboard layout, press Enter with [YES] selected, which will display the menu shown in 圖形 2.5, “選擇鍵盤選單”. To instead use the default layout, use the arrow key to select [NO] and press Enter to skip this menu screen.



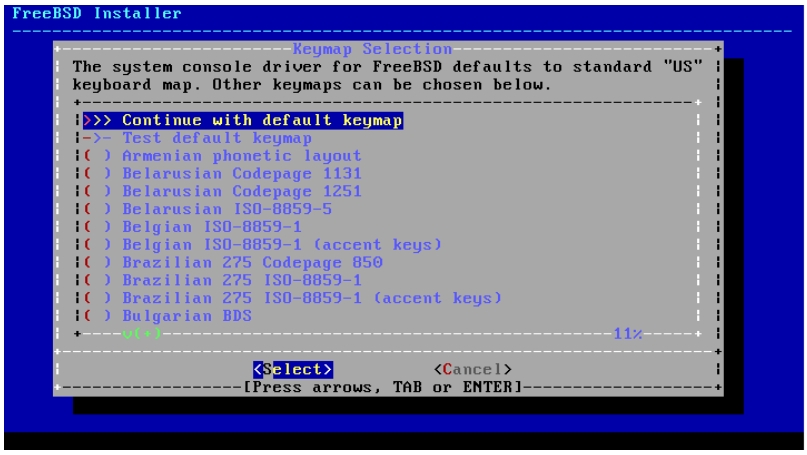
圖形 2.5. 選擇鍵盤選單

When configuring the keyboard layout, use the up and down arrows to select the keymap that most closely represents the mapping of the keyboard attached to the system. Press Enter to save the selection.

注意

Pressing Esc will exit this menu and use the default keymap. If the choice of keymap is not clear, United States of America ISO-8859-1 is also a safe option.

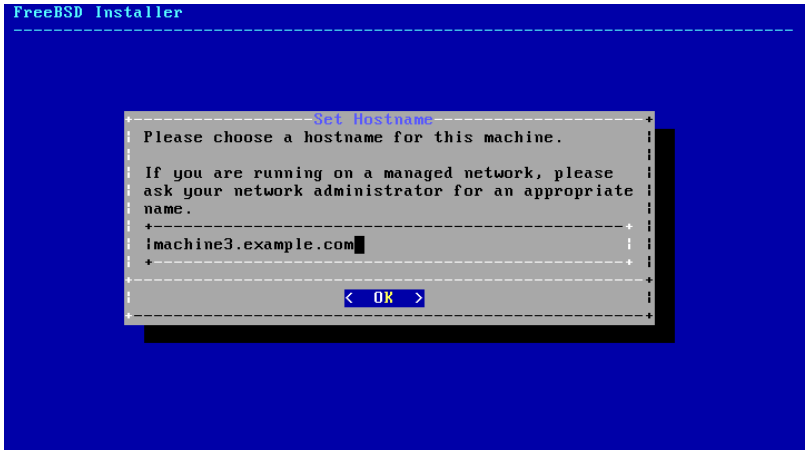
In FreeBSD 10.0-RELEASE and later, this menu has been enhanced. The full selection of keymaps is shown, with the default preselected. In addition, when selecting a different keymap, a dialog is displayed that allows the user to try the keymap and ensure it is correct before proceeding.



圖形 2.6. Enhanced Keymap Menu

2.5.2. 設定主機名稱

The next bsdinstall menu is used to set the hostname for the newly installed system.

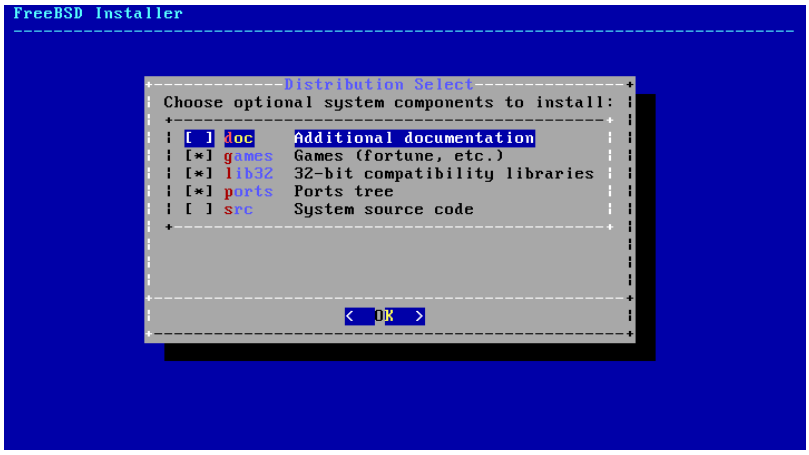


圖形 2.7. 設定主機名稱

Type in a hostname that is unique for the network. It should be a fully-qualified hostname, such as `machine3.example.com` .

2.5.3. 選擇要安裝的組件

Next, bsdinstall will prompt to select optional components to install.



圖形 2.8. 選擇要安裝的組件

Deciding which components to install will depend largely on the intended use of the system and the amount of disk space available. The FreeBSD kernel and userland, collectively known as the base system, are always installed. Depending on the architecture, some of these components may not appear:

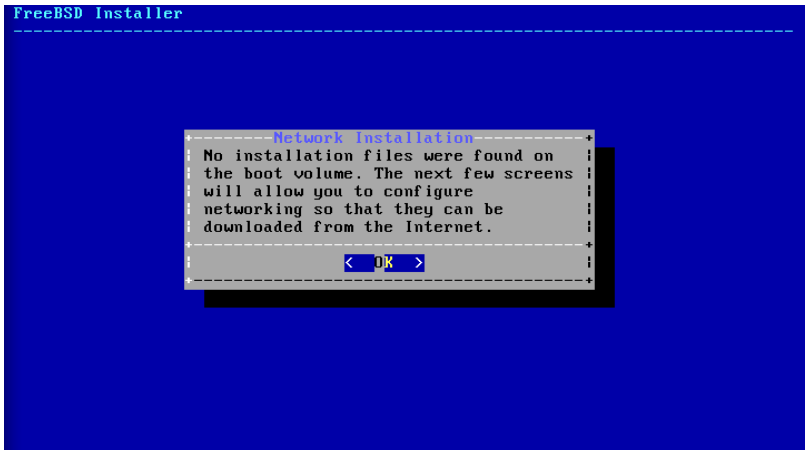
- `doc` - Additional documentation, mostly of historical interest, to install into `/usr/share/doc` . The documentation provided by the FreeBSD Documentation Project may be installed later using the instructions in 節 23.3, “更新文件組” .
- `games` - Several traditional BSD games, including fortune, rot13, and others.
- `lib32` - Compatibility libraries for running 32-bit applications on a 64-bit version of FreeBSD.
- `ports` - The FreeBSD Ports Collection is a collection of files which automates the downloading, compiling and installation of third-party software packages. 章 4, 軟體套件管理篇：Packages 及 Ports 機制 discusses how to use the Ports Collection.

> **警告**
>
> The installation program does not check for adequate disk space. Select this option only if sufficient hard disk space is available. The FreeBSD Ports Collection takes up about 500 MB of disk space.

- `src` - The complete FreeBSD source code for both the kernel and the userland. Although not required for the majority of applications, it may be required to build device drivers, kernel modules, or some applications from the Ports Collection. It is also used for developing FreeBSD itself. The full source tree requires 1 GB of disk space and recompiling the entire FreeBSD system requires an additional 5 GB of space.

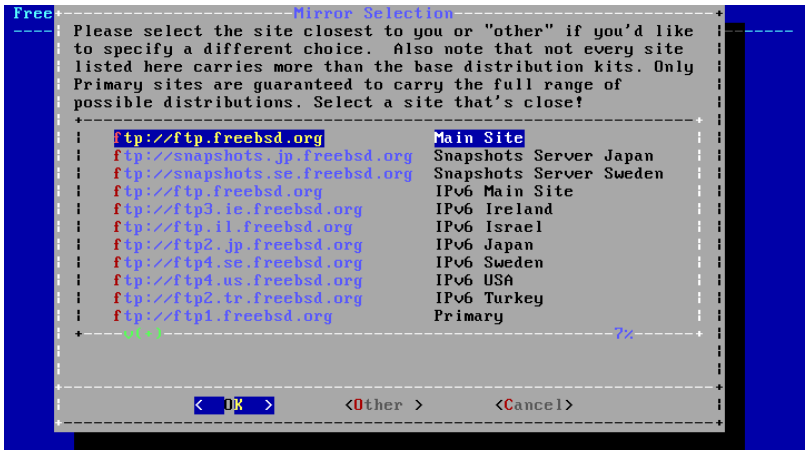
2.5.4. 從網路安裝

The menu shown in 圖形 2.9, “從網路安裝” only appears when installing from a `-bootonly.iso` CD as this installation media does not hold copies of the installation files. Since the installation files must be retrieved over a network connection, this menu indicates that the network interface must be first configured.



圖形 2.9. 從網路安裝

To configure the network connection, press Enter and follow the instructions in 節 2.8.2, “Configuring Network Interfaces”. Once the interface is configured, select a mirror site that is located in the same region of the world as the computer on which FreeBSD is being installed. Files can be retrieved more quickly when the mirror is close to the target computer, reducing installation time.



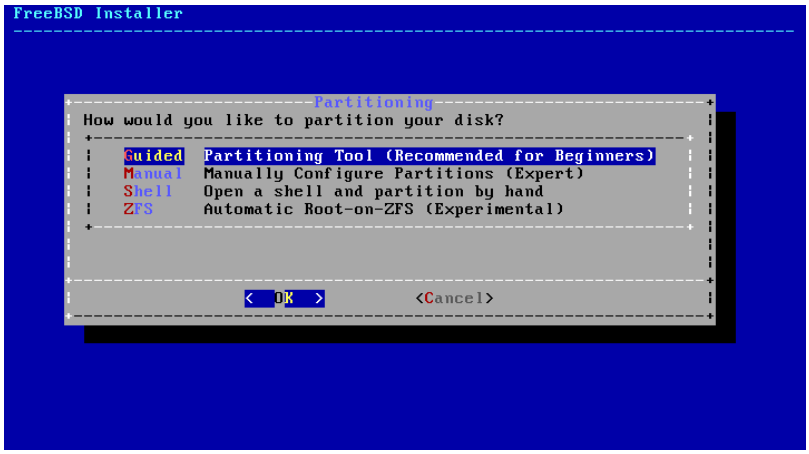
圖形 2.10. 選擇鏡像站

Installation will then continue as if the installation files were located on the local installation media.

2.6. 配置磁碟空間

The next menu is used to determine the method for allocating disk space. The options available in the menu depend upon the version of FreeBSD being installed.

圖形 2.11. Partitioning Choices on FreeBSD 9.x



圖形 2.12. Partitioning Choices on FreeBSD 10.x and Higher

`Guided` partitioning automatically sets up the disk partitions, `Manual` partitioning allows advanced users to create customized partitions from menu options, and `Shell` opens a shell prompt where advanced users can create customized partitions using command-line utilities like gpart(8), fdisk(8), and bsdlabel(8). `ZFS` partitioning, only available in FreeBSD 10 and later, creates an optionally encrypted root-on-ZFS system with support for boot environments.

This section describes what to consider when laying out the disk partitions. It then demonstrates how to use the different partitioning methods.

2.6.1. Designing the Partition Layout

When laying out file systems, remember that hard drives transfer data faster from the outer tracks to the inner. Thus, smaller and heavier-accessed file systems should be closer to the outside of the drive, while larger partitions like `/usr` should be placed toward the inner parts of the disk. It is a good idea to create partitions in an order similar to: `/`, swap, `/var`, and `/usr`.

The size of the `/var` partition reflects the intended machine's usage. This partition is used to hold mailboxes, log files, and printer spools. Mailboxes and log files can grow to unexpected sizes depending on the number of users and how long log files are kept. On average, most users rarely need more than about a gigabyte of free disk space in `/var`.

注意

Sometimes, a lot of disk space is required in `/var/tmp`. When new software is installed, the packaging tools extract a temporary copy of the packages under `/var/tmp`. Large software packages, like Firefox, OpenOffice or LibreOffice may be tricky to install if there is not enough disk space under `/var/tmp`.

The `/usr` partition holds many of the files which support the system, including the FreeBSD Ports Collection and system source code. At least 2 gigabytes is recommended for this partition.

When selecting partition sizes, keep the space requirements in mind. Running out of space in one partition while barely using another can be a hassle.

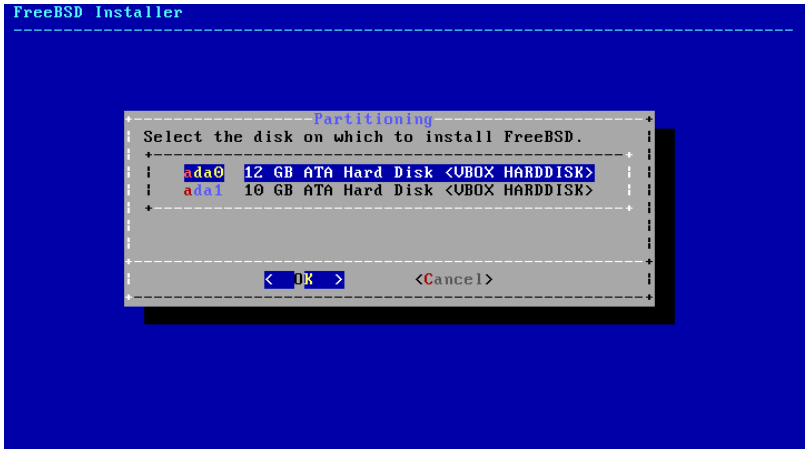
As a rule of thumb, the swap partition should be about double the size of physical memory (RAM). Systems with minimal RAM may perform better with more swap. Configuring too little swap can lead to inefficiencies in the VM page scanning code and might create issues later if more memory is added.

On larger systems with multiple SCSI disks or multiple IDE disks operating on different controllers, it is recommended that swap be configured on each drive, up to four drives. The swap partitions should be approximately the same size. The kernel can handle arbitrary sizes but internal data structures scale to 4 times the largest swap partition. Keeping the swap partitions near the same size will allow the kernel to optimally stripe swap space across disks. Large swap sizes are fine, even if swap is not used much. It might be easier to recover from a runaway program before being forced to reboot.

By properly partitioning a system, fragmentation introduced in the smaller write heavy partitions will not bleed over into the mostly read partitions. Keeping the write loaded partitions closer to the disk's edge will increase I/O performance in the partitions where it occurs the most. While I/O performance in the larger partitions may be needed, shifting them more toward the edge of the disk will not lead to a significant performance improvement over moving `/var` to the edge.

2.6.2. Guided Partitioning

When this method is selected, a menu will display the available disk(s). If multiple disks are connected, choose the one where FreeBSD is to be installed.

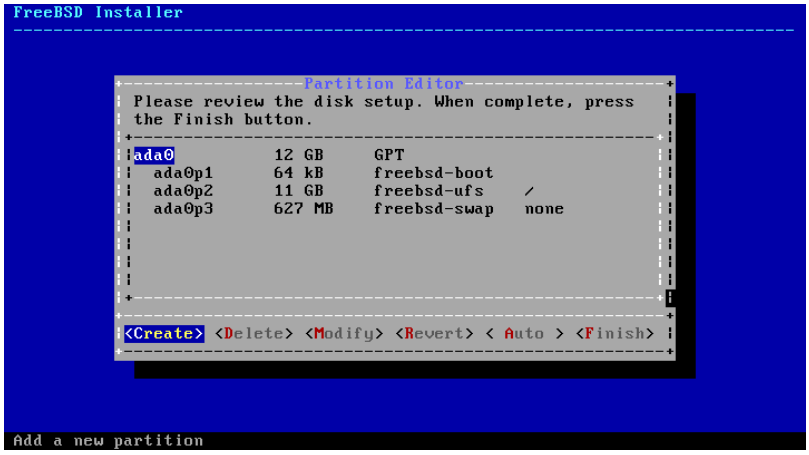


圖形 2.13. Selecting from Multiple Disks

Once the disk is selected, the next menu prompts to install to either the entire disk or to create a partition using free space. If [Entire Disk] is chosen, a general partition layout filling the whole disk is automatically created. Selecting [Partition] creates a partition layout from the unused space on the disk.

圖形 2.14. Selecting Entire Disk or Partition

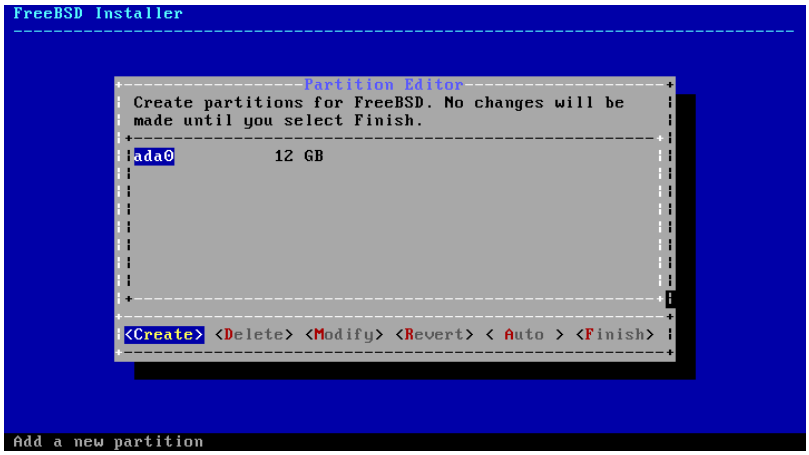
After the partition layout has been created, review it to ensure it meets the needs of the installation. Selecting [Revert] will reset the partitions to their original values and pressing [Auto] will recreate the automatic FreeBSD partitions. Partitions can also be manually created, modified, or deleted. When the partitioning is correct, select [Finish] to continue with the installation.



圖形 2.15. Review Created Partitions

2.6.3. Manual Partitioning

Selecting this method opens the partition editor:



圖形 2.16. Manually Create Partitions

Highlight the installation drive (`ada0` in this example) and select [Create] to display a menu of available partition schemes:

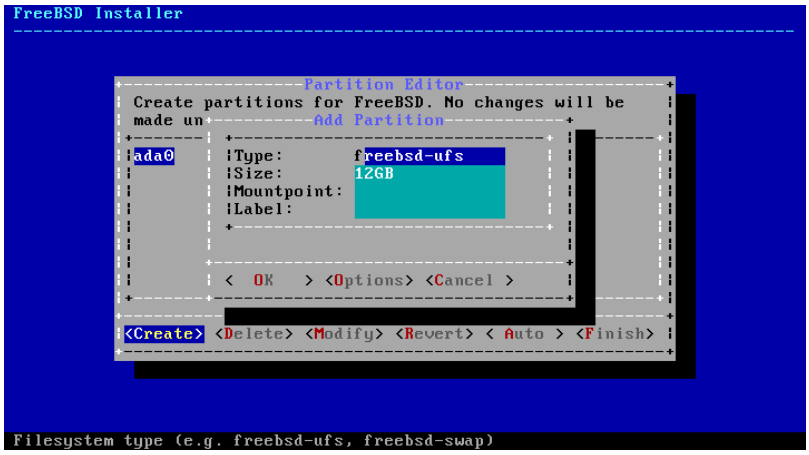
圖形 2.17. Manually Create Partitions

GPT is usually the most appropriate choice for amd64 computers. Older computers that are not compatible with GPT should use MBR. The other partition schemes are generally used for uncommon or older computers.

表格 2.1. Partitioning Schemes

Abbreviation	Description
APM	Apple Partition Map, used by PowerPC®.
BSD	BSD label without an MBR, sometimes called dangerously dedicated mode as non-BSD disk utilities may not recognize it.
GPT	GUID Partition Table (http://en.wikipedia.org/wiki/GUID_Partition_Table).
MBR	Master Boot Record (http://en.wikipedia.org/wiki/Master_boot_record).
PC98	MBR variant used by NEC PC-98 computers (http://en.wikipedia.org/wiki/Pc9801).
VTOC8	Volume Table Of Contents used by Sun SPARC64 and UltraSPARC computers.

After the partitioning scheme has been selected and created, select [Create] again to create the partitions.



圖形 2.18. Manually Create Partitions

A standard FreeBSD GPT installation uses at least three partitions:

- `freebsd-boot` - Holds the FreeBSD boot code.
- `freebsd-ufs` - A FreeBSD UFS file system.
- `freebsd-swap` - FreeBSD swap space.

Another partition type worth noting is `freebsd-zfs` , used for partitions that will contain a FreeBSD ZFS file system (章 19, The Z File System (ZFS)). Refer to gpart(8) for descriptions of the available GPT partition types.

Multiple file system partitions can be created and some people prefer a traditional layout with separate partitions for `/`, `/var`, `/tmp`, and `/usr`. See 範例 2.1, “Creating Traditional Split File System Partitions” for an example.

The `Size` may be entered with common abbreviations: K for kilobytes, M for megabytes, or G for gigabytes.

提示

Proper sector alignment provides the best performance, and making partition sizes even multiples of 4K-bytes helps to ensure alignment on drives with either 512-byte or 4K-byte sectors. Generally, using partition sizes that are even multiples of 1M or 1G is the easiest way to make sure every partition starts at an even multiple of 4K. There is one exception: the freebsd-boot partition should be no larger than 512K due to current boot code limitations.

A `Mountpoint` is needed if the partition will contain a file system. If only a single UFS partition will be created, the mountpoint should be `/`.

The `Label` is a name by which the partition will be known. Drive names or numbers can change if the drive is connected to a different controller or port, but the partition label does not change. Referring to labels instead of drive names and partition numbers in files like `/etc/fstab` makes the system more tolerant to hardware changes. GPT labels appear in `/dev/gpt/` when a disk is attached. Other partitioning schemes have different label capabilities and their labels appear in different directories in `/dev/`.

提示

Use a unique label on every partition to avoid conflicts from identical labels. A few letters from the computer's name, use, or location can be added to the label. For instance, use `labroot` or `rootfslab` for the UFS root partition on the computer named `lab`.

範例 2.1. Creating Traditional Split File System Partitions

For a traditional partition layout where the `/`, `/var`, `/tmp`, and `/usr` directories are separate file systems on their own partitions, create a GPT partitioning scheme, then create the partitions as shown. Partition sizes shown are typical for a 20G target disk. If more space is available on the target disk, larger swap or `/var` partitions may be useful. Labels shown here are prefixed with `ex` for "example", but readers should use other unique label values as described above.

By default, FreeBSD's `gptboot` expects the first UFS partition to be the `/` partition.

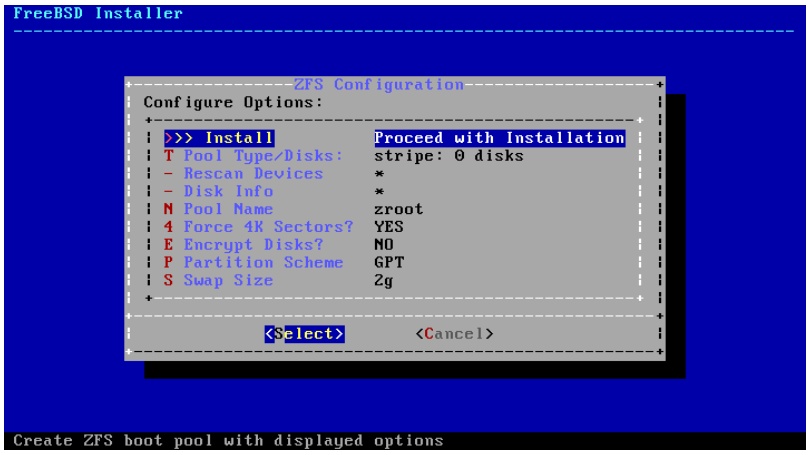
Partition Type	Size	Mountpoint	Label
`freebsd-boot`	`512K`		
`freebsd-ufs`	`2G`	`/`	`exrootfs`
`freebsd-swap`	`4G`		`exswap`
`freebsd-ufs`	`2G`	`/var`	`exvarfs`
`freebsd-ufs`	`1G`	`/tmp`	`extmpfs`
`freebsd-ufs`	accept the default (remainder of the disk)	`/usr`	`exusrfs`

After the custom partitions have been created, select [Finish] to continue with the installation.

2.6.4. Root-on-ZFS Automatic Partitioning

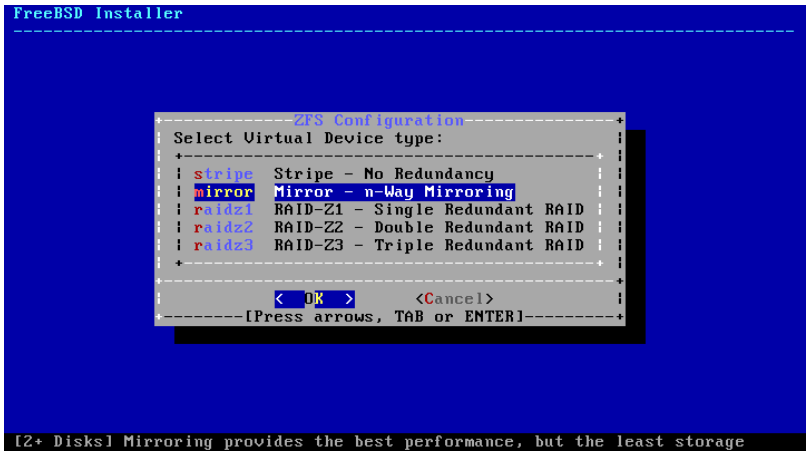
Support for automatic creation of root-on-ZFS installations was added in FreeBSD 10.0-RELEASE. This partitioning mode only works with whole disks and will erase the contents of the entire disk. The installer will automatically create partitions aligned to 4k boundaries and force ZFS to use 4k sectors. This is safe even with 512 byte sector disks, and has the added benefit of ensuring that pools created on 512 byte disks will be able to have 4k sector disks added in the future, either as additional storage space or as replacements for failed disks. The installer can also optionally employ GELI disk encryption as described in 節 17.13.2, "Disk Encryption with `geli`". If encryption is enabled, a 2 GB unencrypted boot pool containing the `/boot` directory is created. It holds the kernel and other files necessary to boot the system. A swap partition of a user selectable size is also created, and all remaining space is used for the ZFS pool.

The main ZFS configuration menu offers a number of options to control the creation of the pool.



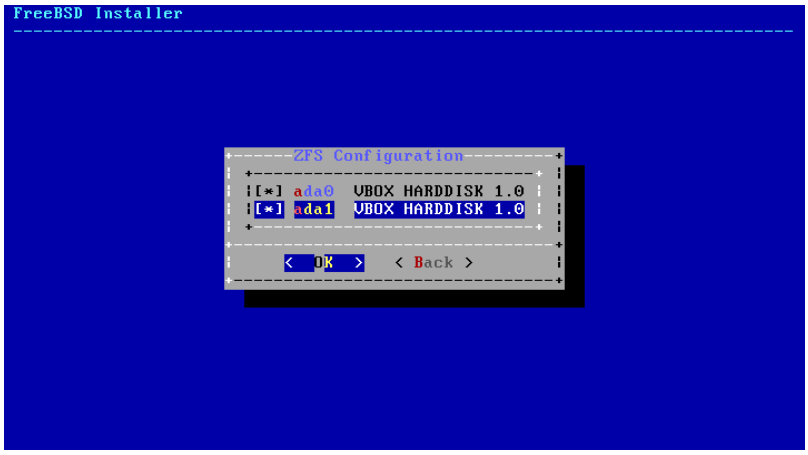
圖形 2.19. ZFS Partitioning Menu

Select T to configure the `Pool Type` and the disk(s) that will constitute the pool. The automatic ZFS installer currently only supports the creation of a single top level vdev, except in stripe mode. To create more complex pools, use the instructions in 節 2.6.5, “Shell Mode Partitioning” to create the pool. The installer supports the creation of various pool types, including stripe (not recommended, no redundancy), mirror (best performance, least usable space), and RAID-Z 1, 2, and 3 (with the capability to withstand the concurrent failure of 1, 2, and 3 disks, respectively). while selecting the pool type, a tooltip is displayed across the bottom of the screen with advice about the number of required disks, and in the case of RAID-Z, the optimal number of disks for each configuration.



圖形 2.20. ZFS Pool Type

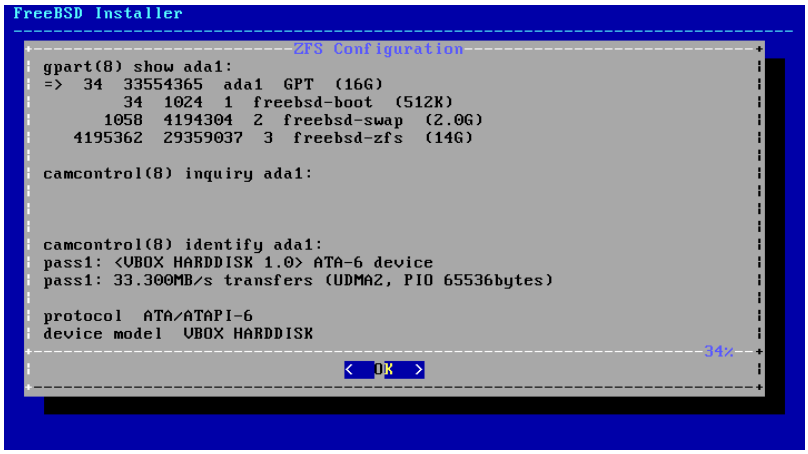
Once a `Pool Type` has been selected, a list of available disks is displayed, and the user is prompted to select one or more disks to make up the pool. The configuration is then validated, to ensure enough disks are selected. If not, select <Change Selection> to return to the list of disks, or <Cancel> to change the pool type.



圖形 2.21. Disk Selection

圖形 2.22. Invalid Selection

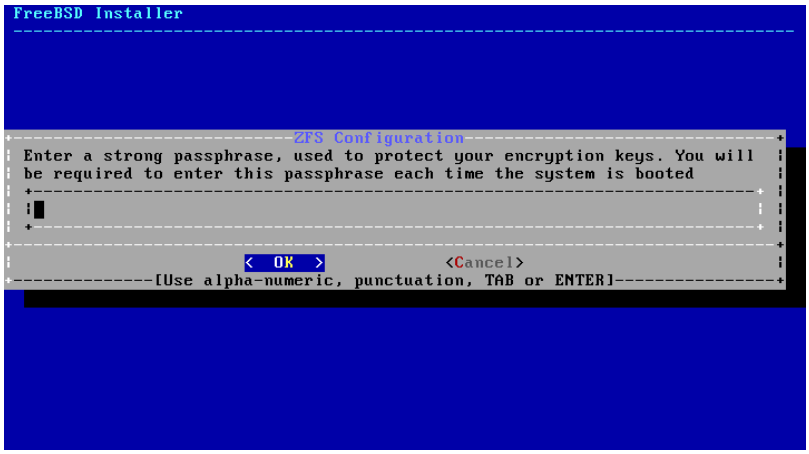
If one or more disks are missing from the list, or if disks were attached after the installer was started, select - Rescan Devices to repopulate the list of available disks. To ensure that the correct disks are selected, so as not to accidently destroy the wrong disks, the - Disk Info menu can be used to inspect each disk, including its partition table and various other information such as the device model number and serial number, if available.



圖形 2.23. Analysing a Disk

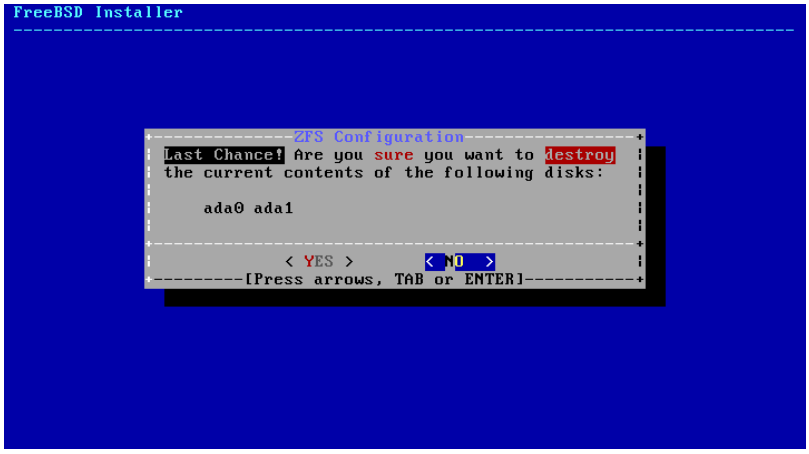
The main ZFS configuration menu also allows the user to enter a pool name, disable forcing 4k sectors, enable or disable encryption, switch between GPT (recommended) and MBR partition table types, and select the amount of swap space. Once all options have been set to the desired values, select the >>> Install option at the top of the menu.

If GELI disk encryption was enabled, the installer will prompt twice for the passphrase to be used to encrypt the disks.



圖形 2.24. Disk Encryption Password

The installer then offers a last chance to cancel before the contents of the selected drives are destroyed to create the ZFS pool.



圖形 2.25. Last Chance

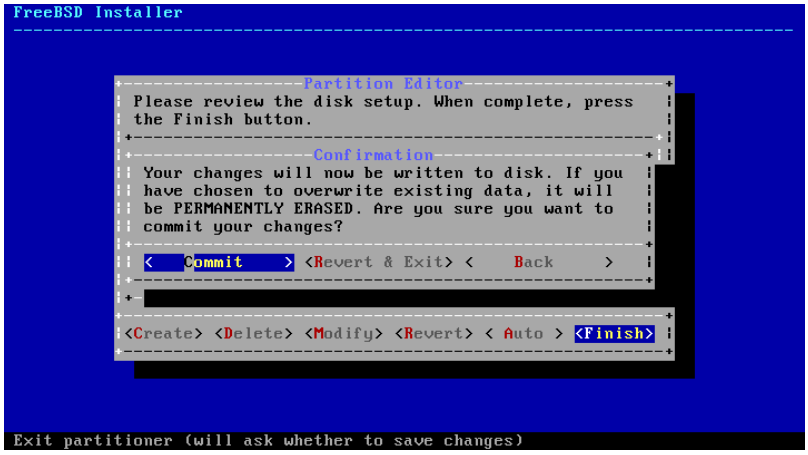
The installation then proceeds normally.

2.6.5. Shell Mode Partitioning

When creating advanced installations, the bsdinstall paritioning menus may not provide the level of flexibility required. Advanced users can select the Shell option from the partitioning menu in order to manually partition the drives, create the file system(s), populate `/tmp/bsdinstall_etc/fstab` , and mount the file systems under `/mnt`. Once this is done, type `exit` to return to bsdinstall and continue the installation.

2.7. Committing to the Installation

Once the disks are configured, the next menu provides the last chance to make changes before the selected hard drive(s) are formatted. If changes need to be made, select [Back] to return to the main partitioning menu. [Revert & Exit] will exit the installer without making any changes to the hard drive.

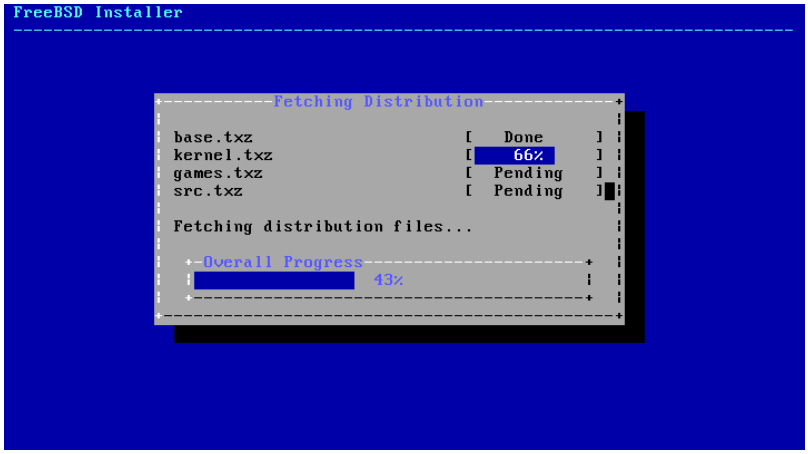


圖形 2.26. Final Confirmation

To instead start the actual installation, select [Commit] and press Enter.

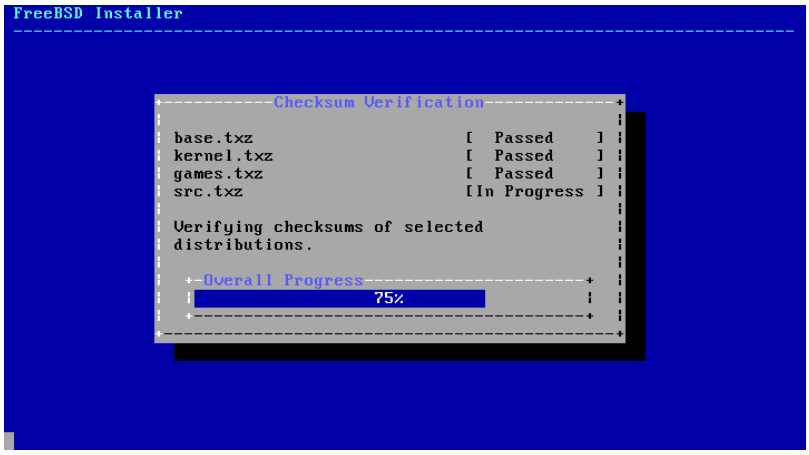
Installation time will vary depending on the distributions chosen, installation media, and speed of the computer. A series of messages will indicate the progress.

First, the installer formats the selected disk(s) and initializes the partitions. Next, in the case of a bootonly media, it downloads the selected components:



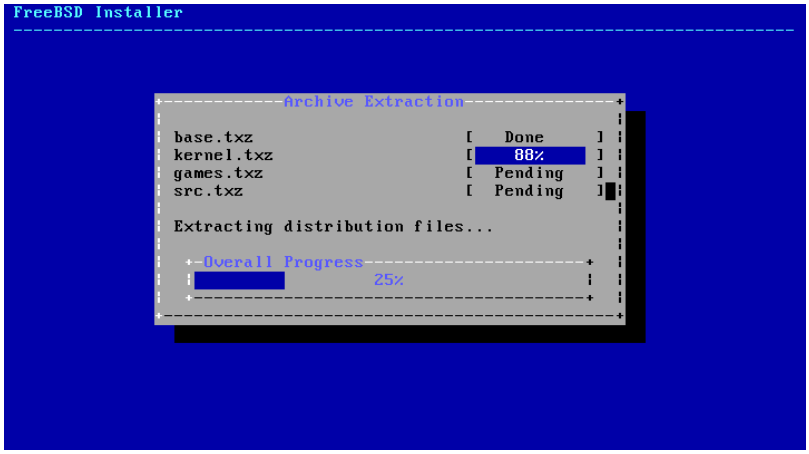
圖形 2.27. Fetching Distribution Files

Next, the integrity of the distribution files is verified to ensure they have not been corrupted during download or misread from the installation media:



圖形 2.28. Verifying Distribution Files

Finally, the verified distribution files are extracted to the disk:



圖形 2.29. Extracting Distribution Files

Once all requested distribution files have been extracted, bsdinstall displays the first post-installation configuration screen. The available post-configuration options are described in the next section.

2.8. Post-Installation

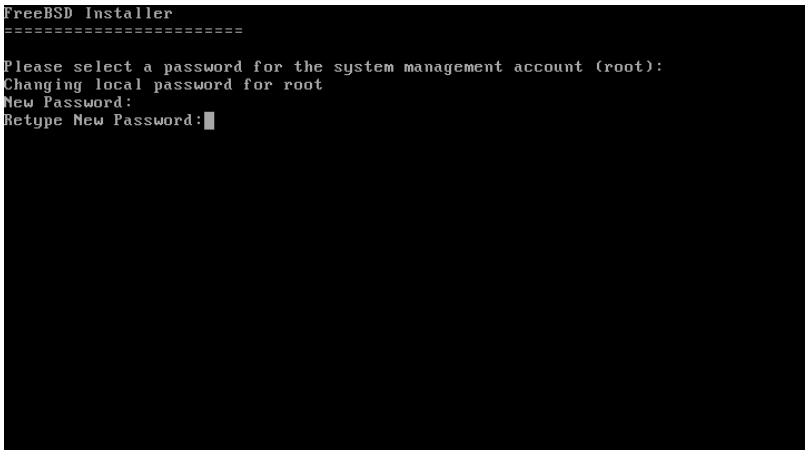
Once FreeBSD is installed, bsdinstall will prompt to configure several options before booting into the newly installed system. This section describes these configuration options.

提示

Once the system has booted, `bsdconfig` provides a menu-driven method for configuring the system using these and additional options.

2.8.1. Setting the `root` Password

First, the `root` password must be set. While entering the password, the characters being typed are not displayed on the screen. After the password has been entered, it must be entered again. This helps prevent typing errors.

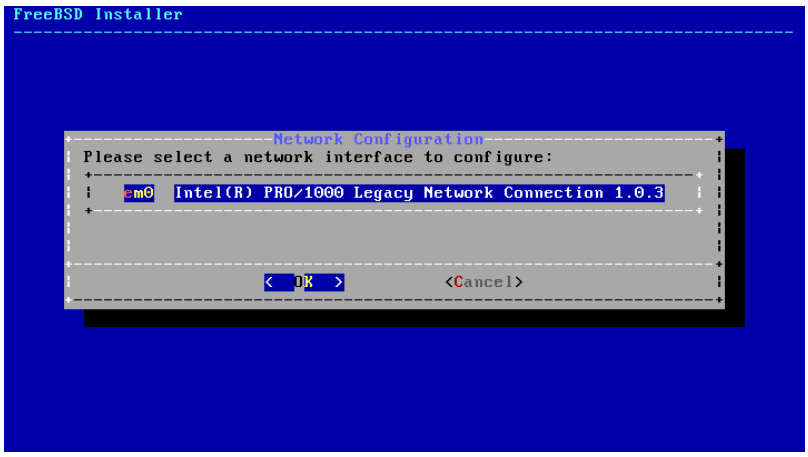


圖形 2.30. Setting the `root` Password

2.8.2. Configuring Network Interfaces

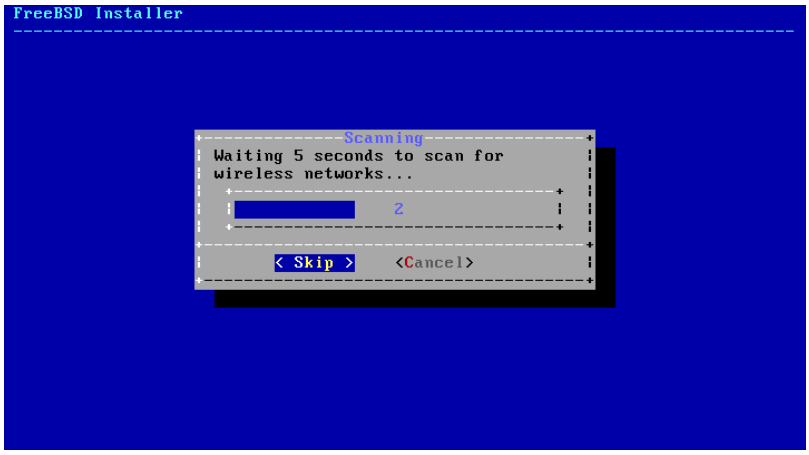
Next, a list of the network interfaces found on the computer is shown. Select the interface to configure.

> **注意**
>
> The network configuration menus will be skipped if the network was previously configured as part of a bootonly installation.



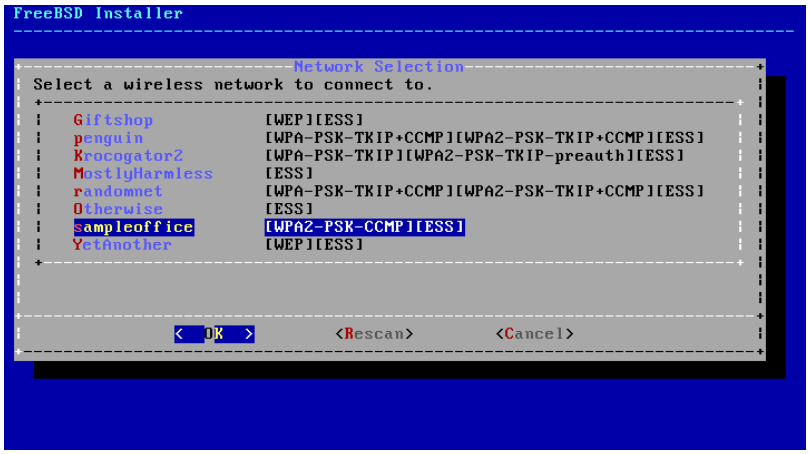
圖形 2.31. Choose a Network Interface

If an Ethernet interface is selected, the installer will skip ahead to the menu shown in 圖形 2.35, “Choose IPv4 Networking”. If a wireless network interface is chosen, the system will instead scan for wireless access points:



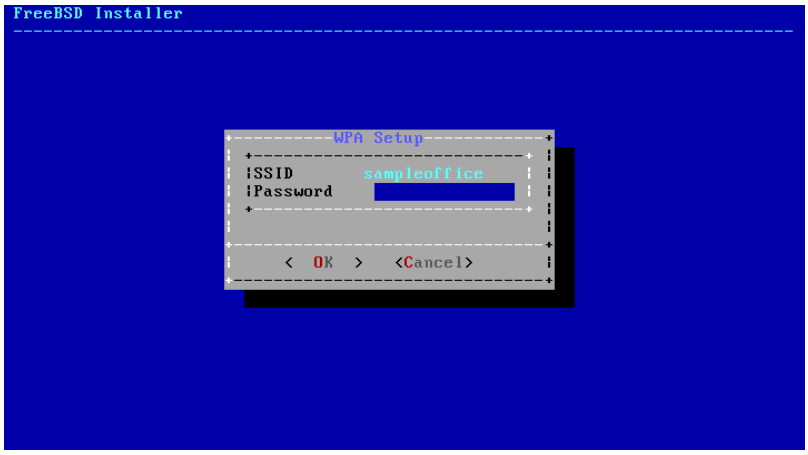
圖形 2.32. Scanning for Wireless Access Points

Wireless networks are identified by a Service Set Identifier (SSID), a short, unique name given to each network. SSIDs found during the scan are listed, followed by a description of the encryption types available for that network. If the desired SSID does not appear in the list, select [Rescan] to scan again. If the desired network still does not appear, check for problems with antenna connections or try moving the computer closer to the access point. Rescan after each change is made.



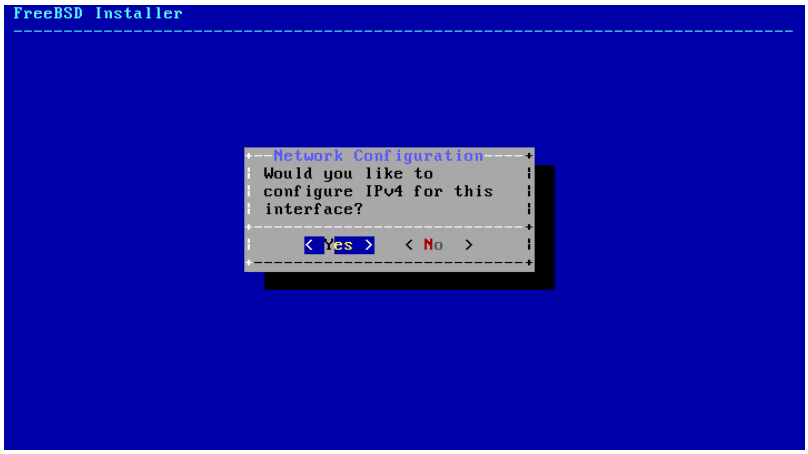
圖形 2.33. Choosing a Wireless Network

Next, enter the encryption information for connecting to the selected wireless network. WPA2 encryption is strongly recommended as older encryption types, like WEP, offer little security. If the network uses WPA2, input the password, also known as the Pre-Shared Key (PSK). For security reasons, the characters typed into the input box are displayed as asterisks.



圖形 2.34. WPA2 Setup

Next, choose whether or not an IPv4 address should be configured on the Ethernet or wireless interface:



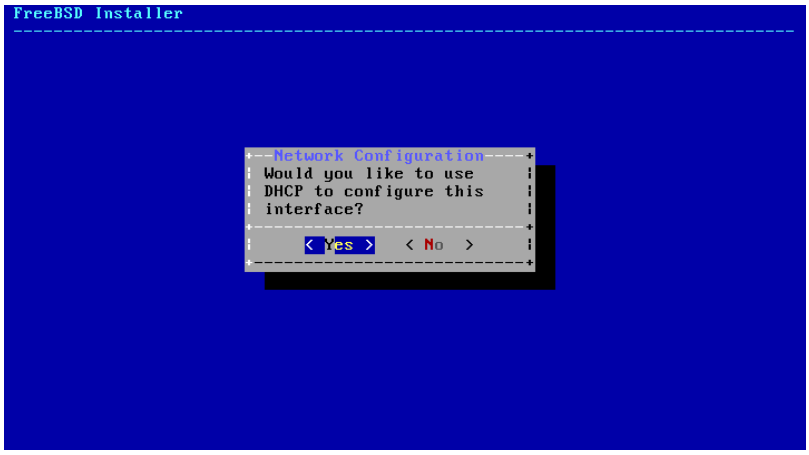
圖形 2.35. Choose IPv4 Networking

There are two methods of IPv4 configuration. DHCP will automatically configure the network interface correctly and should be used if the network provides a DHCP server. Otherwise, the addressing information needs to be input manually as a static configuration.

注意

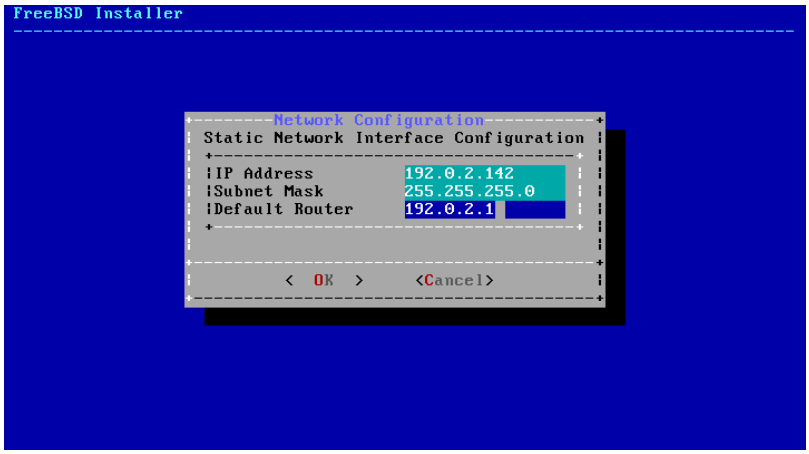
Do not enter random network information as it will not work. If a DHCP server is not available, obtain the information listed in 需要的網路資訊 from the network administrator or Internet service provider.

If a DHCP server is available, select [Yes] in the next menu to automatically configure the network interface. The installer will appear to pause for a minute or so as it finds the DHCP server and obtains the addressing information for the system.



圖形 2.36. Choose IPv4 DHCP Configuration

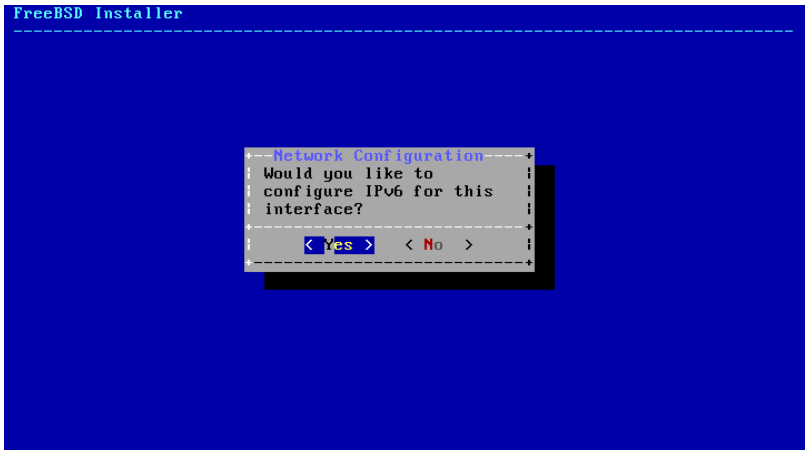
If a DHCP server is not available, select [No] and input the following addressing information in this menu:



圖形 2.37. IPv4 Static Configuration

- `IP Address` - The IPv4 address assigned to this computer. The address must be unique and not already in use by another piece of equipment on the local network.
- `Subnet Mask` - The subnet mask for the network.
- `Default Router` - The IP address of the network's default gateway.

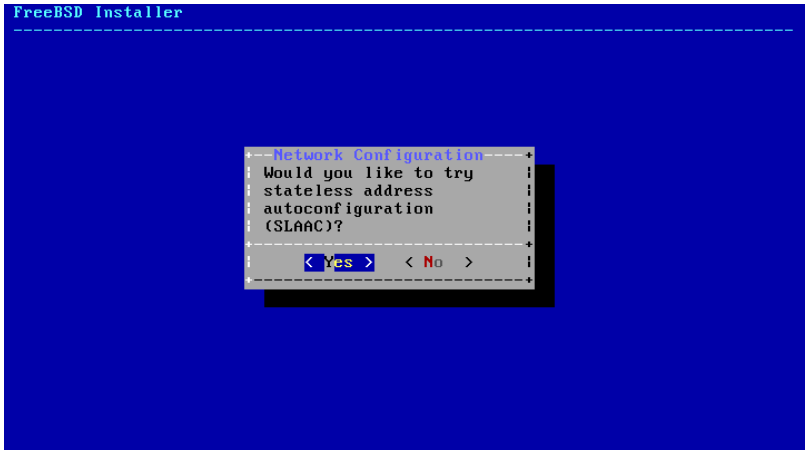
The next screen will ask if the interface should be configured for IPv6. If IPv6 is available and desired, choose [Yes] to select it.



圖形 2.38. Choose IPv6 Networking

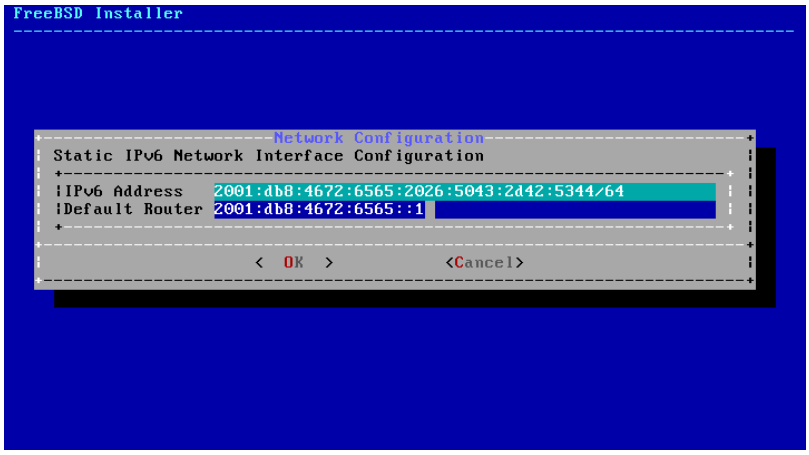
IPv6 also has two methods of configuration. StateLess Address AutoConfiguration (SLAAC) will automatically request the correct configuration information from a local router. Refer to http://tools.ietf.org/html/rfc4862 for more information. Static configuration requires manual entry of network information.

If an IPv6 router is available, select [Yes] in the next menu to automatically configure the network interface. The installer will appear to pause for a minute or so as it finds the router and obtains the addressing information for the system.



圖形 2.39. Choose IPv6 SLAAC Configuration

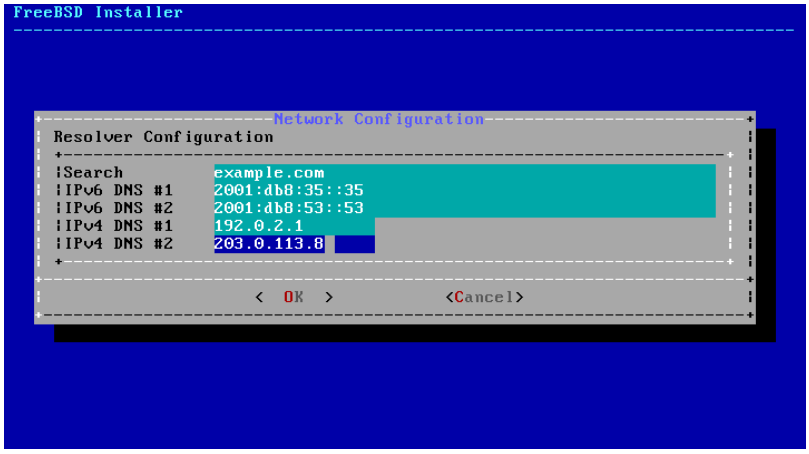
If an IPv6 router is not available, select [No] and input the following addressing information in this menu:



圖形 2.40. IPv6 Static Configuration

- `IPv6 Address` - The IPv6 address assigned to this computer. The address must be unique and not already in use by another piece of equipment on the local network.
- `Default Router` - The IPv6 address of the network's default gateway.

The last network configuration menu is used to configure the Domain Name System (DNS) resolver, which converts hostnames to and from network addresses. If DHCP or SLAAC was used to autoconfigure the network interface, the `Resolver Configuration` values may already be filled in. Otherwise, enter the local network's domain name in the `Search` field. `DNS #1` and `DNS #2` are the IPv4 and/or IPv6 addresses of the DNS servers. At least one DNS server is required.



圖形 2.41. DNS Configuration

2.8.3. 設定時區

The next menu asks if the system clock uses UTC or local time. When in doubt, select [No] to choose the more commonly-used local time.

圖形 2.42. Select Local or UTC Clock

The next series of menus are used to determine the correct local time by selecting the geographic region, country, and time zone. Setting the time zone allows the system to automatically correct for regional time changes, such as daylight savings time, and perform other time zone related functions properly.

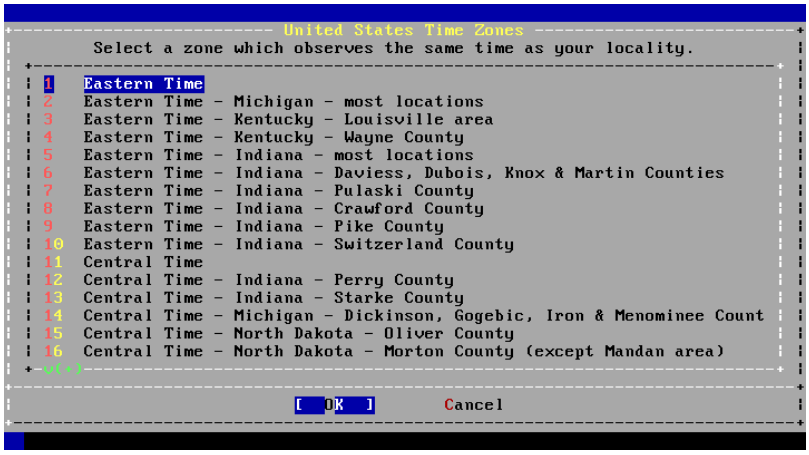
The example shown here is for a machine located in the Eastern time zone of the United States. The selections will vary according to the geographical location.

圖形 2.43. 選擇區域

The appropriate region is selected using the arrow keys and then pressing Enter.

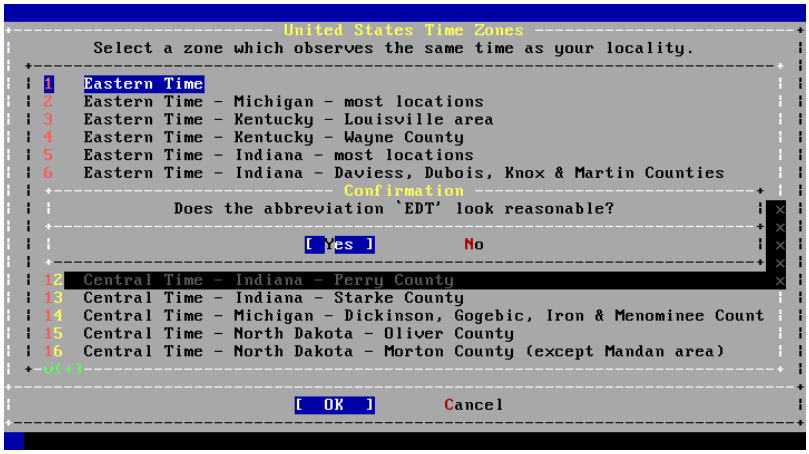
圖形 2.44. 選擇國家

Select the appropriate country using the arrow keys and press Enter.



圖形 2.45. 選擇時區

使用方向鍵選擇適當的時區，並按下 Enter。

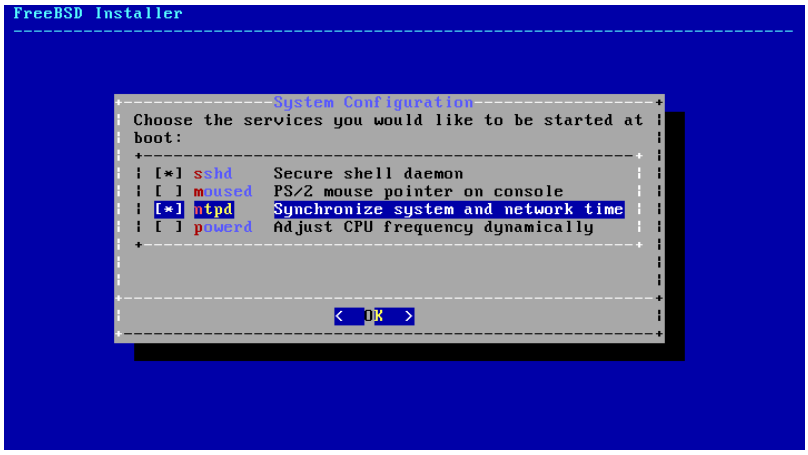


圖形 2.46. 確認時區

Confirm the abbreviation for the time zone is correct. If it is, press Enter to continue with the post-installation configuration.

2.8.4. 開啓服務

The next menu is used to configure which system services will be started whenever the system boots. All of these services are optional. Only start the services that are needed for the system to function.



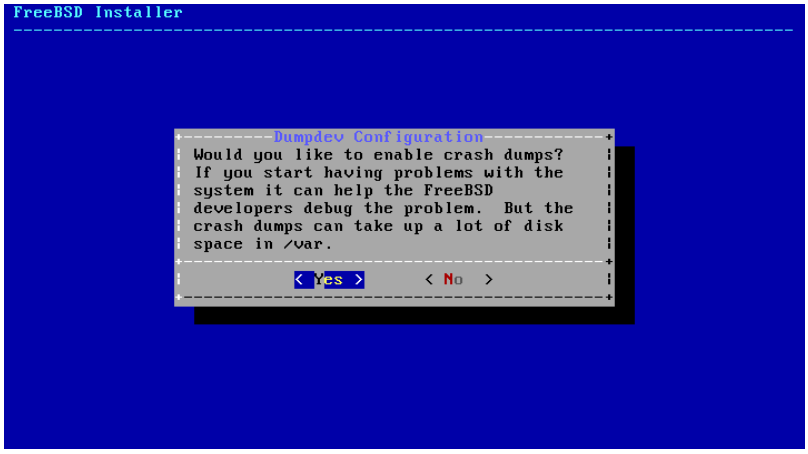
圖形 2.47. Selecting Additional Services to Enable

Here is a summary of the services which can be enabled in this menu:

- `sshd` - The Secure Shell (SSH) daemon is used to remotely access a system over an encrypted connection. Only enable this service if the system should be available for remote logins.
- `moused` - Enable this service if the mouse will be used from the command-line system console.
- `ntpd` - The Network Time Protocol (NTP) daemon for automatic clock synchronization. Enable this service if there is a Windows®, Kerberos, or LDAP server on the network.
- `powerd` - System power control utility for power control and energy saving.

2.8.5. Enabling Crash Dumps

The next menu is used to configure whether or not crash dumps should be enabled. Enabling crash dumps can be useful in debugging issues with the system, so users are encouraged to enable crash dumps.

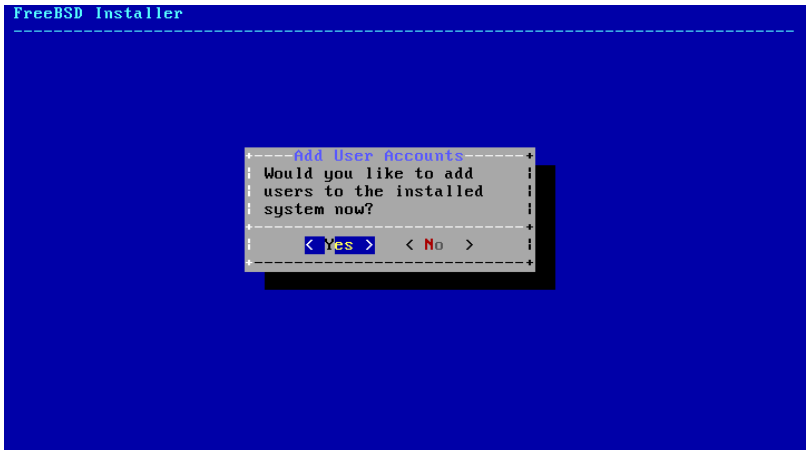


圖形 2.48. Enabling Crash Dumps

2.8.6. 加入使用者

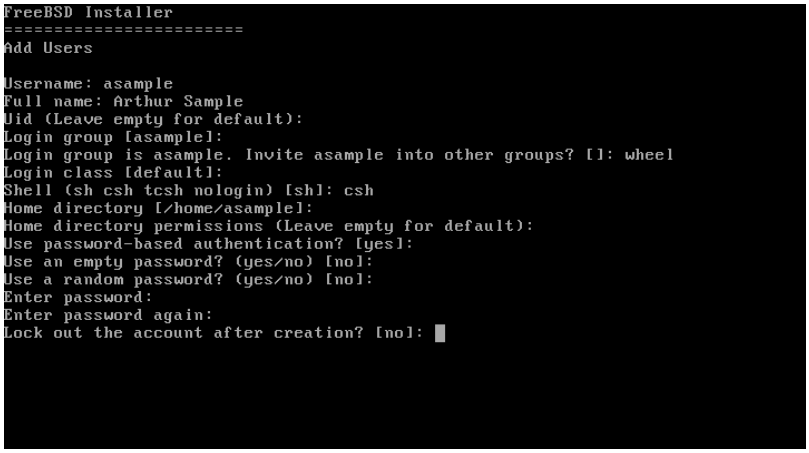
The next menu prompts to create at least one user account. It is recommended to login to the system using a user account rather than as `root`. When logged in as `root`, there are essentially no limits or protection on what can be done. Logging in as a normal user is safer and more secure.

Select [Yes] to add new users.



圖形 2.49. 加入使用者帳號

Follow the prompts and input the requested information for the user account. The example shown in 圖形 2.50, “輸入使用者資訊” creates the `asample` user account.



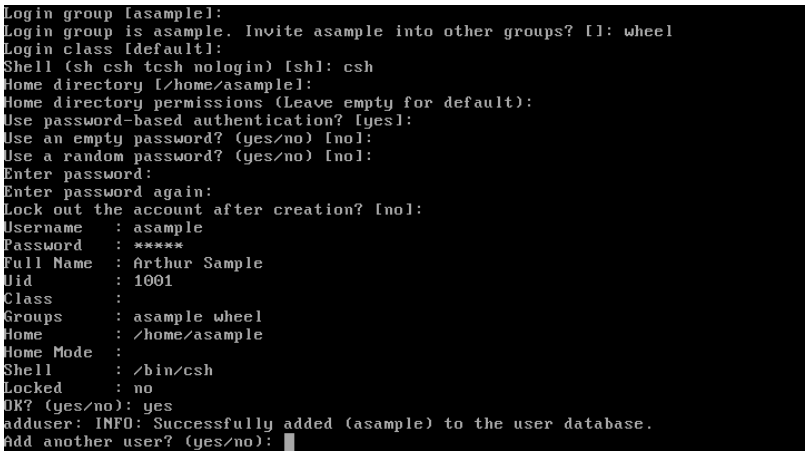
圖形 2.50. 輸入使用者資訊

Here is a summary of the information to input:

- `Username` - The name the user will enter to log in. A common convention is to use the first letter of the first name combined with the last name, as long as each username is unique for the system. The username is case sensitive and should not contain any spaces.
- `Full name` - The user's full name. This can contain spaces and is used as a description for the user account.
- `Uid` - User ID. Typically, this is left blank so the system will assign a value.
- `Login group` - The user's group. Typically this is left blank to accept the default.
- `Invite user into other groups?` - Additional groups to which the user will be added as a member. If the user needs administrative access, type `wheel` here.
- `Login class` - Typically left blank for the default.
- `Shell` - Type in one of the listed values to set the interactive shell for the user. Refer to 節 3.10, “Shells” for more information about shells.
- `Home directory` - The user's home directory. The default is usually correct.

- `Home directory permissions` - Permissions on the user's home directory. The default is usually correct.
- `Use password-based authentication?` - Typically `yes` so that the user is prompted to input their password at login.
- `Use an empty password?` - Typically `no` as it is insecure to have a blank password.
- `Use a random password?` - Typically `no` so that the user can set their own password in the next prompt.
- `Enter password` - The password for this user. Characters typed will not show on the screen.
- `Enter password again` - The password must be typed again for verification.
- `Lock out the account after creation?` - Typically `no` so that the user can login.

After entering everything, a summary is shown for review. If a mistake was made, enter `no` and try again. If everything is correct, enter `yes` to create the new user.



圖形 2.51. 離開使用者和群組管理

If there are more users to add, answer the `Add another user?` question with `yes`. Enter `no` to finish adding users and continue the installation.

For more information on adding users and user management, see 節 3.3, “Users and Basic Account Management”.

2.8.7. 最後設定

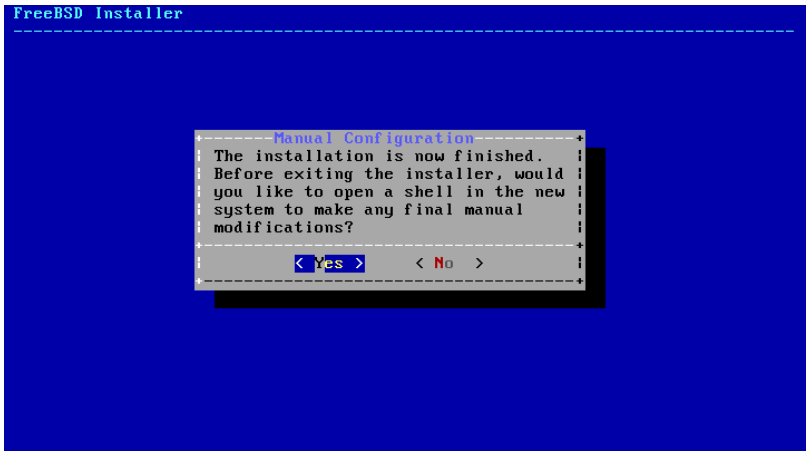
After everything has been installed and configured, a final chance is provided to modify settings.

圖形 2.52. 最後設定

Use this menu to make any changes or do any additional configuration before completing the installation.

- `Add User` - Described in 節 2.8.6, “加入使用者”.
- `Root Password` - Described in 節 2.8.1, “Setting the `root` Password”.
- `Hostname` - Described in 節 2.5.2, “設定主機名稱”.
- `Network` - Described in 節 2.8.2, “Configuring Network Interfaces”.
- `Services` - Described in 節 2.8.4, “開啓服務”.
- `Time Zone` - Described in 節 2.8.3, “設定時區”.
- `Handbook` - Download and install the FreeBSD Handbook.

After any final configuration is complete, select Exit.



圖形 2.53. Manual Configuration

bsdinstall will prompt if there are any additional configuration that needs to be done before rebooting into the new system. Select [Yes] to exit to a shell within the new system or [No] to proceed to the last step of the installation.

圖形 2.54. Complete the Installation

If further configuration or special setup is needed, select [Live CD] to boot the install media into Live CD mode.

If the installation is complete, select [Reboot] to reboot the computer and start the new FreeBSD system. Do not forget to remove the FreeBSD install media or the computer may boot from it again.

As FreeBSD boots, informational messages are displayed. After the system finishes booting, a login prompt is displayed. At the `login:` prompt, enter the username added during the installation. Avoid logging in as `root`. Refer to 節 3.3.1.3, "The Superuser Account" for instructions on how to become the superuser when administrative access is needed.

The messages that appeared during boot can be reviewed by pressing Scroll-Lock to turn on the scroll-back buffer. The PgUp, PgDn, and arrow keys can be used to scroll back through the messages. When finished, press Scroll-Lock again to unlock the display and return to the console. To review these messages once the system has been up for some time, type `less /var/run/dmesg.boot` from a command prompt. Press q to return to the command line after viewing.

If sshd was enabled in 圖形 2.47, "Selecting Additional Services to Enable", the first boot may be a bit slower as the system will generate the RSA and DSA keys. Subsequent boots will be faster. The fingerprints of the keys will be displayed, as seen in this example:

```
Generating public/private rsa1 key pair.
Your identification has been saved in /etc/ssh/ssh_host_key.
Your public key has been saved in /etc/ssh/ssh_host_key.pub.
The key fingerprint is:
10:a0:f5:af:93:ae:a3:1a:b2:bb:3c:35:d9:5a:b3:f3 root@machine3.example.com
The key's randomart image is:
+--[RSA1 1024]----+
|    o..          |
|   o . .         |
|  .   o          |
|       o         |
|    o   S        |
|   + + o         |
|o . + *          |
|o+ ..+ .         |
|==o..o+E         |
+-----------------+
Generating public/private dsa key pair.
Your identification has been saved in /etc/ssh/ssh_host_dsa_key.
Your public key has been saved in /etc/ssh/ssh_host_dsa_key.pub.
The key fingerprint is:
7e:1c:ce:dc:8a:3a:18:13:5b:34:b5:cf:d9:d1:47:b2 root@machine3.example.com
The key's randomart image is:
+--[ DSA 1024]----+
```

```
|       ..     . .|
|      o  .    . + |
|     . ..    . E .|
|    . .  o o . . |
|     +  S = .    |
|    +  . = o     |
|     +  . * .    |
|    . .  o .     |
|      .o. .      |
+-----------------+
Starting sshd.
```

Refer to 節 13.8, “OpenSSH” for more information about fingerprints and SSH.

FreeBSD does not install a graphical environment by default. Refer to 章 5, X Window 視窗系統 for more information about installing and configuring a graphical window manager.

Proper shutdown of a FreeBSD computer helps protect data and hardware from damage. Do not turn off the power before the system has been properly shut down! If the user is a member of the `wheel` group, become the superuser by typing `su` at the command line and entering the `root` password. Then, type `shutdown -p now` and the system will shut down cleanly, and if the hardware supports it, turn itself off.

2.9. 故障排除

This section covers basic installation troubleshooting, such as common problems people have reported.

Check the Hardware Notes (http://www.freebsd.org/releases/index.html) document for the version of FreeBSD to make sure the hardware is supported. If the hardware is supported and lock-ups or other problems occur, build a custom kernel using the instructions in 章 8, 設定 FreeBSD Kernel to add support for devices which are not present in the `GENERIC` kernel. The default kernel assumes that most hardware devices are in their factory default configuration in terms of IRQs, I/O addresses, and DMA channels. If the hardware has been reconfigured, a custom kernel configuration file can tell FreeBSD where to find things.

注意

Some installation problems can be avoided or alleviated by updating the firmware on various hardware components, most notably the motherboard. Motherboard firmware is usually referred to as the BIOS. Most motherboard and computer manufacturers have a website for upgrades and upgrade information.

Manufacturers generally advise against upgrading the motherboard BIOS unless there is a good reason for doing so, like a critical update. The upgrade process can go wrong, leaving the BIOS incomplete and the computer inoperative.

If the system hangs while probing hardware during boot, or it behaves strangely during install, ACPI may be the culprit. FreeBSD makes extensive use of the system ACPI service on the i386, amd64, and ia64 platforms to aid in system configuration if it is detected during boot. Unfortunately, some bugs still exist in both the ACPI driver and within system motherboards and BIOS firmware. ACPI can be disabled by setting the `hint.acpi.0.disabled` hint in the third stage boot loader:

```
set hint.acpi.0.disabled="1"
```

This is reset each time the system is booted, so it is necessary to add `hint.acpi.0.disabled="1"` to the file `/boot/loader.conf`. More information about the boot loader can be found in 節 12.1, “概述”.

2.10. 使用 Live CD

The welcome menu of bsdinstall, shown in 圖形 2.3, “歡迎選單”, provides a [Live CD] option. This is useful for those who are still wondering whether FreeBSD is the right operating system for them and want to test some of the features before installing.

The following points should be noted before using the [Live CD]:

- To gain access to the system, authentication is required. The username is `root` and the password is blank.
- As the system runs directly from the installation media, performance will be significantly slower than that of a system installed on a hard disk.
- This option only provides a command prompt and not a graphical interface.

章 3. UNIX 基礎概念

3.1. 概述

接下來的這一章將涵蓋 FreeBSD 作業系統的基本指令及功能。 大部份的內容在 UNIX®-like 作業系統中都是相通的。 如果您對這些內容熟悉的話，可以放心的跳過。 如果您剛接觸 FreeBSD，那您一定要仔細的讀完這章。

讀完這章，您將了解：

- 如何使用 FreeBSD 的“virtual consoles”。
- UNIX® 檔案權限運作的方式以及 FreeBSD 中檔案的 flags。
- 預設的 FreeBSD 檔案系統配置。
- FreeBSD 的磁碟結構。
- 如何掛載(mount)、卸載(umount)檔案系統
- 什麼是processes、daemons 以及 signals 。
- 什麼是 shell ，以及如何變更您預設的登入環境。
- 如何使用基本的文字編輯器。
- 什麼是 devices 和 device nodes 。
- FreeBSD 下使用的 binary 格式。
- 如何閱讀 manual pages 以獲得更多的資訊。

3.2. Virtual Consoles 和終端機

有很多方法可以操作 FreeBSD ，其中一種就是在文字終端機上打字。 如此使用 FreeBSD 即可輕易的體會到 UNIX® 作業系統的威力和彈性。 這一節描述什麼是“終端機”和“console”，以及可以如何在 FreeBSD 中運用它們。

3.2.1. The Console

如果您沒有將 FreeBSD 設定成開機時自動進入圖形化模式，系統會在啓動的 script 跑完之後顯示登入的提示符號。 您將會看到像是這樣的東西：

```
Additional ABI support:.
Local package initialization:.
Additional TCP options:.

Fri Sep 20 13:01:06 EEST 2002

FreeBSD/i386 (pc3.example.org) (ttyv0)

login:
```

這個訊息在您的系統上會有些許的不同，但是應該會看到類似的東西。 我們感興趣的是最後兩行，最後兩行是：

```
FreeBSD/i386 (pc3.example.org) (ttyv0)
```

這行包含了剛開機完系統的資訊。 您看到的是在 Intel 或相容處理器的 x86 架構上執行的 “FreeBSD”的 console[1]。 這台機器的名字(每台 UNIX® 機器都有一個名字)是 pc3.example.org ，而您現在看到的是它的系統 console—— ttyv0終端機。

最後的一行應該都會是：

```
login:
```

這是您應該要輸入您的“帳號名稱”的地方。 下一小節將告訴您如何登入 FreeBSD。

3.2.2. 登入 FreeBSD

FreeBSD 是一個 multiuser、multiprocessing 的系統。 這是一個正式的名稱，指的是在單一機器上可以同時被不同人使用， 但同時可以執行很多程式的系統。

每一種多使用者系統都需要可以分辨不同“使用者”的方法。 在 FreeBSD （以及所有的 UNIX®-like 作業系統） 中，所有的使用者在執行程式之前必須先“登入”系統。 每個使用者都有一組獨特的帳號名稱(“username”)及密碼(“password”)。 FreeBSD 在允許使用者執行程式前將會先問這兩個問題。

在 FreeBSD 開機並跑完啓動的 script 之後[2]，它將會印出提示字元要求您輸入正確的帳號名稱：

```
login:
```

在這個範例裡，我們假設您的帳號是john。 在提示字元處輸入 john 並按下 Enter 。 接著您應該會看到另一個提示字元要您輸入“密碼” ：

```
login: john
Password:
```

輸入 john 的密碼，再按下 Enter。 輸入的密碼 不會顯示在螢幕上。 您不需要為此擔心，這樣做是為了安全上的問題。

如果您輸入了正確的密碼，您應該已經登入 FreeBSD。 現在就可以嘗試所有可用的指令了。

您應該會看到MOTD (即今日訊息、Messages Of The Day)，後面接著命令提示字元 (一個 #,$, 或是 % 字元)。 這就表示您已經成功登入 FreeBSD 了。

3.2.3. 多重 Console

在一個 Console 下執行 UNIX® 當然是沒有問題，然而 FreeBSD 是可以同時執行很多程式的。 像 FreeBSD 這樣可以同時執行一大堆程式的作業系統，只有一個 console 可以輸入指令實在是有點浪費。 因此 “virtual consoles” 就顯得相當好用。

可以設定讓 FreeBSD 同時有很多 virtual console， 用幾個按鍵的組合就可以從一個 virtual console 跳到別的 virtual console 。 每一個 console 都有自己不同的輸出頻道，當從某一個 virtual console 切換到下一個的時候，FreeBSD 會自動處理鍵盤輸入及螢幕輸出。

FreeBSD 保留了特別的按鍵組合來切換 console [3]。 您可以用 Alt+F1 、 Alt+F2 、到 Alt+F8 來切換 FreeBSD 的不同 console。

[1]這就是 i386 的意義。 注意即使您不是在 Intel 的 386 處理器上執行 FreeBSD ，一樣是i386。 這不是指你的處理器的型號，這裡顯示的是你處理器的“架構”

[2]這些啓動的 script 是在開機的時候 FreeBSD 會自動執行的程式。 他們主要的功能是將所有該執行的東西設定好， 並將您設定成背景執行的服務啓動。

[3]在 syscons(4)、atkbd(4)、vidcontrol(1)、以及 kbdcontrol(1)等 manual page 中，對於 FreeBSD 的 console 及鍵盤驅動程式有詳細的技術說明。 我們在這裡不討論細節， 有興趣的讀者隨時可以在 manual pages 中查到關於運作方式的更詳細且完整的解釋。

當您從一個 console 切換到下一個的時候，FreeBSD 會處理螢幕輸出的儲存及回復。 這就“好像”有很多“虛擬”的螢幕和鍵盤， 可以讓您輸入指令到 FreeBSD 執行。 在某一個 console 上執行的程式並不會因為切到別的 console 而停止執行，切換到另一個 console 時，它們仍會繼續執行。

3.2.4. /etc/ttys 檔

FreeBSD 預設的虛擬 console 總共有 8 個， 但這並非硬性規定，您可輕鬆設定這些虛擬 console 的數量增減。 有關虛擬 console 的編號跟設定都在 /etc/ttys 這檔案內設定。

可以用 /etc/ttys 檔案來設定 FreeBSD 的虛擬 console。 檔案內每行非註解文字(該行開頭沒有 # 這字)都是設定終端機或虛擬 console。 FreeBSD 預設有 9 個虛擬 console 但只啓動 8 個，也就是以下以 ttyv 開頭的那幾行設定。

```
# name  getty                           type    status          comments
#
ttyv0   "/usr/libexec/getty Pc"         cons25  on  secure
# Virtual terminals
ttyv1   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv2   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv3   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv4   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv5   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv6   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv7   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv8   "/usr/X11R6/bin/xdm -nodaemon"  xterm   off secure
```

有關各欄位的設定以及其他選項，請參閱 ttys(5) 說明。

3.2.5. Single User 模式的 Console

有關“single user 模式” 的介紹在 節 12.6.2, “Single-User Mode” 這邊有詳盡介紹。 在 single user 模式時，能夠使用的 console 只有一個，並無虛擬 console 可用。 而 single user 模式相關設定值可以在 /etc/ttys 檔做調整。 下面以 console 開頭的那行，就是了：

```
# name  getty                           type    status          comments
#
# If console is marked "insecure", then init will ask for the root password
# when going to single-user mode.
console none                            unknown off secure
```

注意

在 console 那行前面的註解有提到，可以把那行的 secure 改為 insecure ， 如此一來，即使 FreeBSD 進入 single user 模式， 仍會要求您輸入 root 的密碼。

請審慎考慮是否要改為 **insecure** 。 因為萬一忘記 root 密碼的話，若要登入 single user 模式就有些麻煩了。儘管還有其他方式可以登入，但對不熟 FreeBSD 開機程序的人而言，就會相當棘手。

3.2.6. 更改 console 的顯示畫面

FreeBSD console 預設顯示大小可以調整為 1024x768、1280x1024 或其他顯示卡與螢幕有支援的解析度大小。 要切換顯示大小，必須要重新編譯 kernel 並加入下面這兩項設定：

```
options VESA
options SC_PIXEL_MODE
```

一旦 kernel 有加入這兩項並重新編譯完畢，就可以用 vidcontrol(1) 來偵測目前所支援的模式有哪些。 若要查看支援的模式，可以打：

```
# vidcontrol -i mode
```

該指令會顯示該機器所支援的顯示模式清單。 然後可以在 `root` console 內透過 vidcontrol(1) 指令， 來更改顯示模式：

```
# vidcontrol MODE_279
```

若對新的顯示模式覺得還不錯，可以在 `/etc/rc.conf` 設定之，以讓每次重開機後會自動生效。 以上面這情況為例，就是：

```
allscreens_flags="MODE_279"
```

3.3. Users and Basic Account Management

FreeBSD allows multiple users to use the computer at the same time. While only one user can sit in front of the screen and use the keyboard at any one time, any number of users can log in to the system through the network. To use the system, each user should have their own user account.

This chapter describes:

- The different types of user accounts on a FreeBSD system.
- How to add, remove, and modify user accounts.
- How to set limits to control the resources that users and groups are allowed to access.
- How to create groups and add users as members of a group.

3.3.1. Account Types

Since all access to the FreeBSD system is achieved using accounts and all processes are run by users, user and account management is important.

There are three main types of accounts: system accounts, user accounts, and the superuser account.

3.3.1.1. System Accounts

System accounts are used to run services such as DNS, mail, and web servers. The reason for this is security; if all services ran as the superuser, they could act without restriction.

Examples of system accounts are `daemon`, `operator`, `bind`, `news`, and `www`.

`nobody` is the generic unprivileged system account. However, the more services that use `nobody`, the more files and processes that user will become associated with, and hence the more privileged that user becomes.

3.3.1.2. User Accounts

User accounts are assigned to real people and are used to log in and use the system. Every person accessing the system should have a unique user account. This allows the administrator to find out who is doing what and prevents users from clobbering the settings of other users.

Each user can set up their own environment to accommodate their use of the system, by configuring their default shell, editor, key bindings, and language settings.

Every user account on a FreeBSD system has certain information associated with it:

User name
: The user name is typed at the `login:` prompt. Each user must have a unique user name. There are a number of rules for creating valid user names which are documented in passwd(5). It is recommended to use user

names that consist of eight or fewer, all lower case characters in order to maintain backwards compatibility with applications.

Password
Each account has an associated password.

User ID (UID)
The User ID (UID) is a number used to uniquely identify the user to the FreeBSD system. Commands that allow a user name to be specified will first convert it to the UID. It is recommended to use a UID less than 65535, since higher values may cause compatibility issues with some software.

Group ID (GID)
The Group ID (GID) is a number used to uniquely identify the primary group that the user belongs to. Groups are a mechanism for controlling access to resources based on a user's GID rather than their UID. This can significantly reduce the size of some configuration files and allows users to be members of more than one group. It is recommended to use a GID of 65535 or lower as higher GIDs may break some software.

Login class
Login classes are an extension to the group mechanism that provide additional flexibility when tailoring the system to different users. Login classes are discussed further in 節 13.13.1, “Configuring Login Classes”.

Password change time
By default, passwords do not expire. However, password expiration can be enabled on a per-user basis, forcing some or all users to change their passwords after a certain amount of time has elapsed.

Account expiry time
By default, FreeBSD does not expire accounts. When creating accounts that need a limited lifespan, such as student accounts in a school, specify the account expiry date using pw(8). After the expiry time has elapsed, the account cannot be used to log in to the system, although the account's directories and files will remain.

User's full name
The user name uniquely identifies the account to FreeBSD, but does not necessarily reflect the user's real name. Similar to a comment, this information can contain spaces, uppercase characters, and be more than 8 characters long.

Home directory
The home directory is the full path to a directory on the system. This is the user's starting directory when the user logs in. A common convention is to put all user home directories under `/home/username` or `/usr/home/username`. Each user stores their personal files and subdirectories in their own home directory.

User shell
The shell provides the user's default environment for interacting with the system. There are many different kinds of shells and experienced users will have their own preferences, which can be reflected in their account settings.

3.3.1.3. The Superuser Account

The superuser account, usually called `root`, is used to manage the system with no limitations on privileges. For this reason, it should not be used for day-to-day tasks like sending and receiving mail, general exploration of the system, or programming.

The superuser, unlike other user accounts, can operate without limits, and misuse of the superuser account may result in spectacular disasters. User accounts are unable to destroy the operating system by mistake, so it is recommended to login as a user account and to only become the superuser when a command requires extra privilege.

Always double and triple-check any commands issued as the superuser, since an extra space or missing character can mean irreparable data loss.

There are several ways to gain superuser privilege. While one can log in as `root`, this is highly discouraged.

Instead, use su(1) to become the superuser. If `-` is specified when running this command, the user will also inherit the root user's environment. The user running this command must be in the `wheel` group or else the command will fail. The user must also know the password for the `root` user account.

In this example, the user only becomes superuser in order to run `make install` as this step requires superuser privilege. Once the command completes, the user types `exit` to leave the superuser account and return to the privilege of their user account.

範例 3.1. Install a Program As the Superuser

```
% configure
% make
% su -
Password:
# make install
# exit
%
```

The built-in su(1) framework works well for single systems or small networks with just one system administrator. An alternative is to install the security/sudo package or port. This software provides activity logging and allows the administrator to configure which users can run which commands as the superuser.

3.3.2. Managing Accounts

FreeBSD provides a variety of different commands to manage user accounts. The most common commands are summarized in 表格 3.1, “Utilities for Managing User Accounts”, followed by some examples of their usage. See the manual page for each utility for more details and usage examples.

表格 3.1. Utilities for Managing User Accounts

Command	Summary
adduser(8)	The recommended command-line application for adding new users.
rmuser(8)	The recommended command-line application for removing users.
chpass(1)	A flexible tool for changing user database information.
passwd(1)	The command-line tool to change user passwords.
pw(8)	A powerful and flexible tool for modifying all aspects of user accounts.

3.3.2.1. `adduser`

The recommended program for adding new users is adduser(8). When a new user is added, this program automatically updates `/etc/passwd` and `/etc/group`. It also creates a home directory for the new user, copies in the default configuration files from `/usr/share/skel`, and can optionally mail the new user a welcome message. This utility must be run as the superuser.

The adduser(8) utility is interactive and walks through the steps for creating a new user account. As seen in 範例 3.2, “Adding a User on FreeBSD”, either input the required information or press Return to accept the default value shown in square brackets. In this example, the user has been invited into the `wheel` group, allowing them to become the superuser with su(1). When finished, the utility will prompt to either create another user or to exit.

範例 3.2. Adding a User on FreeBSD

```
# adduser
Username: jru
Full name: J. Random User
Uid (Leave empty for default):
Login group [jru]:
Login group is jru. Invite jru into other groups? []: wheel
Login class [default]:
Shell (sh csh tcsh zsh nologin) [sh]: zsh
Home directory [/home/jru]:
Home directory permissions (Leave empty for default):
Use password-based authentication? [yes]:
Use an empty password? (yes/no) [no]:
Use a random password? (yes/no) [no]:
Enter password:
Enter password again:
Lock out the account after creation? [no]:
Username   : jru
Password   : ****
Full Name  : J. Random User
Uid        : 1001
Class      :
Groups     : jru wheel
Home       : /home/jru
Shell      : /usr/local/bin/zsh
Locked     : no
OK? (yes/no): yes
adduser: INFO: Successfully added (jru) to the user database.
Add another user? (yes/no): no
Goodbye!
#
```

注意

Since the password is not echoed when typed, be careful to not mistype the password when creating the user account.

3.3.2.2. `rmuser`

To completely remove a user from the system, run rmuser(8) as the superuser. This command performs the following steps:

1. Removes the user's crontab(1) entry, if one exists.
2. Removes any at(1) jobs belonging to the user.
3. Kills all processes owned by the user.
4. Removes the user from the system's local password file.
5. Optionally removes the user's home directory, if it is owned by the user.
6. Removes the incoming mail files belonging to the user from `/var/mail` .

7. Removes all files owned by the user from temporary file storage areas such as `/tmp`.

8. Finally, removes the username from all groups to which it belongs in `/etc/group`. If a group becomes empty and the group name is the same as the username, the group is removed. This complements the per-user unique groups created by adduser(8).

rmuser(8) cannot be used to remove superuser accounts since that is almost always an indication of massive destruction.

By default, an interactive mode is used, as shown in the following example.

範例 3.3. **rmuser** Interactive Account Removal

```
# rmuser jru
Matching password entry:
jru:*:1001:1001::0:0:J. Random User:/home/jru:/usr/local/bin/zsh
Is this the entry you wish to remove? y
Remove user's home directory (/home/jru)? y
Removing user (jru): mailspool home passwd.
#
```

3.3.2.3. chpass

Any user can use chpass(1) to change their default shell and personal information associated with their user account. The superuser can use this utility to change additional account information for any user.

When passed no options, aside from an optional username, chpass(1) displays an editor containing user information. When the user exits from the editor, the user database is updated with the new information.

注意

This utility will prompt for the user's password when exiting the editor, unless the utility is run as the superuser.

In 範例 3.4, “Using `chpass` as Superuser”, the superuser has typed `chpass jru` and is now viewing the fields that can be changed for this user. If `jru` runs this command instead, only the last six fields will be displayed and available for editing. This is shown in 範例 3.5, “Using `chpass` as Regular User”.

範例 3.4. Using **chpass** as Superuser

```
#Changing user database information for jru.
Login: jru
Password: *
Uid [#]: 1001
Gid [# or name]: 1001
Change [month day year]:
Expire [month day year]:
Class:
Home directory: /home/jru
Shell: /usr/local/bin/zsh
```

```
Full Name: J. Random User
Office Location:
Office Phone:
Home Phone:
Other information:
```

範例 3.5. Using **chpass** as Regular User

```
#Changing user database information for jru.
Shell: /usr/local/bin/zsh
Full Name: J. Random User
Office Location:
Office Phone:
Home Phone:
Other information:
```

注意

The commands chfn(1) and chsh(1) are links to chpass(1), as are ypchpass(1), ypchfn(1), and ypchsh(1). Since NIS support is automatic, specifying the `yp` before the command is not necessary. How to configure NIS is covered in 章 28, 網路伺服器.

3.3.2.4. passwd

Any user can easily change their password using passwd(1). To prevent accidental or unauthorized changes, this command will prompt for the user's original password before a new password can be set:

範例 3.6. Changing Your Password

```
% passwd
Changing local password for jru.
Old password:
New password:
Retype new password:
passwd: updating the database...
passwd: done
```

The superuser can change any user's password by specifying the username when running passwd(1). When this utility is run as the superuser, it will not prompt for the user's current password. This allows the password to be changed when a user cannot remember the original password.

範例 3.7. Changing Another User's Password as the Superuser

```
# passwd jru
```

```
Changing local password for jru.
New password:
Retype new password:
passwd: updating the database...
passwd: done
```

注意

As with chpass(1), yppasswd(1) is a link to passwd(1), so NIS works with either command.

3.3.2.5. pw

The pw(8) utility can create, remove, modify, and display users and groups. It functions as a front end to the system user and group files. pw(8) has a very powerful set of command line options that make it suitable for use in shell scripts, but new users may find it more complicated than the other commands presented in this section.

3.3.3. Managing Groups

A group is a list of users. A group is identified by its group name and GID. In FreeBSD, the kernel uses the UID of a process, and the list of groups it belongs to, to determine what the process is allowed to do. Most of the time, the GID of a user or process usually means the first group in the list.

The group name to GID mapping is listed in `/etc/group` . This is a plain text file with four colon-delimited fields. The first field is the group name, the second is the encrypted password, the third the GID, and the fourth the comma-delimited list of members. For a more complete description of the syntax, refer to group(5).

The superuser can modify `/etc/group` using a text editor. Alternatively, pw(8) can be used to add and edit groups. For example, to add a group called `teamtwo` and then confirm that it exists:

範例 3.8. Adding a Group Using pw(8)

```
# pw groupadd teamtwo
# pw groupshow teamtwo
teamtwo:*:1100:
```

In this example, `1100` is the GID of `teamtwo` . Right now, `teamtwo` has no members. This command will add `jru` as a member of `teamtwo` .

範例 3.9. Adding User Accounts to a New Group Using pw(8)

```
# pw groupmod teamtwo -M jru
# pw groupshow teamtwo
teamtwo:*:1100:jru
```

The argument to `-M` is a comma-delimited list of users to be added to a new (empty) group or to replace the members of an existing group. To the user, this group membership is different from (and in addition to) the user's primary group listed in the password file. This means that the user will not show up as a member when using `groupshow` with pw(8), but will show up when the information is queried via id(1) or a similar tool. When pw(8) is used to add a user to a group, it only manipulates `/etc/group` and does not attempt to read additional data from `/etc/passwd` .

範例 3.10. Adding a New Member to a Group Using pw(8)

```
# pw groupmod teamtwo -m db
# pw groupshow teamtwo
teamtwo:*:1100:jru,db
```

In this example, the argument to `-m` is a comma-delimited list of users who are to be added to the group. Unlike the previous example, these users are appended to the group and do not replace existing users in the group.

範例 3.11. Using id(1) to Determine Group Membership

```
% id jru
uid=1001(jru) gid=1001(jru) groups=1001(jru), 1100(teamtwo)
```

In this example, `jru` is a member of the groups `jru` and `teamtwo` .

For more information about this command and the format of `/etc/group` , refer to pw(8) and group(5).

3.4. 權限

FreeBSD 源自於 BSD UNIX®，繼承了幾個重要的 UNIX® 概念。 首先也最明顯，它是一款 multi-user 作業系統。 它可以同時處理多人多工， 負責徹底的分享與管理來自每位使用者對硬碟裝置、週邊設備、記憶體及 CPU 時間的要求。

也因為系統能夠支援多使用者， 所以系統管理的一切都有權限來決定誰可以讀取、寫入或執行資源。 這些權限分別使用三組八進位的數字儲存，一組代表檔案的所有者， 一組代表檔案所屬的群組，而最後一組則代表其他所有人。 表示這些數字的方式如下：

值	權限	目錄顯示
0	不可讀取，不可寫入，不可執行	`---`
1	不可讀取，不可寫入，可執行	`--x`
2	不可讀取，可寫入，不可執行	`-w-`
3	不可讀取，可寫入，可執行	`-wx`
4	可讀取，不可寫入，不可執行	`r--`
5	可讀取，不可寫入，可執行	`r-x`
6	可讀取，可寫入，不可執行	`rw-`

值	權限	目錄顯示
7	可讀取，可寫入，可執行	rwx

使用 ls(1) 指令時，可以加上 `-l` 參數， 來檢視詳細的目錄清單。 清單中欄位的資訊包含檔案對所有者、群組及其他人的權限。 在任一個目錄底下執行 `ls -l`，會顯示如下的結果：

```
% ls -l
total 530
-rw-r--r--  1 root  wheel     512 Sep  5 12:31 myfile
-rw-r--r--  1 root  wheel     512 Sep  5 12:31 otherfile
-rw-r--r--  1 root  wheel    7680 Sep  5 12:31 email.txt
...
```

在這裡告所您該如何區分 `ls -l` 第一欄當中的資訊：

```
-rw-r--r--
```

第一個 （最左邊） 的字元用來表示這個檔案的類型為何， 除標準檔案以外，尚有目錄、特殊字元裝置 (Special character `device`)、 Socket 及其他特殊虛擬檔案裝置 (Special pseudo-file `device`)， 在此例當中，`-` 表示該檔案為一個標準的檔案。 範例中接下來的三個字元中，`rw-` 代表所有者對檔案擁有的權限。 再接下來的三個字元， `r--` 則代表群組對檔案擁有的權限， 最後三個字元，`r--` 則代表其他人對檔案擁有的權限。 破折號 (-) 表示沒有權限，範例中的這個檔案的權限， 只允許所有者讀取、寫入檔案，群組以及其他人僅能讀取檔案。 根據以上的表格，此種權限的檔案可以使用 `644` 來表示， 每組數字分別代表檔案的三種權限。

以上是不錯的方式，但系統該如何控制裝置的權限？ 實際上 FreeBSD 對大多的硬碟裝置就如同檔案，程式可以開啓、讀取以及寫入資料如一般檔案。 這些特殊裝置檔案 (Special device file) 都儲存於 `/dev` 目錄中。

目錄也同如檔案，擁有讀取、寫入及執行的權限， 但在執行權限上與檔案有明顯的差異。 當目錄被標示為可執行時，代表可以使用 “cd”（更改目錄）進入該目錄。 也代表能夠存取在此目錄之中的已知檔名的檔案（當然，檔案仍擁有自己的權限）

尤其，要能夠列出目錄內容，必須擁有目錄的讀取權限。 而當要刪除已知檔名的檔案時，也必須擁有檔案所在目錄的寫入 以及 執行的權限。

還有一些權限，但這些權限主要在特殊情況使用，如 setuid binaries 及 sticky `directories`。 如果您還想知道更多檔案權限的資訊及使用方法，請務必參閱 chmod(1) 說明文件。

3.4.1. 權限符號

Contributed by Tom Rhodes.

權限符號可稱做符號表示， 使用字元的方式來取代使用數值來設定檔案或目錄的權限。 符號表示的格式依序為（某人）（動作）（權限），可使用的符號如下：

項目	字母	意義
（某人）	u	使用者
（某人）	g	群組所有者
（某人）	o	其他
（某人）	a	全部(“world”)
（動作）	+	增加權限
（動作）	-	移除權限
（動作）	=	指定權限

項目	字母	意義
（權限）	r	讀取
（權限）	w	寫入
（權限）	x	執行
（權限）	t	Sticky bit
（權限）	s	Set UID 或 GID

如先前同樣使用 chmod(1) 指令來設定，但使用的參數為這些字元。 例如，您可以使用下列指令禁止其他使用者存取檔案 *FILE*:

```
% chmod go= FILE
```

若有兩個以上的符號表示可以使用逗號(,)區隔。 例如，下列指令將會移除群組及其他人對檔案 *FILE* 的寫入權限， 並使全部人(“world”)對該檔有執行權限。

```
% chmod go-w,a+x FILE
```

3.4.2. FreeBSD 檔案旗標(Flag)

Contributed by Tom Rhodes.

除了前面提到的檔案權限外，FreeBSD 支援使用 “檔案旗標” 。 這些旗標增加了檔案的安全性及管理性，但不包含目錄。

檔案旗標增加了管理性，確保在某些時候 `root` 不會意外將檔案修改或移除。

修改的檔案 flag 僅需要使用擁有簡易的介面的 chflags(1) 工具。 例如，標示系統禁止刪除的旗標於檔案 `file1`，使用下列指令：

```
# chflags sunlink file1
```

若要移除系統禁止刪除的旗標，只需要簡單在 `sunlink` 前加上 “no”，例如：

```
# chflags nosunlink file1
```

使用 ls(1) 及參數 `-lo` 可檢視檔案目前的旗標：

```
# ls -lo file1
```

輸出的結果如下:

```
-rw-r--r--  1 trhodes  trhodes  sunlnk 0 Mar  1 05:54 file1
```

多數的旗標僅能由 `root` 使用者來標示或移除，而部份旗標可由檔案所有者設定。 我們建議系統管理者可閱讀 chflags(1) 及 chflags(2) 說明以瞭解相關細節。

3.5. 目錄結構

認識 FreeBSD 的目錄架構，就可對系統有概略的基礎理解。 最重要的莫過於整個目錄的根目錄，就是 “/” 目錄， 該目錄會在開機時最先掛載 (mount)，裡面會有開機所會用到必備檔案。 此外，根目錄還有紀錄其他檔案系統的掛載點相關設定。

「掛載點」就是讓新增的檔案系統，能接到上層的檔案系統（通常就是「根目錄」檔案系統）的目錄。 在 節 3.6, “磁碟組織” 這邊對此有更詳細介紹。 標準的掛載點包括了 `/usr`、`/var`、 `/tmp`、`/mnt` 以及 `/`

cdrom。 這些目錄通常會記錄在 /etc/fstab 設定檔內。 /etc/fstab 是記錄各檔案系統及相關掛載點的表格。 大部分在 /etc/fstab 有記錄的檔案系統，會在開機時由 rc(8) script 來自動掛載，除非它們有設定 noauto 選項。 其中細節說明可參閱 節 3.7.1, “ fstab 檔” 。

有關檔案系統架構的完整說明可參閱 hier(7)。 現在呢，讓我們大致先一窺常見的目錄有哪些吧。

目錄	說明
/	檔案系統的根目錄。
/bin/	single-user、multi-user 兩種模式皆可使用的基本工具 。
/boot/	作業系統開機過程會用到的程式、設定檔。
/boot/defaults/	預設的開機啓動設定檔，詳情請參閱 loader.conf(5) 。
/dev/	Device nodes，詳情請參閱 intro(4)。
/etc/	系統設定檔及一些 script 檔。
/etc/defaults/	預設的系統設定檔，詳情請參閱 rc(8)。
/etc/mail/	MTA(Mail Transport Agent)的相關設定檔，像是 sendmail(8)。
/etc/namedb/	named 設定檔，詳情請參閱 named(8)。
/etc/periodic/	每日、每週、每月透過 cron(8); 執行的定期排程 script， 詳情請參閱 periodic(8)。
/etc/ppp/	ppp 設定檔，詳情請參閱 ppp(8)。
/mnt/	系統管理者慣用充當臨時掛載點的空目錄。
/proc/	Process 檔案系統，詳情請參閱 procfs(5) 及 mount_procfs(8)。
/rescue/	緊急救援用途的一些 statically linked 程式，詳情請參閱 rescue(8)。
/root/	root 帳號的家目錄。
/sbin/	供 single-user 及 multi-user 環境使用的系統程式及管理工具 。
/tmp/	臨時檔案。 一般而言，重開機之後 /tmp 內的東西會被清除掉。 而通常會將 memory-based 檔案系統掛載在 /tmp 上。 這些瑣事可透過 tmpmfs 相關的 rc.conf(5) 環境變數來自動完成 。(或是在 /etc/fstab 內做設定， 詳情請參閱 mdmfs(8)。)
/usr/	主要是使用者所安裝的工具程式、應用程式存放處。
/usr/bin/	常用工具、開發工具、應用軟體。
/usr/include/	標準 C include 的相關 header 檔案庫。
/usr/lib/	函式庫存放處。
/usr/libdata/	其他各式工具的資料檔。
/usr/libexec/	系統 daemons 及系統工具程式(透過其他程式來執行)。
/usr/local/	存放一些自行安裝的執行檔、函式庫等等。 同時，也是 FreeBSD ports 架構的預設安裝目錄。 /usr/local 內的目錄架構大致與 /usr 相同，詳情請

目錄	說明
	參閱 hier(7) 說明。 但 man 目錄例外，它們是直接放在 /usr/local 底下，而非 /usr/local/share，而 ports 所安裝的說明文件則在 share/doc/port 。
/usr/obj/	在編譯 /usr/src 目錄時所產生的相關架構 object 檔案。
/usr/ports	FreeBSD Ports Collection (optional)。
/usr/sbin/	系統 daemon 及系統工具(直接由使用者執行)。
/usr/share/	各架構皆共通的檔案。
/usr/src/	BSD 本身的原始碼(或自行新增的)。
/usr/X11R6/	X11R6 相關套件的執行檔、函式庫等(optional)。
/var/	存放各種用途的 log 檔、臨時或暫時存放、列印或郵件的 spool 檔案。有時候，memory-based 檔案系統也會掛載在 /var。 這些瑣事可透過 varmfs 相關的 rc.conf(5) 環境變數來自動完成。(或是在 /etc/fstab 內做設定，相關細節請參閱 mdmfs(8)。)
/var/log/	各項系統記錄的 log 檔案。
/var/mail/	各使用者的 mailbox 檔案。
/var/spool/	各種印表機、郵件系統的 spool 目錄。
/var/tmp/	臨時檔案。 這些檔案在重開機後通常仍會保留，除非 /var 是屬於 memory-based 檔案系統。
/var/yp	記錄 NIS maps。

3.6. 磁碟組織

FreeBSD 用來尋找檔案的最小單位就是檔案的名稱了。 檔案的名稱有大小寫之分，所以說 readme.txt 和 README.TXT 是兩個不同的檔案。 FreeBSD 並不使用副檔名 (.txt) 來判別這是一個程式檔、文件檔或是其他類型的檔案。

檔案存在目錄裡面。 一個目錄中可能沒有任何檔案，也可能有好幾百個檔案。 目錄之中也可以包含其他的目錄； 您可以建立階層式的目錄以便資料的管理。

檔案或目錄的對應是藉由給定的檔案或目錄名稱，然後加上正斜線符號 (/)；之後再視需要加上其他的目錄名稱。 如果您有一個目錄 foo ，裡面有一個目錄叫作 bar，這個目錄中又包含了一個叫 readme.txt 的檔案，那麼這個檔案的全名，或者說檔案的路徑就是 foo/bar/readme.txt 。

目錄及檔案儲存在檔案系統之中。 每個檔案系統都有唯一一個最上層的目錄，叫做根目錄 (root directory)。 然後在這個根目錄下面才能有其他的目錄。

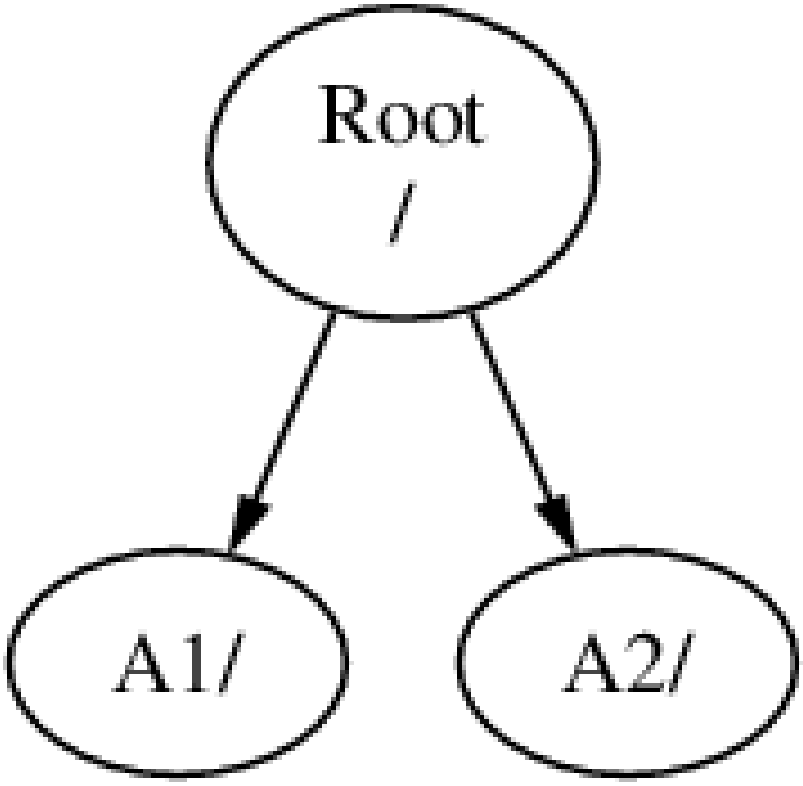
到目前為止大概和其他您用過的的作業系統都差不多。 還是有些不一樣的地方就是了，例如 MS-DOS® 用 \ 當檔案和目錄名稱的分隔符號，而 Mac OS® 則是用 : 符號。

FreeBSD 的路徑中並沒有使用磁碟機代號或其他的磁碟名稱。 因此，您不可以使用像 c:/foo/bar/readme.txt 這樣子的檔案名稱。

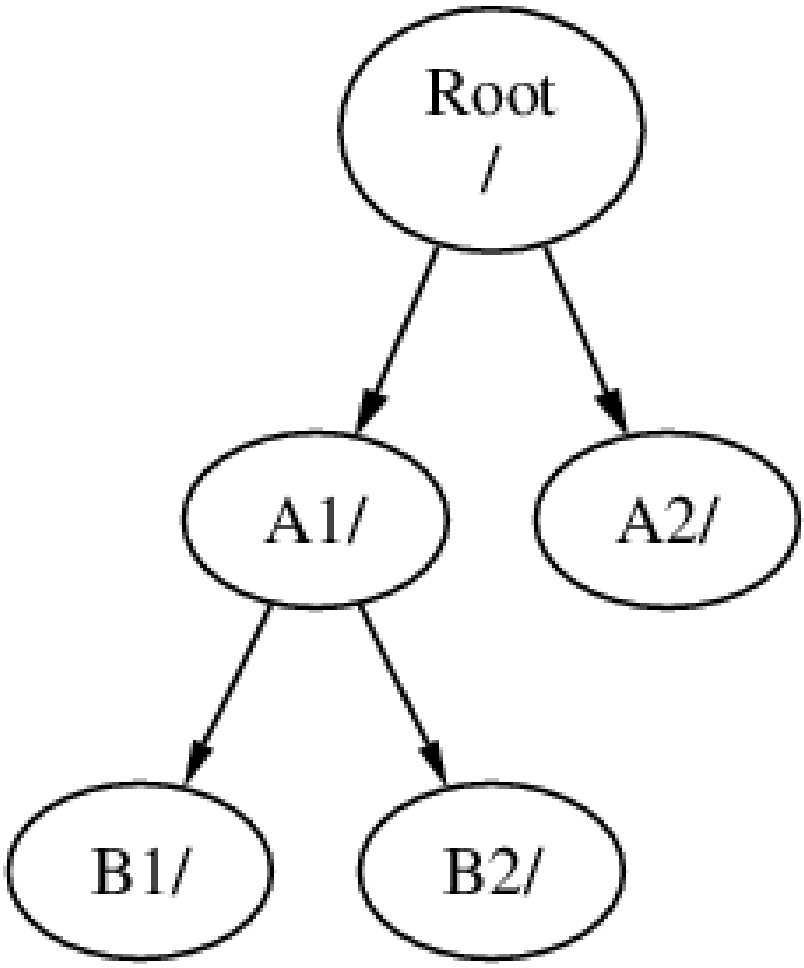
相對的，在 FreeBSD 系統中有一個檔案系統被指定為根檔案系統。 根檔案系統的根目錄由 / 表示。 然後其他的檔案系統再掛載 (mount) 在根檔案系統之下。因此無論您的 FreeBSD 系統上有多少顆硬碟，每一個目錄看起來就像在同一個磁碟上。

假設您有三個檔案系統，分別叫作 A、B 及 C。每個檔案系統都包含兩個目錄，叫做 A1、A2（依此類推得 B1、B2 及 C1、C2）。

稱 A 為主要的檔案系統；如果您用 ls 指令查看此目錄的內容，您會看到兩個子目錄： A1 及 A2，如下所示：

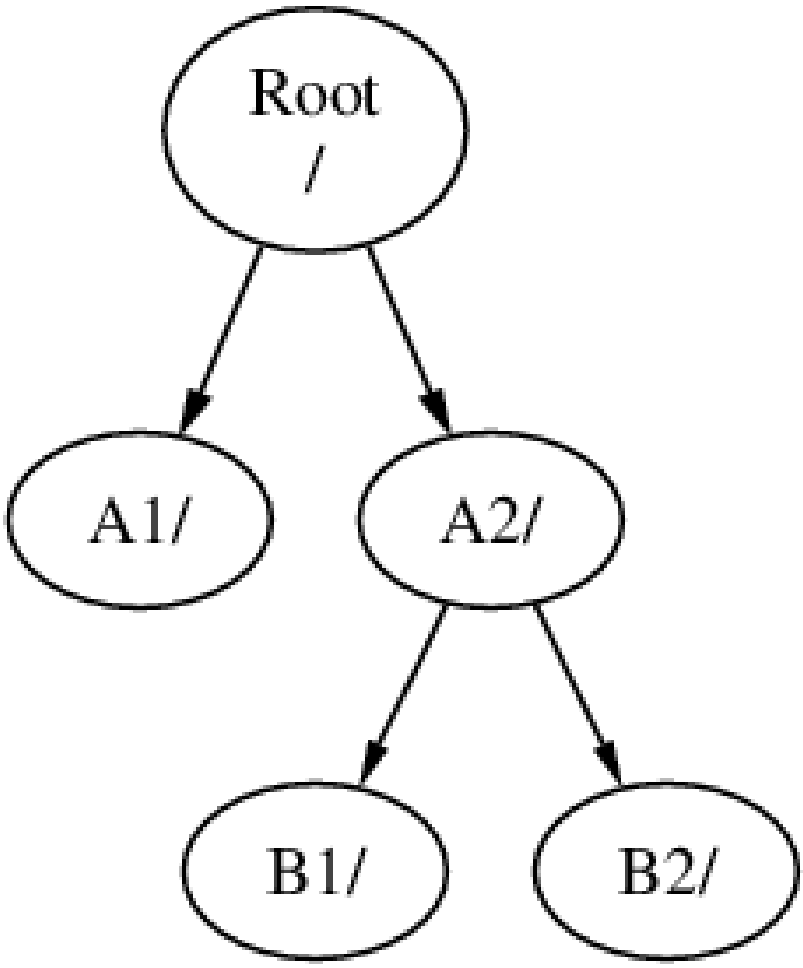


一個檔案系統必須以目錄形式掛載於另一個檔案系統上。因此，假設您將 B 掛載於 A1 之上，則 B 的根目錄就變成了 A1，而在 B 之下的任何目錄的路徑也隨之改變：



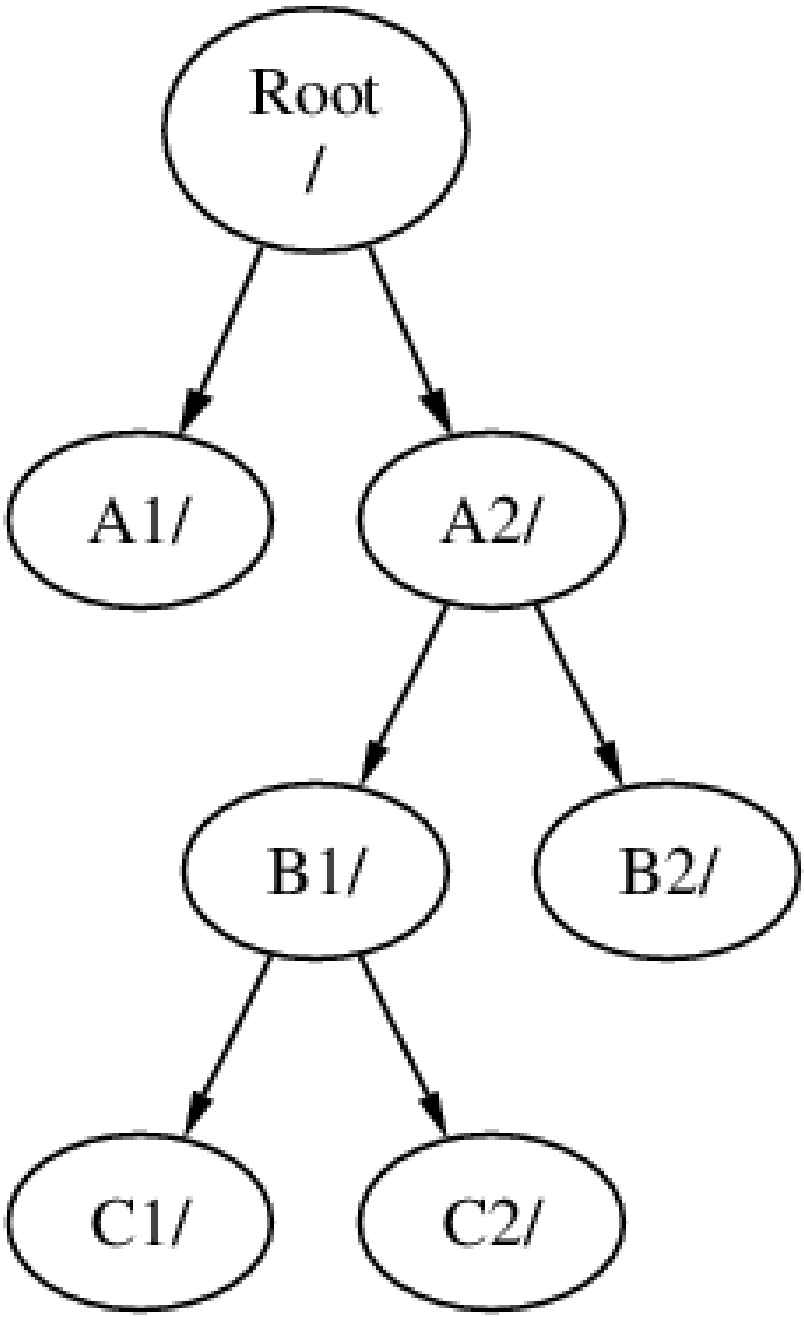
在 B1 或 B2 目錄中的任何檔案必須經由路徑 /A1/B1 或 /A1/B2 才能達到。 所有原來在 /A1 中的檔案會暫時被隱藏起來，直到 B 被「移除 (unmounted)」後才會再顯現出來。

如果 B 掛載在 A2 之上，則會變成：

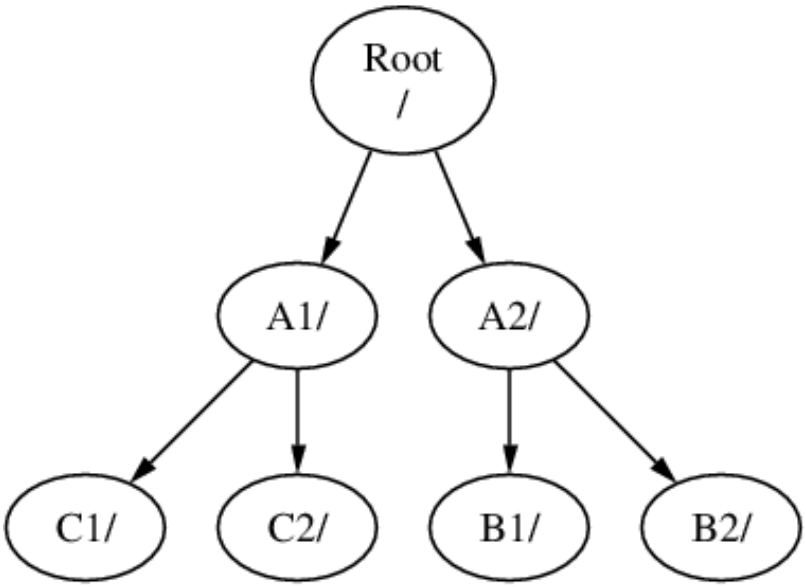


上面的路徑分別為 /A2/B1 及 /A2/B2。

檔案系統可以掛在其他檔案系統的目錄之上。 延續之前的例子，C 檔案系統可以掛在檔案系統 B 的 B1 目錄之上，如圖所示：



或者 C 直接掛載於 A 的 A1 目錄之上：



如果您熟悉 MS-DOS® 的話，這和 `join` 指令很類似（雖然不儘相同）。

一般情況下您不需要擔心這些東西。 除非您要安裝新的磁碟，不然通常在您安裝 FreeBSD 時建立好檔案系統並決定好要掛載在何處之後就不會再做任何更動了。

您完全可以使用單一的一個大的根檔案系統 (root file system) 而不建立其他的檔案系統。 這樣有好處也有有壞處。

- 不同的檔案系統在掛上的時候可以有不同的 掛載參數。 舉例來說，為求謹慎您可以將根檔案系統設成唯讀， 以避免不小心刪除或修改掉重要的檔案。 將使用者可寫入的檔案系統（例如 `/home`）獨立出來也可以讓他們用 nosuid 的參數掛載，此選項可以讓在這個檔案系統中執行檔的 suid/guid bits 失效，也許可以讓系統更安全。
- FreeBSD 會自動根據您檔案系統的使用方式來做最佳的檔案配置方式。 因此，一個有很多小檔案、 常常寫入的檔案系統跟只有幾個較大的檔案的檔案系統配置是不一樣的。 如果您只有單一一個大的檔案系統，這部分就沒用了。
- FreeBSD 的檔案系統在停電的時候很穩固。 然而，在某些重要的時候停電仍然會對檔案系統結構造成損害。 分割成許多個檔案系統的話在系統在停電後比較能夠正常啓動， 以便您在需要的時候將備份資料回存回來。
- 檔案系統的大小是固定的。 您當初安裝 FreeBSD 的時候應該會給定一個大小，可是後來您可能會想把空間加大。 如果沒有備份的話是很難達成的； 您必須將檔案系統重新建立為您需要的大小，然後將備份回存回來。

> **重要**
>
> FreeBSD 的 growfs(8) 指令可以突破此限制直接變更檔案系統的大小。

檔案系統包含在分割區裡面。 因為 FreeBSD 承襲 UNIX® 架構，這邊講的分割區和一般提到的分割區（例如 MS-DOS® 分割區）不同。 每一個分割區由一個代號（字母）表示，從 `a` 到 `h`。 每個分割區只能包含一個檔案系統。 因此除了說常見到用檔案系統同的掛載點來表示檔案系統外， 也可以用包含他的分割區代號來表示。

FreeBSD 也會拿磁碟空間來當 swap space。 Swap space 給 FreeBSD 當作虛擬記憶體用。 這讓您的電腦好像擁有比實際更多的記憶體。 當 FreeBSD 的記憶體用完的時候，它會把一些目前沒用到的資料移到 swap space，然後在用到的時候移回去（同時移出部份沒用到的）。

某些分割區有慣例的使用方式如下：

分割區	慣例
a	通常包含根檔案系統 (root file system)
b	通常是 swap space
c	通常和整個 slice 的大小一樣，給一些會用到整個 slice 的工具程式（例如硬碟壞軌檢查工具）來使用。 一般來說您應該不會把檔案系統建立在這個分割區。
d	分割區 d 曾經有代表特殊意義，但是已經不再使用。 所以現在 d 就和其他一般的分割區相同了。

每個包含有檔案系統的分割區是存在所謂的 slice 裡面。 FreeBSD 的 slice 就是指平常我們稱為分割區 (partition) 的東西。 同樣地，會這樣子稱呼也是因為 FreeBSD 的 UNIX® 色彩。 而 slice 是有編號的，從 1 號編到 4 號。

slice 號碼跟在裝置名稱後面，先接一個字母 s，然後從 1 號開始編下去。 因此 “da0s1” 就是指第一個 SCSI 硬碟的第一個 slice。 一個磁碟上只能有四個實體的 slice，但是在實體的 slice 中您可以塞進適當類型的邏輯 slice。 這些延伸的 slice 編號從 5 開始，所以 “ad0s5” 是第一個 IDE 硬碟上的第一個延伸 slice。 檔案系統在裝置 (device) 裡就是在一個 slice 之中。

Slices、“dangerously dedicated” 模式的實體磁碟機，以及其他包含分割區(partition) 的磁碟都是以字母 a 到 h 的編號來表示。 編號是接在裝置名稱的後面的，因此 “da0a” 是磁碟機 da 上的第一個 “dangerously dedicated”模式之分割區。 而 “ad1s3e” 則是第二顆 IDE 硬碟上第三個 slice 的第五個分割區。

最後，我們就可以把系統上的每個磁碟都區分出來了。 一個磁碟的名稱會有一個代碼來表示這個磁碟的類型，接著是一個數字， 表示這是哪一個磁碟。 這邊跟 slice 每個磁碟編號從 0 開始不一樣。 常見的代碼可以參考 表格 3.2, “磁碟機代號” 。

當要參照一個分割區的時候，FreeBSD 會要您一併輸入包含這個分割區的 slice 及磁碟機名稱；當要參照一個 slice 的時候，也必須輸入包含這個 slice 的磁碟名稱。 怎麼做呢？首先先列出磁碟名稱，然後 s 加上 slice 編號，最後再輸入分割區字母代號。 範例可以參考 範例 3.12, “磁碟、slice 及分割區命名範例” .

範例 3.13, “磁碟的概念模型” 示範了一個基本的磁碟分布模式，相信對您有些幫助。

要安裝 FreeBSD，您必須先建置磁碟的 slice，接著於 slice 中建立要給 FreeBSD 用的分割區。 最後在這些分割區中建立檔案系統（或 swap space) 並決定要將這些檔案系統掛載於哪裡。

表格 3.2. 磁碟機代號

代號	意義
ad	ATAPI(IDE) 磁碟機
da	SCSI 直接存取磁碟機
acd	ATAPI(IDE) 光碟機
cd	SCSI 光碟機
fd	軟碟機

範例 3.12. 磁碟、slice 及分割區命名範例

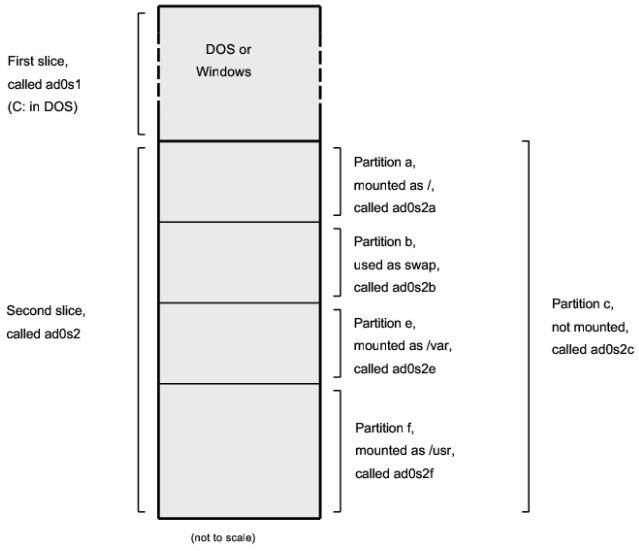
名稱	意義
ad0s1a	第一個 IDE 硬碟 (ad0) 上第一個 slice (s1)的第一個分割區(a) 。

名稱	意義
da1s2e	第二個 SCSI 硬碟 (da1) 上第二個 slice (s2) 的第五個分割區 (e)。

範例 3.13. 磁碟的概念模型

此圖顯示 FreeBSD 中接到系統的第一個 IDE 磁碟機內部配置圖。 假設這個磁碟的容量是 4 GB，並且包含了兩個 2 GB 的 slice (MS-DOS® 的分割區)。 第一個 slice 是 DOS 的 C: 磁碟機，第二個則安裝了 FreeBSD。 本範例的 FreeBSD 有三個分割區以及一個 swap 分割區。

這三個分割區每個都是一個檔案系統。 a 分割是根 (root) 檔案系統；分割 e 是 /var；而 f 分割是 /usr 目錄結構。



3.7. 掛載與卸載檔案系統

檔案系統就像一顆樹。/ 就像是樹根，而 /dev，/usr 以及其他在根目錄下的目錄就像是樹枝，而這些樹枝上面又還有分支，像是 /usr/local 等。

因為某些原因，我們會將一些目錄分別放在不同的檔案系統上。 如 /var 包含了可能會滿出來的 log/，spool/ 等目錄以及各式各樣的暫存檔。 把根檔案系統塞到滿出來顯然不是個好主意，所以我們往往會比較傾向把 /var 從 / 中拉出來。

另一個常見到把某些目錄放在不同檔案系統上的理由是： 這些檔案在不同的實體或虛擬磁碟機上。 像是網路檔案系統 (Network File System) 或是光碟機。

3.7.1. fstab 檔

在 /etc/fstab 裡面有設定的檔案系統會在開機 的過程中自動地被掛載 (除非該檔案系統有被加上 noauto 參數)。

`/etc/fstab` 檔案內容的格式如下：

```
device          /mount-point  fstype     options      dumpfreq     passno
```

`device`
裝置名稱（該裝置必須真的存在）。 詳情請參閱 節 17.2, “裝置名稱”.

`mount-point`
檔案系統要掛載到的目錄（該目錄必須真的存在）。

`fstype`
檔案系統類型，這是要傳給 mount(8) 的參數。 FreeBSD 預設的檔案系統是 `ufs`。

`options`
可讀可寫的檔案系統用 `rw`，而唯讀的檔案系統則是用 `ro`，後面視需要還可以加其他選項。 常見的選項如 `noauto` 是用在不要於開機過程中自動的掛載的檔案系統。 其他選項可參閱 mount(8) 說明。

`dumpfreq`
dump(8) 由此項目決定那些檔案系統需要傾印。 如果這格空白則以零為預設值。

`passno`
這個項目決定檔案系統檢查的順序。 對於要跳過檢查的檔案系統，它們的 `passno` 值要設為零。 根檔案系統的 `passno` 值應設為一（因為需要比所有其他的還要先檢查），而其他的檔案系統的 `passno` 值應該要設得比一大。 若有多個檔案系統具有相同的 `passno` 值，則 fsck(8) 會試著平行地（如果可能的話）檢查這些檔案系統。

更多關於 `/etc/fstab` 檔案格式及選項的資訊請參閱 fstab(5) 說明文件。

3.7.2. `mount` 指令

mount(8) 指令是拿來掛載檔案系統用的。

基本的操作指令格式如下：

```
# mount device mountpoint
```

在 mount(8) 裡面有提到一大堆的選項，不過最常用的就是這些：

`-a`
把 `/etc/fstab` 裡面所有還沒有被掛載、沒有被標記成“noauto”而且沒有用 `-t` 排除的檔案系統掛載起來。

`-d`
執行所有的動作，但是不真的去呼叫掛載的 system `call`。 這個選項和 `-v` 搭配拿來推測 mount(8) 將要做什麼動作時很好用。

`-f`
強迫掛載不乾淨的檔案系統（危險），或是用來強制取消寫入權限（把檔案系統的掛載狀態從可存取變成唯讀）。

`-r`
用唯讀的方式掛載檔案系統。 這個選項和在 `-o` 選項中指定 `ro`（在 FreeBSD 5.2之前的版本是用 `rdonly`）參數是一樣的。

`-t` *`fstype`*
用指定的檔案系統型態 (fstype) 來掛載指定的檔案系統，或是在有 `-a` 選項時只掛載指定型態的檔案系統。

預設的檔案系統是 “ufs”。

`-u`
更新檔案系統的掛載選項。

`-v`
顯示較詳細資訊。

`-w`
以可存取的模式掛載檔案系統。

`-o` 選項後面會接著以逗號分隔的參數，例如：

noexec
不允許在這個檔案系統上執行二進位程式碼， 這也是一個蠻有用的安全選項。

nosuid
不解析檔案系統上的 setuid 或 setgid 旗標， 這也是一個蠻有用的安全選項。

3.7.3. umount 指令

umount(8) 指令的參數可以是掛載點 (mountpoint)，裝置名稱，以及 `-a` 或是 `-A` 等選項。

加上 `-f` 可以强制卸載，加上 `-v` 則是會顯示詳細資訊。 要注意的是一般來說用 `-f` 並不是個好主意，强制卸載檔案系統有可能會造成電腦當機， 或者損壞檔案系統內的資料。

`-a` 和 `-A` 是用來卸載所有已掛載的檔案系統，另外還可以用 `-t` 來指定要卸載的是哪些種類的檔案系統。 要注意的是 `-A` 並不會試圖卸載根檔案系統。

3.8. 程序

FreeBSD 是一個多工的作業系統，也就是說在同一時間內可以跑超過一個程式。 每一個正在花時間跑的程式就叫做 程序 (process)。 您下的每個指令都至少會開啓一個新的程序， 而有些系統程序是一直在跑以維持系統正常運作的。

每一個程序都有一個不重覆的數字叫做 process ID ，或稱為 PID ，而且就像檔案一樣，每一個程序也有擁有者及群組。 擁有者及群組的資訊是用來決定什麼檔案或裝置是這個程序可以開啓的（前面有提到過檔案權限）。 大部份的程序都有父程序。 父程序是開啓這個程序的程序，例如：您對 shell 輸入指令，`she11` 本身就是一個程序，而您執行的指令也是程序。 每一個您用這種方式跑的程序的父程序都是 `she11`。 有一個特別的程序叫做 init(8) 是個例外。`init` 永遠是第一個程序，所以他的 PID 一直都會是 `1`。 在 FreeBSD 開機的時候 `init` 會自動地被 kernel 開啓。

要看系統執行中的程序，有兩個相當有用的指令可用： ps(1) 以及 top(1)。`ps` 指令是用來列出正在執行之程序，而且可以秀它們的 PID、用了多少記憶體、執行的指令名稱及其後之參數是什麼等等。 `top` 指令則是顯示所有正在執行的程序， 並且數秒鐘更新一次。因此您可以互動式的觀看您的電腦正在做什麼。

在預設的情況下，`ps` 指令只會顯示您所擁有的的程序。 例如：

```
% ps
  PID  TT  STAT      TIME COMMAND
  298  p0  Ss     0:01.10 tcsh
 7078  p0  S      2:40.88 xemacs mdoc.xsl (xemacs-21.1.14)
37393  p0  I      0:03.11 xemacs freebsd.dsl (xemacs-21.1.14)
48630  p0  S      2:50.89 /usr/local/lib/netscape-linux/navigator-linux-4.77.bi
48730  p0  IW     0:00.00 (dns helper) (navigator-linux-)
72210  p0  R+     0:00.00 ps
  390  p1  Is     0:01.14 tcsh
 7059  p2  Is+    1:36.18 /usr/local/bin/mutt -y
 6688  p3  IWs    0:00.00 tcsh
10735  p4  IWs    0:00.00 tcsh
20256  p5  IWs    0:00.00 tcsh
```

```
  262  v0  IWs    0:00.00 -tcsh (tcsh)
  270  v0  IW+    0:00.00 /bin/sh /usr/X11R6/bin/startx -- -bpp 16
  280  v0  IW+    0:00.00 xinit /home/nik/.xinitrc -- -bpp 16
  284  v0  IW     0:00.00 /bin/sh /home/nik/.xinitrc
  285  v0  S      0:38.45 /usr/X11R6/bin/sawfish
```

在這個範例裡可以看到 ps(1) 的輸出分成好幾個欄位。 PID 就是前面有提到的 process ID。 PID 的分配是從 1 開始一直到 99999，如果用完的話又會繞回來重頭開始分配（若該 PID 已經在用了，則 PID 不會重新分配）。 TT 欄位是指這個程式在哪個 tty 上執行，在這裡可以先忽略不管。 STAT 是程式的狀態，也可以先不要管。 TIME 是這個程式在 CPU 上執行的時間——這通常不是程式總共花的時間， 因為當您開始執行程式後，大部份的程式在 CPU 上執行前會先花上不少時間等待 。 最後，COMMAND 是執行這個程式的命令列。

ps(1) 有幾個不同的選項組合可以用來變更顯示出來的資訊，其中一個最有用的組合是 auxww。 a 可以顯示所有正在跑的程序的指令，不只是您自己的。 u 則是顯示程序的擁有者名稱以及記憶體使用情況。 x 可以把 daemon 程序顯示出來， 而 ww 可讓 ps(1) 顯示出每個程序完整的內容， 而不致因過長而被螢幕截掉了。

top(1) 也有類似的輸出。 一般的情況看像是這樣：

```
% top
last pid: 72257;  load averages:  0.13,  0.09,  0.03    up 0+13:38:33  22:39:10
47 processes:  1 running, 46 sleeping
CPU states: 12.6% user,  0.0% nice,  7.8% system,  0.0% interrupt, 79.7% idle
Mem: 36M Active, 5256K Inact, 13M Wired, 6312K Cache, 15M Buf, 408K Free
Swap: 256M Total, 38M Used, 217M Free, 15% Inuse

  PID USERNAME PRI NICE  SIZE    RES STATE    TIME   WCPU    CPU COMMAND
72257 nik       28   0  1960K  1044K RUN      0:00 14.86%  1.42% top
 7078 nik        2   0 15280K 10960K select   2:54  0.88%  0.88% xemacs-21.1.14
  281 nik        2   0 18636K  7112K select   5:36  0.73%  0.73% XF86_SVGA
  296 nik        2   0  3240K  1644K select   0:12  0.05%  0.05% xterm
48630 nik        2   0 29816K  9148K select   3:18  0.00%  0.00% navigator-linu
  175 root       2   0   924K   252K select   1:41  0.00%  0.00% syslogd
 7059 nik        2   0  7260K  4644K poll     1:38  0.00%  0.00% mutt
...
```

輸出的資訊分成兩個部份。開頭（前五行）秀出最近一個程序的 PID、系統平均負載（系統有多忙錄的測試）、系統的開機時間（從上次重開算起）以及現在的時間等。 在開頭裡面的其他數字分別是在講有多少程序正在執行（在本例中為47）、有多少記憶體及 swap space 被占用了，還有就是系統分別花了多少時間在不同的 CPU 狀態上。

接下來的部份是由好幾個欄位所構成，和 ps(1) 輸出的資訊類似。 就如同前例，您可以看到 PID、使用者名稱、CPU 花費的時間以及正在執行的指令。 top(1) 在預設的情況下還會告訴您程序用掉了多少的記憶體空間。 在這邊會分成兩欄，一個是總用量 (total size)，另一個是實際用量 (resident size)——總用量是指這個應用程式需要的記憶體空間， 而實際用量則是指實際上該程式的記憶體使用量。 在這個例子裡面您可以看到 Netscape® 要了幾乎到 30 MB 的 RAM，但是只有用到 9 MB。

top(1) 每隔 2 秒鐘會自動更新顯示內容，可用 s 選項來改變間隔的時間。

3.9. Daemon、信號及終止程序

當在執行文書編輯器時，您可以很容易地使用它，叫它讀取檔案或是什麼的。 可以這樣做是因為編輯器有提供這些功能， 還有就是編輯器依附在一個終端機 (Terminal) 之上。 有些程式並不是設計成一直在接收使用者的輸入的， 所以它們在一開始執行的時候就從終端機斷開了。 例如說， 網頁伺服器整天都在回應網頁方面的要求，它通常不需要您輸入任何東西。 另外，像是把信從一個站傳送到另一個站的程式，也是這種類型的應用程式。

我們把這種程式稱作 daemon。 Daemon（惡魔、守護神）是希臘神話中的角色：祂們不屬於善良陣營或邪惡陣營，是守護的小精靈。 大致上來說祂們就是在替人類做一些有用的事情， 跟今天的網頁伺服器或是郵

件伺服器很像。 這也就是為何 BSD 的吉祥物，長期以來都是一隻穿著帆布鞋拿著三叉耙的快樂小惡魔的原因。

通常來說 deamon 程式的名字後面都會加一個字母 “d”。 BIND 是 Berkeley Internet Name Domain 的縮寫（但實際上執行的程式名稱是 named）、Apache 網頁伺服器的程式名稱是 httpd、印表機服務程式是 lpd，依此類推。 這是習慣用法，並沒有硬性規定，例如 Sendmail 主要的寄信 daemon 是叫做 sendmail 而不是 maild，跟您想像的不一樣。

有些時候會需要跟某個 daemon 程序溝通， 這些溝通是透過所謂的信號(signal)來傳遞給該 daemon 程序（或是其他執行中的程序）。 藉由送出信號，您可以和一個 daemon（或是任何一個正在跑的程序）溝通。 信號有很多種——有些有特定的意義，有些則是會由應用程式來解讀。 應用程式的說明文件會告訴您該程式是如何解讀信號的。 您只能送信號給您擁有的程序，送 kill(1) 或 kill(2) 的信號給別人的程序是不被允許的。 不過 root 不受此限制，他可以送信號給任何人的程序。

FreeBSD 本身在某些情況也會送信號給應用程式。 假設有個應用程式寫得很爛，然後企圖要存取它不該碰的記憶體的時候，FreeBSD 會送一個 Segmentation Violation 信號 (SIGSEGV) 給這個程序。 又如果有一個應用程式用了 alarm(3) 的 system call 要求系統在過一段時間之後叫他一下，時間到了的時候鬧鐘的信號 (SIGALRM) 就會被送出了，其他的依此類推。

SIGTERM and SIGKILL 這兩個信號可以拿來終止程序。 用 SIGTERM 結束程序是比較有禮貌的方式，該程序會捕捉 (catch) 這個信號而了解到您想要把他關掉。 接著下來它會把它自己開的記錄檔通通關掉， 然後在關掉程序之前結束掉手邊的工作。 在某些情況下程序有可能會裝作沒看見 SIGTERM，假如它正在做一些不能中斷的工作的話。

SIGKILL 就沒有辦法被程序忽略了。 這是一個 “我管你正在幹嘛，現在就給我停下來” 的信號。 如果您送了 SIGKILL 信號給某個程序，FreeBSD 將會把它停掉[4]。

這些是其他您有可能會要用到的信號： SIGHUP，SIGUSR1，以及 SIGUSR2。 這些是通用的信號，當送出時不同的應用程式會有不同的反應。

假設您更動了您的網頁伺服器的設定檔—— 您想要叫網頁伺服器去重新讀取設定值。 您可以關閉後再重新啓動 httpd，但是這麼做會造成網頁伺服器暫停服務一段時間， 這樣子可能不太好。 大部份的 daemon 都寫成會去回應 SIGHUP。 當收到這個信號之後，它們會去重新讀取自己的設定檔。 因此您可以用送 SIGHUP 信號來取代關掉重開。 又因為沒有標準在規範如何回應這些信號，不同的 daemon 可能會有不同的行為，所以有疑問的話請先確認並翻閱 deamon 的說明文件。

信號是由 kill(1) 指令送出的，如範例所示：

過程 3.1. 送信號給程序

這個範例將會示範如何送一個信號給 inetd(8)。 inetd 的設定檔是 /etc/inetd.conf ，而 inetd 會在收到 SIGHUP 的時候重新讀取這個設定檔。

1. 找出您想要送信號的那個程序的 ID。 您會用到 ps(1) 以及 grep(1) 這兩個指令。 grep(1) 是用來在輸出中搜尋， 找出您指定的字串。 這個指令是由一般使用者執行，而 inetd(8) 是由 root 執行，所以在使用 ps(1) 時需要加上 ax 選項。

   ```
   % ps -ax | grep inetd
     198  ??  IWs    0:00.00 inetd -wW
   ```

   因此可知 inetd(8) 的 PID 為 198。 在某些情況下 grep inetd 這個指令本身也會出現在輸出裡。 這是因為 ps(1) 乃是找所有執行中的程序的方式造成的。

2. 用 kill(1) 來送信號。 又因為 inetd(8) 是由 root 執行的，您必須用 su(1) 切換成 root 先。

[4]不完全正確——還是有少數東西不能被中斷。 例如有個程序正在從網路上的別的電腦讀一個檔案， 而那部電腦因為某些理由連不到（機器被關掉，或是網路爛掉了）， 那這個程序我們就說他是一個 “不能中斷的” 程序。 通常在經過兩分鐘左右之後這個程序會逾時。 當發生逾時的時候這個程序就會被結束掉了。

```
% su
Password:
# /bin/kill -s HUP 198
```

一般情況對大多數 UNIX® 指令來講，當 kill(1) 執行成功時並不會輸出任何訊息。 假設您送一個信號給某個不是您所擁有的程序， 那麼您就會吃到這個錯誤訊息： kill: *PID*: Operation not permitted。 而如果您打錯 PID 的話，那就會把信號送給錯誤的程序。 這樣可能會很糟， 不過如果您夠幸運的話，可能剛好就只是把信號送給一個非使用中的 PID，那您就只會看到 kill: *PID*: No such process 而已。

為什麼用 /bin/kill ？

很多 shell 有提供內建的 kill 指令。 也就是說這種 shell 會直接送信號，而不是執行 /bin/kill 。 這樣是蠻方便的沒錯啦，但是不同的 shell 會有不同的語法來指定信號的名稱等。 與其嘗試去把它們通通學會，不如就單純的直接用 /bin/kill ... 吧。

要送其他的信號的話也是非常類似，就視需要把指令中的 TERM 或 KILL 替換掉即可。

重要

隨便抓一個系統中的程序然後把他砍掉並不是個好主意。 特別是 init(8)， process ID 1，一個非常特別的程序。 執行 /bin/kill -s KILL 1 的結果就是系統立刻關機。 因此在您按下 Return 要執行 kill(1)之前， 請一定要記得再次確認您下的參數。

3.10. Shells

在 FreeBSD 中，很多日常的工作是在一個叫做 shell 的文字介面中完成的。 Shell 的主要工作就是從輸入中收到命令並執行它們。 許多 shell 也有內建一些有助於日常工作的指令， 像是檔案管理、檔案比對、命令列編輯、指令巨集以及環境變數等。 FreeBSD 有內附了幾個 shell，像是 sh， Bourne Shell，以及 tcsh，改良版的 C-shell。 還有許多其他的 shell 可以從 FreeBSD Ports Collection 中取得，像是 zsh 以及 bash 等。

您用哪個 shell 呢？ 其實每個人的喜好都不一樣。 如果您是一個 C 程式設計師，那對於使用像是 tcsh 這種 C-like 的 shell 可能會感到相當愉快。 如果你是從 Linux 跳過來的，或者您是一個 UNIX® 新手，那您也許會想要用 bash 來當作文字介面。 每一個 shell 都有自己獨特之處，至於這些特點能不能配合您的工作環境？ 那就是您選擇 shell 的重點了。

檔名自動補齊就是常見的 shell 功能。 首先輸入指令或檔案的前幾個字母，這時通常您只需要按下 Tab 鍵，接下來 shell 就會自動把指令或是檔案名稱剩餘的部份補齊。 假設您有兩個檔案分別叫作 foobar 及 foo.bar。 現在要刪掉 foo.bar，那麼可以輸入： rm fo[Tab].[Tab]

Shell 會印出這個： rm foo[#].bar 。

[嗶] 是 console 的響鈴，這嗶的一聲是 shell 在告訴我說它沒有辦法完全自動補齊檔名，因為有不只一個檔名符合條件。 foobar 和 foo.bar 都是 fo 開頭的檔名，不過它至少可以補齊到 foo。 如果您接著輸入 . 然後再按 Tab 一次，那 shell 就能夠替您把剩下的檔名填滿了。

Shell 的另一項特點是使用了環境變數。 環境變數是以變數與鍵值（variable/key）的對應關係儲存於 shell 的環境空間中，任何由 shell 所產生的程序都可以讀取此空間， 因此這個空間儲存了許多程序的設定組態。 在此附上 一份常見環境變數與其涵義的列表：

變數	詳細說明
USER	目前登入的使用者名稱。
PATH	以冒號（:）隔開的目錄列表，用以搜尋執行檔的路徑。
DISPLAY	若存在這個環境變數，則代表 X11 連結顯示器的網路名稱。
SHELL	目前使用的 shell。
TERM	使用者終端機的名稱，能藉由此變數判斷終端機的能力。
TERMCAP	Database entry of the terminal escape codes to perform various terminal functions.
OSTYPE	作業系統的種類，如：FreeBSD。
MACHTYPE	目前系統所用的 CPU 架構。
EDITOR	使用者偏好的文字編輯器。
PAGER	使用者偏好的文字分頁器（text pager）。
MANPATH	以冒號（:）隔開的目錄列表，用以搜尋 manual pages 的路徑。

在不同的 shell 底下設定環境變數的方式也有所不同。 舉例來說，在 C-Style 的 shell 底下，像是 tcsh 和 csh，你必須使用 setenv 來設定環境變數。 但在 Bourne shells 底下，像是 sh 和 bash，你則必須使用 export 來設定你所使用的環境變數。 再舉個例子來說，若要設定或是修改 EDITOR 這個環境變數，在 csh 或 tcsh 下設定 EDITOR 這個環境變數為 /usr/local/bin/emacs 的指令是：

```
% setenv EDITOR /usr/local/bin/emacs
```

在 Bourne shells 下則是：

```
% export EDITOR="/usr/local/bin/emacs"
```

大多數的 shell 都支援使用者在命令列中將 $ 字元放在變數之前，以取得環境變數的值。 舉例來說，echo $TERM 會 顯示出 $TERM 的設定值，這是因為 shell 取得了 $TERM 的設定值， 並將其傳給 echo 顯示出來。

Shell 中有某些特別的字元是來表示特殊的資料，我們將其稱作 meta-characters。 其中最常見的是 * 字元，他代表了檔名中的任意字元。 這些特殊字元可以用在檔名展開（filename globbing）上，舉例來說，輸入 echo * 會和輸入 ls 得到幾乎相同的結果，這是因為 shell 會將所有符合 * 字元的檔案傳到命令列上，再由 echo 顯示出來。

為了避免 shell 轉譯這些特殊字元，我們可以在這些特殊字元前放一個反斜線 (\) 字元使他們跳脫(escape) shell 的轉譯。舉例來說， echo $TERM 會印出你目前設定的終端機格式， echo \$TERM 則會直接印出 $TERM 這幾個字。

3.10.1. 變更你的 Shell

變更 shell 最簡單的方法就是透過 chsh 命令。 執行 chsh 將會呼叫環境變數中 EDITOR 指定的文字編輯器。 如果沒有設定，則預設是 vi。 請依照需求去修改 “Shell:” 的值。

你也可以透過 chsh 的參數 -s， 這可以直接設定你的 shell 而不需要透過任何文字編輯器。 例如， 假設想把所用的 shell 改為 bash， 可以透過下列的方式：

```
% chsh -s /usr/local/bin/bash
```

注意

你所使用的 shell 必須 列於 /etc/shells 裡頭。 如果是由 Ports Collection 來裝 shell， 那這個步驟已經完成了。 但若是手動安裝了一個 shell， 那麼就必須為新安裝的 shell 進行設定。

舉例來說，若手動安裝了 bash 並將它置於 /usr/local/bin 底下，你還得：

```
# echo "/usr/local/bin/bash" >> /etc/shells
```

然後再重新執行 chsh。

3.11. 文字編輯器

在 FreeBSD 中有許多設定必須透過編輯文字檔完成。 因此，若能熟悉文字編輯器是再好不過的。 FreeBSD 本身（指 base system）就附有幾種文字編輯器， 此外，你也可以透過 Ports Collection 來安裝其他的文字編輯器。

最簡單易學的文字編輯器叫做 ee， 代表了其全名 easy editor。 要開始使用 ee， 必須在命令列上輸入 ee filename， 這邊的 *filename* 代表你想要編輯的檔案名稱。 舉例來說，要編輯 /etc/rc.conf ，就要輸入 ee /etc/rc.conf 。 而在 ee 的操作介面下， 所有編輯器的功能與操作都會顯示在螢幕的正上方。 其中的插入符號(^)代表鍵盤上的 Ctrl 鍵，所以 ^e 就等同於 Ctrl+e 。 若要結束 ee，請按下 Esc 鍵，接著選擇 leave editor 即可。 此時如果該檔案有修改過，編輯器會提醒你是否要存檔。

此外，FreeBSD 也內附了幾個好用的文字編輯器，像是 base system 的 vi 及 FreeBSD Ports Collection 內的其他編輯器， 比如 Emacs 及 vim (editors/emacs 及 editors/vim)。 這些文字編輯器提供更強的功能，但是也比較難學習。 然而若要從事大量文字編輯工作， 那麼花點時間來學習這些好用的編輯器， 會在日後為您省下更多的時間。

3.12. 設備及設備節點

設備(device)主要是指跟硬體比較有關的術語， 包括磁碟、印表機、顯示卡和鍵盤。 FreeBSD 開機過程當中， 大多數硬體通常都能偵測到並顯示出來，也可以查閱 /var/run/dmesg.boot 內有開機的相關訊息。

舉例來說，acd0即為第一台 IDE 光碟機的代號， 而 kbd0 則代表鍵盤。

在 UNIX® 作業系統， 大部分的設備都是透過叫做 device nodes(設備節點)的特殊檔案來作存取， 而這些檔案都位於 /dev 目錄。

3.12.1. 建立設備節點

若要在系統上建立新節點，或者是要編譯某些新硬體的支援軟體， 那麼就要先新增設備節點。

3.12.1.1. DEVFS (DEVice File System)

設備檔案系統(或稱為 DEVFS) 是指在整體檔案系統 namespace 提供 kernel 的設備 namespace。 DEVFS 乃是維護這些檔案系統，而不能新增或修改這些設備節點。

細節請參閱 devfs(5) 說明。

3.13. 更多資訊

3.13.1. Manual 線上說明

在使用 FreeBSD 時，最詳細的使用說明莫過於 man 線上說明。 幾乎各程式都會有附上簡短說明，以介紹該程式的基本功能跟相關參數用法。 可以透過 man 指令來閱讀這些說明，而 man 指令的使用相當簡單易懂：

```
% man command
```

command 處就是想要知道的指令。 舉個例子， 若要知道 ls 的詳細用法，就可以打：

```
% man ls
```

而各線上說明因為性質不同，而區分為下列的數字章節：

1. 使用者指令。
2. 系統呼叫(System call) 及錯誤代號。
3. C 語言函式庫。
4. 各設備的驅動程式。
5. 檔案格式。
6. 小遊戲程式及其他娛樂程式。
7. 雜項工具、其他資訊。
8. 系統維護、操作的指令。
9. Kernel 開發用途。

有些情況會有同樣主題但不同章節。 舉個例子，系統內會有 chmod 指令，但也有 chmod() 系統呼叫。 在這種情況，man 應該要指定所要查詢的章節：

```
% man 1 chmod
```

如此一來就會查 chmod 指令部分。 通常在寫文件時會把有參考到某特定章節的 man 號碼也一併寫在括號內。 所以 chmod(1) 就是指 chmod 指令，而 chmod(2) 則是指系統呼叫的部分。

如果您已經知道命令的名稱，只是不知道要怎樣使用的話，那就比較好辦。 但若不知道要用哪個指令時，該怎麼辦呢？ 這個時候，就可以利用 man 的搜尋關鍵字功能， 以在各說明的介紹部分搜尋相關字眼。，它的選項是 -k：

```
% man -k mail
```

如此一來會看到一堆有 “mail” 關鍵字的說明， 事實上該功能與 apropos 指令是一樣的。

而有時你會看到像是 /usr/bin 有許多看起來頗炫的指令，但不知其用途？ 只要簡單輸入：

```
% cd /usr/bin
% man -f *
```

或者是

```
% cd /usr/bin
% whatis *
```

這兩者的指令效果是一樣的。

3.13.2. GNU Info 檔案

FreeBSD 有許多程式跟工具來自於自由軟體基金會(FSF)。 除了 man 線上說明之外，這些程式提供了另外一種更具有彈性的 hypertext 格式文件， 叫做 `info`。 可以用 `info` 指令來閱讀，或者若有裝 emacs 亦可透過 emacs 的 info 模式閱讀。

要用 info(1) 指令，只需打：

```
% info
```

按 h 會有簡單說明，而若要快速查閱相關操作方式， 則請按 ?。

章 4. 軟體套件管理篇：Packages 及 Ports 機制

4.1. 概述

儘管 FreeBSD 在 base system 已加了很多系統工具。 然而，在實務運用上，您可能仍需要安裝額外的軟體。 FreeBSD 提供了 2 種安裝應用程式的套件管理系統：Ports Collection（以 soucre 來編譯、安裝）和 package（預先編譯好的 binary 檔）。 上述的方式，無論要用哪一種，都可以由像是 CDROM 等或網路上來安裝想裝的最新版軟體。

讀完這章，您將了解：

- 如何以 packages 來安裝軟體。
- 如何以 ports 來安裝軟體。
- 已安裝的 packages 或 ports 要如何移除。
- 如何更改(override) ports collection 所使用的預設值。
- 如何在套件管理系統中，找出想裝的軟體。
- 如何升級已安裝的軟體。

4.2. 安裝軟體的各種方式介紹

通常要在 UNIX® 系統上安裝軟體時，有幾個步驟要作：

1. 先下載該軟體壓縮檔（tarball），有可能是原始碼或是 binary 執行檔。
2. 解開該壓縮檔。（通常是以 compress(1)，gzip(1) 或 bzip2(1) 壓縮的）
3. 閱讀相關文件檔，以了解如何安裝。（通常檔名是 `INSTALL` 或 `README` ，或在 `doc/` 目錄下的一些文件）
4. 如果所下載的是原始碼，可能要先修改 `Makefile` 或是執行 `./configure` 之類的 script ，接著再編譯該軟體。
5. 最後測試再測試與安裝。

如果一切順利的話，就這麼簡單。 如果在安裝非專門設計（移植）給 FreeBSD 的軟體時出問題， 那可能需要修改一下它的程式碼，才能正常使用。

當然，我們可以在 FreeBSD 上使用上述的傳統方式來安裝軟體， 但是，我們還有更簡單的選擇。 FreeBSD 提供了兩種省事的軟體管理機制： packages 和 ports。 就在寫這篇文章的時候， 已經有超過 24,000 個 port 軟體可以使用。

所謂的 FreeBSD package 就是別人把該應用程式編譯、打包完畢。 該 package 會包括該應用程式的所有執行檔、設定檔、文件等。 而下載到硬碟上的 package 都可透過 FreeBSD 套件管理指令來進行管理，比如：pkg_add(1)、pkg_delete(1)、pkg_info(1) 等指令。 所以，只需簡單打個指令就可輕鬆安裝新的應用程式了。

而 FreeBSD port 則是用一些檔案，來自動處理應用程式的安裝流程。

請記住：如果打算自己來編譯的話，需要執行很多操作步驟（下載、解壓、patch、編譯、安裝）。 而 port 呢，則是涵蓋所有需要完成這些工作的必備步驟， 所以只需打一些簡單的指令，那些原始程式碼就會自動下載、解壓、 patch、編譯，直至安裝完畢。

事實上，ports 機制還可以用來產生 packages，以便他人可以用 pkg_add 來安裝， 或是稍後會介紹到的其他套件管理指令。

而 packages 以及 ports 它們都是一樣會認 dependencies(軟體相依關係)。 假設：您想安裝某程式，但它有相依另一個已裝的函式庫(library)， 而在 FreeBSD 的 port 以及 package 都有這程式以及該函式庫了。 所以無論是用 pkg_add 指令或者 port 方式來裝該程式， 這兩者(package、port)都會先檢查有沒有裝該函式庫， 若沒有就會自動先裝該函式庫了。

這兩種技術都很相似，您可能會好奇為什麼 FreeBSD 會弄出這兩種技術來呢。 其實，packages 和 ports 都有它們各自的長處， 使用哪一種完全取決於您自己的喜好。

- 同樣是壓縮過的 package 與原始碼 tarball 相比， 前者通常會比後者小多了。
- package 並不需再進行編譯。 對大型應用程式如 Mozilla、 KDE、 GNOME 而言，這點顯得相當重要， 尤其是使用速度緩慢的機器。
- 不需要瞭解如何在 FreeBSD 上編譯軟體的相關細節過程， 即可使用 package。
- 為了讓 package 能在大多數系統上順利執行， 通常在編譯時會使用比較保守的選項。 然而， 透過 port 安裝的話，則可針對特定環境(比如： Pentium 4 或 Athlon CPU) 來調整選項，以符合需求。
- 有些程式在編譯時，會有一些選項可以選擇。 舉例來說，Apache 可以設定一大堆的編譯選項。 若透過 port 來安裝的話， 會比較彈性多了，可以自己選而不必使用預設的編譯選項。

  在某些情況，同樣的程式但不同編譯選項，則會分成不同的 package。 比如： Ghostscript 會因為是否要裝 X11 server， 而劃分為 ghostscript 以及 ghostscript-nox11 這兩種 package。 如此的調整對 package 算是可成立的， 但若該程式有一個以上或兩種不同的編譯選項時， 這對 package 就沒辦法了。
- 某些軟體的禁止以 binary 方式散佈， 或者說必須以原始碼方式散佈才可。
- 有些人並不信任 binary 套件機制，因為他們覺得至少有原始碼，(理論上)就可以自己檢閱，並尋找是否有潛在的問題。
- 若要對軟體加上自己改過的 patch， 那麼就必須要先有原始碼才能去上相關 patch 修正。
- 有些人喜歡有原始碼在手邊， 所以他們無聊時就可以自己閱讀、鑽研、借用（當然要符合原始碼本身的授權規定)原始碼等等。

若想注意 port 更新動態的話，可以訂閱 FreeBSD ports 郵遞論壇 以及 FreeBSD ports bugs 郵遞論壇。

警告

在安裝軟體前，最好先看 http://vuxml.freebsd.org/ 內是否有該軟體的安全漏洞通報。

此外，也可以裝 ports-mgmt/portaudit，它會自動檢查所有已裝的 的軟體是否有已知的安全漏洞，另外，它還會在裝軟體的編譯過程前先行檢查。 也可以在裝了某些軟體之後，用 portaudit -F -a 來作全面強制安檢。

本章接下來將介紹如何在 FreeBSD 使用 package 及 port 來安裝、管理 third-party 軟體。

4.3. 尋找想裝的軟體

在安裝任何軟體之前，你必須先了解你想要什麼的軟體， 以及該軟體叫做什麼名稱。

FreeBSD 上可裝的軟體清單不斷在增加中， 不過，我們很慶幸有幾種方式可以來找你想裝的軟體：

- FreeBSD 網站上有更新頻繁的軟體清單，在 http://www.FreeBSD.org/ports/ 。 各 ports 皆依其性質而分門別類，既可以透過軟體名稱來搜尋（如果知道名字的話）， 也可以在分類中列出所有可用的軟體。

- 由 Dan Langille 所維護 FreshPorts 網站，網址在 `http://www.FreshPorts.org/` 。 FreshPorts 會不斷追蹤 port tree 中的各種變化， 也可以針對某些 port 以列入 “追蹤名單(watch)” 內， 當有任何軟體升級時，就會發 email 提醒。

- 如果不知道想裝的軟體名稱，那麼可透過像是 FreshMeat (`http://www.freshmeat.net/`)這類的網站來找， 如果找到了，可以回 FreeBSD 網站去看一下這個應用程式是否已經被 port 進去了。

- 若知道該 port 的正確名稱，但不知道放在哪個分類目錄，可以用 whereis(1) 指令來找出來。 只要打 `whereis file` 即可，而 *`file`* 的地方請改為想裝的軟體名稱。 若找到該軟體，就會告訴你，就像下面這樣：

  ```
  # whereis lsof
  lsof: /usr/ports/sysutils/lsof
  ```

  如此一來，就會知道 `lsof`（系統工具程式）是放在 `/usr/ports/sysutils/lsof` 目錄。

- 此外，也可以用 echo(1) 輕鬆找出該 port 是位於 porte tree 的何處。 舉例來說：

  ```
  # echo /usr/ports/*/*lsof*
  /usr/ports/sysutils/lsof
  ```

  請注意，這也會顯示 `/usr/ports/distfiles` 目錄內有符合檔名的檔案。

- 還有另一招，就是用 Ports Collection 本身內建的搜尋機制。 要用的時候，請先切換到 `/usr/ports` 目錄。 然後，打 `make search name=####` ，其中 `####` 請改為想找的軟體名稱。 舉例來說，若要找的是 `lsof` 的話，那麼就是：

  ```
  # cd /usr/ports
  # make search name=lsof
  Port:   lsof-4.56.4
  Path:   /usr/ports/sysutils/lsof
  Info:   Lists information about open files (similar to fstat(1))
  Maint:  obrien@FreeBSD.org
  Index:  sysutils
  B-deps:
  R-deps:
  ```

  這些搜尋結果中，要注意的是 “Path:” 這行， 因為這行會告訴你可以在哪邊找到該 port。 而搜尋結果的其他部分，因為與 port 安裝較無關係，所以這裡就不講了。

  若要更徹底的搜尋，那麼可以改用 `make search key=string` ，其中 *`string`* 請改為想搜尋的關鍵字。 如此一來會找 port 名稱、軟體簡介(comments)、軟體敘述檔(descriptions) 以及軟體相依關係(dependencies)裡面是否有符合關鍵字， 此外，不清楚軟體名稱的話，也可以拿來找有符合關鍵字主題的 port。

  剛講的這兩種方式，搜尋字眼都是 case-insensitive(不必區分大小寫)。 比如，搜尋 “LSOF” 與 “lsof” 兩者結果都會是一樣的。

4.4. Using pkg for Binary Package Management

pkg is the next generation replacement for the traditional FreeBSD package management tools, offering many features that make dealing with binary packages faster and easier.

pkg is not a replacement for port management tools like ports-mgmt/portmaster or ports-mgmt/portupgrade. These tools can be used to install third-party software from both binary packages and the Ports Collection, while pkg installs only binary packages.

4.4.1. Getting Started with pkg

FreeBSD 8.4 and later includes a bootstrap utility which can be used to download and install pkg, along with its manual pages.

To bootstrap the system, run:

```
# /usr/sbin/pkg
```

For earlier FreeBSD versions, pkg must instead be installed from the Ports Collection or as a binary package.

To install the port, run:

```
# cd /usr/ports/ports-mgmt/pkg
# make
# make install clean
```

When upgrading an existing system that originally used the older package system, the database must be converted to the new format, so that the new tools are aware of the already installed packages. Once pkg has been installed, the package database must be converted from the traditional format to the new format by running this command:

```
# pkg2ng
```

注意

This step is not required for new installations that do not yet have any third-party software installed.

重要

This step is not reversible. Once the package database has been converted to the pkg format, the traditional `pkg_*` tools should no longer be used.

注意

The package database conversion may emit errors as the contents are converted to the new version. Generally, these errors can be safely ignored. However, a list of third-party software that was not successfully converted will be listed after `pkg2ng` has finished and these applications must be manually reinstalled.

To ensure that the FreeBSD Ports Collection registers new software with pkg, and not the traditional packages format, FreeBSD versions earlier than 10.*X* require this line in `/etc/make.conf` :

```
WITH_PKGNG= yes
```

The pkg package management system uses a package repository for most operations. The default package repository location is defined in `/usr/local/etc/pkg.conf` or by the `PACKAGESITE` environment variable, which overrides the configuration file.

Additional pkg configuration options are described in pkg.conf(5).

Usage information for pkg is available in pkg(8) or by running `pkg` without additional arguments.

Each pkg command argument is documented in a command-specific manual page. To read the manual page for `pkg install` , for example, run either of these commands:

```
# pkg help install
```

```
# man pkg-install
```

The rest of this section demonstrates common binary package management tasks which can be performed using pkg. Each demonstrated command provides many switches to customize its use. Refer to a command's help or man page for details and more examples.

4.4.2. Obtaining Information About Installed Packages

Information about the packages installed on a system can be viewed by running `pkg info` which, when run without any switches, will list the package version for either all installed packages or the specified package.

For example, to see which version of pkg is installed, run:

```
# pkg info pkg
pkg-1.1.4_1
```

4.4.3. Installing and Removing Packages

To install a binary package use the following command, where *`packagename`* is the name of the package to install:

```
# pkg install packagename
```

This command uses repository data to determine which version of the software to install and if it has any uninstalled dependencies. For example, to install curl:

```
# pkg install curl
Updating repository catalogue
/usr/local/tmp/All/curl-7.31.0_1.txz          100% of 1181 kB 1380 kBps 00m01s

/usr/local/tmp/All/ca_root_nss-3.15.1_1.txz   100% of  288 kB 1700 kBps 00m00s

Updating repository catalogue
The following 2 packages will be installed:

        Installing ca_root_nss: 3.15.1_1
        Installing curl: 7.31.0_1

The installation will require 3 MB more space

0 B to be downloaded

Proceed with installing packages [y/N]: y
Checking integrity... done
[1/2] Installing ca_root_nss-3.15.5_1... done
[2/2] Installing curl-7.31.0_1... done
Cleaning up cache files...Done
```

The new package and any additional packages that were installed as dependencies can be seen in the installed packages list:

```
# pkg info
```

```
ca_root_nss-3.15.5_1 The root certificate bundle from the Mozilla Project
curl-7.31.0_1 Non-interactive tool to get files from FTP, GOPHER, HTTP(S) servers
pkg-1.1.4_6 New generation package manager
```

Packages that are no longer needed can be removed with `pkg delete`. For example:

```
# pkg delete curl
The following packages will be deleted:

 curl-7.31.0_1

The deletion will free 3 MB

Proceed with deleting packages [y/N]: y
[1/1] Deleting curl-7.31.0_1... done
```

4.4.4. Upgrading Installed Packages

Packages that are outdated can be found with `pkg version`. If a local ports tree does not exist, pkg-version(8) will use the remote repository catalogue. Otherwise, the local ports tree will be used to identify package versions.

Installed packages can be upgraded to their latest versions by typing `pkg upgrade`. This command will compare the installed versions with those available in the repository catalogue. When finished, it will list the applications that have newer versions. Type **y** to proceed with the upgrade or **n** to cancel the upgrade.

4.4.5. Auditing Installed Packages

Occasionally, software vulnerabilities may be discovered in third-party applications. To address this, pkg includes a built-in auditing mechanism. To determine if there are any known vulnerabilities for the software installed on the system, run:

```
# pkg audit -F
```

4.4.6. Automatically Removing Leaf Dependencies

Removing a package may leave behind dependencies which are no longer required. Unneeded packages that were installed as dependencies can be automatically detected and removed using:

```
# pkg autoremove
Packages to be autoremoved:
 ca_root_nss-3.13.5

The autoremoval will free 723 kB

Proceed with autoremoval of packages [y/N]: y
Deinstalling ca_root_nss-3.15.1_1... done
```

4.4.7. Backing Up the Package Database

Unlike the traditional package management system, pkg includes its own package database backup mechanism. To manually back up the contents of the package database, run the following command, replacing *pkgng.db* with a suitable file name:

```
# pkg backup -d pkgng.db
```

Additionally, pkg includes a periodic(8) script to automatically perform a daily back up of the package database. This functionality is enabled if `daily_backup_pkgdb_enable` is set to `YES` in periodic.conf(5).

提示

To disable the periodic script from backing up the package database, set `daily_backup_pkgdb_enable` to `NO` in periodic.conf(5).

To restore the contents of a previous package database backup, run:

```
# pkg backup -r /path/to/pkgng.db
```

4.4.8. Removing Stale Packages

By default, pkg stores binary packages in a cache directory defined by `PKG_CACHEDIR` in pkg.conf(5). When upgrading packages with `pkg upgrade`, old versions of the upgraded packages are not automatically removed.

To remove these outdated binary packages, run:

```
# pkg clean
```

4.4.9. Modifying Package Metadata

Software within the FreeBSD Ports Collection can undergo major version number changes. To address this, pkg has a built-in command to update package origins. This can be useful, for example, if lang/php5 is renamed to lang/php53 so that lang/php5 can now represent version `5.4`.

To change the package origin for the above example, run:

```
# pkg set -o lang/php5:lang/php53
```

As another example, to update lang/ruby18 to lang/ruby19, run:

```
# pkg set -o lang/ruby18:lang/ruby19
```

As a final example, to change the origin of the `libglut` shared libraries from graphics/libglut to graphics/freeglut, run:

```
# pkg set -o graphics/libglut:graphics/freeglut
```

注意

When changing package origins, it is important to reinstall packages that are dependent on the package with the modified origin. To force a reinstallation of dependent packages, run:

```
# pkg install -Rf graphics/freeglut
```

4.5. 使用 Ports 管理機制

The Ports Collection is a set of `Makefiles`, patches, and description files stored in `/usr/ports`. This set of files is used to compile and install applications on FreeBSD. Before an application can be compiled using a port, the Ports Collection must first be installed. If it was not installed during the installation of FreeBSD, use one of the following methods to install it:

過程 4.1. Portsnap 方式

The base system of FreeBSD includes Portsnap. This is a fast and user-friendly tool for retrieving the Ports Collection and is the recommended choice for most users. This utility connects to a FreeBSD site, verifies the secure key, and downloads a new copy of the Ports Collection. The key is used to verify the integrity of all downloaded files.

1. To download a compressed snapshot of the Ports Collection into `/var/db/portsnap` :

   ```
   # portsnap fetch
   ```

2. 若是第一次跑 Portsnap 的話，則需要先解壓到 `/usr/ports` ：

   ```
   # portsnap extract
   ```

3. After the first use of Portsnap has been completed as shown above, `/usr/ports` can be updated as needed by running:

   ```
   # portsnap fetch
   # portsnap update
   ```

   When using `fetch`, the `extract` or the `update` operation may be run consecutively, like so:

   ```
   # portsnap fetch update
   ```

過程 4.2. Subversion Method

If more control over the ports tree is needed or if local changes need to be maintained, Subversion can be used to obtain the Ports Collection. Refer to the Subversion Primer for a detailed description of Subversion.

1. Subversion must be installed before it can be used to check out the ports tree. If a copy of the ports tree is already present, install Subversion like this:

   ```
   # cd /usr/ports/devel/subversion
   # make install clean
   ```

   If the ports tree is not available, or pkg is being used to manage packages, Subversion can be installed as a package:

   ```
   # pkg install subversion
   ```

2. Check out a copy of the ports tree. For better performance, replace *`svn0.us-east.FreeBSD.org`* with a Subversion mirror close to your geographic location:

   ```
   # svn checkout https:// svn0.us-east.FreeBSD.org /ports/head /usr/ports
   ```

3. As needed, update `/usr/ports` after the initial Subversion checkout:

   ```
   # svn update /usr/ports
   ```

The Ports Collection installs a series of directories representing software categories with each category having a subdirectory for each application. Each subdirectory, also referred to as a ports skeleton, contains a set of files that tell FreeBSD how to compile and install that program. Each port skeleton includes these files and directories:

- `Makefile`: contains statements that specify how the application should be compiled and where its components should be installed.
- `distinfo`: contains the names and checksums of the files that must be downloaded to build the port.
- `files/`: this directory contains any patches needed for the program to compile and install on FreeBSD. This directory may also contain other files used to build the port.

- `pkg-descr` : provides a more detailed description of the program.
- `pkg-plist` : a list of all the files that will be installed by the port. It also tells the ports system which files to remove upon deinstallation.

Some ports include `pkg-message` or other files to handle special situations. For more details on these files, and on ports in general, refer to the FreeBSD Porter's Handbook.

The port does not include the actual source code, also known as a `distfile` . The extract portion of building a port will automatically save the downloaded source to `/usr/ports/distfiles` .

4.5.1. Ports 的安裝方式

下面我們會介紹如何使用 Ports Collection 來安裝、移除軟體的基本用法。 至於其他可用的 `make` 詳細用法與環境設定，可參閱 ports(7)。

警告

Before compiling any port, be sure to update the Ports Collection as described in the previous section. Since the installation of any third-party software can introduce security vulnerabilities, it is recommended to first check `http://vuxml.freebsd.org/` for known security issues related to the port. Alternately, if ports-mgmt/portaudit is installed, run `portaudit -F` before installing a new port. This command can be configured to automatically perform a security audit and an update of the vulnerability database during the daily security system check. For more information, refer to the manual page for portaudit and periodic(8).

提到 Ports `Collection`，首先要先說明的是：何謂 “skeleton”。 簡單來講，`port` skeleton 就是讓軟體如何在 FreeBSD 順利編譯、安裝的最基本檔案組合。 每份 port skeleton 基本上會有：

- `Makefile` 檔。 這個 `Makefile` 內容有分許多部分， 是用來指定要如何編譯，以及該裝在系統的何處。
- `distinfo` 檔。 編譯該軟體所需下載的檔案、`checksum`(使用 md5(1) 及 sha256(1) 來檢驗檔案)都會記錄在這檔， 以確保所下載的檔案是正確無誤的。
- `files` 目錄。 這目錄放的是讓軟體正常編譯、 安裝的 patch 檔。 Patches 檔基本上是一些小檔案，並針對特定檔案來做修改， 而且是純文字檔格式， 基本上內容通常會像是 “Remove line `10`(刪除第 10 行)” 或 “Change line 26 to this ...(把第 26 行改為...)” 之類的。 這些 Patches 通常也稱為 “diffs”，因為都是由 diff(1) 程式所產生的。

  此外，本目錄也可能會放一些協助編譯該 port 的檔案。
- `pkg-descr` 檔，內容是比較詳細的軟體介紹， 通常會寫得比較多行。
- `pkg-plist` 檔，該 port 會安裝的所有檔案清單。 也是告訴系統在移除該 port 時，需要刪除哪些檔案。

有些 port 還會有其他檔案，像是 `pkg-message` 檔。 port 系統在一些情況時，會用這些檔案。 如果想知道這些檔案的更多細節用途，以及 port 一般用法，請參閱 FreeBSD Porter's Handbook。

port 內寫的是告訴系統如何編譯 source code 的相關指令， 但並不是真正的 source `code`。 而 source code 可以從光碟或網路(Internet)來取得， 該軟體開發者可能會把 source code 以各種格式來發佈。 通常是以 tar 以及 gzip 這兩者工具一起壓縮的檔案， 也有可能是以其他工具壓縮，或根本沒壓縮。 而軟體的 source code 無論是以哪一種壓縮檔型態，我們都稱之為 “distfile”。 下面將介紹兩種安裝 FreeBSD port 的方式。

注意

要安裝 port 的話，請務必切為 `root` 身份。

警告

在安裝任何 port 之前，請務必確認有更新 Ports Collection 到最新版， 此外請檢閱 `http://vuxml.freebsd.org/` 來檢查所要裝的 port 是否有相關安全漏洞議題需要注意的。

portaudit 會在安裝任何 port 之前， 先自動檢查是否有相關已知的安全漏洞。這個工具在 Ports Collection 內有 (ports-mgmt/portaudit)。 在安裝 port 之前，可以先跑 `portaudit -F` 指令， 如此一來就會抓最新的資安漏洞資料庫回來核對。 每天的系統定期安檢會自動更新資料庫，並作安全稽核。 詳情請參閱 portaudit(1) 以及 periodic(8) 的線上說明。

Ports Collection 會假設你的網路是可正常連線的。 如果沒有的話，那麼需手動把所需的 distfile 檔複製到 `/usr/ports/distfiles` 才行。

開始操作之前，要先進入打算安裝的 port 目錄內：

```
# cd /usr/ports/sysutils/lsof
```

一旦進入 `lsof` 目錄後，就可以看到這個 port 的 skeleton 結構。 接下來，就是編譯，也就是 “build” 這個 port。 只需簡單輸入 `make` 指令，就可輕鬆完成編譯。 完成後，應該可以看到類似下面訊息：

```
# make
>> lsof_4.57D.freebsd.tar.gz doesn't seem to exist in /usr/ports/distfiles/.
>> Attempting to fetch from ftp://lsof.itap.purdue.edu/pub/tools/unix/lsof/.
===>  Extracting for lsof-4.57
...
[extraction output snipped]
...
>> Checksum OK for lsof_4.57D.freebsd.tar.gz.
===>  Patching for lsof-4.57
===>  Applying FreeBSD patches for lsof-4.57
===>  Configuring for lsof-4.57
...
[configure output snipped]
...
===>  Building for lsof-4.57
...
[compilation output snipped]
...
#
```

請注意：編譯完成後，就會回到提示列(prompt)。接下來就是安裝該 port 了，要裝的話，只需在原本的 `make` 指令後面再加上一個字即可， 那個字就是 `install`：

```
# make install
===>  Installing for lsof-4.57
...
[installation output snipped]
```

```
...
===>   Generating temporary packing list
===>   Compressing manual pages for lsof-4.57
===>   Registering installation for lsof-4.57
===>  SECURITY NOTE:
      This port has installed the following binaries which execute with
      increased privileges.
#
```

一旦回到提示列(prompt)，就可以執行剛裝的程式了。 另外，因為 lsof 這程式執行時會有額外權限， 所以會出現安全警告。在編譯、安裝 port 的時候， 請留意任何出現的警告。

此外，建議刪除編譯用的工作目錄(預設是 work)， 這目錄內為在編譯過程中所用到的一些臨時檔案， 這些檔案不只佔硬碟空間，而且也可能會在該 port 升級新版時， 造成不必要的困擾。

```
# make clean
===>  Cleaning for lsof-4.57
#
```

注意

用 make install clean 就可以一口氣完成剛所說 make、make install 、make clean 這三個步驟了。

注意

有些 shell 會依據 PATH 環境變數的路徑， 把那些路徑的執行檔 cache 起來，來加速搜尋執行檔。 如果你用的是這類的 shell，那麼在裝完 port 後需要打 rehash 指令，才能執行新裝的執行檔，而 rehash 指令可以在 tcsh 之類的 shell 上使用，若是 sh 的話，則是 hash -r。 詳情請參閱你所使用的 shell 相關文件。

有些由所謂 third-party 所發行的 DVD-ROM 產品，像是 FreeBSD Mall 所發行的 FreeBSD Toolkit 會包括 distfiles 檔案， 這些檔案可用來搭配 Ports Collection。 把 DVD-ROM 掛載在 /cdrom。 若使用其他掛載點的話，要記得設定 CD_MOUNTPTS 環境變數為相對應的掛載點。 如此一來，光碟上若有所需的 distfiles 就會自動使用光碟的檔案。

注意

請注意，有少數 port 並不允許透過光碟來發佈檔案。 可能的原因有：需先填註冊單才能下載或散佈檔案，或其他原因。 如果想安裝在光碟上沒附上的 port，就需連上網路才能繼續進行安裝。

ports 系統採用 fetch(1) 來下載檔案， 它有許多可調整的環境變數，包括：FTP_PASSIVE_MODE 、FTP_PROXY 、FTP_PASSWORD 。 如果是處於有防火牆的環境， 或者需要使用 FTP/HTTP proxy，那麼就需要設定這些變數。 使用細節請參閱 fetch(3) 說明。

若無法隨時一直上網的話，那麼可以利用 make fetch 。 只要在 port 的最上層路徑(/usr/ports)打這指令，那麼所有需要用到的檔案都會下載。 這指令也可以在下層目錄使用，例如： /usr/ports/net 。 請注意，若該 port 有相依的 library 或者其他 port 的話， 那麼它並不會跟著一起下載其他所相依的檔案。 若想一次下載所有相依的 port 所有檔案，那麼指令參數請改用 fetch-recursive 而非 fetch。

注意

可以在某類別或最上層路徑打 make 指令來編譯所有的 port，或者以上述的 make fetch 指令來下載所有檔案。 然而，這樣是相當危險，因為有些 port 不能並存。 也有另一種情況，有些 port 可能會以相同檔名， 但是實際上卻是不同內容的檔案。

在某些罕見情況，可能需加上 MASTER_SITES （檔案的原始下載處）之外的下載點，以下載所需的檔案。可以用下列指令，來更改預設的 MASTER_SITES 下載點：

```
# cd /usr/ports/directory
# make MASTER_SITE_OVERRIDE= \
ftp://ftp.FreeBSD.org/pub/FreeBSD/ports/distfiles/ fetch
```

上面這例子，是把 MASTER_SITES 改設 ftp.FreeBSD.org/pub/FreeBSD/ports/distfiles/ 為下載點。

注意

有些 port 允許（或要求）您得指定編譯選項， 以啓用、停用該軟體中非必須的功能、安全選項以及其他可自訂的選項。 具有代表性的包括了 www/mozilla、security/gpgme、mail/sylpheed-claws。 若有這類選項時，通常在編譯時會出現相關提示訊息。

4.5.1.1. 更改(Override)預設的 Ports 目錄

有時候，會發現到使用其他目錄作為 port、distfiles 目錄可能相當有用（甚至是必須），可以設定 PORTSDIR 及 PREFIX 環境變數以修改預設的 port 目錄。舉例：

```
# make PORTSDIR=/usr/home/example/ports install
```

以上會在 /usr/home/example/ports 內進行編譯， 並把所有檔案安裝到 /usr/local 內。

```
# make PREFIX=/usr/home/example/local install
```

則會在 /usr/ports 目錄內編譯， 並把所有檔案安裝到 /usr/home/example/local 內。

當然囉，

```
# make PORTSDIR=../ports PREFIX=../local install
```

則會同時包含兩種設定（還有很多變化以致無法在本頁全部都有寫到， 但您應該已經有抓到大概概念了吧）。

此外，這些變數也以作為環境變數來設定。 請依您所使用的 shell 去參閱相關說明，以瞭解如何設定。

4.5.1.2. 處理 imake

有些 port 會使用 imake（X Window 系統的一部份）無法正常運用 PREFIX 變數， 它們會堅持把檔案都安裝到 /usr/X11R6 目錄。 同樣地，也有一些 Perl port 會忽略 PREFIX 並把檔案安裝到 Perl 目錄架構內。 讓這些 ports respect PREFIX 是相當困難，甚至是不可能的事。

4.5.1.3. 重新設定 Ports 選項

在編譯某些 port 時會出現選單畫面(ncurses-based)， 可以用來選擇安裝選項。 通常裝好該 port 之後，便不太會需要重加、 移除、更改一些當初安裝的選項。 但日後若有需要的話， 也有許多方式可以調整這些選項。 其中一種方式便是切到該 port 目錄， 並打 `make config` 即可再次回到選項畫面去作調整。 另外還可用 `make showconfig` 以顯示該 port 安裝時所用的選項。 也可以用 `make rmconfig` 來把所有選項回到初始設定。 這些選項跟其他動作都可參閱 ports(7) 內的詳細說明。

4.5.2. 移除已安裝的 Ports

現在您已經知道如何安裝 port，而開始想瞭解如何移除。 比如裝了一個 port 後才意識到裝錯 port 了。 在此，我們將移除前面例子所裝的那個 port （沒仔細注意的話，我們再提醒一下就是 `lsof`）。 跟移除 package 時相當類似，都是使用 pkg_delete(1) 指令：

```
# pkg_delete lsof-4.57
```

4.5.3. 升級已安裝的 Ports

首先，用 pkg_version(1) 指令來列出目前 Ports Collection 中提供了那些可升級的 port 版本：

```
# pkg_version -v
```

4.5.3.1. /usr/ports/UPDATING

每次更新完 Ports Collection 之後，請務必記得在升級 port 前， 先看看 `/usr/ports/UPDATING` ， 這裡會寫升級方面的各式問題，比如：檔案格式改變、變更設定檔位置、 與舊版不相容的問題等，以及怎麼解決的完整步驟。

若 `UPDATING` 內容與你看到的其他文件有些不同 、相衝的話， 那麼請以 `UPDATING` 為準。

4.5.3.2. 以 Portupgrade 來升級已安裝的 Ports

portupgrade 可以輕鬆升級已裝的軟體。 該工具可從 ports-mgmt/portupgrade port 安裝， 安裝方式就如同其他 port 一樣，用 `make install clean` 指令就可以了：

```
# cd /usr/ports/ports-mgmt/portupgrade
# make install clean
```

首先最好先以 `pkgdb -F` 來掃瞄已裝的 ports 資料庫是否有誤，並修正有問題的地方。 在每次做升級之前，最好定期做一下 `pkgdb -F` 動作會較為妥當。

跑 `portupgrade -a` 的話， portupgrade 會升級系統上所有已裝的過舊 ports。 若用 `-i` 則在升級每個 port 過程當中， 會要求確認相關動作是否符合所需。

```
# portupgrade -ai
```

若只想升級某特定程式而非全部，那麼可以用 `portupgrade pkgname` 來做指定。 若想要 portupgrade 優先升級某 port 所相依的相關套件，則請用 `-R` 參數即可。

```
# portupgrade -R firefox
```

若要用 package 而非 port 來安裝，則需指定 `-P` 才可以。 若有指定這選項，則 portupgrade 會搜尋 `PKG_PATH` 變數所指定的本機目錄， 若找不到則透過網路來下載安裝。 若本機跟網路都沒有可用的 package 的話，則 portupgrade 會使用 port 方式安裝。 若不想如此又變成使用 port 方式安裝，則用 `-PP` 即可强制避免使用 port 方式安裝。

```
# portupgrade -PP gnome2
```

若只想下載 distfiles(或者若指定 -P 的話，則是 package)而不想編譯或安裝檔案，可以使用 -F。 詳情請參閱 portupgrade(1) 的說明。

4.5.3.3. 以 Portmanager 來升級已安裝的 Ports

Portmanager 也可以用來輕鬆升級已裝的軟體。 該工具可從 ports-mgmt/portmanager port 安裝：

```
# cd /usr/ports/ports-mgmt/portmanager
# make install clean
```

所有已裝的軟體，都可以輕鬆用類似下列指令來升級：

```
# portmanager -u
```

此外，使用參數可以改為 -ui，如此一來 Portmanager 在升級一些有特殊選項的軟體時 ，就會詢問該如何升級。 Portmanager 也可以用來裝新 port。與以往常用的 make install clean 指令不同之處在於：它會先升級你要裝的 port 所相依的所有 ports，然後才開始編譯、 安裝要裝的 port。

```
# portmanager x11/gnome2
```

若要裝的 port 之軟體相依關係有問題時，也可以用 Portmanager 使它們重歸正軌。 而 Portmanager 解決相依問題完畢之後，該 port 也會重新編譯，以因應正確的相依關係。

```
# portmanager graphics/gimp -f
```

其餘運用法門，請參閱 portmanager(1) 說明。

4.5.4. Ports 與硬碟空間

因為使用 Ports Collection 遲早可能會用光硬碟空間， 所以在裝完軟體後，記得要以 make clean 指令來清除臨時的 work 目錄。 此外，可以用下列指令來清除整個 Ports Collection 內的臨時目錄：

```
# portsclean -C
```

ports 用久了，您可能會在 distfiles 目錄內會累積著許多的原始碼檔案。 可以手動刪除這些檔案， 或者用下列指令來清除所有 port 都不使用的舊檔：

```
# portsclean -D
```

或者要清除所有已裝的 port 都不再使用的舊檔：

```
# portsclean -DD
```

注意

portsclean 這工具乃是 portupgrade 套件的一部分。

不要忘了移除那些已經安裝，但不再需要用到的 ports。 有個 ports-mgmt/pkg_cutleaves port，正是可自動完成這功能的好工具。

4.6. 安裝之後，有什麼後續注意事項嗎？

通常，安裝完軟體後，我們可以閱讀所附的一些文件，或需要編輯設定檔， 來確保這個軟體能順利運作，或在機器開機的時候啓動(如果是 daemon 的話) 等等。

不同的軟體會有不同的設定步驟。不管怎樣，如果裝好了軟體， 但是不知道下一步怎麼辦的時候， 可以試試看這些小技巧：

- 善用 pkg_info(1) ，這指令可以顯示：透過套件管理系統 (Packages/Ports)裝了哪些軟體、檔案裝在哪邊。舉例來說，若剛裝了 FooPackage（版本 1.0.0），那麼下面這指令：

  ```
  # pkg_info -L foopackage-1.0.0 | less
  ```

  就會顯示這軟體所安裝的檔案清單。 請特別注意在 man/ 目錄內是說明檔、 etc/ 目錄內是設定檔、 doc/ 目錄內是完整文件。

  若不確定已裝的套件版本為何，可以用類似下列指令來查：

  ```
  # pkg_info | grep -i foopackage
  ```

  以上將會搜尋所有已裝的套件，列出有符合 *foopackage* 的套件名稱。 請自行依需求，修改 *foopackage* 為想找的套件名稱。

- 一旦確認該程式的線上說明有安裝，就可以用 man(1) 來翻閱。 同樣地，若該程式有提供的話，也可以參考設定檔樣本，以及其他文件。

- 若該程式有官網的話，還可以透過網站來找文件、常見問答集(FAQ)等。 若不知道網址，請用下列指令：

  ```
  # pkg_info foopackage-1.0.0
  ```

  若該程式有官網的話，則會有一行 WWW: 開頭的出現，這行會列出該程式的官網網址(URL)。

- Port 若須在開機時就會啓動(就像 Internet 主機)，通常都會安裝 script 到 /usr/local/etc/rc.d 目錄。 您可以檢閱這 script 的正確與否，或若有需要，也可以修改、改名。 詳情請參閱 啓動 Services。

4.7. 如何處理爛掉(Broken)的 Ports？

如果發現某個 port 無法順利安裝、運作， 有幾種方法可以試試看：

1. 從 Problem Report 資料庫 中挖寶看看，說不定已經有人送可用的 patch 上去囉， 那麼或許就可以順利解決問題哩。

2. 向該 port 的 maintainer 尋求協助：請打 make maintainer 或翻閱 Makefile 以查詢 maintainer 的 email address。記得寄信給 maintainer 時，要附註該 port 的名稱、版本(或是把 Makefile 內的 $FreeBSD: 那一整行附上) 以及相關錯誤訊息。

   ### 注意

   有些 port 不是由專門的單一 maintainer 負責，而是透過 mailing list 的專題討論。許多(但非全部)的聯絡 email 格式通常是 <freebsd-list##@FreeBSD.org > 。發問時，請記得把『freebsd–list名稱』改為相關討論的 mailing list 名稱。

   尤其當 port 的 maintainer 欄位是 <freebsd-ports@FreeBSD.org > 時，事實上已經沒人當該 port maintainer 了。 因此若該 port 仍有修正或其他技術支援的話，相關討論都會在 freebsd-ports 郵遞論壇上出現。 喔，對了，如果有熟悉該軟體者，志願當該 port maintainer 的話，我們也都很歡迎您的加入喔。

   若 port maintainer 沒有回覆您的信件， 則可以用 send-pr(1) 來提交問題報告 PR。(請參閱 Writing FreeBSD Problem Reports)。

3. 試試看修正它吧! Porter's Handbook 包括了 “Ports” 架構的細節部份，這些書中內容有助您修好有問題的 port 甚至提交自己的 port！

4. 從較近的 FTP 站點下載編譯好的 package。 package collection 的最上游站是在 ftp.FreeBSD.org 上的 packages 目錄內，但請記得先檢查是否已有 local mirror 站！ 通常情況下這些 package 都可以直接使用， 而且應該比自行編譯快一些。 用 pkg_add(1) 即可順利安裝 package 。

章 5. X Window 視窗系統

Updated for X.Org's X11 server by Ken Tom 且 Marc Fonvieille.

5.1. 概述

FreeBSD 使用 X11 來提供使用者相當好用的 GUI 介面。 X11 是 X Window 系統，包括 Xorg 以及 XFree86™ 實作的自由軟體版本（以及其他未在本章有介紹的軟體）。 FreeBSD 一直到 FreeBSD 5.2.1-RELEASE 都仍可在預設的安裝程式內去裝 XFree86™（由 The XFree86™ Project, Inc 發行的 X11 `server`）。 而 FreeBSD 5.3-RELEASE 起，預設的 X11 改為 `Xorg`（由 X.Org 基金會所開發的 X11 `server`，並採用與 FreeBSD 相當類似的 `license`）。 此外，當然也有商業 X servers 的 FreeBSD 版。

本章主要是介紹 X11（主要著重於 Xorg 7.7 版部分）的安裝與設定。 若欲瞭解 XFree86™ 的詳細資料（早期的 FreeBSD 內， XFree86™ 乃是預設的 X11 套件），請參閱舊版的 FreeBSD `Handbook`，網址為 `http://docs.FreeBSD.org/doc/` 。

欲知 X11 對於顯示方面硬體的支援情況，請參閱 Xorg 網站。

讀完這章，您將了解：

- X Window 系統的各組成部份，以及它們是如何相互運作。
- 如何安裝、設定 `X11`。
- 如何安裝並使用不同的 window `managers`。
- 如何在 X11 上使用 TrueType® 字型。
- 如何設定系統以使用圖形登入介面。 (XDM)

在開始閱讀這章之前，您需要：

- 知道如何運用 `ports`、`packages` 來安裝軟體。 (章 4, 軟體套件管理篇：Packages 及 Ports 機制)

5.2. 瞭解 X 的世界

第一次接觸 X 的人，大概都會有些震撼，尤其是熟悉其他 GUI 介面（像是 Microsoft® Windows® 或 Mac OS®）的使用者。

雖然 X 各元件的所有細節及運作方式，並不是必須要知道的。 但對它們有些基本概念會更容易上手。

5.2.1. 爲何叫做 X？

X 並非 UNIX® 上第一套視窗系統，但它卻是最廣為流傳運用。 原本的 X 研發團隊在研發 X 之前有開發另一套視窗系統。 那套系統叫做 “W”（取 “Window” 的第一個字）。 而 X 則是 W 之後的下一個羅馬字母。

X 亦被稱之為 “X”、“X Window System”、 “X11”，以及其他一些詞彙。 使用 “X Windows” 這字眼來稱呼 `X11`，可能會讓有些人不爽；這部分細節可參閱 X(7) 說明。

5.2.2. X 的 Client/Server 架構

X 一開始是設計為網路架構環境，並採用 “client-server” 架構。

在 X 架構下， “X server” 是在有鍵盤、螢幕、滑鼠的電腦上運作。 而 server 部份則是負責像是顯示部份的管理、 處理來自鍵盤、滑鼠及其他設備（比方像是以繪圖板來輸入、 或者是顯示到投影機）的輸入等等，每個 X 程式（像是 `XTerm`，或 Netscape®）都是 “client”。 client 會傳訊息到 server 上，比如：“Please draw a window at these coordinates”，接著 server 會傳回訊息，比如： “The user just clicked on the OK button”。

在家庭或小辦公室環境，通常 X server 跟 X client 都是在同一台電腦上執行的。 然而，也可以在比較爛的桌機上執行 X server， 並在比較强、比較貴的電腦上跑 X 程式(client)來做事情。 在這種場景，X client 與 server 之間的溝通就需透過網路來進行。

這點可能會讓有些人產生困惑，因為 X 術語與他們原本的認知剛好相反。 他們原本以為 “X server” 是要在最强悍的機器上跑才行，而 “X client” 則是在他們桌機上面跑。 實際上卻不是這樣。

有點相當重要，請記住 X server 是在有接螢幕、鍵盤的機器上運作， 而 X client 則是顯示這些視窗的程式。

協定(protocol)內並無强制規定 client 以及 server 兩邊機器都得是同一作業系統，或者得是同型機器才可以。 換句話說，也可以在 Microsoft® Windows® 或蘋果電腦(Apple)的 Mac OS® 上跑 X server，而且可以透過許多免費或商業軟體完成這些安裝、設定。

5.2.3. The Window Manager

X 設計哲學與 UNIX® 設計哲學相當類似，都是 “tools, not policy”。 也就是說，X 不會試圖强制規定某任務應該要如何完成，而是只提供使用者一些工具， 至於如何運用這些工具，則是使用者本身的事了。

X 延續這哲學，它並不規定：螢幕上的視窗該長什麼樣、要如何移動滑鼠指標、 該用什麼組合鍵來切換各視窗(比如：在 Microsoft® Windows® 的 Alt+Tab鍵)、各視窗的標題列長相，以及是否該有關閉鈕等等。

事實上，X 把這部分交給所謂的 “Window Manager” 來管理。 有一堆 window manager 程式，像是: AfterStep 、Blackbox、ctwm 、Enlightenment、 fvwm、Sawfish、 twm、 Window Maker 等等。每一種 window manager 都提供不同的使用經驗； 有些還可使用 “virtual desktops(虛擬桌面)”；有些則可自訂組合鍵來管理桌面；有些會有 “Start(開始)”鈕或其他類似設計；有些則是 “可更換佈景主題”， 可自行安裝新的佈景主題以更換外觀。 這些跟其他的 window manager 在 Ports Collection 內的 `x11-wm` 目錄內都有。

此外，KDE 及 GNOME 桌面環境則有其自屬並整合完整的 window manager。

每個 window manager 也各有其不同的設定機制；有些需手動寫設定檔， 而有的則可透過 GUI 工具來完成大部分的設定。舉個例子： Sawfish 就有以 Lisp 語言寫的設定檔。

Focus Policy

window manager 的另一特色就是負責滑鼠指標的 “focus policy”。 每一種視窗系統都需要選擇作用視窗的方式 ，以接受鍵盤輸入，以及決定目前哪個視窗是處於使用中的狀態。

通常較為人熟悉的 focus policy 叫做 “click-to-focus”， 這是 Microsoft® Windows® 所採用的模式，也就是指標在該視窗按一下的話， 該視窗就會處於使用中的狀態。

X 並不支援一些特殊的 focus policy。 換句話說，window manager 會控制哪個視窗在何時是作用中。 不同的 window manager 有不同的支援方式。 但它們都支援 click-to-focus， 而且大多數都有支援多種方式。

以下是目前最流行的 focus policy：

focus-follows-mouse
: 滑鼠移到哪個視窗就是使用該視窗。 該視窗不一定位於其他視窗上面， 但只要把滑鼠移到該視窗就可以改變作用中的視窗， 而不需在它上面點擊。

sloppy-focus
: 該 policy 是針對 focus-follows-mouse 的小小延伸。 對於 focus-follows-mouse 而言，若把游標移到最初的視窗(或桌面)， 那所有其他視窗都會處於非作用中，而且所有鍵盤輸入也會失效。 若是選用 sloppy-focus，則只有在游標移到新視窗時， 作用中的視窗才會變成新的， 而只離開目前作用中的視窗仍不會改變作用狀態。

click-to-focus
由游標點擊才會決定作用中的視窗。 並且該視窗會被 “raised(凸顯)” 到所有其他視窗之前， 即使游標移到其他視窗，所有的鍵盤輸入仍會由該視窗所接收。

許多 window manager 也支援其他 policy，與這些相比起來又有些不同， 細節部分請參閱該 window manager 的文件說明。

5.2.4. Widgets

The X approach of providing tools and not policy extends to the widgets seen on screen in each application.

“Widget” is a term for all the items in the user interface that can be clicked or manipulated in some way; buttons, check boxes, radio buttons, icons, lists, and so on. Microsoft® Windows® calls these “controls”.

Microsoft® Windows® and Apple's Mac OS® both have a very rigid widget policy. Application developers are supposed to ensure that their applications share a common look and feel. With X, it was not considered sensible to mandate a particular graphical style, or set of widgets to adhere to.

As a result, do not expect X applications to have a common look and feel. There are several popular widget sets and variations, including the original Athena widget set from MIT, Motif® (on which the widget set in Microsoft® Windows® was modeled, all bevelled edges and three shades of grey), OpenLook, and others.

Most newer X applications today will use a modern-looking widget set, either Qt, used by KDE, or GTK+, used by the GNOME project. In this respect, there is some convergence in look-and-feel of the UNIX® desktop, which certainly makes things easier for the novice user.

5.3. 安裝 X11

Xorg 是 FreeBSD 預設的 X11 實作。 Xorg 是由 X.Org 基金會所發行之開放源碼軟體 X Window 系統實作的 X server。 Xorg 乃是以 XFree86™ 4.4RC2 以及 X11R6.6 為基礎所產生的。 目前 FreeBSD Ports Collection 內的 Xorg 版本為 7.7。

從 Ports Collection 來安裝 Xorg 的安裝方式：

```
# cd /usr/ports/x11/xorg
# make install clean
```

注意

若要編譯完整的 Xorg， 請先確認至少有 4 GB 的磁碟空間。

此外 X11 也可直接透過 package 方式來安裝，可使用 pkg_add(1) 來安裝編譯好的 X11 套件，記得在透過網路安裝時不要指定版本即可， pkg_add(1) 會自動抓該套件最新版的套件回來。

若要自動透過 package 方式來裝 Xorg ，直接打下面這行即可：

```
# pkg_add -r xorg
```

注意

上面的例子會裝完整的 X11 套件，包括 `server`、`client`、字型等。 此外，還有其他的 X11 子套件可透過 package 或 port 方式來單獨安裝。

本章其餘部分將介紹如何設定 `X11`， 以及如何打造高生產力的桌面環境。

5.4. 設定 X11

Contributed by Christopher Shumway.

5.4.1. 在開始之前

在開始設定 X11 之前，要先瞭解所要裝的機器資料為何：

- 螢幕規格
- 顯示卡的晶片規格
- 顯示卡的記憶體容量

X11 會依螢幕規格來決定解析度以及更新頻率。 這些規格通常可從螢幕所附的文件或廠商網站上取得。 最重要的是要知道水平、垂直更新頻率為何。

而顯示卡晶片則決定 X11 要用哪一種驅動程式模組。 大多數的晶片都可以自動偵測，但最好還是要知道是何種晶片， 以免萬一自動偵測失敗。

Video memory on the graphic adapter determines the resolution and color depth which the system can run at. This is important to know so the user knows the limitations of the system.

5.4.2. 設定 X11

Xorg 自 7.3 版起不再需任何設定檔，只要打下列即可：

```
% startx
```

若這指令不行或預設設定無法使用，那麼就需要手動設定 `X11`。 設定 X11 需要幾個步驟，首先是以系統管理者帳號來建立初始設定檔：

```
# Xorg -configure
```

這會在 `/root` 目錄內產生 `xorg.conf.new` 設定檔(無論是用 su(1) 或直接登入為 `root`，都會改變 root 預設的 `$HOME` 環境變數)。 X11 程式接著會偵測系統的顯示卡相關硬體，並將偵測到硬體訊息寫入設定檔，以便載入正確的驅動程式。

下一步是測試現有的設定檔，以便確認 Xorg 可以與顯示卡、螢幕相關硬體正確運作：

```
# Xorg -config xorg.conf.new
```

若看得到一堆黑灰夾雜的網格畫面，以及 X 形的滑鼠游標， 那麼設定檔就是成功的。 要退出測試，只要同時按下 Ctrl+Alt+Backspace 即可。

注意

若滑鼠不正確運作，那麼需要先對其作設定。

Next, tune the `xorg.conf.new` configuration file to taste. Open the file in a text editor such as emacs(1) or ee(1). First, add the frequencies for the target system's monitor. These are usually expressed as a horizontal and vertical synchronization rate. These values are added to the `xorg.conf.new` file under the `"Monitor"` section:

```
Section "Monitor"
        Identifier   "Monitor0"
        VendorName   "Monitor Vendor"
        ModelName    "Monitor Model"
        HorizSync    30-107
        VertRefresh  48-120
EndSection
```

The `HorizSync` and `VertRefresh` keywords may be missing in the configuration file. If they are, they need to be added, with the correct horizontal synchronization rate placed after the `HorizSync` keyword and the vertical synchronization rate after the `VertRefresh` keyword. In the example above the target monitor's rates were entered.

X allows DPMS (Energy Star) features to be used with capable monitors. The xset(1) program controls the time-outs and can force standby, suspend, or off modes. If you wish to enable DPMS features for your monitor, you must add the following line to the monitor section:

```

        Option       "DPMS"
```

While the `xorg.conf.new` configuration file is still open in an editor, select the default resolution and color depth desired. This is defined in the `"Screen"` section:

```
Section "Screen"
        Identifier "Screen0"
        Device     "Card0"
        Monitor    "Monitor0"
        DefaultDepth 24
        SubSection "Display"
                Viewport  0 0
                Depth     24
                Modes     "1024x768"
        EndSubSection
EndSection
```

The `DefaultDepth` keyword describes the color depth to run at by default. This can be overridden with the `-depth` command line switch to Xorg(1). The `Modes` keyword describes the resolution to run at for the given color depth. Note that only VESA standard modes are supported as defined by the target system's graphics hardware. In the example above, the default color depth is twenty-four bits per pixel. At this color depth, the accepted resolution is 1024 by 768 pixels.

Finally, write the configuration file and test it using the test mode given above.

注意

One of the tools available to assist you during troubleshooting process are the X11 log files, which contain information on each device that the X11 server attaches to. Xorg log file names

are in the format of `/var/log/Xorg.0.log` . The exact name of the log can vary from `Xorg.0.log` to `Xorg.8.log` and so forth.

If all is well, the configuration file needs to be installed in a common location where Xorg(1) can find it. This is typically `/etc/X11/xorg.conf` or `/usr/local/etc/X11/xorg.conf` .

```
# cp xorg.conf.new /etc/X11/xorg.conf
```

The X11 configuration process is now complete. Xorg 目前可透過 startx(1) 來啓動之。 The X11 server may also be started with the use of xdm(1).

注意

There is also a graphical configuration tool, xorgcfg(1), which comes with the X11 distribution. It allows you to interactively define your configuration by choosing the appropriate drivers and settings. This program can be invoked from the console, by typing the command `xorgcfg -textmode` . For more details, refer to the xorgcfg(1) manual pages.

Alternatively, there is also a tool called xorgconfig(1). This program is a console utility that is less user friendly, but it may work in situations where the other tools do not.

5.4.3. 進階設定專欄

5.4.3.1. 設定 Intel® i810 繪圖晶片組

Configuration with Intel® i810 integrated chipsets requires the `agpgart` AGP programming interface for X11 to drive the card. 詳情請參閱 agp(4) 說明。

This will allow configuration of the hardware as any other graphics board. Note on systems without the agp(4) driver compiled in the kernel, trying to load the module with kldload(8) will not work. This driver has to be in the kernel at boot time through being compiled in or using `/boot/loader.conf` .

5.4.3.2. 爲寬螢幕打造更舒適環境

本節假設各位已經有些微進階設定的功力。 如果試著使用上述設定工具會有問題的話，請多利用相關 log 檔（會記錄相關訊息）以便找出解法。 找尋解法過程中，可能會需要用到文字編輯器作為輔助。

目前的寬螢幕 (WSXGA, WSXGA+, WUXGA, WXGA, WXGA+ 等) 都有支援 16:10 及 10:9 比例，以及一些可能有問題的比例。 以下是一些常見的 16:10 螢幕解析度：

- 2560x1600
- 1920x1200
- 1680x1050
- 1440x900
- 1280x800

某方面而言，要增加這些解析度設定也是相當容易的， 只要在 `Section "Screen"` 內的 `Mode` 加上去就好，比如：

```
Section "Screen"
```

```
Identifier "Screen0"
Device     "Card0"
Monitor    "Monitor0"
DefaultDepth 24
SubSection "Display"
 Viewport  0 0
 Depth     24
 Modes     "1680x1050"
EndSubSection
EndSection
```

Xorg 可以透過 I2C/DDC 來得知該寬螢幕所支援的解析度等相關資訊， 因此就能正確偵測出該螢幕所能支援的頻率、解析度。

若驅動程式並未包括 `ModeLine` 訊息的話， 那麼就要為 Xorg 做些設定才行。 我們可以透過 `/var/log/Xorg.0.log` 檔來取得 `ModeLine` 相關設定資料，即可讓螢幕正常顯示。 應該可以看到類似下面的訊息：

```
(II) MGA(0): Supported additional Video Mode:
(II) MGA(0): clock: 146.2 MHz   Image Size:  433 x 271 mm
(II) MGA(0): h_active: 1680  h_sync: 1784  h_sync_end 1960 h_blank_end 2240 h_border: 0
(II) MGA(0): v_active: 1050  v_sync: 1053  v_sync_end 1059 v_blanking: 1089 v_border: 0
(II) MGA(0): Ranges: V min: 48  V max: 85 Hz, H min: 30  H max: 94 kHz, PixClock max ↺
170 MHz
```

這些訊息被稱為 EDID 訊息。 可以藉由這些資料， 搭配下列的正確順序來產生 `ModeLine` 設定：

```
 ModeLine <name> <clock> <4 horiz. timings> <4 vert. timings>
```

所以這個案例 `Section "Monitor"` 的 `ModeLine` 就會是像下面這樣：

```
Section "Monitor"
Identifier      "Monitor1"
VendorName      "Bigname"
ModelName       "BestModel"
ModeLine        "1680x1050" 146.2 1680 1784 1960 2240 1050 1053 1059 1089
Option          "DPMS"
EndSection
```

這樣子就簡單完成了，X 視窗就可以打造為新的寬螢幕環境囉。

5.5. 在 X11 中使用字型

Contributed by Murray Stokely.

5.5.1. Type1 規格的字型

The default fonts that ship with X11 are less than ideal for typical desktop publishing applications. Large presentation fonts show up jagged and unprofessional looking, and small fonts in Netscape® are almost completely unintelligible. However, there are several free, high quality Type1 (PostScript®) fonts available which can be readily used with X11. For instance, the URW font collection (x11-fonts/urwfonts) includes high quality versions of standard type1 fonts (Times Roman®, Helvetica®, Palatino® and others). The Freefonts collection (x11-fonts/freefonts) includes many more fonts, but most of them are intended for use in graphics software such as the Gimp, and are not complete enough to serve as screen fonts. In addition, X11 can be configured to use TrueType® fonts with a minimum of effort. For more details on this, see the X(7) manual page or the section on TrueType® fonts.

To install the above Type1 font collections from the ports collection, run the following commands:

```
# cd /usr/ports/x11-fonts/urwfonts
# make install clean
```

And likewise with the freefont or other collections. To have the X server detect these fonts, add an appropriate line to the X server configuration file (`/etc/X11/xorg.conf`), which reads:

```
FontPath "/usr/local/lib/X11/fonts/URW/"
```

Alternatively, at the command line in the X session run:

```
% xset fp+ /usr/local/lib/X11/fonts/URW
% xset fp rehash
```

This will work but will be lost when the X session is closed, unless it is added to the startup file (`~/.xinitrc` for a normal `startx` session, or `~/.xsession` when logging in through a graphical login manager like XDM). A third way is to use the new `/usr/local/etc/fonts/local.conf` file: see the section on anti-aliasing.

5.5.2. TrueType® 規格的字型

Xorg has built in support for rendering TrueType® fonts. There are two different modules that can enable this functionality. The freetype module is used in this example because it is more consistent with the other font rendering back-ends. To enable the freetype module just add the following line to the `"Module"` section of the `/etc/X11/xorg.conf` file.

```
Load  "freetype"
```

Now make a directory for the TrueType® fonts (for example, `/usr/local/lib/X11/fonts/TrueType`) and copy all of the TrueType® fonts into this directory. Keep in mind that TrueType® fonts cannot be directly taken from a Macintosh®; they must be in UNIX®/MS-DOS®/Windows® format for use by X11. Once the files have been copied into this directory, use ttmkfdir to create a `fonts.dir` file, so that the X font renderer knows that these new files have been installed. `ttmkfdir` is available from the FreeBSD Ports Collection as x11-fonts/ttmkfdir.

```
# cd /usr/local/lib/X11/fonts/TrueType
# ttmkfdir -o fonts.dir
```

Now add the TrueType® directory to the font path. This is just the same as described above for Type1 fonts, that is, use

```
% xset fp+ /usr/local/lib/X11/fonts/TrueType
% xset fp rehash
```

or add a `FontPath` line to the `xorg.conf` file.

That's it. Now Netscape®, Gimp, StarOffice™, and all of the other X applications should now recognize the installed TrueType® fonts. Extremely small fonts (as with text in a high resolution display on a web page) and extremely large fonts (within StarOffice™) will look much better now.

5.5.3. Anti-Aliased 規格的字型

Updated by Joe Marcus Clarke.

Anti-aliasing has been available in X11 since XFree86™ 4.0.2. However, font configuration was cumbersome before the introduction of XFree86™ 4.3.0. Beginning with XFree86™ 4.3.0, all fonts in X11 that are found in `/usr/local/lib/X11/fonts/` and `~/.fonts/` are automatically made available for anti-aliasing to Xft-aware applications. Not all applications are Xft-aware, but many have received Xft support. Examples of Xft-aware applications include Qt 2.3 and higher (the toolkit for the KDE desktop), GTK+ 2.0 and higher (the toolkit for the GNOME desktop), and Mozilla 1.2 and higher.

In order to control which fonts are anti-aliased, or to configure anti-aliasing properties, create (or edit, if it already exists) the file `/usr/local/etc/fonts/local.conf` . Several advanced features of the Xft font system

can be tuned using this file; this section describes only some simple possibilities. For more details, please see fonts-conf(5).

This file must be in XML format. Pay careful attention to case, and make sure all tags are properly closed. The file begins with the usual XML header followed by a DOCTYPE definition, and then the `<fontconfig>` tag:

```
<?xml version="1.0"?>
<!DOCTYPE fontconfig SYSTEM "fonts.dtd">
<fontconfig>
```

As previously stated, all fonts in `/usr/local/lib/X11/fonts/` as well as `~/.fonts/` are already made available to Xft-aware applications. If you wish to add another directory outside of these two directory trees, add a line similar to the following to `/usr/local/etc/fonts/local.conf` :

```
<dir>/path/to/my/fonts</dir>
```

After adding new fonts, and especially new font directories, you should run the following command to rebuild the font caches:

```
# fc-cache -f
```

Anti-aliasing makes borders slightly fuzzy, which makes very small text more readable and removes “staircases” from large text, but can cause eyestrain if applied to normal text. To exclude font sizes smaller than 14 point from anti-aliasing, include these lines:

```
        <match target="font">
            <test name="size" compare="less">
                <double>14</double>
            </test>
            <edit name="antialias" mode="assign">
                <bool>false</bool>
            </edit>
        </match>
        <match target="font">
            <test name="pixelsize" compare="less" qual="any">
                <double>14</double>
            </test>
            <edit mode="assign" name="antialias">
                <bool>false</bool>
            </edit>
        </match>
```

Spacing for some monospaced fonts may also be inappropriate with anti-aliasing. This seems to be an issue with KDE, in particular. One possible fix for this is to force the spacing for such fonts to be 100. Add the following lines:

```
       <match target="pattern" name="family">
           <test qual="any" name="family">
               <string>fixed</string>
           </test>
           <edit name="family" mode="assign">
               <string>mono</string>
           </edit>
       </match>
       <match target="pattern" name="family">
           <test qual="any" name="family">
               <string>console</string>
           </test>
           <edit name="family" mode="assign">
               <string>mono</string>
           </edit>
```

```
        </match>
```

(this aliases the other common names for fixed fonts as `"mono"`), and then add:

```
        <match target="pattern" name="family">
            <test qual="any" name="family">
                <string>mono</string>
            </test>
            <edit name="spacing" mode="assign">
                <int>100</int>
            </edit>
        </match>
```

Certain fonts, such as Helvetica, may have a problem when anti-aliased. Usually this manifests itself as a font that seems cut in half vertically. At worst, it may cause applications such as Mozilla to crash. To avoid this, consider adding the following to `local.conf`:

```
        <match target="pattern" name="family">
            <test qual="any" name="family">
                <string>Helvetica</string>
            </test>
            <edit name="family" mode="assign">
                <string>sans-serif</string>
            </edit>
        </match>
```

Once you have finished editing `local.conf` make sure you end the file with the `</fontconfig>` tag. Not doing this will cause your changes to be ignored.

The default font set that comes with X11 is not very desirable when it comes to anti-aliasing. A much better set of default fonts can be found in the x11-fonts/bitstream-vera port. This port will install a `/usr/local/etc/fonts/local.conf` file if one does not exist already. If the file does exist, the port will create a `/usr/local/etc/fonts/local.conf-vera` file. Merge the contents of this file into `/usr/local/etc/fonts/local.conf`, and the Bitstream fonts will automatically replace the default X11 Serif, Sans Serif, and Monospaced fonts.

Finally, users can add their own settings via their personal `.fonts.conf` files. To do this, each user should simply create a `~/.fonts.conf`. This file must also be in XML format.

One last point: with an LCD screen, sub-pixel sampling may be desired. This basically treats the (horizontally separated) red, green and blue components separately to improve the horizontal resolution; the results can be dramatic. To enable this, add the line somewhere in the `local.conf` file:

```
        <match target="font">
            <test qual="all" name="rgba">
                <const>unknown</const>
            </test>
            <edit name="rgba" mode="assign">
                <const>rgb</const>
            </edit>
        </match>
```

注意

Depending on the sort of display, `rgb` may need to be changed to `bgr`, `vrgb` or `vbgr`: experiment and see which works best.

Anti-aliasing should be enabled the next time the X server is started. However, programs must know how to take advantage of it. At present, the Qt toolkit does, so the entire KDE environment can use anti-aliased fonts. GTK+ and GNOME can also be made to use anti-aliasing via the "Font" capplet (see 節 5.7.1.3, "Anti-aliased Fonts with GNOME" for details). By default, Mozilla 1.2 and greater will automatically use anti-aliasing. To disable this, rebuild Mozilla with the `-DWITHOUT_XFT` flag.

5.6. The X Display Manager

Contributed by Seth Kingsley.

5.6.1. Overview

The X Display Manager (XDM) is an optional part of the X Window System that is used for login session management. This is useful for several types of situations, including minimal "X Terminals", desktops, and large network display servers. Since the X Window System is network and protocol independent, there are a wide variety of possible configurations for running X clients and servers on different machines connected by a network. XDM provides a graphical interface for choosing which display server to connect to, and entering authorization information such as a login and password combination.

Think of XDM as providing the same functionality to the user as the getty(8) utility (see 節 25.3.2, "Configuration" for details). That is, it performs system logins to the display being connected to and then runs a session manager on behalf of the user (usually an X window manager). XDM then waits for this program to exit, signaling that the user is done and should be logged out of the display. At this point, XDM can display the login and display chooser screens for the next user to login.

5.6.2. Using XDM

The XDM daemon program is located in `/usr/local/bin/xdm` . This program can be run at any time as `root` and it will start managing the X display on the local machine. If XDM is to be run every time the machine boots up, a convenient way to do this is by adding an entry to `/etc/ttys` . For more information about the format and usage of this file, see 節 25.3.2.1, "Adding an Entry to `/etc/ttys`". There is a line in the default `/etc/ttys` file for running the XDM daemon on a virtual terminal:

```
ttyv8   "/usr/local/bin/xdm -nodaemon"  xterm   off secure
```

By default this entry is disabled; in order to enable it change field 5 from `off` to `on` and restart init(8) using the directions in 節 25.3.2.2, "Force `init` to Reread `/etc/ttys`". The first field, the name of the terminal this program will manage, is `ttyv8`. This means that XDM will start running on the 9th virtual terminal.

5.6.3. Configuring XDM

The XDM configuration directory is located in `/usr/local/lib/X11/xdm` . In this directory there are several files used to change the behavior and appearance of XDM. Typically these files will be found:

File	Description
`Xaccess`	Client authorization ruleset.
`Xresources`	Default X resource values.
`Xservers`	List of remote and local displays to manage.
`Xsession`	Default session script for logins.
`Xsetup_*`	Script to launch applications before the login interface.
`xdm-config`	Global configuration for all displays running on this machine.

File	Description
`xdm-errors`	Errors generated by the server program.
`xdm-pid`	The process ID of the currently running XDM.

Also in this directory are a few scripts and programs used to set up the desktop when XDM is running. The purpose of each of these files will be briefly described. The exact syntax and usage of all of these files is described in xdm(1).

The default configuration is a simple rectangular login window with the hostname of the machine displayed at the top in a large font and "Login:" and "Password:" prompts below. This is a good starting point for changing the look and feel of XDM screens.

5.6.3.1. Xaccess

The protocol for connecting to XDM-controlled displays is called the X Display Manager Connection Protocol (XDMCP). This file is a ruleset for controlling XDMCP connections from remote machines. It is ignored unless the `xdm-config` is changed to listen for remote connections. By default, it does not allow any clients to connect.

5.6.3.2. Xresources

This is an application-defaults file for the display chooser and login screens. In it, the appearance of the login program can be modified. The format is identical to the app-defaults file described in the X11 documentation.

5.6.3.3. Xservers

This is a list of the remote displays the chooser should provide as choices.

5.6.3.4. Xsession

This is the default session script for XDM to run after a user has logged in. Normally each user will have a customized session script in `~/.xsession` that overrides this script.

5.6.3.5. Xsetup_*

These will be run automatically before displaying the chooser or login interfaces. There is a script for each display being used, named `Xsetup_` followed by the local display number (for instance `Xsetup_0`). Typically these scripts will run one or two programs in the background such as `xconsole`.

5.6.3.6. xdm-config

This contains settings in the form of app-defaults that are applicable to every display that this installation manages.

5.6.3.7. xdm-errors

This contains the output of the X servers that XDM is trying to run. If a display that XDM is trying to start hangs for some reason, this is a good place to look for error messages. These messages are also written to the user's `~/.xsession-errors` file on a per-session basis.

5.6.4. Running a Network Display Server

In order for other clients to connect to the display server, you must edit the access control rules, and enable the connection listener. By default these are set to conservative values. To make XDM listen for connections, first comment out a line in the `xdm-config` file:

```
! SECURITY: do not listen for XDMCP or Chooser requests
! Comment out this line if you want to manage X terminals with xdm
DisplayManager.requestPort:     0
```

and then restart XDM. Remember that comments in app-defaults files begin with a "!" character, not the usual "#". More strict access controls may be desired —— look at the example entries in `Xaccess`, and refer to the xdm(1) manual page for further infomation.

5.6.5. Replacements for XDM

Several replacements for the default XDM program exist. One of them, kdm (bundled with KDE) is described later in this chapter. The kdm display manager offers many visual improvements and cosmetic frills, as well as the functionality to allow users to choose their window manager of choice at login time.

5.7. 桌面環境

Contributed by Valentino Vaschetto.

本章會介紹在 FreeBSD 中的 X 裡頭，有哪些不同的桌面環境。 "桌面環境"範圍很廣，從簡單的 window manager 到 完整的桌面應用程式，例如 KDE 或 GNOME。

5.7.1. GNOME

5.7.1.1. 關於 GNOME

GNOME is a user-friendly desktop environment that enables users to easily use and configure their computers. GNOME includes a panel (for starting applications and displaying status), a desktop (where data and applications can be placed), a set of standard desktop tools and applications, and a set of conventions that make it easy for applications to cooperate and be consistent with each other. Users of other operating systems or environments should feel right at home using the powerful graphics-driven environment that GNOME provides. More information regarding GNOME on FreeBSD can be found on the FreeBSD GNOME Project's web site. The web site also contains fairly comprehensive FAQs about installing, configuring, and managing GNOME.

5.7.1.2. Installing GNOME

可透過 package 或 Ports Collection 的方式來輕鬆安裝：

透過網路利用 package 安裝 GNOME：

```
# pkg_add -r gnome2
```

從 ports tree 透過原始碼編譯安裝 GNOME：

```
# cd /usr/ports/x11/gnome2
# make install clean
```

當 GNOME 安裝完成後， 必須告訴 X server 啓動 GNOME 而非原本的 window manager。

啓動 GNOME 最簡單的方法是利 用 GDM(GNOME Display Manager)。 GDM, which is installed as a part of the GNOME desktop (but is disabled by default), can be enabled by adding `gdm_enable="YES"` to `/etc/rc.conf`. Once you have rebooted, GNOME will start automatically once you log in —— no further configuration is necessary.

GNOME may also be started from the command-line by properly configuring a file named `.xinitrc`. If a custom `.xinitrc` is already in place, simply replace the line that starts the current window manager with one that starts /usr/local/bin/gnome-session instead. If nothing special has been done to the configuration file, then it is enough simply to type:

```
% echo "/usr/local/bin/gnome-session" > ~/.xinitrc
```

Next, type `startx`, and the GNOME desktop environment will be started.

注意

If an older display manager, like XDM, is being used, this will not work. Instead, create an executable `.xsession` file with the same command in it. To do this, edit the file and replace the existing window manager command with /usr/local/bin/gnome-session:

```
% echo "#!/bin/sh" > ~/.xsession
% echo "/usr/local/bin/gnome-session" >> ~/.xsession
% chmod +x ~/.xsession
```

Yet another option is to configure the display manager to allow choosing the window manager at login time; the section on KDE details explains how to do this for kdm, the display manager of KDE.

5.7.1.3. Anti-aliased Fonts with GNOME

X11 supports anti-aliasing via its "RENDER" extension. GTK+ 2.0 and greater (the toolkit used by GNOME) can make use of this functionality. Configuring anti-aliasing is described in 節 5.5.3, "Anti-Aliased 規格的字型" . So, with up-to-date software, anti-aliasing is possible within the GNOME desktop. Just go to Applications → Desktop Preferences → Font, and select either Best shapes, Best contrast, or Subpixel smoothing (LCDs). For a GTK+ application that is not part of the GNOME desktop, set the environment variable `GDK_USE_XFT` to `1` before launching the program.

5.7.2. KDE

5.7.2.1. About KDE

KDE is an easy to use contemporary desktop environment. Some of the things that KDE brings to the user are:

- A beautiful contemporary desktop
- A desktop exhibiting complete network transparency
- An integrated help system allowing for convenient, consistent access to help on the use of the KDE desktop and its applications
- Consistent look and feel of all KDE applications
- Standardized menu and toolbars, keybindings, color-schemes, etc.
- Internationalization: KDE is available in more than 40 languages
- Centralized, consistent, dialog-driven desktop configuration
- A great number of useful KDE applications

KDE comes with a web browser called Konqueror, which is a solid competitor to other existing web browsers on UNIX® systems. More information on KDE can be found on the KDE website. For FreeBSD specific information and resources on KDE, consult the KDE on FreeBSD team's website.

5.7.2.2. 安裝 KDE

如同 GNOME 或其他桌面管理軟體一樣， 也可以輕鬆透過 package 或 Ports Collection 來安裝：

To install the KDE package from the network, simply type:

```
# pkg_add -r kde
```

pkg_add(1) will automatically fetch the latest version of the application.

To build KDE from source, use the ports tree:

```
# cd /usr/ports/x11/kde3
# make install clean
```

After KDE has been installed, the X server must be told to launch this application instead of the default window manager. This is accomplished by editing the `.xinitrc` file:

```
% echo "exec startkde" > ~/.xinitrc
```

Now, whenever the X Window System is invoked with `startx`, KDE will be the desktop.

If a display manager such as XDM is being used, the configuration is slightly different. Edit the `.xsession` file instead. Instructions for kdm are described later in this chapter.

5.7.3. More Details on KDE

Now that KDE is installed on the system, most things can be discovered through the help pages, or just by pointing and clicking at various menus. Windows® or Mac® users will feel quite at home.

The best reference for KDE is the on-line documentation. KDE comes with its own web browser, Konqueror, dozens of useful applications, and extensive documentation. The remainder of this section discusses the technical items that are difficult to learn by random exploration.

5.7.3.1. The KDE Display Manager

An administrator of a multi-user system may wish to have a graphical login screen to welcome users. XDM can be used, as described earlier. However, KDE includes an alternative, kdm, which is designed to look more attractive and include more login-time options. In particular, users can easily choose (via a menu) which desktop environment (KDE, GNOME, or something else) to run after logging on.

To enable kdm, the `ttyv8` entry in `/etc/ttys` has to be adapted. The line should look as follows:

```
ttyv8 "/usr/local/bin/kdm -nodaemon" xterm on secure
```

5.7.4. XFce

5.7.4.1. About XFce

XFce is a desktop environment based on the GTK+ toolkit used by GNOME, but is much more lightweight and meant for those who want a simple, efficient desktop which is nevertheless easy to use and configure. Visually, it looks very much like CDE, found on commercial UNIX® systems. Some of XFce's features are:

- A simple, easy-to-handle desktop
- Fully configurable via mouse, with drag and drop, etc.
- Main panel similar to CDE, with menus, applets and applications launchers
- Integrated window manager, file manager, sound manager, GNOME compliance module, and more
- Themeable (since it uses GTK+)
- Fast, light and efficient: ideal for older/slower machines or machines with memory limitations

More information on XFce can be found on the XFce website.

5.7.4.2. Installing XFce

A binary package for XFce exists (at the time of writing). To install, simply type:

```
# pkg_add -r xfce4
```

Alternatively, to build from source, use the ports collection:

```
# cd /usr/ports/x11-wm/xfce4
# make install clean
```

Now, tell the X server to launch XFce the next time X is started. Simply type this:

```
% echo "/usr/local/bin/startxfce4" > ~/.xinitrc
```

The next time X is started, XFce will be the desktop. As before, if a display manager like XDM is being used, create an `.xsession` , as described in the section on GNOME, but with the `/usr/local/bin/startxfce4` command; or, configure the display manager to allow choosing a desktop at login time, as explained in the section on kdm.

部 II. 一般性工作

既然基礎的部分已經提過了，接下來的這個部分將會討論一些常會用到的 FreeBSD 的特色，這些章節包括：

- 介紹給您常見且實用的桌面應用軟體：網頁瀏覽器、生產力工具、文件檢視程式等。
- 介紹給您衆多 FreeBSD 上可用的多媒體工具。
- 解釋如何編譯自訂 FreeBSD 核心以增加額外系統功能的流程。
- 詳細描述列印系統，包含桌上型印表機及網路印表機的設定。
- 展示給您看如何在您的 FreeBSD 系統中執行 Linux 應用軟體。

這些章節中有些需要您預先閱讀些相關文件，在各章節開頭的概要內會提及。

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章 6. 桌面環境應用程式

Contributed by Christophe Juniet.

6.1. 概述

在 FreeBSD 上面可以執行非常多種類的桌面應用程式， 像是網頁瀏覽器和文字處理軟體等。 這些程式大都可以透過套件來安裝或是從 Ports Collection 中自動編譯安裝。 許多新的使用者會希望能在在他們的桌面系統中找到這些程式。 這章將會告訴你如何不用費太多功夫去安裝一些熱門的桌面應用程式， 不管是從套件或是從 Ports Collection 中安裝。

需要注意到的是：當從 ports 中安裝程式的時候， 它們是從原始碼開始編譯的。依照你編譯的 ports 和電腦速度(硬體等級)， 有可能會花很長一段時間才能完成。 如果從原始碼編譯對你來說會花太多時間的話，大部分的 ports 你都能找到事先編譯好的套件來安裝。

因為 FreeBSD 具有相容 Linux 二進制的特性， 許多原先在 Linux 上開發的應用程式都能在你的 FreeBSD 桌面環境執行。 在安裝任何 Linux 應用程式之前，強烈建議你先閱讀 章 10, Linux® 二進位檔的相容性 Linux 執行相容模式這個章節。 而許多用 Linux 二進制相容模式的軟體在 ports 裡頭通常都會用 “linux-” 開頭。 當你在搜尋某個特定軟體時，記住這點，並且可以使用 whereis(1) 來找。 在下列的說明中， 都假設你在安裝任何 Linux 應用軟體之前， 已經事先啓用了 Linux 二進制相容模式。

下列目錄是這章中所涵蓋的應用程式：

- 瀏覽器（像是 Mozilla, Opera, Firefox, Konqueror)
- 辦公軟體（像是 KOffice, AbiWord, The GIMP, OpenOffice.org)
- 文件瀏覽軟體（像是 Acrobat Reader®, gv, Xpdf, GQview)
- 財務處理軟體（像是 GnuCash, Gnumeric, Abacus)

在閱讀這章之前，你必須

- 知道如何安裝其他的軟體(third-party software) (章 4, 軟體套件管理篇：Packages 及 Ports 機制).
- 知道如何安裝 Linux 軟體 (章 10, Linux® 二進位檔的相容性).

要知道更多關於多媒體環境的資訊，請先閱讀 章 7, 多媒體影音娛樂(Multimedia) 多媒體章節。 如果你想要設定和使用電子郵件，也請你先看 章 27, 電子郵件郵件章節。

6.2. 瀏覽器

在 FreeBSD 中並沒有預先安裝好的特定瀏覽器。 但在 Ports Collection 之中卻有許多瀏覽器可供你安裝使用。 如果你沒有足夠時間去編譯所有的東西（在某些情況下這可能會花上很長的一段時間）， 這些都有現成的套件可供直接安裝。

KDE 和 GNOME 桌面環境都已提供 HTML 瀏覽器。 請參考 節 5.7, “桌面環境” 來了解更多有關如何設定這些完整的桌面環境系統資訊。

如果你在尋找輕量化的瀏覽器，你可以從 Ports Collection 中找到下面的幾種： www/dillo, www/links, 或 www/w3m。

這節介紹這些瀏覽器：

瀏覽器名稱	所需的系統資源	從 ports 安裝時間	主要相依的軟體
Mozilla	多	長	Gtk+

瀏覽器名稱	所需的系統資源	從 ports 安裝時間	主要相依的軟體
Opera	少	短	FreeBSD 和 Linux 的版本都有。 Linux 的版本需要 Linux 二進制相容模組以及 linux-openmotif.
Firefox	中度	長	Gtk+
Konqueror	中度	長	KDE 函式庫

6.2.1. Mozilla

Mozilla 是相當現代化、穩定且完全移植至 FreeBSD 系統上。 它也具備有十分符合 HTML 標準的顯示引擎，它更提供了郵件及新聞群組的閱讀功能。 此外如果你打算要自己寫一些網頁的話，它還提供了 HTML 的編輯器。 如果是 Netscape® 的使用者， 你可能會認出這跟 Communicator 很像， 它們其實同樣是使用相同基礎的瀏覽器。

在速度較慢，像是 CPU 速度少於 233MHz 或是小於 64MB 記憶體的機器上面， 完全使用 Mozilla 會是件極度耗費資源的事。 所以在這樣的機器上面，你可能會想要使用 Opera 這樣輕量級的瀏覽器，而接下來後面會提到。

如果你有什麼原因不能或是不想編譯 Mozilla 的話，FreeBSD GNOME 團隊已經為你做好了這件事。 只要用下面的指令透過網路安裝套件就行了：

```
# pkg_add -r mozilla
```

如果沒有找到套件可以使用，而你也有足夠的時間和磁碟空間來編譯 Mozilla 並安裝到你的系統中， 你可以透過下列步驟來安裝：

```
# cd /usr/ports/www/mozilla
# make install clean
```

Mozilla 需要使用 root 的權限來執行 chrome 註冊來確保正確的初始化。 另外，如果你需要抓一些額外的外掛程式像是 mouse gestures， 你就必須要使用 root 的權限來安裝， 以適當的安裝這些外掛程式。

一旦你完成了 Mozilla 的安裝，你就再也不需要 root 的權限了。 你可以直接打下面的指令來啓動 Mozilla：

```
% mozilla
```

也可以直接打下列指令，直接啓動郵件和新聞閱讀器：

```
% mozilla -mail
```

6.2.2. Firefox

Firefox 是以 Mozilla 原始碼為基礎的新世代瀏覽器。 Mozilla 是一堆應用軟體的整合套裝， 像是瀏覽器、郵件程式、聊天室軟體等所組成。 Firefox 則純粹是瀏覽器， 這也是為何它能短小精悍之故。

可以打下列指令來安裝：

```
#pkg_add -r firefox
```

也可以透過 Ports Collection，以編譯原始碼的方式來安裝：

```
#cd /usr/ports/www/firefox
# make install clean
```

6.2.3. Firefox, Mozilla 的 Java™ plugin 程式

注意

本節以及下一節，均假設您已裝好 Firefox 或 Mozilla。

FreeBSD 基金會與 Sun Microsystems 有達成授權協議， 可以散播 Java Runtime Environment(JRE™) 及 Java Developement Kit(JDK™) 的 FreeBSD 版 binary(執行檔)。 FreeBSD 版的 binary 可以在 FreeBSD 基金會 網站下載。

要讓 Firefox 或 Mozilla 支援 Java™ 的話，首先要先裝 java/javavmwrapper 這個 port。 然後再去 `http://www.freebsdfoundation.org/downloads/java.shtml` 下載 Diablo JRE™，並以 pkg_add(1) 指令來安裝之。

接著啓動瀏覽器，在網址列輸入 `about:plugins` 然後按 Enter 鍵，就會顯示目前已裝的 plugins 清單，這時應該就可以看到 Java™ 也有列出來。 若仍未看到的話，那就切換為 `root` 帳號， 打下列指令：

```
# ln -s /usr/local/diablo-jre1.5.0/plugin/i386/ns7/libjavaplugin_oji.so \
  /usr/local/lib/browser_plugins/
```

最後，重啓瀏覽器即可。

6.2.4. Firefox, Mozilla 的 Macromedia® Flash™ plugin 程式

Macromedia® Flash™ plugin 程式並沒有 FreeBSD 版， 然而可以透過軟體層(wrapper)來執行 Linux 版的 plugin 程式。 這個 wrapper 同時也支援 Adobe® Acrobat® 以及 RealPlayer® plugin 等。

接下來去裝 www/linuxpluginwrapper。 linuxpluginwrapper 需要先裝一個很大的 emulators/linux_baseport。 然後根據 port 所指示的作法， 去正確地設定你的 `/etc/libmap.conf` ！設定的範例檔案位於 `/usr/local/share/examples/linuxpluginwrapper/` 的目錄底下。

下一步，則是裝 www/linux-flashplugin7。 裝好後，再啓動瀏覽器，在網址列輸入 `about:plugins` ，然後按 Enter 鍵就會顯示目前已裝的 plugin 清單。

若 Flash™ plugin 沒出現的話，大多可能是因為漏了做 symlink 連結之故。 請切為 `root` 帳號，打下列指令：

```
# ln -s /usr/local/lib/npapi/linux-flashplugin/libflashplayer.so \
  /usr/local/lib/browser_plugins/
# ln -s /usr/local/lib/npapi/linux-flashplugin/flashplayer.xpt \
  /usr/local/lib/browser_plugins/
```

最後，重啓瀏覽器應該就可看到了。

注意

linuxpluginwrapper 只能在 i386™ 的系統架構下運行。

6.2.5. Opera

Opera 是個具備完整功能、符合標準的瀏覽器。 它同時也具備了內建的郵件、新聞閱讀器、IRC、RSS/Atom feeds 閱讀器等。 此外 Opera 更是個輕量級、 執行速度又快的瀏覽器。 它在 ports 中有兩種版本：「原生」的 FreeBSD 版本還有在 Linux 模擬模式下的版本。

要用 Opera 的 FreeBSD 版本來瀏覽網頁的話， 用下面的指令安裝：

```
# pkg_add -r opera
```

有些 FTP 站台並沒有全部的套件， 但是打下面的指令就能從 Ports Collection 中安裝：

```
# cd /usr/ports/www/opera
# make install clean
```

要安裝 Opera 的 Linux 版本的話， 請將上面例子中的 `opera` 替換成 `linux-opera` 。有些時候， Linux 的版本是十分有用的， 像是只有 Linux 版本外掛程式的時候。 但在其他方面來說， FreeBSD 和 Linux 的版本功能上是一樣的。

6.2.6. Konqueror

Konqueror 是 KDE 桌面系統的一部分，但是它也可以藉由安裝 x11/kdebase3 在 KDE 環境以外使用。 Konqueror 不只是個網頁瀏覽器， 他同時也是檔案管理器和多媒體瀏覽器。

Konqueror 也有許多的外掛程式， 這些外掛程式可以從 misc/konq-plugins 中安裝。

Konqueror 也支援 Flash™ 的外掛程式。 如何安裝的說明請參閱：`http://freebsd.kde.org/howto.php` 。

6.3. 辦公室軟體

當開始進行辦公， 新的使用者通常會去找好用的辦公室軟體或是好上手的文字處理器。 目前 有些桌面環境 像是 KDE已經提供了辦公軟體組合的套件。 FreeBSD 提供了所需的所有辦公軟體，桌面環境也不例外。

這節涵蓋了下列的這些軟體：

軟體名稱	所需系統資源	從 Ports 安裝的時間	主要相依套件
KOffice	少	長	KDE
AbiWord	少	短	Gtk+ 或是 GNOME
The Gimp	少	長	Gtk+
OpenOffice.org	多	很久	JDK™ 1.4, Mozilla

6.3.1. KOffice

KDE 社群在它的桌面環境裡頭提供了一個可以在 KDE 外使用的辦公軟體組合。 它包含了四種模組： KWord 是文字處理器， KSpread 是試算表程式， KPresenter 是簡報播放程式， 另外 Karbon14 讓你可以產生圖形化的文件。 [1]

在安裝最新版的 KOffice 之前， 請先確定你有最新版本的 KDE。

若要用套件來安裝 KOffice， 請依照下面的指令：

```
# pkg_add -r koffice
```

如果套件不存在的話，你可以使用 ports collection. 例如要安裝 KDE3 中的 KOffice，請使用下列指令安裝：

[1]譯註：Karbon14 是向量繪圖軟體，以前叫 Kontour，更早之前稱為 Killustrator。

```
# cd /usr/ports/editors/koffice-kde3
# make install clean
```

6.3.2. AbiWord

AbiWord 是一個免費的文字處理軟體，外觀和感覺都近似於 Microsoft® Word。 它適合處理文件、信件、報告、備忘錄等等。 它也非常快速，包含了許多功能而且非常容易上手。

AbiWord 可以輸入或輸出許多檔案格式， 包括一些有專利的格式，例如微軟(Microsoft)公司的 .doc 格式。

AbiWord 也能用套件安裝， 你可以用下列指令來安裝：

```
# pkg_add -r abiword
```

如果找不到套件的話，它也可以從 Ports Collection 中編譯安裝。 而 Ports Collection 應該要保持在最新的狀態。 AbiWord 可以透過下列方式編譯安裝：

```
# cd /usr/ports/editors/abiword
# make install clean
```

6.3.3. The GIMP

對於影像的編輯及修改來說，GIMP 是非常精緻的影像處理軟體。 它可以當作簡單的繪圖軟體或是高品質的相片處理軟體。 它支援為數眾多的外掛程式及指令稿 (script-fu) 介面。 GIMP 可以讀寫許多檔案格式。它也支援掃描器 [2] 和手寫板。

譯註：GIMP 在目前是 2.x 版，如果你想要安裝 1.x 版的話，請用 Ports Collection 中的 graphics/gimp1。另外如果你已經使用習慣 Adobe Photoshop，而且不習慣 GIMP 介面的話，你也可以嘗試安裝 graphics/gimpshop， 它的使用介面十分類似 Adobe Photoshop。

你可以使用下面指令安裝套件：

```
# pkg_add -r gimp
```

如果的你的 FTP 站台沒有這個套件，你可以使用 Ports Collection。 在 Ports Collection 的 graphics 目錄下也包含了 The Gimp Manual(GIMP 使用手冊)。 下面示範如何安裝這些程式：

```
# cd /usr/ports/graphics/gimp
# make install clean
# cd /usr/ports/graphics/gimp-manual-pdf
# make install clean
```

譯註：另外在 Ports Collection 中也有一些外掛程式可以使用， 例如說可以處理數位相機 raw 檔案格式的 gimp-ufraw。

注意

GIMP 使用手冊也有 HTML 格式的，你可以在 graphics/gimp-manual-html 中安裝。

6.3.4. OpenOffice.org

[2] 譯註：你必須透過 sane-frontends 或 xsane 來掃描

OpenOffice.org 包含了所有完整的辦公軟體組合： 文字處理器、試算表、簡報軟體還有繪圖軟體。 除了它的使用者介面非常類似其他的辦公軟體， 他還能夠輸入和輸出許多熱門的檔案格式。 它也包含了不同語言的使用者介面、拼字檢查和字典。

OpenOffice.org 的文字處理器使用 XML 檔案格式來增加移植性及彈性。 試算表程式支援巨集(macro)功能而且能夠使用外來的資料庫介面。 OpenOffice.org 已經十分穩定， 並且能夠在 Windows®, Solaris™, Linux, FreeBSD 及 Mac OS® X 等作業系統上面執行。 想知道更多關於 OpenOffice.org 的資訊可以在 OpenOffice.org 網頁 上查詢。你也可以在 FreeBSD OpenOffice.org 移植團隊 的網頁上查詢關於 FreeBSD 上 OpenOffice 特定的資訊或直接下載已編譯好的套件

要安裝 OpenOffice.org， 請用以下方式來執行：

```
# pkg_add -r openoffice.org
```

注意

當你在使用 FreeBSD -RELEASE 版本的時候，上面的作法應該行得通。 要是其他的版本，你應該看一下 FreeBSD OpenOffice.org 移植團隊的網站，並且用 pkg_add(1) 安裝合適的套件。 在這個站台都可以下載到穩定的釋出版(release)或開發中的版本。

當已經安裝完之後，你只要鍵入下面的指令就能執行 OpenOffice.org：

```
% openoffice.org
```

譯註：端看你的版本，有時候需要輸入如 openoffice.org-2.0.1 之類的指令，不過你也可以用 shell 中的 alias 或是用 symbolic link 來處理。

注意

在第一次啓動的時候，OpenOffice 會問到一些問題。 而且在你的家目錄底下會自動建立 .openoffice.org2 的資料夾。

如果無法取得 OpenOffice.org 的套件，你仍然可以選擇從 port 編譯。 不過你必須謹記在心：編譯的過程會需要大量的磁碟空間且相當耗時。

```
# cd /usr/ports/editors/openoffice.org-2
# make install clean
```

注意

如果你想要安裝本地化的版本，把前面的指令代換成下面的：

```
# make LOCALIZED_LANG=#### install clean
```

你必須把#### 換成正確的語言 ISO-code [3] 所支援的語言代碼清單可以在 port 目錄裡的 files/Makefile.localized 檔案中找到。

一旦完成了上述步驟， OpenOffice.org 可用以下指令啓動：

[3]譯註：臺灣正體中文使用者為 zh-TW。

```
% openoffice.org
```

6.4. 文件閱覽器

近年來有些文件格式變得愈來愈流行， 基本的系統中也許不會有這些格式所需的標準閱覽器。 在這一節，我們來看看怎麼安裝這些軟體。

這張涵蓋了下列的軟體

軟體名稱	所需系統資源	從 Ports 安裝時間	主要相依套件
Acrobat Reader®	少	短	Linux 二進制相容模組
gv	少	短	Xaw3d
Xpdf	少	短	FreeType
GQview	少	短	Gtk+ 或是 GNOME

6.4.1. Acrobat Reader®

許多文件在散佈的時候都是用 PDF 的檔案格式， 這個格式是基於 “可攜式文件格式(Portable Document Format)”。 其中一個推薦的閱覽軟體就是Acrobat Reader®， 它是由 Adobe 公司發行給 Linux 使用的版本。 因為 FreeBSD 也可以執行 Linux 二進位檔案， 所以它也能在 FreeBSD 上面執行。

要從 Ports Collection 中安裝 Acrobat Reader® 7 只要：

```
# cd /usr/ports/print/acroread7
# make install clean
```

因為授權的限制，所以不提供編譯好的套件。

6.4.2. gv

gv是 PostScript® 和 PDF 的閱覽器。 它建構於 ghostview的基礎上， 不過因為使用 Xaw3d 函式庫， 所以外觀看起來比較漂亮。 gv 速度快，介面簡潔並且有許多功能， 比如說方向性、紙張大小、縮放比例、和反鋸齒(antialias)等。 而且幾乎所有的使用都可以從鍵盤或滑鼠來完成。

用套件來安裝 gv，使用下列指令：

```
# pkg_add -r gv
```

如果你不能取得套件，你可以使用 Ports Collection：

```
# cd /usr/ports/print/gv
# make install clean
```

6.4.3. Xpdf

如果你想要一個小型的 FreeBSD PDF 閱覽軟體， Xpdf是個輕量級而且有效率的閱覽器。 它只需要非常少的資源而且十分穩定。 它只使用標準的 X 字型而不需要 Motif® 或是其他的 X 工具組(toolkit)。

用套件來安裝 Xpdf，使用下列指令：

```
# pkg_add -r xpdf
```

如果套件不存在或是你偏好使用 Ports Collection， 使用以下指令：

```
# cd /usr/ports/graphics/xpdf
```

```
# make install clean
```

一旦完成了安裝，你可以啓動 Xpdf 並且使用滑鼠右鍵去使用選單。

6.4.4. GQview

GQview 是影像管理軟體。 你可以用單鍵來閱覽檔案、啓動額外的編輯器、縮圖預覽等功能。 它也有幻燈片播放(slideshow)及一些基本的檔案操作功能。 你可用 GQview 管理影像集並能輕鬆地找出重複的檔案。 GQview 能夠使用全螢幕觀看並支援國際化。

如果你想要安裝 GQview的套件， 請使用下列指令：

```
# pkg_add -r gqview
```

如果套件無法取得，或是你比較喜歡使用 Ports Collection，只要：

```
# cd /usr/ports/graphics/gqview
# make install clean
```

6.5. 財務

如果有任何理由你想要在你的 FreeBSD 桌面環境上管理你的個人財務， 這裡有一些功能强大、使用簡單的應用程式可供安裝。 這些財務管理軟體之中有些是相容於流行的 Quicken 或 Excel 文件。

這節涵蓋了下面這些軟體：

軟體名稱	所需系統資源	從 Ports 安裝的時間	主要的相依套件
GnuCash	少	長	GNOME
Gnumeric	少	長	GNOME
Abacus	少	短	Tcl/Tk

6.5.1. GnuCash

GnuCash 是 GNOME 團隊努力成果中的一部分， 而 GNOME 主要是提供終端使用者(end-users) 親切而强大的桌面應用程式。 使用 GnuCash， 你可以持續紀錄你的收入及花費、你的銀行帳戶、或是你的股票證券等。 它的特性是介面直覺但功能仍非常專業。

GnuCash 提供了一個智慧的註冊器、 帳戶層級系統、許多快速鍵及自動完成(auto-completion)模式。 它也能分開單一的報表至數個詳細的部份。 GnuCash 也能夠輸入及合併 Quicken QIF 檔案。 它也能處理大部分國際的日期及通用貨幣之格式。

要安裝 GnuCash 到你的系統中， 只要做下列步驟：

```
# pkg_add -r gnucash
```

如果不能取得套件，你可以使用 Ports Collection:

```
# cd /usr/ports/finance/gnucash
# make install clean
```

6.5.2. Gnumeric

Gnumeric 是 GNOME 桌面環境中的試算表。 它的特點是能夠根據儲存格格式(cell format)及自動補齊的系統， 來方便自動地「猜出」使用者的輸入。 它也能夠輸入許多熱門的檔案格式，像是 Excel, Lotus 1-2-3, 或

是 Quattro Pro。 Gnumeric 支援使用 math/guppi 繪圖軟體來繪圖。 它有許多內建的函數而且允許一般的儲存格格式，像是: 數字、貨幣、日期、時間及其他格式等。

要用套件安裝 Gnumeric，只要打以下指令：

```
# pkg_add -r gnumeric
```

如果套件不存在，你可以做下面的步驟來使用 Ports Collection 編譯安裝：

```
# cd /usr/ports/math/gnumeric
# make install clean
```

6.5.3. Abacus

Abacus 是個小巧又使用簡單的試算表。 它包含了許多內建的函數，在相關的領域如統計學、財務、數學中很實用。 它也可以輸出輸入 Excel 的檔案格式。 另外 Abacus也能夠輸出 PostScript® 格式。

從套件安裝 Abacus 只要做：

```
# pkg_add -r abacus
```

如果套件不能取得的話，你可以使用 Ports Collection， 並用以下指令：

```
# cd /usr/ports/deskutils/abacus
# make install clean
```

6.6. 摘要

雖然 FreeBSD 是因為效能及穩定性而在 ISP 之間很流行， 不過它也可以完全當作桌面環境(desktop)來使用， 並不侷限於使用在伺服器上面。目前有數千種應用程式的 套件(packages) 或 ports, 可供使用，你可以根據你的需求打造出一個完美的桌面環境。

下面是這章涵蓋的所有桌面應用軟體之快速回顧表：

軟體名稱	套件名稱	Ports 名稱
Mozilla	mozilla	www/mozilla
Opera	opera	www/opera
Firefox	firefox	www/firefox
KOffice	koffice-kde3	editors/koffice-kde3
AbiWord	abiword	editors/abiword
The GIMP	gimp	graphics/gimp
OpenOffice.org	openoffice	editors/openoffice-1.1
Acrobat Reader®	acroread	print/acroread7
gv	gv	print/gv
Xpdf	xpdf	graphics/xpdf
GQview	gqview	graphics/gqview
GnuCash	gnucash	finance/gnucash
Gnumeric	gnumeric	math/gnumeric
Abacus	abacus	deskutils/abacus

章 7. 多媒體影音娛樂(Multimedia)

Edited by Ross Lippert.

7.1. 概述

FreeBSD 廣泛地支援各種音效卡， 讓您可以享受來自電腦上的高傳真音質(Hi-Fi)， 此外還包括了錄製和播放 MPEG Audio Layer 3 (MP3)、 WAV、 以及 Ogg Vorbis 等許多種格式聲音的能力。同時 FreeBSD Ports Collection 也包括了許多的應用程式， 讓您可以錄音、編修音效以及控制 MIDI 配備。

要是喜歡動手嘗試不同的體驗， FreeBSD 也能播放一般的視訊檔和 DVD。 編碼、轉換和播放視訊的程式比起處理聲音的程式略少一些。例如， 在撰寫這章時， FreeBSD Ports Collection 中還沒有類似 audio/sox 那樣好用的編碼工具，能夠用來轉換不同的格式。 不過，這個領域的軟體研發進展是相當迅速的。

本章將介紹設定音效卡的必要步驟。先前介紹到的 X11 (章 5, X Window 視窗系統) 安裝和設定裡，已經講到了顯示卡的部份， 但要想有更好的播放效果， 仍需要一些細部調整。

讀完這章，您將了解：

- 如何設定系統，以正確識別音效卡。
- 如何運用樣本程式，以測試音效卡是否正常運作。
- 如何解決音效卡的設定問題。
- 如何播放、錄製 MP3 及其他聲音檔案格式。
- X server 是如何支援顯示卡。
- Ports Collections 內有哪些好用的影像播放、錄製軟體。
- 如何播放 DVD 的 `.mpg` 及 `.avi` 檔
- 如何從 CD 和 DVD 中擷取(rip)檔案。
- 如何設定電視卡
- 如何設定掃描器

在閱讀這章之前，您應當了解：

- 知道如何設定、安裝新的 kernel (章 8, 設定 FreeBSD Kernel)。

警告

如果要用 mount(8) 指令來 mount 音樂光碟的話，通常會發生錯誤， 甚至導致 kernel panic。 這是因為音樂光碟是特殊編碼，而非一般的 ISO 檔案系統之故。

7.2. 設定音效卡

Contributed by Moses Moore.
FreeBSD 5.X ####Marc Fonvieille.

7.2.1. 設定系統

開始設定之前，必須先知道你的音效卡型號、晶片為何，以及是 PCI 或 ISA 規格。 FreeBSD 有支援許多種的 PCI、ISA 音效卡，請檢查支援的音效硬體表 Hardware Notes，以確認你的音效卡是否支援。 本文也會提到相對應該卡的驅動程式。

要使用音效卡，必須要載入正確的驅動程式才行。有兩種方式都可以完成這動作， 最簡單方式就是以 kldload(8) 來輕鬆載入 kernel 動態模組(module)， 像是下列指令：

```
# kldload snd_emu10k1
```

或者把相關驅動程式加到 /boot/loader.conf 檔，像是：

```
snd_emu10k1_load="YES"
```

上面例子是給 Creative SoundBlaster® Live! 音效卡使用的。 其他可用的音效卡驅動程式模組，可參考 /boot/defaults/loader.conf 範例。 若不確定到底該用哪一種驅動程式，那麼可以試試載入 snd_driver 模組看看：

```
# kldload snd_driver
```

This is a metadriver loading the most common device drivers at once. This speeds up the search for the correct driver. It is also possible to load all sound drivers via the /boot/loader.conf facility.

If you wish to find out the driver selected for your soundcard after loading the snd_driver metadriver, you may check the /dev/sndstat file with the cat /dev/sndstat command.

注意

Under FreeBSD 4.X, to load all sound drivers, you have to load the snd module instead of snd_driver .

A second method is to statically compile in support for your sound card in your kernel. The section below provides the information you need to add support for your hardware in this manner. For more information about recompiling your kernel, please see 章 8, 設定 FreeBSD Kernel.

7.2.1.1. Configuring a Custom Kernel with Sound Support

The first thing to do is adding the generic audio driver sound(4) to the kernel, for that you will need to add the following line to the kernel configuration file:

```
device sound
```

Under FreeBSD 4.X, you would use the following line:

```
device pcm
```

Then we have to add the support for our sound card. Therefore, we need to know which driver supports the card. Check the supported audio devices list of the Hardware Notes, to determine the correct driver for your sound card. For example, a Creative SoundBlaster® Live! sound card is supported by the snd_emu10k1(4) driver. To add the support for this card, use the following:

```
device snd_emu10k1
```

Be sure to read the manual page of the driver for the syntax to use. Information regarding the syntax of sound drivers in the kernel configuration can also be found in the /usr/src/sys/conf/NOTES file (/usr/src/sys/i386/conf/LINT for FreeBSD 4.X).

Non-PnP ISA cards may require you to provide the kernel with information on the sound card settings (IRQ, I/O port, etc). This is done via the /boot/device.hints file. At system boot, the loader(8) will read this file

and pass the settings to the kernel. For example, an old Creative SoundBlaster® 16 ISA non-PnP card will use the snd_sbc(4) driver in conjunction with snd_sb16(4). For this card the following lines have to be added to the kernel configuration file:

```
device snd_sbc
device snd_sb16
```

as well as the following in `/boot/device.hints` :

```
hint.sbc.0.at="isa"
hint.sbc.0.port="0x220"
hint.sbc.0.irq="5"
hint.sbc.0.drq="1"
hint.sbc.0.flags="0x15"
```

In this case, the card uses the `0x220` I/O port and the IRQ `5`.

The syntax used in the `/boot/device.hints` file is covered in the sound driver manual page. On FreeBSD 4.X, these settings are directly written in the kernel configuration file. In the case of our ISA card, we would only use this line:

```
device sbc0 at isa? port 0x220 irq 5 drq 1 flags 0x15
```

The settings shown above are the defaults. In some cases, you may need to change the IRQ or the other settings to match your card. See the snd_sbc(4) manual page for more information.

注意

Under FreeBSD 4.X, some systems with built-in motherboard sound devices may require the following option in the kernel configuration:

```
options PNPBIOS
```

7.2.2. Testing the Sound Card

After rebooting with the modified kernel, or after loading the required module, the sound card should appear in your system message buffer (dmesg(8)) as something like:

```
pcm0: <Intel ICH3 (82801CA)> port 0xdc80-0xdcbf,0xd800-0xd8ff irq 5 at device 31.5 on ↺
pci0
pcm0: [GIANT-LOCKED]
pcm0: <Cirrus Logic CS4205 AC97 Codec>
```

The status of the sound card may be checked via the `/dev/sndstat` file:

```
# cat /dev/sndstat
FreeBSD Audio Driver (newpcm)
Installed devices:
pcm0: <Intel ICH3 (82801CA)> at io 0xd800, 0xdc80 irq 5 bufsz 16384
kld snd_ich (1p/2r/0v channels duplex default)
```

The output from your system may vary. If no `pcm` devices show up, go back and review what was done earlier. Go through your kernel configuration file again and make sure the correct device is chosen. Common problems are listed in 節 7.2.2.1, “Common Problems”.

If all goes well, you should now have a functioning sound card. If your CD-ROM or DVD-ROM drive is properly coupled to your sound card, you can put a CD in the drive and play it with cdcontrol(1):

```
% cdcontrol -f /dev/acd0 play 1
```

Various applications, such as audio/workman can provide a friendlier interface. You may want to install an application such as audio/mpg123 to listen to MP3 audio files. A quick way to test the card is sending data to the `/dev/dsp`, like this:

```
% cat filename > /dev/dsp
```

where *`filename`* can be any file. This command line should produce some noise, confirming the sound card is actually working.

注意

FreeBSD 4.X users need to create the sound card device nodes before being able to use it. If the card showed up in message buffer as `pcm0`, you will have to run the following as `root`:

```
# cd /dev
# sh MAKEDEV snd0
```

If the card detection returned `pcm1`, follow the same steps as shown above, replacing `snd0` with `snd1`.

`MAKEDEV` will create a group of device nodes that will be used by the different sound related applications.

Sound card mixer levels can be changed via the mixer(8) command. More details can be found in the mixer(8) manual page.

7.2.2.1. Common Problems

Error	Solution
unsupported subdevice XX	One or more of the device nodes was not created correctly. Repeat the steps above.
sb_dspwr(XX) timed out	The I/O port is not set correctly.
bad irq XX	The IRQ is set incorrectly. Make sure that the set IRQ and the sound IRQ are the same.
xxx: gus pcm not attached, out of memory	There is not enough available memory to use the device.
xxx: can't open /dev/dsp!	Check with `fstat | grep dsp` if another application is holding the device open. Noteworthy troublemakers are esound and KDE's sound support.

7.2.3. Utilizing Multiple Sound Sources

Contributed by Munish Chopra.

It is often desirable to have multiple sources of sound that are able to play simultaneously, such as when esound or artsd do not support sharing of the sound device with a certain application.

FreeBSD lets you do this through Virtual Sound Channels, which can be set with the sysctl(8) facility. Virtual channels allow you to multiplex your sound card's playback channels by mixing sound in the kernel.

To set the number of virtual channels, there are two sysctl knobs which, if you are the `root` user, can be set like this:

```
# sysctl hw.snd.pcm0.vchans=4
# sysctl hw.snd.maxautovchans=4
```

The above example allocates four virtual channels, which is a practical number for everyday use. `hw.snd.pcm0.vchans` is the number of virtual channels `pcm0` has, and is configurable once a device has been attached. `hw.snd.maxautovchans` is the number of virtual channels a new audio device is given when it is attached using kldload(8). Since the `pcm` module can be loaded independently of the hardware drivers, `hw.snd.maxautovchans` can store how many virtual channels any devices which are attached later will be given.

注意

You cannot change the number of virtual channels for a device while it is in use. First close any programs using the device, such as music players or sound daemons.

If you are not using devfs(5), you will have to point your applications at `/dev/dsp0.x`, where *x* is 0 to 3 if `hw.snd.pcm.0.vchans` is set to 4 as in the above example. On a system using devfs(5), the above will automatically be allocated transparently to the user.

7.2.4. 設定預設(Mixer Channel)的音量大小

Contributed by Josef El-Rayes.

注意

本功能只有在 FreeBSD 5.3-RELEASE 及之後版本才有支援。

The default values for the different mixer channels are hardcoded in the sourcecode of the pcm(4) driver. There are a lot of different applications and daemons that allow you to set values for the mixer they remember and set each time they are started, but this is not a clean solution, we want to have default values at the driver level. This is accomplished by defining the appropriate values in `/boot/device.hints`. E.g.:

```
hint.pcm.0.vol="100"
```

This will set the volume channel to a default value of 100, when the pcm(4) module is loaded.

7.3. MP3 音樂

Contributed by Chern Lee.

MP3 (MPEG Layer 3 Audio) accomplishes near CD-quality sound, leaving no reason to let your FreeBSD workstation fall short of its offerings.

7.3.1. MP3 Players

By far, the most popular X11 MP3 player is XMMS (X Multimedia System). Winamp skins can be used with XMMS since the GUI is almost identical to that of Nullsoft's Winamp. XMMS also has native plug-in support.

XMMS can be installed from the multimedia/xmms port or package.

XMMS' interface is intuitive, with a playlist, graphic equalizer, and more. Those familiar with Winamp will find XMMS simple to use.

The audio/mpg123 port is an alternative, command-line MP3 player.

mpg123 can be run by specifying the sound device and the MP3 file on the command line, as shown below:

```
# mpg123 -a /dev/dsp1.0 Foobar-GreatestHits.mp3
High Performance MPEG 1.0/2.0/2.5 Audio Player for Layer 1, 2 and 3.
Version 0.59r (1999/Jun/15). Written and copyrights by Michael Hipp.
Uses code from various people. See 'README' for more!
THIS SOFTWARE COMES WITH ABSOLUTELY NO WARRANTY! USE AT YOUR OWN RISK!




Playing MPEG stream from Foobar-GreatestHits.mp3 ...
MPEG 1.0 layer III, 128 kbit/s, 44100 Hz joint-stereo
```

`/dev/dsp1.0` should be replaced with the `dsp` device entry on your system.

7.3.2. Ripping CD Audio Tracks

Before encoding a CD or CD track to MP3, the audio data on the CD must be ripped onto the hard drive. This is done by copying the raw CDDA (CD Digital Audio) data to WAV files.

The `cdda2wav` tool, which is a part of the sysutils/cdrtools suite, is used for ripping audio information from CDs and the information associated with them.

With the audio CD in the drive, the following command can be issued (as `root`) to rip an entire CD into individual (per track) WAV files:

```
# cdda2wav -D 0,1,0 -B
```

cdda2wav will support ATAPI (IDE) CDROM drives. To rip from an IDE drive, specify the device name in place of the SCSI unit numbers. For example, to rip track 7 from an IDE drive:

```
# cdda2wav -D /dev/acd0a -t 7
```

The `-D 0,1,0` indicates the SCSI device `0,1,0`, which corresponds to the output of `cdrecord -scanbus`.

To rip individual tracks, make use of the `-t` option as shown:

```
# cdda2wav -D 0,1,0 -t 7
```

This example rips track seven of the audio CDROM. To rip a range of tracks, for example, track one to seven, specify a range:

```
# cdda2wav -D 0,1,0 -t 1+7
```

The utility dd(1) can also be used to extract audio tracks on ATAPI drives, read 節 17.6.5, “Duplicating Audio CDs” for more information on that possibility.

7.3.3. Encoding MP3s

Nowadays, the mp3 encoder of choice is lame. Lame can be found at audio/lame in the ports tree.

Using the ripped WAV files, the following command will convert `audio01.wav` to `audio01.mp3`:

```
# lame -h -b 128 \
--tt "Foo Song Title" \
--ta "FooBar Artist" \
--tl "FooBar Album" \
--ty "2001" \
--tc "Ripped and encoded by Foo" \
```

```
--tg "Genre" \
audio01.wav audio01.mp3
```

128 kbits seems to be the standard MP3 bitrate in use. Many enjoy the higher quality 160, or 192. The higher the bitrate, the more disk space the resulting MP3 will consume--but the quality will be higher. The `-h` option turns on the "higher quality but a little slower" mode. The options beginning with `--t` indicate ID3 tags, which usually contain song information, to be embedded within the MP3 file. Additional encoding options can be found by consulting the lame man page.

7.3.4. Decoding MP3s

In order to burn an audio CD from MP3s, they must be converted to a non-compressed WAV format. Both XMMS and mpg123 support the output of MP3 to an uncompressed file format.

Writing to Disk in XMMS:

1. Launch XMMS.
2. Right-click on the window to bring up the XMMS menu.
3. Select `Preference` under `Options`.
4. Change the Output Plugin to "Disk Writer Plugin".
5. Press `Configure`.
6. Enter (or choose browse) a directory to write the uncompressed files to.
7. Load the MP3 file into XMMS as usual, with volume at 100% and EQ settings turned off.
8. Press `Play` —— XMMS will appear as if it is playing the MP3, but no music will be heard. It is actually playing the MP3 to a file.
9. Be sure to set the default Output Plugin back to what it was before in order to listen to MP3s again.

Writing to stdout in mpg123:

- Run `mpg123 -s audio01.mp3 > audio01.pcm`

XMMS writes a file in the WAV format, while mpg123 converts the MP3 into raw PCM audio data. Both of these formats can be used with cdrecord to create audio CDs. You have to use raw PCM with burncd(8). If you use WAV files, you will notice a small tick sound at the beginning of each track, this sound is the header of the WAV file. You can simply remove the header of a WAV file with the utility SoX (it can be installed from the audio/sox port or package):

```
% sox -t wav -r 44100 -s -w -c 2 track.wav track.raw
```

Read 節 17.6, "Creating and Using CD Media" for more information on using a CD burner in FreeBSD.

7.4. 播放影片

Contributed by Ross Lippert.

Video playback is a very new and rapidly developing application area. Be patient. Not everything is going to work as smoothly as it did with sound.

Before you begin, you should know the model of the video card you have and the chip it uses. While Xorg and XFree86™ support a wide variety of video cards, fewer give good playback performance. To obtain a list of extensions supported by the X server using your card use the command xdpyinfo(1) while X11 is running.

It is a good idea to have a short MPEG file which can be treated as a test file for evaluating various players and options. Since some DVD players will look for DVD media in `/dev/dvd` by default, or have this device name hardcoded in them, you might find it useful to make symbolic links to the proper devices:

```
# ln -sf /dev/acd0c /dev/dvd
# ln -sf /dev/racd0c /dev/rdvd
```

On FreeBSD 5.X, which uses devfs(5) there is a slightly different set of recommended links:

```
# ln -sf /dev/acd0 /dev/dvd
# ln -sf /dev/acd0 /dev/rdvd
```

Note that due to the nature of devfs(5), manually created links like these will not persist if you reboot your system. In order to create the symbolic links automatically whenever you boot your system, add the following lines to `/etc/devfs.conf` :

```
link acd0 dvd
link acd0 rdvd
```

Additionally, DVD decryption, which requires invoking special DVD-ROM functions, requires write permission on the DVD devices.

Some of the ports discussed rely on the following kernel options to build correctly. Before attempting to build, add this option to the kernel configuration file, build a new kernel, and reboot:

```
options CPU_ENABLE_SSE
```

注意

On FreeBSD 4.X `options USER_LDT` should be added to the kernel configuration file. This option is not available on FreeBSD 5.X and later version.

To enhance the shared memory X11 interface, it is recommended that the values of some sysctl(8) variables should be increased:

```
kern.ipc.shmmax=67108864
kern.ipc.shmall=32768
```

7.4.1. Determining Video Capabilities

There are several possible ways to display video under X11. What will really work is largely hardware dependent. Each method described below will have varying quality across different hardware. Secondly, the rendering of video in X11 is a topic receiving a lot of attention lately, and with each version of Xorg, or of XFree86™, there may be significant improvement.

A list of common video interfaces:

1. X11: normal X11 output using shared memory.
2. XVideo: an extension to the X11 interface which supports video in any X11 drawable.
3. SDL: the Simple Directmedia Layer.
4. DGA: the Direct Graphics Access.
5. SVGAlib: low level console graphics layer.

7.4.1.1. XVideo

Xorg and XFree86™ 4.X have an extension called XVideo (aka Xvideo, aka Xv, aka xv) which allows video to be directly displayed in drawable objects through a special acceleration. This extension provides very good quality playback even on low-end machines.

To check whether the extension is running, use `xvinfo`:

```
% xvinfo
```

XVideo is supported for your card if the result looks like:

```
X-Video Extension version 2.2
screen #0
  Adaptor #0: "Savage Streams Engine"
    number of ports: 1
    port base: 43
    operations supported: PutImage
    supported visuals:
      depth 16, visualID 0x22
      depth 16, visualID 0x23
    number of attributes: 5
      "XV_COLORKEY" (range 0 to 16777215)
              client settable attribute
              client gettable attribute (current value is 2110)
      "XV_BRIGHTNESS" (range -128 to 127)
              client settable attribute
              client gettable attribute (current value is 0)
      "XV_CONTRAST" (range 0 to 255)
              client settable attribute
              client gettable attribute (current value is 128)
      "XV_SATURATION" (range 0 to 255)
              client settable attribute
              client gettable attribute (current value is 128)
      "XV_HUE" (range -180 to 180)
              client settable attribute
              client gettable attribute (current value is 0)
    maximum XvImage size: 1024 x 1024
    Number of image formats: 7
      id: 0x32595559 (YUY2)
        guid: 59555932-0000-0010-8000-00aa00389b71
        bits per pixel: 16
        number of planes: 1
        type: YUV (packed)
      id: 0x32315659 (YV12)
        guid: 59563132-0000-0010-8000-00aa00389b71
        bits per pixel: 12
        number of planes: 3
        type: YUV (planar)
      id: 0x30323449 (I420)
        guid: 49343230-0000-0010-8000-00aa00389b71
        bits per pixel: 12
        number of planes: 3
        type: YUV (planar)
      id: 0x36315652 (RV16)
        guid: 52563135-0000-0000-0000-000000000000
        bits per pixel: 16
        number of planes: 1
        type: RGB (packed)
        depth: 0
        red, green, blue masks: 0x1f, 0x3e0, 0x7c00
      id: 0x35315652 (RV15)
        guid: 52563136-0000-0000-0000-000000000000
        bits per pixel: 16
        number of planes: 1
        type: RGB (packed)
```

```
        depth: 0
        red, green, blue masks: 0x1f, 0x7e0, 0xf800
      id: 0x31313259 (Y211)
        guid: 59323131-0000-0010-8000-00aa00389b71
        bits per pixel: 6
        number of planes: 3
        type: YUV (packed)
      id: 0x0
        guid: 00000000-0000-0000-0000-000000000000
        bits per pixel: 0
        number of planes: 0
        type: RGB (packed)
        depth: 1
        red, green, blue masks: 0x0, 0x0, 0x0
```

Also note that the formats listed (YUV2, YUV12, etc) are not present with every implementation of XVideo and their absence may hinder some players.

If the result looks like:

```
X-Video Extension version 2.2
screen #0
no adaptors present
```

Then XVideo is probably not supported for your card.

If XVideo is not supported for your card, this only means that it will be more difficult for your display to meet the computational demands of rendering video. Depending on your video card and processor, though, you might still be able to have a satisfying experience. You should probably read about ways of improving performance in the advanced reading 節 7.4.3, “Further Reading”.

7.4.1.2. Simple Directmedia Layer

The Simple Directmedia Layer, SDL, was intended to be a porting layer between Microsoft® Windows®, BeOS, and UNIX®, allowing cross-platform applications to be developed which made efficient use of sound and graphics. The SDL layer provides a low-level abstraction to the hardware which can sometimes be more efficient than the X11 interface.

The SDL can be found at devel/sdl12.

7.4.1.3. Direct Graphics Access

Direct Graphics Access is an X11 extension which allows a program to bypass the X server and directly alter the framebuffer. Because it relies on a low level memory mapping to effect this sharing, programs using it must be run as `root`.

The DGA extension can be tested and benchmarked by dga(1). When `dga` is running, it changes the colors of the display whenever a key is pressed. To quit, use q.

7.4.2. Ports and Packages Dealing with Video

This section discusses the software available from the FreeBSD Ports Collection which can be used for video playback. Video playback is a very active area of software development, and the capabilities of various applications are bound to diverge somewhat from the descriptions given here.

Firstly, it is important to know that many of the video applications which run on FreeBSD were developed as Linux applications. Many of these applications are still beta-quality. Some of the problems that you may encounter with video packages on FreeBSD include:

1. An application cannot playback a file which another application produced.

2. An application cannot playback a file which the application itself produced.

3. The same application on two different machines, rebuilt on each machine for that machine, plays back the same file differently.

4. A seemingly trivial filter like rescaling of the image size results in very bad artifacts from a buggy rescaling routine.

5. An application frequently dumps core.

6. Documentation is not installed with the port and can be found either on the web or under the port's `work` directory.

Many of these applications may also exhibit "Linux-isms". That is, there may be issues resulting from the way some standard libraries are implemented in the Linux distributions, or some features of the Linux kernel which have been assumed by the authors of the applications. These issues are not always noticed and worked around by the port maintainers, which can lead to problems like these:

1. The use of `/proc/cpuinfo` to detect processor characteristics.

2. A misuse of threads which causes a program to hang upon completion instead of truly terminating.

3. Software not yet in the FreeBSD Ports Collection which is commonly used in conjunction with the application.

So far, these application developers have been cooperative with port maintainers to minimize the work-arounds needed for port-ing.

7.4.2.1. MPlayer

MPlayer is a recently developed and rapidly developing video player. The goals of the MPlayer team are speed and flexibility on Linux and other Unices. The project was started when the team founder got fed up with bad playback performance on then available players. Some would say that the graphical interface has been sacrificed for a streamlined design. However, once you get used to the command line options and the key-stroke controls, it works very well.

7.4.2.1.1. Building MPlayer

MPlayer resides in multimedia/mplayer. MPlayer performs a variety of hardware checks during the build process, resulting in a binary which will not be portable from one system to another. Therefore, it is important to build it from ports and not to use a binary package. Additionally, a number of options can be specified in the `make` command line, as described in the `Makefile` and at the start of the build:

```
# cd /usr/ports/multimedia/mplayer
# make
N - O - T - E

Take a careful look into the Makefile in order
to learn how to tune mplayer towards you personal preferences!
For example,
make WITH_GTK1
builds MPlayer with GTK1-GUI support.
If you want to use the GUI, you can either install
/usr/ports/multimedia/mplayer-skins
or download official skin collections from
http://www.mplayerhq.hu/homepage/dload.html
```

The default port options should be sufficient for most users. However, if you need the XviD codec, you have to specify the `WITH_XVID` option in the command line. The default DVD device can also be defined with the `WITH_DVD_DEVICE` option, by default `/dev/acd0` will be used.

As of this writing, the MPlayer port will build its HTML documentation and two executables, `mplayer`, and `mencoder`, which is a tool for re-encoding video.

The HTML documentation for MPlayer is very informative. If the reader finds the information on video hardware and interfaces in this chapter lacking, the MPlayer documentation is a very thorough supplement. You should definitely take the time to read the MPlayer documentation if you are looking for information about video support in UNIX®.

7.4.2.1.2. Using MPlayer

Any user of MPlayer must set up a `.mplayer` subdirectory of her home directory. To create this necessary subdirectory, you can type the following:

```
% cd /usr/ports/multimedia/mplayer
% make install-user
```

The command options for `mplayer` are listed in the manual page. For even more detail there is HTML documentation. In this section, we will describe only a few common uses.

To play a file, such as `testfile.avi` , through one of the various video interfaces set the `-vo` option:

```
% mplayer -vo xv testfile.avi
```

```
% mplayer -vo sdl testfile.avi
```

```
% mplayer -vo x11 testfile.avi
```

```
# mplayer -vo dga testfile.avi
```

```
# mplayer -vo 'sdl:dga' testfile.avi
```

It is worth trying all of these options, as their relative performance depends on many factors and will vary significantly with hardware.

To play from a DVD, replace the `testfile.avi` with `dvd://`*`N`* `-dvd-device` *`DEVICE`* where *`N`* is the title number to play and `DEVICE` is the device node for the DVD-ROM. For example, to play title 3 from `/dev/dvd`:

```
# mplayer -vo xv dvd://3 -dvd-device /dev/dvd
```

注意

The default DVD device can be defined during the build of the MPlayer port via the `WITH_DVD_DEVICE` option. By default, this device is `/dev/acd0` . More details can be found in the port `Makefile` .

To stop, pause, advance and so on, consult the keybindings, which are output by running `mplayer -h` or read the manual page.

Additional important options for playback are: `-fs` `-zoom` which engages the fullscreen mode and `-framedrop` which helps performance.

In order for the mplayer command line to not become too large, the user can create a file `.mplayer/config` and set default options there:

```
vo=xv
fs=yes
zoom=yes
```

Finally, `mplayer` can be used to rip a DVD title into a `.vob` file. To dump out the second title from a DVD, type this:

```
# mplayer -dumpstream -dumpfile out.vob dvd://2 -dvd-device /dev/dvd
```

The output file, `out.vob`, will be MPEG and can be manipulated by the other packages described in this section.

7.4.2.1.3. mencoder

Before using `mencoder` it is a good idea to familiarize yourself with the options from the HTML documentation. There is a manual page, but it is not very useful without the HTML documentation. There are innumerable ways to improve quality, lower bitrate, and change formats, and some of these tricks may make the difference between good or bad performance. Here are a couple of examples to get you going. First a simple copy:

```
% mencoder input.avi -oac copy -ovc copy -o output.avi
```

Improper combinations of command line options can yield output files that are unplayable even by `mplayer`. Thus, if you just want to rip to a file, stick to the `-dumpfile` in `mplayer`.

To convert `input.avi` to the MPEG4 codec with MPEG3 audio encoding (audio/lame is required):

```
% mencoder input.avi -oac mp3lame -lameopts br=192 \
  -ovc lavc -lavcopts vcodec=mpeg4:vhq -o output.avi
```

This has produced output playable by `mplayer` and `xine`.

`input.avi` can be replaced with `dvd://1 -dvd-device /dev/dvd` and run as `root` to re-encode a DVD title directly. Since you are likely to be dissatisfied with your results the first time around, it is recommended you dump the title to a file and work on the file.

7.4.2.2. The xine Video Player

The xine video player is a project of wide scope aiming not only at being an all in one video solution, but also in producing a reusable base library and a modular executable which can be extended with plugins. It comes both as a package and as a port, multimedia/xine.

The xine player is still very rough around the edges, but it is clearly off to a good start. In practice, xine requires either a fast CPU with a fast video card, or support for the XVideo extension. The GUI is usable, but a bit clumsy.

As of this writing, there is no input module shipped with xine which will play CSS encoded DVD's. There are third party builds which do have modules for this built in them, but none of these are in the FreeBSD Ports Collection.

Compared to MPlayer, xine does more for the user, but at the same time, takes some of the more fine-grained control away from the user. The xine video player performs best on XVideo interfaces.

By default, xine player will start up in a graphical user interface. The menus can then be used to open a specific file:

```
% xine
```

Alternatively, it may be invoked to play a file immediately without the GUI with the command:

```
% xine -g -p mymovie.avi
```

7.4.2.3. The transcode Utilities

The software transcode is not a player, but a suite of tools for re-encoding video and audio files. With transcode, one has the ability to merge video files, repair broken files, using command line tools with `stdin/stdout` stream interfaces.

A great number of options can be specified during the build from the multimedia/transcode port, we recommend the following command line to build transcode:

```
# make WITH_OPTIMIZED_CFLAGS=yes WITH_LIBA52=yes WITH_LAME=yes ↺
WITH_OGG=yes \
```

```
WITH_MJPEG=yes -DWITH_XVID=yes
```

The proposed settings should be sufficient for most users.

To illustrate `transcode` capacities, one example to show how to convert a DivX file into a PAL MPEG-1 file (PAL VCD):

```
% transcode -i input.avi -V --export_prof vcd-pal -o output_vcd
% mplex -f 1 -o output_vcd.mpg output_vcd.m1v output_vcd.mpa
```

The resulting MPEG file, `output_vcd.mpg` , is ready to be played with MPlayer. You could even burn the file on a CD-R media to create a Video CD, in this case you will need to install and use both multimedia/vcdimager and sysutils/cdrdao programs.

There is a manual page for `transcode` , but you should also consult the transcode wiki for further information and examples.

7.4.3. Further Reading

The various video software packages for FreeBSD are developing rapidly. It is quite possible that in the near future many of the problems discussed here will have been resolved. In the mean time, those who want to get the very most out of FreeBSD's A/V capabilities will have to cobble together knowledge from several FAQs and tutorials and use a few different applications. This section exists to give the reader pointers to such additional information.

The MPlayer documentation is very technically informative. These documents should probably be consulted by anyone wishing to obtain a high level of expertise with UNIX® video. The MPlayer mailing list is hostile to anyone who has not bothered to read the documentation, so if you plan on making bug reports to them, RTFM.

The xine HOWTO contains a chapter on performance improvement which is general to all players.

Finally, there are some other promising applications which the reader may try:

- Avifile which is also a port multimedia/avifile.
- Ogle which is also a port multimedia/ogle.
- Xtheater
- multimedia/dvdauthor, an open source package for authoring DVD content.

7.5. 設定電視卡(TV Cards)

Original contribution by Josef El-Rayes.
Enhanced and adapted by Marc Fonvieille.

7.5.1. 介紹

電視卡(TV card)可以讓您用電腦來看無線、有線電視節目。許多卡都是透過 RCA 或 S-video 輸入端子來接收視訊，而且有些卡還可接收 FM 廣播的功能。

FreeBSD 可透過 bktr(4) 驅動程式，來支援 PCI 介面的電視卡，只要這些卡使用的是 Brooktree Bt848/849/878/879 或 Conexant CN-878/Fusion 878a 視訊擷取晶片。此外，要再確認哪些卡上所附的選台功能是否有支援，可以參考 bktr(4) 說明，以查看所支援的硬體清單。

7.5.2. 設定相關驅動程式

要用電視卡的話，就要載入 bktr(4) 驅動程式，這個可以透過在 `/boot/loader.conf` 檔加上下面這一行就可以了：

```
bktr_load="YES"
```

此外，也可以把該 kernel module 直接與 kernel 編譯在一起，作法就是在你的 kernel 設定檔內，加上下面這幾行：

```
device  bktr
device iicbus
device iicbb
device smbus
```

之所以要加上這些額外的驅動程式，是因為卡的各組成部分都是透過 I2C 匯流排而相互連接的。接下來，請重新編譯、安裝新的 kernel 。

安裝好新的 kernel 之後，要重開機才會生效。開機時，應該會看到類似下面的正確偵測到 TV card 訊息：

```
bktr0: <BrookTree 848A> mem 0xd7000000-0xd7000fff irq 10 at device 10.0 on pci0
iicbb0: <I2C bit-banging driver> on bti2c0
iicbus0: <Philips I2C bus> on iicbb0 master-only
iicbus1: <Philips I2C bus> on iicbb0 master-only
smbus0: <System Management Bus> on bti2c0
bktr0: Pinnacle/Miro TV, Philips SECAM tuner.
```

當然，這些訊息可能因您的硬體不同而有所不同。However you should check if the tuner is correctly detected; it is still possible to override some of the detected parameters with sysctl(8) MIBs and kernel configuration file options. For example, if you want to force the tuner to a Philips SECAM tuner, you should add the following line to your kernel configuration file:

```
options OVERRIDE_TUNER=6
```

or you can directly use sysctl(8):

```
# sysctl hw.bt848.tuner=6
```

See the bktr(4) manual page and the `/usr/src/sys/conf/NOTES` file for more details on the available options. (If you are under FreeBSD 4.X, `/usr/src/sys/conf/NOTES` is replaced with `/usr/src/sys/i386/conf/LINT` .)

7.5.3. 好用的程式

要用電視卡，可以視需要安裝下列應用程式之一：

- multimedia/fxtv provides TV-in-a-window and image/audio/video capture capabilities.
- multimedia/xawtv is also a TV application, with the same features as fxtv.
- misc/alevt decodes and displays Videotext/Teletext.
- audio/xmradio, an application to use the FM radio tuner coming with some TV cards.
- audio/wmtune, a handy desktop application for radio tuners.

More applications are available in the FreeBSD Ports Collection.

7.5.4. Troubleshooting

If you encounter any problem with your TV card, you should check at first if the video capture chip and the tuner are really supported by the bktr(4) driver and if you used the right configuration options. For more support and various questions about your TV card you may want to contact and use the archives of the freebsd-multimedia mailing list.

7.6. 掃描器

Written by Marc Fonvieille.

7.6.1. 介紹

FreeBSD 就像任何現代作業系統一樣，都可以使用掃描器。 在 FreeBSD 是透過 Ports Collection 內的 SANE(Scanner Access Now Easy) 所提供的 API 來操作掃描器。 SANE 也會使用一些 FreeBSD 的驅動程式來控制掃描器硬體。

FreeBSD 同時支援 SCSI 和 USB 兩種介面的掃描器。在做任何設定之前，請確保 SANE 有支援您的掃描器。SANE 有張 支援硬體 的清單，這裡有介紹掃描器的支援情況和狀態訊息。 在 uscanner(4) 內也有提供一份 USB 掃描器的支援列表。

7.6.2. Kernel 的設定

如同上述所提的 SCSI 和 USB 界面都有支援。這要取決於您的掃描器界面，而需要不同的設備驅動程式。

7.6.2.1. USB 介面

The `GENERIC` kernel by default includes the device drivers needed to support USB scanners. Should you decide to use a custom kernel, be sure that the following lines are present in your kernel configuration file:

```
device usb
device uhci
device ohci
device uscanner
```

Depending upon the USB chipset on your motherboard, you will only need either `device uhci` or `device ohci`, however having both in the kernel configuration file is harmless.

If you do not want to rebuild your kernel and your kernel is not the `GENERIC` one, you can directly load the uscanner(4) device driver module with the kldload(8) command:

```
# kldload uscanner
```

To load this module at each system startup, add the following line to `/boot/loader.conf` :

```
uscanner_load="YES"
```

After rebooting with the correct kernel, or after loading the required module, plug in your USB scanner. The scanner should appear in your system message buffer (dmesg(8)) as something like:

```
uscanner0: EPSON EPSON Scanner, rev 1.10/3.02, addr 2
```

This shows that our scanner is using the `/dev/uscanner0` device node.

注意

On FreeBSD 4.X, the USB daemon (usbd(8)) must be running to be able to see some USB devices. To enable this, add `usbd_enable="YES"` to your `/etc/rc.conf` file and reboot the machine.

7.6.2.2. SCSI 介面

If your scanner comes with a SCSI interface, it is important to know which SCSI controller board you will use. According to the SCSI chipset used, you will have to tune your kernel configuration file. The `GENERIC` kernel

supports the most common SCSI controllers. Be sure to read the `NOTES` file (`LINT` under FreeBSD 4.X) and add the correct line to your kernel configuration file. In addition to the SCSI adapter driver, you need to have the following lines in your kernel configuration file:

```
device scbus
device pass
```

Once your kernel has been properly compiled, you should be able to see the devices in your system message buffer, when booting:

```
pass2 at aic0 bus 0 target 2 lun 0
pass2: <AGFA SNAPSCAN 600 1.10> Fixed Scanner SCSI-2 device
pass2: 3.300MB/s transfers
```

If your scanner was not powered-on at system boot, it is still possible to manually force the detection by performing a SCSI bus scan with the camcontrol(8) command:

```
# camcontrol rescan all
Re-scan of bus 0 was successful
Re-scan of bus 1 was successful
Re-scan of bus 2 was successful
Re-scan of bus 3 was successful
```

Then the scanner will appear in the SCSI devices list:

```
# camcontrol devlist
<IBM DDRS-34560 S97B>              at scbus0 target 5 lun 0 (pass0,da0)
<IBM DDRS-34560 S97B>              at scbus0 target 6 lun 0 (pass1,da1)
<AGFA SNAPSCAN 600 1.10>           at scbus1 target 2 lun 0 (pass3)
<PHILIPS CDD3610 CD-R/RW 1.00>     at scbus2 target 0 lun 0 (pass2,cd0)
```

More details about SCSI devices, are available in the scsi(4) and camcontrol(8) manual pages.

7.6.3. 設定 SANE

The SANE system has been splitted in two parts: the backends (graphics/sane-backends) and the frontends (graphics/sane-frontends). The backends part provides access to the scanner itself. The SANE's supported devices list specifies which backend will support your image scanner. It is mandatory to determine the correct backend for your scanner if you want to be able to use your device. The frontends part provides the graphical scanning interface (xscanimage).

The first thing to do is install the graphics/sane-backends port or package. Then, use the `sane-find-scanner` command to check the scanner detection by the SANE system:

```
# sane-find-scanner -q
found SCSI scanner "AGFA SNAPSCAN 600 1.10" at /dev/pass3
```

The output will show the interface type of the scanner and the device node used to attach the scanner to the system. The vendor and the product model may not appear, it is not important.

注意

Some USB scanners require you to load a firmware, this is explained in the backend manual page. You should also read sane-find-scanner(1) and sane(7) manual pages.

Now we have to check if the scanner will be identified by a scanning frontend. By default, the SANE backends comes with a command line tool called scanimage(1). This command allows you to list the devices and to perform an image acquisition from the command line. The `-L` option is used to list the scanner device:

```
# scanimage -L
device `snapscan:/dev/pass3' is a AGFA SNAPSCAN 600 flatbed scanner
```

No output or a message saying that no scanners were identified indicates that scanimage(1) is unable to identify the scanner. If this happens, you will need to edit the backend configuration file and define the scanner device used. The `/usr/local/etc/sane.d/` directory contains all backends configuration files. This identification problem does appear with certain USB scanners.

For example, with the USB scanner used in the 節 7.6.2.1, “USB 介面”, `sane-find-scanner` gives us the following information:

```
# sane-find-scanner -q
found USB scanner (UNKNOWN vendor and product) at device /dev/uscanner0
```

The scanner is correctly detected, it uses the USB interface and is attached to the `/dev/uscanner0` device node. We can now check if the scanner is correctly identified:

```
# scanimage -L

No scanners were identified. If you were expecting something different,
check that the scanner is plugged in, turned on and detected by the
sane-find-scanner tool (if appropriate). Please read the documentation
which came with this software (README, FAQ, manpages).
```

Since the scanner is not identified, we will need to edit the `/usr/local/etc/sane.d/epson.conf` file. The scanner model used was the EPSON Perfection® 1650, so we know the scanner will use the `epson` backend. Be sure to read the help comments in the backends configuration files. Line changes are quite simple: comment out all lines that have the wrong interface for your scanner (in our case, we will comment out all lines starting with the word `scsi` as our scanner uses the USB interface), then add at the end of the file a line specifying the interface and the device node used. In this case, we add the following line:

```
usb /dev/uscanner0
```

Please be sure to read the comments provided in the backend configuration file as well as the backend manual page for more details and correct syntax to use. We can now verify if the scanner is identified:

```
# scanimage -L
device `epson:/dev/uscanner0' is a Epson GT-8200 flatbed scanner
```

Our USB scanner has been identified. It is not important if the brand and the model do not match. The key item to be concerned with is the `` `epson:/dev/uscanner0' `` field, which give us the right backend name and the right device node.

Once the `scanimage -L` command is able to see the scanner, the configuration is complete. The device is now ready to scan.

While scanimage(1) does allow us to perform an image acquisition from the command line, it is preferable to use a graphical user interface to perform image scanning. SANE offers a simple but efficient graphical interface: xscanimage (graphics/sane-frontends).

Xsane (graphics/xsane) is another popular graphical scanning frontend. This frontend offers advanced features such as various scanning mode (photocopy, fax, etc.), color correction, batch scans, etc. Both of these applications are useable as a GIMP plugin.

7.6.4. Allowing Scanner Access to Other Users

All previous operations have been done with `root` privileges. You may however, need other users to have access to the scanner. The user will need read and write permissions to the device node used by the scanner. As an example, our USB scanner uses the device node `/dev/uscanner0` which is owned by the `operator` group. Adding the user `joe` to the `operator` group will allow him to use the scanner:

```
# pw groupmod operator -m joe
```

For more details read the pw(8) manual page. You also have to set the correct write permissions (0660 or 0664) on the `/dev/uscanner0` device node, by default the `operator` group can only read the device node. This is done by adding the following lines to the `/etc/devfs.rules` file:

```
[system=5]
add path uscanner0 mode 660
```

Then add the following to `/etc/rc.conf` and reboot the machine:

```
devfs_system_ruleset="system"
```

More information regarding these lines can be found in the devfs(8) manual page. Under FreeBSD 4.X, the `operator` group has, by default, read and write permissions to `/dev/uscanner0` .

注意

Of course, for security reasons, you should think twice before adding a user to any group, especially the `operator` group.

章 8. 設定 FreeBSD Kernel

更新、重排：Jim Mock.
原作爲：Jake Hamby.

8.1. 概述

kernel 是整個 FreeBSD 作業系統的核心。 它控制了系統的整體運作，包含和記憶體管理、安全控管、網路、硬碟存取等等。 儘管目前 FreeBSD 大多可以用動態 module 來載入、卸載所需功能， 但有時候仍有必要學會重新調配 `kernel`。

讀完這章，您將了解：

- 為何需要重新調配、編譯 `kernel`？
- 要怎麼修改 kernel 設定檔？
- 如何以 kernel 設定檔來建立、編譯新的 kernel 呢？
- 如何安裝新的 `kernel`。
- 如何處理 kernel 錯誤無法開機的情形。

本章所舉例的相關指令都是以 `root` 權限來進行。

8.2. 爲何需要重新調配、編譯 kernel？

早期的 FreeBSD 的 kernel 被戲稱為 “monolithic” `kernel`。 這意思是說當時的 kernel 是個大塊頭程式，且只支援固定的硬體而已。 如果您想改變 kernel 的設定，那麼必須編譯一個新的並重新開機，才能啓用。

現在的 FreeBSD 已快速成長到新型態的管理模式，其重要特色是： kernel 功能可以隨時依據需求， 而以動態載入或卸載相關的 kernel `module`。 這使得 kernel 能夠快速因應新的環境而作調整（有點像是：筆記型電腦上的 PCMCIA 卡一樣即插即用），或是增加其他原本的預設 kernel(`GENERIC`)所沒有的功能。 這種模式，就叫做 modular `kernel`（核心模組）。

儘管如此，還是有一些功能仍須編譯在 kernel 內才行。因為有時候是因為這些功能與 kernel 結合的相當複雜緊密，而無法將它們弄成可動態載入的 module ；而有時候，則是因為沒有人有空來弄那些 kernel module 的實作。

重新調配、編譯 kernel 幾乎是每位 BSD 使用者所必須經歷的過程。 儘管這項工作可能比較耗時，但在 FreeBSD 的使用上會有許多好處。 跟必須支援大多數各式硬體的 `GENERIC` kernel 相比的話， 自行調配 kernel 不同處在於：可以更『體貼』，只支援『自己硬體』的部分就好。 好處在於，譬如：

- 開機速度更快：因為自行調配的 kernel 只需要偵測您系統上的硬體， 所以讓啓動所花的過程更流暢快速。
- 佔用的記憶體更少：自行調配的 kernel 通常會比 `GENERIC` 核心使用更少的記憶體，由於 kernel 必須一直存放在記憶體內，因此這就顯得更加重要。因此， 對於記憶體較小的系統來說， 自行調配的 kernel 就可發揮更多的作用、揮灑空間。
- 可支援更多硬體：您可在自行調配的 kernel 增加一些原本 `GENERIC` 核心沒有提供的硬體支援，像是音效卡之類的。

8.3. 探測系統硬體

Written by Tom Rhodes.

在進行 kernel 設定的探索之旅前， 先把該機器各項硬體資訊作點調查會是明智之舉。 若 FreeBSD 並非主要的作業系統，那麼也可以輕鬆透過目前所使用的作業系統， 來查看相關硬體資訊表。 舉例來說，Microsoft® 的 裝置管理員(Device Manager) 內通常會有目前有裝的硬體資訊。 而 裝置管理員 是在控制台。

注意

Microsoft® Windows® 某些版本則是先透過 系統(System) 再進入 裝置管理員。

若該機器尚未安裝任何作業系統，那麼就要親自找出相關硬體資訊。 其中一種方式是透過 dmesg(8) 以及 man(1)。 FreeBSD 上大多硬體都會有相關的 man 說明有支援的規格型號， 並且開機的偵測過程中，也會列出有找到的硬體。 舉個例子， 下面這幾行是說有偵測到滑鼠，並且是以 psm 驅動程式：

```
psm0: <PS/2 Mouse> irq 12 on atkbdc0
psm0: [GIANT-LOCKED]
psm0: [ITHREAD]
psm0: model Generic PS/2 mouse, device ID 0
```

驅動程式必須要在自訂的 kernel 設定檔內加入，或者是用 loader.conf(5)。

dmesg 有時只顯示系統訊息而沒有開機偵測的部份， 遇到這種情況請查閱 /var/run/dmesg.boot 檔。

另外也可以透過 pciconf(8) 來列出更詳細的相關資訊。 舉例說明：

```
ath0@pci0:3:0:0:        class=0x020000 card=0x058a1014 chip=0x1014168c rev=0x01 hdr=0x00
    vendor     = 'Atheros Communications Inc.'
    device     = 'AR5212 Atheros AR5212 802.11abg wireless'
    class      = network
    subclass   = ethernet
```

上面顯示是透過 pciconf -lv 所看到的 ath 無線網卡驅動程式。 可以用 man ath 來查看 ath(4) 的相關說明。

在使用 man(1) 時，加上 -k 參數也可以提供比較精準的資訊。 以上述例子而言，可以改為打：

```
# man -k Atheros
```

就會列出有含上述關鍵字的相關 man 說明：

```
ath(4)                   - Atheros IEEE 802.11 wireless network driver
ath_hal(4)               - Atheros Hardware Access Layer (HAL)
```

知己知彼，先瞭解相關硬體環境，才能讓接下來的自訂 kernel 打造過程更為順利。

8.4. 重新調配、編譯 kernel

首先對 kernel 相關目錄作快速介紹。 這裡所提到的所有目錄都在 /usr/src/sys 內， 也可以用 /sys 這個 symbolic link 來連到這。 這裡的許多子目錄分別擺放 kernel 的各組成部分，但對打造 kernel 影響最重要的目錄是 arch/conf， 這裡是可以針對需求來修改自訂 kernel 相關設定。 此外，還有在編譯 kernel 過程中會暫時擺放的 compile 目錄。 剛講到的 *arch* 可以是右列架構之一： i386、alpha、amd64、ia64、 powerpc、sparc64、 pc98(在日本較流行的另一種 PC 硬體架構)。 在各特定硬體架構目錄的東西，只搭配相對應的硬體架構而已。 而其餘的原始碼則是與硬體架構無關，可以在所有

FreeBSD 可裝的平台上共用。 整體目錄架構都是有邏輯可循，像是各項有支援的硬體設備、檔案系統， 以及相關選項通常都會擺在它們自己的子目錄內。

本章所用到的例子，都是你使用 i386 架構的機器。 請依實際情況，對相關目錄作調整即可。

注意

若您系統上 沒裝 /usr/src/sys 目錄， 也就是說沒裝 kernel source code 的話，那麼最簡單安裝方式就是以 root 權限來執行 sysinstall ， 接著請選 Configure，然後選 Distributions 接著為 src 再選 base 最後選 sys。 若不喜歡用 sysinstall 而且手邊有“正式的” FreeBSD 光碟可以用的話， 那麼也可以用以下指令來安裝：

```
# mount /cdrom
# mkdir -p /usr/src/sys
# ln -s /usr/src/sys /sys
# cat /cdrom/src/ssys.[a-d]* | tar -xzvf -
# cat /cdrom/src/sbase.[a-d]* | tar -xzvf -
```

接下來，切換到 arch/conf 目錄， 複製 GENERIC 設定檔為你想稱呼的新 kernel 名稱。 例如：

```
# cd /usr/src/sys/i386/conf
# cp GENERIC MYKERNEL
```

通常，命名方式都是大寫。如果你負責維護許多不同硬體架構的 FreeBSD 機器的話，那麼照該機器名稱(hostname)來命名會是比較明智。 上面例子中之所以命名為 MYKERNEL 就是因為這緣故。

提示

建議不要把改過的 kernel 設定檔直接放在 /usr/src 。 因為若編譯遇到其他問題時，直接砍掉 /usr/src 再重練， 可能會是比較乾脆的選擇之一。 一旦真的砍了之後，你可能幾秒之後才會醒悟到： 你同時也砍掉自己改的 kernel 設定檔。 此外，也不要直接修改 GENERIC ，因為下次你 更新 source tree 時， 它會被新版覆蓋，而相關修改也將隨之而逝。

你也可考慮把 kernel 設定檔改放到其他地方，然後再到 i386 目錄內建個指向它的 symbolic link。

舉例：

```
# cd /usr/src/sys/i386/conf
# mkdir /root/kernels
# cp GENERIC /root/kernels/MYKERNEL
# ln -s /root/kernels/MYKERNEL
```

現在，就開始用自己喜歡的編輯器來修改 MYKERNEL 。 若才剛裝好 FreeBSD 而已，唯一可用的編輯器很可能是 vi 了，由於它的用法很多種，礙於篇幅將不詳細介紹， 你可在 參考書目 內找到相關書籍。 不過，FreeBSD 也提供另一個更好用的編輯器，它叫做 ee，對新手而言，這可能是蠻好的選擇。 你可以任意修改檔案內的相關註解以說明相關設定為何， 或者其他想改的 GENERIC 設定內容。

若你有在 SunOS™ 或者其他種 BSD 作業系統下進行編譯 kernel 的經驗， 那麼應該已經很熟悉本篇所介紹的大部分步驟。 換句話說，若您之前用的是 DOS 這類作業系統，那麼 GENERIC 設定檔的內容就可能比較難懂些，沒關係， 我們將在下面的 kernel 設定 會循序漸進地介紹。

注意

若有從 FreeBSD 計劃去更新你的 source tree 的話， 則切記在進行任何升級之前，務必要察看 /usr/src/UPDATING 。 這檔會介紹在更新過程中的重大議題或要注意的事項。 由於 /usr/src/UPDATING 是對應於你機器上目前的 FreeBSD source code 版本，因此會提供比本手冊更新的內容。

現在開始來編譯 kernel 吧。

過程 8.1. 編譯 Kernel

1. 請切換至 /usr/src 目錄：

```
# cd /usr/src
```

2. 編譯 kernel：

```
# make buildkernel KERNCONF=MYKERNEL
```

3. 安裝新 kernel：

```
# make installkernel KERNCONF=MYKERNEL
```

注意

要有完整的 FreeBSD source tree 才能編譯 kernel。

提示

預設情況下，在編譯自訂 kernel 時，全部的 kernel modules 也會一起重編。 若要快速升級 kernel， 或是只想重編所需的 kernel module，那麼在編譯 kernel 前要先改一下 /etc/make.conf ，比如：

```
MODULES_OVERRIDE = linux acpi sound/sound sound/driver/ds1 ntfs
```

上面該設定值為所希望重編的 kernel module 列表。

```
WITHOUT_MODULES = linux acpi sound/sound sound/driver/ds1 ntfs
```

而上面這設定值則為不要編入的 kernel module 列表。 若想更瞭解其他 kernel 編譯的相關變數，請參閱 make.conf(5) 說明。

新的 kernel 會複製到 /boot/kernel 目錄內的 /boot/kernel/kernel ，而舊的則移至 /boot/kernel.old/kernel 。 現在呢，先關機，然後就會以新 kernel 重開機 若有問題的話，本章後面會介紹一些疑難雜症來協助你。 若新 kernel 無法開機的話，請參閱 這裡 以恢復系統運作。

注意

至於開機過程的其他相關檔案、設定，比如 loader(8) 及其設定，則放在 /boot。 Third party 或自訂的 kernel modules 則會放在 /boot/kernel，不過，應注意要保持 kernel module 與 kernel 是否有同步， 這點很重要，否則會導致不穩或出問題。

8.5. kernel 設定檔解說

Updated for FreeBSD 6.X by Joel Dahl.

kernel 設定檔的內容格式相當簡單。 每一行都包括一個關鍵字，以及一個或多個參數。事實上， 很多行大多只有一個參數。任何以 # 開頭的敘述都將被視為註解而被忽略。 接下來將以在 GENERIC 所出現的順序一一介紹之。 若要看與該平台架構有關的各選項、設備列表， 請參閱與 GENERIC 檔同目錄的 NOTES 檔。 而與平台架構差異較無關的通用部份，則可參閱 /usr/src/sys/conf/NOTES 。

注意

若為了測試，而需要一份含有所有可用設定的設定檔，那麼請以 root 身份下：

```
# cd /usr/src/sys/i386/conf && make LINT
```

下面為 GENERIC 設定檔的範例， 其中包括說明用的註釋。 這例子應該與您機器上的 /usr/src/sys/i386/conf/GENERIC 相當接近。

```
machine  i386
```

此處是指機器架構，必須為 alpha、amd64、 i386、ia64、 pc98、powerpc、 sparc64 其中之一。

```
cpu          I486_CPU
cpu          I586_CPU
cpu          I686_CPU
```

上面設定是指定要用哪一種 CPU 型號。 也可以同時加上多組 CPU 型號 （比如說萬一不確定是否要用 I586_CPU 或 I686_CPU）。 然而自訂 kernel 的話，建議先確認自己的 CPU 型號，然後只用最適合的那組就好了。 若不確定 CPU 到底是用哪一種， 可以查閱 /var/run/dmesg.boot 的開機訊息以確定。

```
ident          GENERIC
```

這是設定該 kernel 名稱為何，可以隨意命名之，像是取名為 MYKERNEL，若是有照先前說明來作大概會取這樣名字。 ident 後面的字串會在開機時顯示，因此若要辨認新 kernel 與常用 kernel 的話，就設定不同組名稱即可(比如在自訂實驗用的 kernel)。

```
#To statically compile in device wiring instead of /boot/device.hints
#hints          "GENERIC.hints"         # Default places to look for devices.
```

device.hints(5) 可用來設定各項驅動程式的選項。 開機時 loader(8) 會檢查預設的 /boot/device.hints 設定檔。 使用 hints 選項，就可以把這些 hints 靜態編入 kernel 內。 如此一來就不必在 /boot 內建立 device.hints 檔。

```
makeoptions     DEBUG=-g          # Build kernel with gdb(1) debug symbols
```

加上 `-g` 選項的話，FreeBSD 會在編譯過程加上 debug 用的資訊，透過這選項會讓 gcc(1) 啓用 debug 所會用到的相關資訊。

```
options         SCHED_4BSD          # 4BSD scheduler
```

FreeBSD. 傳統所用(並且是預設)的系統 CPU `scheduler`。 若您不清楚要如何設定 ，請保留這設定。

```
options         PREEMPTION          # Enable kernel thread preemption
```

Allows threads that are in the kernel to be preempted by higher priority threads. It helps with interactivity and allows interrupt threads to run sooner rather than waiting.

```
options         INET                # InterNETworking
```

Networking support. Leave this in, even if you do not plan to be connected to a network. Most programs require at least loopback networking (i.e., making network connections within your PC), so this is essentially mandatory.

```
options         INET6               # IPv6 communications protocols
```

This enables the IPv6 communication protocols.

```
options         FFS                 # Berkeley Fast Filesystem
```

This is the basic hard drive file system. Leave it in if you boot from the hard disk.

```
options         SOFTUPDATES         # Enable FFS Soft Updates support
```

This option enables Soft Updates in the kernel, this will help speed up write access on the disks. Even when this functionality is provided by the kernel, it must be turned on for specific disks. Review the output from mount(8) to see if Soft Updates is enabled for your system disks. If you do not see the `soft-updates` option then you will need to activate it using the tunefs(8) (for existing file systems) or newfs(8) (for new file systems) commands.

```
options         UFS_ACL             # Support for access control lists
```

This option enables kernel support for access control lists. This relies on the use of extended attributes and UFS2, and the feature is described in detail in 節 13.9, “Access Control Lists”. ACLs are enabled by default and should not be disabled in the kernel if they have been used previously on a file system, as this will remove the access control lists, changing the way files are protected in unpredictable ways.

```
options         UFS_DIRHASH         # Improve performance on big directories
```

This option includes functionality to speed up disk operations on large directories, at the expense of using additional memory. You would normally keep this for a large server, or interactive workstation, and remove it if you are using FreeBSD on a smaller system where memory is at a premium and disk access speed is less important, such as a firewall.

```
options         MD_ROOT             # MD is a potential root device
```

This option enables support for a memory backed virtual disk used as a root device.

```
options         NFSCLIENT           # Network Filesystem Client
options         NFSSERVER           # Network Filesystem Server
options         NFS_ROOT            # NFS usable as /, requires NFSCLIENT
```

The network file system. Unless you plan to mount partitions from a UNIX® file server over TCP/IP, you can comment these out.

```
options         MSDOSFS             # MSDOS Filesystem
```

The MS-DOS® file system. Unless you plan to mount a DOS formatted hard drive partition at boot time, you can safely comment this out. It will be automatically loaded the first time you mount a DOS partition, as described

above. Also, the excellent emulators/mtools software allows you to access DOS floppies without having to mount and unmount them (and does not require MSDOSFS at all).

```
options         CD9660          # ISO 9660 Filesystem
```

The ISO 9660 file system for CDROMs. Comment it out if you do not have a CDROM drive or only mount data CDs occasionally (since it will be dynamically loaded the first time you mount a data CD). Audio CDs do not need this file system.

```
options         PROCFS          # Process filesystem(requires PSEUDOFS)
```

The process file system. This is a "pretend" file system mounted on /proc which allows programs like ps(1) to give you more information on what processes are running. Use of PROCFS is not required under most circumstances, as most debugging and monitoring tools have been adapted to run without PROCFS: installs will not mount this file system by default.

```
options         PSEUDOFS        # Pseudo-filesystem framework
```

6.X kernels making use of PROCFS must also include support for PSEUDOFS.

```
options         GEOM_GPT        # GUID Partition Tables.
```

This option brings the ability to have a large number of partitions on a single disk.

```
options         COMPAT_43       # Compatible with BSD 4.3 [KEEP THIS!]
```

Compatibility with 4.3BSD. Leave this in; some programs will act strangely if you comment this out.

```
options         COMPAT_FREEBSD4 # Compatible with FreeBSD4
```

This option is required on FreeBSD 5.X i386™ and Alpha systems to support applications compiled on older versions of FreeBSD that use older system call interfaces. It is recommended that this option be used on all i386™ and Alpha systems that may run older applications; platforms that gained support only in 5.X, such as ia64 and Sparc64®, do not require this option.

```
options         COMPAT_FREEBSD5 # # FreeBSD5 ##
```

此行是 FreeBSD 6.X 及更新的版本若需支援 FreeBSD 5.X 系統呼叫才需要設定。

```
options         SCSI_DELAY=5000  # Delay (in ms) before probing SCSI
```

This causes the kernel to pause for 5 seconds before probing each SCSI device in your system. If you only have IDE hard drives, you can ignore this, otherwise you can try to lower this number, to speed up booting. Of course, if you do this and FreeBSD has trouble recognizing your SCSI devices, you will have to raise it again.

```
options         KTRACE          # ktrace(1) support
```

This enables kernel process tracing, which is useful in debugging.

```
options         SYSVSHM         # SYSV-style shared memory
```

This option provides for System V shared memory. The most common use of this is the XSHM extension in X, which many graphics-intensive programs will automatically take advantage of for extra speed. If you use X, you will definitely want to include this.

```
options         SYSVMSG         # SYSV-style message queues
```

Support for System V messages. This option only adds a few hundred bytes to the kernel.

```
options         SYSVSEM         # SYSV-style semaphores
```

Support for System V semaphores. Less commonly used but only adds a few hundred bytes to the kernel.

注意

The `-p` option of the ipcs(1) command will list any processes using each of these System V facilities.

```
options         _KPOSIX_PRIORITY_SCHEDULING # POSIX P1003_1B real-time extensions
```

Real-time extensions added in the 1993 POSIX®. Certain applications in the Ports Collection use these (such as StarOffice™).

```
options         KBD_INSTALL_CDEV  # install a CDEV entry in /dev
```

This option is required to allow the creation of keyboard device nodes in `/dev`.

```
options         ADAPTIVE_GIANT    # Giant mutex is adaptive.
```

Giant is the name of a mutual exclusion mechanism (a sleep mutex) that protects a large set of kernel resources. Today, this is an unacceptable performance bottleneck which is actively being replaced with locks that protect individual resources. The `ADAPTIVE_GIANT` option causes Giant to be included in the set of mutexes adaptively spun on. That is, when a thread wants to lock the Giant mutex, but it is already locked by a thread on another CPU, the first thread will keep running and wait for the lock to be released. Normally, the thread would instead go back to sleep and wait for its next chance to run. If you are not sure, leave this in.

注意

Note that on FreeBSD 8.0-CURRENT and later versions, all mutexes are adaptive by default, unless explicitly set to non-adaptive by compiling with the `NO_ADAPTIVE_MUTEXES` option. As a result, Giant is adaptive by default now, and the `ADAPTIVE_GIANT` option has been removed from the kernel configuration.

```
device          apic              # I/O APIC
```

The apic device enables the use of the I/O APIC for interrupt delivery. The apic device can be used in both UP and SMP kernels, but is required for SMP kernels. Add `options SMP` to include support for multiple processors.

注意

apic 只限 i386 架構才有，其他架構則不必加上這行。

```
device          eisa
```

Include this if you have an EISA motherboard. This enables auto-detection and configuration support for all devices on the EISA bus.

```
device          pci
```

Include this if you have a PCI motherboard. This enables auto-detection of PCI cards and gatewaying from the PCI to ISA bus.

```
# Floppy drives
device          fdc
```

This is the floppy drive controller.

```
# ATA and ATAPI devices
device          ata
```

This driver supports all ATA and ATAPI devices. You only need one `device ata` line for the kernel to detect all PCI ATA/ATAPI devices on modern machines.

```
device          atadisk                 # ATA disk drives
```

This is needed along with `device ata` for ATA disk drives.

```
device          ataraid                 # ATA RAID drives
```

This is needed along with `device ata` for ATA RAID drives.

```
device          atapicd                 # ATAPI CDROM drives
```

This is needed along with `device ata` for ATAPI CDROM drives.

```
device          atapifd                 # ATAPI floppy drives
```

This is needed along with `device ata` for ATAPI floppy drives.

```
device          atapist                 # ATAPI tape drives
```

This is needed along with `device ata` for ATAPI tape drives.

```
options         ATA_STATIC_ID           # Static device numbering
```

This makes the controller number static; without this, the device numbers are dynamically allocated.

```
# SCSI Controllers
device          ahb        # EISA AHA1742 family
device          ahc        # AHA2940 and onboard AIC7xxx devices
options         AHC_REG_PRETTY_PRINT    # Print register bitfields in debug
                                        # output.  Adds ~128k to driver.
device          ahd        # AHA39320/29320 and onboard AIC79xx devices
options         AHD_REG_PRETTY_PRINT    # Print register bitfields in debug
            # output.  Adds ~215k to driver.
device          amd        # AMD 53C974 (Teckram DC-390(T))
device          isp        # Qlogic family
device          ispfw      # Firmware for QLogic HBAs- normally a module
device          mpt        # LSI-Logic MPT-Fusion
#device         ncr        # NCR/Symbios Logic
device          sym        # NCR/Symbios Logic (newer chipsets + those of `ncr')
device          trm        # Tekram DC395U/UW/F DC315U adapters

device          adv        # Advansys SCSI adapters
device          adw        # Advansys wide SCSI adapters
device          aha        # Adaptec 154x SCSI adapters
device          aic        # Adaptec 15[012]x SCSI adapters, AIC-6[23]60.
device          bt         # Buslogic/Mylex MultiMaster SCSI adapters

device          ncv        # NCR 53C500
device          nsp        # Workbit Ninja SCSI-3
device          stg        # TMC 18C30/18C50
```

SCSI controllers. Comment out any you do not have in your system. If you have an IDE only system, you can remove these altogether. The `*_REG_PRETTY_PRINT` lines are debugging options for their respective drivers.

```
# SCSI peripherals
device          scbus      # SCSI bus (required for SCSI)
device          ch         # SCSI media changers
device          da         # Direct Access (disks)
device          sa         # Sequential Access (tape etc)
device          cd         # CD
device          pass       # Passthrough device (direct SCSI access)
device          ses        # SCSI Environmental Services (and SAF-TE)
```

SCSI peripherals. Again, comment out any you do not have, or if you have only IDE hardware, you can remove them completely.

注意

The USB umass(4) driver and a few other drivers use the SCSI subsystem even though they are not real SCSI devices. Therefore make sure not to remove SCSI support, if any such drivers are included in the kernel configuration.

```
# RAID controllers interfaced to the SCSI subsystem
device          amr        # AMI MegaRAID
device          arcmsr     # Areca SATA II RAID
device          asr        # DPT SmartRAID V, VI and Adaptec SCSI RAID
device          ciss       # Compaq Smart RAID 5*
device          dpt        # DPT Smartcache III, IV - See NOTES for options
device          hptmv      # Highpoint RocketRAID 182x
device          rr232x     # Highpoint RocketRAID 232x
device          iir        # Intel Integrated RAID
device          ips        # IBM (Adaptec) ServeRAID
device          mly        # Mylex AcceleRAID/eXtremeRAID
device          twa        # 3ware 9000 series PATA/SATA RAID

# RAID controllers
device          aac        # Adaptec FSA RAID
device          aacp       # SCSI passthrough for aac (requires CAM)
device          ida        # Compaq Smart RAID
device          mfi        # LSI MegaRAID SAS
device          mlx        # Mylex DAC960 family
device          pst        # Promise Supertrak SX6000
device          twe        # 3ware ATA RAID
```

Supported RAID controllers. If you do not have any of these, you can comment them out or remove them.

```
# atkbdc0 controls both the keyboard and the PS/2 mouse
device          atkbdc     # AT keyboard controller
```

The keyboard controller (`atkbdc`) provides I/O services for the AT keyboard and PS/2 style pointing devices. This controller is required by the keyboard driver (`atkbd`) and the PS/2 pointing device driver (`psm`).

```
device          atkbd      # AT keyboard
```

The `atkbd` driver, together with `atkbdc` controller, provides access to the AT 84 keyboard or the AT enhanced keyboard which is connected to the AT keyboard controller.

```
device          psm        # PS/2 mouse
```

Use this device if your mouse plugs into the PS/2 mouse port.

```
device          kbdmux        # keyboard multiplexer
```

多重鍵盤的支援。 若不打算同時接多組鍵盤的話， 那麼若要移除該行也沒關係。

```
device          vga        # VGA video card driver
```

The video card driver.

```
device          splash     # Splash screen and screen saver support
```

Splash screen at start up! Screen savers require this too.

```
# syscons is the default console driver, resembling an SCO console
device          sc
```

`sc` is the default console driver and resembles a SCO console. Since most full-screen programs access the console through a terminal database library like `termcap`, it should not matter whether you use this or `vt`, the `VT220` compatible console driver. When you log in, set your `TERM` variable to `scoansi` if full-screen programs have trouble running under this console.

```
# Enable this for the pcvt (VT220 compatible) console driver
#device          vt
#options         XSERVER          # support for X server on a vt console
#options         FAT_CURSOR       # start with block cursor
```

This is a VT220-compatible console driver, backward compatible to VT100/102. It works well on some laptops which have hardware incompatibilities with `sc`. Also set your `TERM` variable to `vt100` or `vt220` when you log in. This driver might also prove useful when connecting to a large number of different machines over the network, where `termcap` or `terminfo` entries for the `sc` device are often not available —— `vt100` should be available on virtually any platform.

```
device          agp
```

Include this if you have an AGP card in the system. This will enable support for AGP, and AGP GART for boards which have these features.

```
# Power management support (see NOTES for more options)
#device          apm
```

Advanced Power Management support. Useful for laptops, although in FreeBSD 5.X and above this is disabled in `GENERIC` by default.

```
# Add suspend/resume support for the i8254.
device          pmtimer
```

Timer device driver for power management events, such as APM and ACPI.

```
# PCCARD (PCMCIA) support
# PCMCIA and cardbus bridge support
device          cbb             # cardbus (yenta) bridge
device          pccard          # PC Card (16-bit) bus
device          cardbus         # CardBus (32-bit) bus
```

PCMCIA support. You want this if you are using a laptop.

```
# Serial (COM) ports
device          sio             # 8250, 16[45]50 based serial ports
```

These are the serial ports referred to as `COM` ports in the MS-DOS®/Windows® world.

注意

If you have an internal modem on `COM4` and a serial port at `COM2`, you will have to change the IRQ of the modem to 2 (for obscure technical reasons, IRQ2 = IRQ 9) in order to access it

from FreeBSD. If you have a multiport serial card, check the manual page for sio(4) for more information on the proper values to add to your `/boot/device.hints` . Some video cards (notably those based on S3 chips) use IO addresses in the form of `0x*2e8`, and since many cheap serial cards do not fully decode the 16-bit IO address space, they clash with these cards making the `COM4` port practically unavailable.

Each serial port is required to have a unique IRQ (unless you are using one of the multiport cards where shared interrupts are supported), so the default IRQs for `COM3` and `COM4` cannot be used.

```
# Parallel port
device          ppc
```

This is the ISA-bus parallel port interface.

```
device          ppbus      # Parallel port bus (required)
```

Provides support for the parallel port bus.

```
device          lpt        # Printer
```

Support for parallel port printers.

注意

All three of the above are required to enable parallel printer support.

```
device          plip       # TCP/IP over parallel
```

This is the driver for the parallel network interface.

```
device          ppi        # Parallel port interface device
```

The general-purpose I/O (“geek port”) + IEEE1284 I/O.

```
#device         vpo        # Requires scbus and da
```

This is for an Iomega Zip drive. It requires `scbus` and `da` support. Best performance is achieved with ports in EPP 1.9 mode.

```
#device         puc
```

Uncomment this device if you have a “dumb” serial or parallel PCI card that is supported by the puc(4) glue driver.

```
# PCI Ethernet NICs.
device          de         # DEC/Intel DC21x4x (“Tulip”)
device          em         # Intel PRO/1000 adapter Gigabit Ethernet Card
device          ixgb       # Intel PRO/10GbE Ethernet Card
device          txp        # 3Com 3cR990 (“Typhoon”)
device          vx         # 3Com 3c590, 3c595 (“Vortex”)
```

Various PCI network card drivers. Comment out or remove any of these not present in your system.

```
# PCI Ethernet NICs that use the common MII bus controller code.
# NOTE: Be sure to keep the 'device miibus' line in order to use these NICs!
```

```
device          miibus     # MII bus support
```

MII bus support is required for some PCI 10/100 Ethernet NICs, namely those which use MII-compliant transceivers or implement transceiver control interfaces that operate like an MII. Adding `device miibus` to the kernel config pulls in support for the generic miibus API and all of the PHY drivers, including a generic one for PHYs that are not specifically handled by an individual driver.

```
device          bce        # Broadcom BCM5706/BCM5708 Gigabit Ethernet
device          bfe        # Broadcom BCM440x 10/100 Ethernet
device          bge        # Broadcom BCM570xx Gigabit Ethernet
device          dc         # DEC/Intel 21143 and various workalikes
device          fxp        # Intel EtherExpress PRO/100B (82557, 82558)
device          lge        # Level 1 LXT1001 gigabit ethernet
device          msk        # Marvell/SysKonnect Yukon II Gigabit Ethernet
device          nge        # NatSemi DP83820 gigabit ethernet
device          nve        # nVidia nForce MCP on-board Ethernet Networking
device          pcn        # AMD Am79C97x PCI 10/100 (precedence over 'lnc')
device          re         # RealTek 8139C+/8169/8169S/8110S
device          rl         # RealTek 8129/8139
device          sf         # Adaptec AIC-6915 (“Starfire”)
device          sis        # Silicon Integrated Systems SiS 900/SiS 7016
device          sk         # SysKonnect SK-984x & SK-982x gigabit Ethernet
device          ste        # Sundance ST201 (D-Link DFE-550TX)
device          stge       # Sundance/Tamarack TC9021 gigabit Ethernet
device          ti         # Alteon Networks Tigon I/II gigabit Ethernet
device          tl         # Texas Instruments ThunderLAN
device          tx         # SMC EtherPower II (83c170 “EPIC”)
device          vge        # VIA VT612x gigabit ethernet
device          vr         # VIA Rhine, Rhine II
device          wb         # Winbond W89C840F
device          xl         # 3Com 3c90x (“Boomerang”, “Cyclone”)
```

Drivers that use the MII bus controller code.

```
# ISA Ethernet NICs.  pccard NICs included.
device          cs         # Crystal Semiconductor CS89x0 NIC
# 'device ed' requires 'device miibus'
device          ed         # NE[12]000, SMC Ultra, 3c503, DS8390 cards
device          ex         # Intel EtherExpress Pro/10 and Pro/10+
device          ep         # Etherlink III based cards
device          fe         # Fujitsu MB8696x based cards
device          ie         # EtherExpress 8/16, 3C507, StarLAN 10 etc.
device          lnc        # NE2100, NE32-VL Lance Ethernet cards
device          sn         # SMC's 9000 series of Ethernet chips
device          xe         # Xircom pccard Ethernet

# ISA devices that use the old ISA shims
#device         le
```

ISA Ethernet drivers. See `/usr/src/sys/i386/conf/NOTES` for details of which cards are supported by which driver.

```
# Wireless NIC cards
device          wlan       # 802.11 support
```

對 802.11 標準的支援。 若要無線上網，則需加上這行。

```
device          wlan_wep        # 802.11 WEP support
device          wlan_ccmp       # 802.11 CCMP support
device          wlan_tkip       # 802.11 TKIP support
```

對 802.11 加密設備的支援。 若要安全加密以及 802.11i 安全協定， 則需加上這行。

```
device          an         # Aironet 4500/4800 802.11 wireless NICs.
```

```
device          ath             # Atheros pci/cardbus NIC's
device          ath_hal         # Atheros HAL (Hardware Access Layer)
device          ath_rate_sample # SampleRate tx rate control for ath
device          an          # Aironet 4500/4800 802.11 wireless NICs.
device          awi         # BayStack 660 and others
device          ral         # Ralink Technology RT2500 wireless NICs.
device          wi          # WaveLAN/Intersil/Symbol 802.11 wireless NICs.
#device         wl          # Older non 802.11 Wavelan wireless NIC.
```

Support for various wireless cards.

```
# Pseudo devices
device   loop           # Network loopback
```

This is the generic loopback device for TCP/IP. If you telnet or FTP to `localhost` (a.k.a. `127.0.0.1`) it will come back at you through this device. This is mandatory.

```
device   random         # Entropy device
```

Cryptographically secure random number generator.

```
device   ether          # Ethernet support
```

`ether` is only needed if you have an Ethernet card. It includes generic Ethernet protocol code.

```
device   sl             # Kernel SLIP
```

`sl` is for SLIP support. This has been almost entirely supplanted by PPP, which is easier to set up, better suited for modem-to-modem connection, and more powerful.

```
device   ppp            # Kernel PPP
```

This is for kernel PPP support for dial-up connections. There is also a version of PPP implemented as a userland application that uses `tun` and offers more flexibility and features such as demand dialing.

```
device   tun            # Packet tunnel.
```

This is used by the userland PPP software. See the PPP section of this book for more information.

```
device   pty            # Pseudo-ttys (telnet etc)
```

This is a “pseudo-terminal” or simulated login port. It is used by incoming `telnet` and `rlogin` sessions, xterm, and some other applications such as Emacs.

```
device   md             # Memory “disks”
```

Memory disk pseudo-devices.

```
device   gif            # IPv6 and IPv4 tunneling
```

This implements IPv6 over IPv4 tunneling, IPv4 over IPv6 tunneling, IPv4 over IPv4 tunneling, and IPv6 over IPv6 tunneling. The `gif` device is “auto-cloning”, and will create device nodes as needed.

```
device   faith          # IPv6-to-IPv4 relaying (translation)
```

This pseudo-device captures packets that are sent to it and diverts them to the IPv4/IPv6 translation daemon.

```
# The `bpf' device enables the Berkeley Packet Filter.
# Be aware of the administrative consequences of enabling this!
# Note that 'bpf' is required for DHCP.
device   bpf            # Berkeley packet filter
```

This is the Berkeley Packet Filter. This pseudo-device allows network interfaces to be placed in promiscuous mode, capturing every packet on a broadcast network (e.g., an Ethernet). These packets can be captured to disk and or examined with the tcpdump(1) program.

注意

The bpf(4) device is also used by dhclient(8) to obtain the IP address of the default router (gateway) and so on. If you use DHCP, leave this uncommented.

```
# USB support
device          uhci          # UHCI PCI->USB interface
device          ohci          # OHCI PCI->USB interface
device          ehci          # EHCI PCI->USB interface (USB 2.0)
device          usb           # USB Bus (required)
#device         udbp          # USB Double Bulk Pipe devices
device          ugen          # Generic
device          uhid          # “Human Interface Devices”
device          ukbd          # Keyboard
device          ulpt          # Printer
device          umass         # Disks/Mass storage - Requires scbus and da
device          ums           # Mouse
device          ural          # Ralink Technology RT2500USB wireless NICs
device          urio          # Diamond Rio 500 MP3 player
device          uscanner      # Scanners
# USB Ethernet, requires mii
device          aue           # ADMtek USB Ethernet
device          axe           # ASIX Electronics USB Ethernet
device          cdce          # Generic USB over Ethernet
device          cue           # CATC USB Ethernet
device          kue           # Kawasaki LSI USB Ethernet
device          rue           # RealTek RTL8150 USB Ethernet
```

Support for various USB devices.

```
# FireWire support
device          firewire      # FireWire bus code
device          sbp           # SCSI over FireWire (Requires scbus and da)
device          fwe           # Ethernet over FireWire (non-standard!)
```

Support for various Firewire devices.

For more information and additional devices supported by FreeBSD, see `/usr/src/sys/i386/conf/NOTES`.

8.5.1. Large Memory Configurations (PAE)

Large memory configuration machines require access to more than the 4 gigabyte limit on User+Kernel Virtual Address (KVA) space. Due to this limitation, Intel added support for 36-bit physical address space access in the Pentium® Pro and later line of CPUs.

The Physical Address Extension (PAE) capability of the Intel® Pentium® Pro and later CPUs allows memory configurations of up to 64 gigabytes. FreeBSD provides support for this capability via the PAE kernel configuration option, available in all current release versions of FreeBSD. Due to the limitations of the Intel memory architecture, no distinction is made for memory above or below 4 gigabytes. Memory allocated above 4 gigabytes is simply added to the pool of available memory.

To enable PAE support in the kernel, simply add the following line to your kernel configuration file:

```
options      PAE
```

注意

The PAE support in FreeBSD is only available for Intel® IA-32 processors. It should also be noted, that the PAE support in FreeBSD has not received wide testing, and should be considered beta quality compared to other stable features of FreeBSD.

PAE support in FreeBSD has a few limitations:

- A process is not able to access more than 4 gigabytes of VM space.
- KLD modules cannot be loaded into a PAE enabled kernel, due to the differences in the build framework of a module and the kernel.
- Device drivers that do not use the bus_dma(9) interface will cause data corruption in a PAE enabled kernel and are not recommended for use. For this reason, a `PAE` kernel configuration file is provided in FreeBSD which excludes all drivers not known to work in a PAE enabled kernel.
- Some system tunables determine memory resource usage by the amount of available physical memory. Such tunables can unnecessarily over-allocate due to the large memory nature of a PAE system. One such example is the `kern.maxvnodes` sysctl, which controls the maximum number of vnodes allowed in the kernel. It is advised to adjust this and other such tunables to a reasonable value.
- It might be necessary to increase the kernel virtual address (KVA) space or to reduce the amount of specific kernel resource that is heavily used (see above) in order to avoid KVA exhaustion. The `KVA_PAGES` kernel option can be used for increasing the KVA space.

For performance and stability concerns, it is advised to consult the tuning(7) manual page. The pae(4) manual page contains up-to-date information on FreeBSD's PAE support.

8.6. If Something Goes Wrong

There are five categories of trouble that can occur when building a custom kernel. They are:

`config` fails:
: If the config(8) command fails when you give it your kernel description, you have probably made a simple error somewhere. Fortunately, config(8) will print the line number that it had trouble with, so that you can quickly locate the line containing the error. For example, if you see:

```
config: line 17: syntax error
```

Make sure the keyword is typed correctly by comparing it to the `GENERIC` kernel or another reference.

`make` fails:
: If the `make` command fails, it usually signals an error in your kernel description which is not severe enough for config(8) to catch. Again, look over your configuration, and if you still cannot resolve the problem, send mail to the FreeBSD general questions 郵遞論壇 with your kernel configuration, and it should be diagnosed quickly.

The kernel does not boot:
: If your new kernel does not boot, or fails to recognize your devices, do not panic! Fortunately, FreeBSD has an excellent mechanism for recovering from incompatible kernels. Simply choose the kernel you want to boot from at the FreeBSD boot loader. You can access this when the system boot menu appears. Select the “Escape to a loader prompt” option, number six. At the prompt, type `unload kernel` and then type `boot /boot/`

`kernel.old/kernel` , or the filename of any other kernel that will boot properly. When reconfiguring a kernel, it is always a good idea to keep a kernel that is known to work on hand.

After booting with a good kernel you can check over your configuration file and try to build it again. One helpful resource is the `/var/log/messages` file which records, among other things, all of the kernel messages from every successful boot. Also, the dmesg(8) command will print the kernel messages from the current boot.

注意

If you are having trouble building a kernel, make sure to keep a `GENERIC` , or some other kernel that is known to work on hand as a different name that will not get erased on the next build. You cannot rely on `kernel.old` because when installing a new kernel, `kernel.old` is overwritten with the last installed kernel which may be non-functional. Also, as soon as possible, move the working kernel to the proper `/boot/kernel` location or commands such as ps(1) may not work properly. To do this, simply rename the directory containing the good kernel:

```
# mv /boot/kernel /boot/kernel.bad
# mv /boot/kernel.good /boot/kernel
```

The kernel works, but ps(1) does not work any more:

If you have installed a different version of the kernel from the one that the system utilities have been built with, for example, a -CURRENT kernel on a -RELEASE, many system-status commands like ps(1) and vmstat(8) will not work any more. You should recompile and install a world built with the same version of the source tree as your kernel. This is one reason it is not normally a good idea to use a different version of the kernel from the rest of the operating system.

章 9. 列印

Contributed by Sean Kelly.
Restructured and updated by Jim Mock.

9.1. 概述

FreeBSD 可以和各式各樣的印表機搭配列印， 從最老的撞針式印表機到最新的雷射印表機都沒問題， 讓您的應用程式可以產生出高品質的文件列印輸出。

也可以把 FreeBSD 設定成一台網路列印伺服器；這時候的 FreeBSD 能接收其他電腦送來的列印工作，包括其他 FreeBSD 的電腦、Windows® 的電腦以及 Mac OS® 的電腦。 FreeBSD 會確保同時只有一件文件正在列印，而且可以統計哪個使用者及機器印得最多， 還有就是印出接下來是誰的文件這類的“標題”頁等。

讀完這章，您將了解：

- 如何設定 FreeBSD 的列印多工緩衝處理器。
- 如何安裝列印過濾器以分別處理特殊的列印工作， 包括把收到的文件轉換成您的印表機看得懂的列印格式等。
- 了解如何在您列印時順便印出頁首或標題。
- 如何利用別台電腦上的印表機列印。
- 如何利用直接接在網路上的印表機列印。
- 如何控制印表機的權限，包括限制列印工作的檔案大小， 以及不允許特定使用者列印等。
- 如何記下印表機的統計資料，以及各帳號的印表機使用量。
- 如何解決列印時遇到的問題。

在開始閱讀這章之前，您需要：

- 要有設定、編譯 kernel 的基礎概念 (章 8, 設定 FreeBSD Kernel)。

9.2. 介紹

要在 FreeBSD 上使用印表機，您需要設定好 Berkeley 行列式印表機列印緩衝系統，又稱為 LPD 列印緩衝系統，或者就叫他 LPD 吧。 這是 FreeBSD 標準的印表機控制系統，本章會介紹並教您如何設定 LPD。

如果您已經對 LPD 或是其他列印緩衝系統很熟悉了， 您可以直接跳到基本設定。

LPD 控制著主機上印表機的一切。 它負責這些工作：

- 控制本機及網路印表機的使用。
- 讓使用者可以列印文件，送出的文件稱為工作。
- 為每台印表機準備一個佇列， 避免多個使用者同時使用同一台印表機。
- 列印 header pages（又稱為 banner or burst pages），方便使用者在出紙閘中找到自己列印的文件。
- 把接在串列埠上的印表機的通訊參數設定好。

- 利用網路傳送列印工作給別台主機上的 LPD。
- 執行特別的過濾程式將列印工作格式化以配合不同的列印語言或印表機。
- 統計印表機的使用情況。

藉由設定檔 (`/etc/printcap`) 以及過濾程式的幫助， 您可以讓大多數的印表機配合 LPD 達成上述全部或部份的功能。

9.2.1. 爲什麼需要使用多工緩衝處理器

如果您的系統是個人使用， 不需要控制存取權限、列印標題頁或者統計使用情況等功能時， 您可能會覺得很奇怪為什麼還需要去管這個多工緩衝處理器。 當然要直接控制印表機可行的， 不過無論如何您還是需要多工緩衝處理器，因為：

- LPD 可以在背景 (background) 列印，您不需要在那邊等文件送到印表機。
- LPD 可以很輕鬆地用過濾器增加日期 / 時間於頁首或是把特別的檔案格式（像是 TeX DVI 檔）轉換成印表機看得懂的的格式，您不需要手動去做這些步驟。
- 許多免費或商業軟體提供的列印功能通常都是和多工緩衝處理器溝通。 透過設定緩衝系統，支援您現有或是即將要安裝的其他軟體將變得更容易。

9.3. 基礎設定

要用印表機搭配 LPD 多工緩衝系統，您需要有印表機這個硬體以及 LPD 這套軟體。 本手冊提供了兩階段的設定說明：

- 閱讀 簡易印表機設定 來學習如何連接印表機、讓印表機和 LPD 溝通以及列印純文字文件。
- 閱讀 進階印表機設定 來學習如何列印各種特殊格式文件、列印首頁、網路列印、 控制印表機權限以及統計使用狀況等。

9.3.1. 簡易印表機設定

本章節會告訴您如何設定印表機設備和 LPD 軟體以使用印表機， 基本教學內容：

- 硬體設定 會提示如何將印表機接上電腦的連接埠。
- 軟體設定 會示範如何寫 LPD 緩衝器設定檔 (`/etc/printcap`)。

如果您要把印表機設定接收網路列印資料而不是本機端的話，請參考 印表機及網路資料傳輸介面。

這個章節雖然叫做“簡易印表機設定”， 實際上還是有點複雜的。 最困難的部份是讓你的印表機和電腦上的 LPD 緩衝器能夠正常運作。 一旦印表機可以正常工作之後， 像是印首頁或是做列印統計這些進階的功能就不難做到了。

9.3.1.1. 硬體設定

本章節討論各種連接印表機到 PC 的方式。 這裡會提到不同種類的連接埠和連接線， 以及為了讓 FreeBSD 能和印表機溝通您可能會需要開啓的核心參數等。

如果您已經把印表機接上電腦， 而且在其他作業系統上有成功列印過的話，可以直接跳至 軟體設定。

9.3.1.1.1. 連接埠和排線

市售個人電腦印表機一般來說不出這三種界面：

- 序列 (Serial) 界面，又稱為 RS-232 或 COM 埠， 用您電腦上的序列埠傳送資料到印表機。 序列界面廣泛的為電腦業界所採用， 所以排線容易取得，要設定連線並不困難。 然而序列介面有時候會需要使用較特別的排線， 這時候就有可能需要設定一些較為複雜的通訊參數了。 大部份 PC 序列埠的傳輸速度最高只到 115200 bps， 因此想要用序列埠來列印大圖是不切實際的。

- 並列 (Parallel) 界面利用電腦的並列埠將資料送到印表機。 並列埠比 RS-232 序列埠還快，也是一種電腦業界常用的界面。 這種界面的排線非常容易取得，但是較難用手工打造。 通常來說並列界面並沒有什麼通訊參數需要指定， 所以設定起來超級容易。

  並列埠界面有時候也會被稱為 “Centronics” 界面，這是印表機的接頭的名稱。

- USB 界面，也就是通用序列匯流排，傳輸速率比並列界面或是 RS-232 序列界面都來得快，而且 USB 排線單純又便宜。 對列印工作而言，USB 比 RS-232 序列埠或是並列埠都來得好，但是在 UNIX® 系統上的支援度較差。 購買同時具有 USB 及並列埠兩種界面的印表機可以避免掉這種問題。

一般而言，並列界面只能提供單向傳輸 (電腦至印表機)，而要用 USB 才能提供雙向。 然而在 FreeBSD 下，使用較新的並列埠 (EPP 和 ECP) 以及印表機，再配合使用 IEEE-1284 相容排線也可以做到雙向溝通。

電腦和印表機之間藉由並列埠行進雙向溝通的方式有兩種。 第一種是使用特製的、能和特定印表機溝通的 FreeBSD 印表機驅動程式。 這種方式在噴墨印表機上很常見，用來回報墨水存量以及其他狀態資訊等。 第二種方法是用 PostScript®，如果印表機有支援的話。

PostScript® jobs are actually programs sent to the printer; they need not produce paper at all and may return results directly to the computer. PostScript® also uses two-way communication to tell the computer about problems, such as errors in the PostScript® program or paper jams. Your users may be appreciative of such information. Furthermore, the best way to do effective accounting with a PostScript® printer requires two-way communication: you ask the printer for its page count (how many pages it has printed in its lifetime), then send the user's job, then ask again for its page count. Subtract the two values and you know how much paper to charge to the user.

9.3.1.1.2. Parallel Ports

To hook up a printer using a parallel interface, connect the Centronics cable between the printer and the computer. The instructions that came with the printer, the computer, or both should give you complete guidance.

Remember which parallel port you used on the computer. The first parallel port is `ppc0` to FreeBSD; the second is `ppc1`, and so on. The printer device name uses the same scheme: `/dev/lpt0` for the printer on the first parallel ports etc.

9.3.1.1.3. Serial Ports

To hook up a printer using a serial interface, connect the proper serial cable between the printer and the computer. The instructions that came with the printer, the computer, or both should give you complete guidance.

If you are unsure what the “proper serial cable” is, you may wish to try one of the following alternatives:

- A modem cable connects each pin of the connector on one end of the cable straight through to its corresponding pin of the connector on the other end. This type of cable is also known as a “DTE-to-DCE” cable.

- A null-modem cable connects some pins straight through, swaps others (send data to receive data, for example), and shorts some internally in each connector hood. This type of cable is also known as a “DTE-to-DTE” cable.

- A serial printer cable, required for some unusual printers, is like the null-modem cable, but sends some signals to their counterparts instead of being internally shorted.

You should also set up the communications parameters for the printer, usually through front-panel controls or DIP switches on the printer. Choose the highest `bps` (bits per second, sometimes baud rate) that both your computer and the printer can support. Choose 7 or 8 data bits; none, even, or odd parity; and 1 or 2 stop bits. Also choose a

flow control protocol: either none, or XON/XOFF (also known as “in-band” or “software”) flow control. Remember these settings for the software configuration that follows.

9.3.1.2. Software Setup

This section describes the software setup necessary to print with the LPD spooling system in FreeBSD.

Here is an outline of the steps involved:

1. Configure your kernel, if necessary, for the port you are using for the printer; section Kernel Configuration tells you what you need to do.
2. Set the communications mode for the parallel port, if you are using a parallel port; section Setting the Communication Mode for the Parallel Port gives details.
3. Test if the operating system can send data to the printer. Section Checking Printer Communications gives some suggestions on how to do this.
4. Set up LPD for the printer by modifying the file `/etc/printcap` . You will find out how to do this later in this chapter.

9.3.1.2.1. Kernel Configuration

The operating system kernel is compiled to work with a specific set of devices. The serial or parallel interface for your printer is a part of that set. Therefore, it might be necessary to add support for an additional serial or parallel port if your kernel is not already configured for one.

To find out if the kernel you are currently using supports a serial interface, type:

```
# grep sioN /var/run/dmesg.boot
```

Where *N* is the number of the serial port, starting from zero. If you see output similar to the following:

```
sio2 at port 0x3e8-0x3ef irq 5 on isa
sio2: type 16550A
```

then the kernel supports the port.

To find out if the kernel supports a parallel interface, type:

```
# grep ppcN /var/run/dmesg.boot
```

Where *N* is the number of the parallel port, starting from zero. If you see output similar to the following:

```
ppc0: <Parallel port> at port 0x378-0x37f irq 7 on isa0
ppc0: SMC-like chipset (ECP/EPP/PS2/NIBBLE) in COMPATIBLE mode
ppc0: FIFO with 16/16/8 bytes threshold
```

then the kernel supports the port.

You might have to reconfigure your kernel in order for the operating system to recognize and use the parallel or serial port you are using for the printer.

To add support for a serial port, see the section on kernel configuration. To add support for a parallel port, see that section and the section that follows.

9.3.1.3. Setting the Communication Mode for the Parallel Port

When you are using the parallel interface, you can choose whether FreeBSD should use interrupt-driven or polled communication with the printer. The generic printer device driver (lpt(4)) on FreeBSD uses the ppbus(4) system, which controls the port chipset with the ppc(4) driver.

- The interrupt-driven method is the default with the GENERIC kernel. With this method, the operating system uses an IRQ line to determine when the printer is ready for data.
- The polled method directs the operating system to repeatedly ask the printer if it is ready for more data. When it responds ready, the kernel sends more data.

The interrupt-driven method is usually somewhat faster but uses up a precious IRQ line. Some newer HP printers are claimed not to work correctly in interrupt mode, apparently due to some (not yet exactly understood) timing problem. These printers need polled mode. You should use whichever one works. Some printers will work in both modes, but are painfully slow in interrupt mode.

You can set the communications mode in two ways: by configuring the kernel or by using the lptcontrol(8) program.

To set the communications mode by configuring the kernel:

1. Edit your kernel configuration file. Look for an `ppc0` entry. If you are setting up the second parallel port, use `ppc1` instead. Use `ppc2` for the third port, and so on.

   - If you want interrupt-driven mode, edit the following line:

     ```
     hint.ppc.0.irq="N"
     ```

     in the `/boot/device.hints` file and replace *N* with the right IRQ number. The kernel configuration file must also contain the ppc(4) driver:

     ```
     device ppc
     ```

   - If you want polled mode, remove in your `/boot/device.hints` file, the following line:

     ```
     hint.ppc.0.irq="N"
     ```

     In some cases, this is not enough to put the port in polled mode under FreeBSD. Most of time it comes from acpi(4) driver, this latter is able to probe and attach devices, and therefore, control the access mode to the printer port. You should check your acpi(4) configuration to correct this problem.

2. Save the file. Then configure, build, and install the kernel, then reboot. See kernel configuration for more details.

To set the communications mode with lptcontrol(8):

1. Type:

   ```
   # lptcontrol -i -d /dev/lptN
   ```

   to set interrupt-driven mode for `lptN`.

2. Type:

   ```
   # lptcontrol -p -d /dev/lptN
   ```

   to set polled-mode for `lptN`.

You could put these commands in your `/etc/rc.local` file to set the mode each time your system boots. See lptcontrol(8) for more information.

9.3.1.4. Checking Printer Communications

Before proceeding to configure the spooling system, you should make sure the operating system can successfully send data to your printer. It is a lot easier to debug printer communication and the spooling system separately.

To test the printer, we will send some text to it. For printers that can immediately print characters sent to them, the program lptest(1) is perfect: it generates all 96 printable ASCII characters in 96 lines.

For a PostScript® (or other language-based) printer, we will need a more sophisticated test. A small PostScript® program, such as the following, will suffice:

```
%!PS
100 100 moveto 300 300 lineto stroke
310 310 moveto /Helvetica findfont 12 scalefont setfont
(Is this thing working?) show
showpage
```

The above PostScript® code can be placed into a file and used as shown in the examples appearing in the following sections.

注意

When this document refers to a printer language, it is assuming a language like PostScript®, and not Hewlett Packard's PCL. Although PCL has great functionality, you can intermingle plain text with its escape sequences. PostScript® cannot directly print plain text, and that is the kind of printer language for which we must make special accommodations.

9.3.1.4.1. Checking a Parallel Printer

This section tells you how to check if FreeBSD can communicate with a printer connected to a parallel port.

To test a printer on a parallel port:

1. Become `root` with su(1).
2. Send data to the printer.
   - If the printer can print plain text, then use lptest(1). Type:

     ```
     # lptest > /dev/lptN
     ```

     Where *N* is the number of the parallel port, starting from zero.
   - If the printer understands PostScript® or other printer language, then send a small program to the printer. Type:

     ```
     # cat > /dev/lptN
     ```

     Then, line by line, type the program carefully as you cannot edit a line once you have pressed RETURN or ENTER. When you have finished entering the program, press CONTROL+D , or whatever your end of file key is.

     Alternatively, you can put the program in a file and type:

     ```
     # cat file > /dev/lptN
     ```

     Where *file* is the name of the file containing the program you want to send to the printer.

You should see something print. Do not worry if the text does not look right; we will fix such things later.

9.3.1.4.2. Checking a Serial Printer

This section tells you how to check if FreeBSD can communicate with a printer on a serial port.

To test a printer on a serial port:

1. Become `root` with su(1).

2. Edit the file `/etc/remote` . Add the following entry:

   ```
   printer:dv=/dev/port:br#bps-rate:pa=parity
   ```

   Where *`port`* is the device entry for the serial port (`ttyd0`, `ttyd1`, etc.), *`bps-rate`* is the bits-per-second rate at which the printer communicates, and *`parity`* is the parity required by the printer (either `even`, `odd`, `none`, or `zero`).

   Here is a sample entry for a printer connected via a serial line to the third serial port at 19200 bps with no parity:

   ```
   printer:dv=/dev/ttyd2:br#19200:pa=none
   ```

3. Connect to the printer with tip(1). Type:

   ```
   # tip printer
   ```

   If this step does not work, edit the file `/etc/remote` again and try using `/dev/cuaaN` instead of `/dev/ttydN`.

4. Send data to the printer.

   - If the printer can print plain text, then use lptest(1). Type:

     ```
     % $lptest
     ```

   - If the printer understands PostScript® or other printer language, then send a small program to the printer. Type the program, line by line, very carefully as backspacing or other editing keys may be significant to the printer. You may also need to type a special end-of-file key for the printer so it knows it received the whole program. For PostScript® printers, press `CONTROL+D` .

     Alternatively, you can put the program in a file and type:

     ```
     % >file
     ```

     Where *`file`* is the name of the file containing the program. After tip(1) sends the file, press any required end-of-file key.

You should see something print. Do not worry if the text does not look right; we will fix that later.

9.3.1.5. Enabling the Spooler: the `/etc/printcap` File

At this point, your printer should be hooked up, your kernel configured to communicate with it (if necessary), and you have been able to send some simple data to the printer. Now, we are ready to configure LPD to control access to your printer.

You configure LPD by editing the file `/etc/printcap` . The LPD spooling system reads this file each time the spooler is used, so updates to the file take immediate effect.

The format of the printcap(5) file is straightforward. Use your favorite text editor to make changes to `/etc/printcap` . The format is identical to other capability files like `/usr/share/misc/termcap` and `/etc/remote` . For complete information about the format, see the cgetent(3).

The simple spooler configuration consists of the following steps:

1. Pick a name (and a few convenient aliases) for the printer, and put them in the `/etc/printcap` file; see the Naming the Printer section for more information on naming.

2. Turn off header pages (which are on by default) by inserting the `sh` capability; see the Suppressing Header Pages section for more information.

3. Make a spooling directory, and specify its location with the `sd` capability; see the Making the Spooling Directory section for more information.

4. Set the `/dev` entry to use for the printer, and note it in `/etc/printcap` with the `lp` capability; see the Identifying the Printer Device for more information. Also, if the printer is on a serial port, set up the communication parameters with the `ms#` capability which is discussed in the Configuring Spooler Communications Parameters section.

5. Install a plain text input filter; see the Installing the Text Filter section for details.

6. Test the setup by printing something with the lpr(1) command. More details are available in the Trying It Out and Troubleshooting sections.

注意

Language-based printers, such as PostScript® printers, cannot directly print plain text. The simple setup outlined above and described in the following sections assumes that if you are installing such a printer you will print only files that the printer can understand.

Users often expect that they can print plain text to any of the printers installed on your system. Programs that interface to LPD to do their printing usually make the same assumption. If you are installing such a printer and want to be able to print jobs in the printer language and print plain text jobs, you are strongly urged to add an additional step to the simple setup outlined above: install an automatic plain-text-to-PostScript® (or other printer language) conversion program. The section entitled Accommodating Plain Text Jobs on PostScript® Printers tells how to do this.

9.3.1.5.1. Naming the Printer

The first (easy) step is to pick a name for your printer. It really does not matter whether you choose functional or whimsical names since you can also provide a number of aliases for the printer.

At least one of the printers specified in the `/etc/printcap` should have the alias `lp`. This is the default printer's name. If users do not have the `PRINTER` environment variable nor specify a printer name on the command line of any of the LPD commands, then `lp` will be the default printer they get to use.

Also, it is common practice to make the last alias for a printer be a full description of the printer, including make and model.

Once you have picked a name and some common aliases, put them in the `/etc/printcap` file. The name of the printer should start in the leftmost column. Separate each alias with a vertical bar and put a colon after the last alias.

In the following example, we start with a skeletal `/etc/printcap` that defines two printers (a Diablo 630 line printer and a Panasonic KX-P4455 PostScript® laser printer):

```
#
#  /etc/printcap for host rose
#
rattan|line|diablo|lp|Diablo 630 Line Printer:
```

```
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:
```

In this example, the first printer is named `rattan` and has as aliases `line`, `diablo`, `lp`, and `Diablo 630 Line Printer`. Since it has the alias `lp`, it is also the default printer. The second is named `bamboo`, and has as aliases `ps`, `PS`, `S`, `panasonic`, and `Panasonic KX-P4455 PostScript v51.4`.

9.3.1.5.2. Suppressing Header Pages

The LPD spooling system will by default print a header page for each job. The header page contains the user name who requested the job, the host from which the job came, and the name of the job, in nice large letters. Unfortunately, all this extra text gets in the way of debugging the simple printer setup, so we will suppress header pages.

To suppress header pages, add the `sh` capability to the entry for the printer in `/etc/printcap`. Here is an example `/etc/printcap` with `sh` added:

```
#
#  /etc/printcap for host rose - no header pages anywhere
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:
```

Note how we used the correct format: the first line starts in the leftmost column, and subsequent lines are indented. Every line in an entry except the last ends in a backslash character.

9.3.1.5.3. Making the Spooling Directory

The next step in the simple spooler setup is to make a spooling directory, a directory where print jobs reside until they are printed, and where a number of other spooler support files live.

Because of the variable nature of spooling directories, it is customary to put these directories under `/var/spool`. It is not necessary to backup the contents of spooling directories, either. Recreating them is as simple as running mkdir(1).

It is also customary to make the directory with a name that is identical to the name of the printer, as shown below:

```
# mkdir /var/spool/printer-name
```

However, if you have a lot of printers on your network, you might want to put the spooling directories under a single directory that you reserve just for printing with LPD. We will do this for our two example printers `rattan` and `bamboo`:

```
# mkdir /var/spool/lpd
# mkdir /var/spool/lpd/rattan
# mkdir /var/spool/lpd/bamboo
```

注意

If you are concerned about the privacy of jobs that users print, you might want to protect the spooling directory so it is not publicly accessible. Spooling directories should be owned and be readable, writable, and searchable by user daemon and group daemon, and no one else. We will do this for our example printers:

```
# chown daemon:daemon /var/spool/lpd/rattan
# chown daemon:daemon /var/spool/lpd/bamboo
# chmod 770 /var/spool/lpd/rattan
```

```
# chmod 770 /var/spool/lpd/bamboo
```

Finally, you need to tell LPD about these directories using the `/etc/printcap` file. You specify the pathname of the spooling directory with the `sd` capability:

```
#
#  /etc/printcap for host rose - added spooling directories
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:
```

Note that the name of the printer starts in the first column but all other entries describing the printer should be indented and each line end escaped with a backslash.

If you do not specify a spooling directory with `sd`, the spooling system will use `/var/spool/lpd` as a default.

9.3.1.5.4. Identifying the Printer Device

In the Entries for the Ports section, we identified which entry in the `/dev` directory FreeBSD will use to communicate with the printer. Now, we tell LPD that information. When the spooling system has a job to print, it will open the specified device on behalf of the filter program (which is responsible for passing data to the printer).

List the `/dev` entry pathname in the `/etc/printcap` file using the `lp` capability.

In our running example, let us assume that `rattan` is on the first parallel port, and `bamboo` is on a sixth serial port; here are the additions to `/etc/printcap` :

```
#
#  /etc/printcap for host rose - identified what devices to use
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:
```

If you do not specify the `lp` capability for a printer in your `/etc/printcap` file, LPD uses `/dev/lp` as a default. `/dev/lp` currently does not exist in FreeBSD.

If the printer you are installing is connected to a parallel port, skip to the section entitled, Installing the Text Filter. Otherwise, be sure to follow the instructions in the next section.

9.3.1.5.5. Configuring Spooler Communication Parameters

For printers on serial ports, LPD can set up the bps rate, parity, and other serial communication parameters on behalf of the filter program that sends data to the printer. This is advantageous since:

- It lets you try different communication parameters by simply editing the `/etc/printcap` file; you do not have to recompile the filter program.
- It enables the spooling system to use the same filter program for multiple printers which may have different serial communication settings.

The following `/etc/printcap` capabilities control serial communication parameters of the device listed in the `lp` capability:

`br#bps-rate`
: Sets the communications speed of the device to *`bps-rate`*, where *`bps-rate`* can be 50, 75, 110, 134, 150, 200, 300, 600, 1200, 1800, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 bits-per-second.

`ms#stty-mode`
: Sets the options for the terminal device after opening the device. stty(1) explains the available options.

When LPD opens the device specified by the `lp` capability, it sets the characteristics of the device to those specified with the `ms#` capability. Of particular interest will be the `parenb`, `parodd`, `cs5`, `cs6`, `cs7`, `cs8`, `cstopb`, `crtscts`, and `ixon` modes, which are explained in the stty(1) manual page.

Let us add to our example printer on the sixth serial port. We will set the bps rate to 38400. For the mode, we will set no parity with `-parenb`, 8-bit characters with `cs8`, no modem control with `clocal` and hardware flow control with `crtscts`:

```
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:
```

9.3.1.5.6. Installing the Text Filter

We are now ready to tell LPD what text filter to use to send jobs to the printer. A text filter, also known as an input filter, is a program that LPD runs when it has a job to print. When LPD runs the text filter for a printer, it sets the filter's standard input to the job to print, and its standard output to the printer device specified with the `lp` capability. The filter is expected to read the job from standard input, perform any necessary translation for the printer, and write the results to standard output, which will get printed. For more information on the text filter, see the Filters section.

For our simple printer setup, the text filter can be a small shell script that just executes `/bin/cat` to send the job to the printer. FreeBSD comes with another filter called `lpf` that handles backspacing and underlining for printers that might not deal with such character streams well. And, of course, you can use any other filter program you want. The filter `lpf` is described in detail in section entitled lpf: a Text Filter.

First, let us make the shell script `/usr/local/libexec/if-simple` be a simple text filter. Put the following text into that file with your favorite text editor:

```
#!/bin/sh
#
# if-simple - Simple text input filter for lpd
# Installed in /usr/local/libexec/if-simple
#
# Simply copies stdin to stdout.  Ignores all filter arguments.

/bin/cat && exit 0
exit 2
```

Make the file executable:

```
# chmod 555 /usr/local/libexec/if-simple
```

And then tell LPD to use it by specifying it with the `if` capability in `/etc/printcap`. We will add it to the two printers we have so far in the example `/etc/printcap`:

```
#
#  /etc/printcap for host rose - added text filter
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\ :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
```

```
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:\
        :if=/usr/local/libexec/if-simple:
```

注意

A copy of the `if-simple` script can be found in the `/usr/share/examples/printing` directory.

9.3.1.5.7. Turn on LPD

lpd(8) is run from `/etc/rc`, controlled by the `lpd_enable` variable. This variable defaults to `NO`. If you have not done so already, add the line:

```
lpd_enable="YES"
```

to `/etc/rc.conf`, and then either restart your machine, or just run lpd(8).

```
# lpd
```

9.3.1.5.8. Trying It Out

You have reached the end of the simple LPD setup. Unfortunately, congratulations are not quite yet in order, since we still have to test the setup and correct any problems. To test the setup, try printing something. To print with the LPD system, you use the command lpr(1), which submits a job for printing.

You can combine lpr(1) with the lptest(1) program, introduced in section Checking Printer Communications to generate some test text.

To test the simple LPD setup:

Type:

```
# lptest 20 5 | lpr -Pprinter-name
```

Where *`printer-name`* is a the name of a printer (or an alias) specified in `/etc/printcap`. To test the default printer, type lpr(1) without any `-P` argument. Again, if you are testing a printer that expects PostScript®, send a PostScript® program in that language instead of using lptest(1). You can do so by putting the program in a file and typing `lpr file`.

For a PostScript® printer, you should get the results of the program. If you are using lptest(1), then your results should look like the following:

```
!"#$%&'()*+,-./01234
"#$%&'()*+,-./012345
#$%&'()*+,-./0123456
$%&'()*+,-./01234567
%&'()*+,-./012345678
```

To further test the printer, try downloading larger programs (for language-based printers) or running lptest(1) with different arguments. For example, `lptest 80 60` will produce 60 lines of 80 characters each.

If the printer did not work, see the Troubleshooting section.

9.4. Advanced Printer Setup

This section describes filters for printing specially formatted files, header pages, printing across networks, and restricting and accounting for printer usage.

9.4.1. Filters

Although LPD handles network protocols, queuing, access control, and other aspects of printing, most of the real work happens in the filters. Filters are programs that communicate with the printer and handle its device dependencies and special requirements. In the simple printer setup, we installed a plain text filter——an extremely simple one that should work with most printers (section Installing the Text Filter).

However, in order to take advantage of format conversion, printer accounting, specific printer quirks, and so on, you should understand how filters work. It will ultimately be the filter's responsibility to handle these aspects. And the bad news is that most of the time you have to provide filters yourself. The good news is that many are generally available; when they are not, they are usually easy to write.

Also, FreeBSD comes with one, `/usr/libexec/lpr/lpf` , that works with many printers that can print plain text. (It handles backspacing and tabs in the file, and does accounting, but that is about all it does.) There are also several filters and filter components in the FreeBSD Ports Collection.

Here is what you will find in this section:

- Section How Filters Work, tries to give an overview of a filter's role in the printing process. You should read this section to get an understanding of what is happening “under the hood” when LPD uses filters. This knowledge could help you anticipate and debug problems you might encounter as you install more and more filters on each of your printers.
- LPD expects every printer to be able to print plain text by default. This presents a problem for PostScript® (or other language-based printers) which cannot directly print plain text. Section Accommodating Plain Text Jobs on PostScript® Printers tells you what you should do to overcome this problem. You should read this section if you have a PostScript® printer.
- PostScript® is a popular output format for many programs. Some people even write PostScript® code directly. Unfortunately, PostScript® printers are expensive. Section Simulating PostScript® on Non PostScript® Printers tells how you can further modify a printer's text filter to accept and print PostScript® data on a non PostScript® printer. You should read this section if you do not have a PostScript® printer.
- Section Conversion Filters tells about a way you can automate the conversion of specific file formats, such as graphic or typesetting data, into formats your printer can understand. After reading this section, you should be able to set up your printers such that users can type `lpr -t` to print troff data, or `lpr -d` to print TeX DVI data, or `lpr -v` to print raster image data, and so forth. I recommend reading this section.
- Section Output Filters tells all about a not often used feature of LPD: output filters. Unless you are printing header pages (see Header Pages), you can probably skip that section altogether.
- Section lpf: a Text Filter describes `lpf`, a fairly complete if simple text filter for line printers (and laser printers that act like line printers) that comes with FreeBSD. If you need a quick way to get printer accounting working for plain text, or if you have a printer which emits smoke when it sees backspace characters, you should definitely consider `lpf`.

注意

A copy of the various scripts described below can be found in the `/usr/share/examples/printing` directory.

9.4.1.1. How Filters Work

As mentioned before, a filter is an executable program started by LPD to handle the device-dependent part of communicating with the printer.

When LPD wants to print a file in a job, it starts a filter program. It sets the filter's standard input to the file to print, its standard output to the printer, and its standard error to the error logging file (specified in the `lf` capability in `/etc/printcap` , or `/dev/console` by default).

Which filter LPD starts and the filter's arguments depend on what is listed in the `/etc/printcap` file and what arguments the user specified for the job on the lpr(1) command line. For example, if the user typed `lpr -t`, LPD would start the troff filter, listed in the `tf` capability for the destination printer. If the user wanted to print plain text, it would start the `if` filter (this is mostly true: see Output Filters for details).

There are three kinds of filters you can specify in `/etc/printcap` :

- The text filter, confusingly called the input filter in LPD documentation, handles regular text printing. Think of it as the default filter. LPD expects every printer to be able to print plain text by default, and it is the text filter's job to make sure backspaces, tabs, or other special characters do not confuse the printer. If you are in an environment where you have to account for printer usage, the text filter must also account for pages printed, usually by counting the number of lines printed and comparing that to the number of lines per page the printer supports. The text filter is started with the following argument list:

  `filter-name` [-c] -w*width* -l*length* -i*indent* -n *login* -h *host acct-file*
  where

  `-c`
  appears if the job is submitted with `lpr -l`

  width
  is the value from the `pw` (page width) capability specified in `/etc/printcap` , default 132

  length
  is the value from the `pl` (page length) capability, default 66

  indent
  is the amount of the indentation from `lpr -i`, default 0

  login
  is the account name of the user printing the file

  host
  is the host name from which the job was submitted

  acct-file
  is the name of the accounting file from the `af` capability.

- A conversion filter converts a specific file format into one the printer can render onto paper. For example, ditroff typesetting data cannot be directly printed, but you can install a conversion filter for ditroff files to convert the ditroff data into a form the printer can digest and print. Section Conversion Filters tells all about them. Conversion filters also need to do accounting, if you need printer accounting. Conversion filters are started with the following arguments:

  `filter-name` -x*pixel-width* -y*pixel-height* -n *login* -h *host acct-file*
  where *pixel-width* is the value from the px capability (default 0) and *pixel-height* is the value from the py capability (default 0).

- The output filter is used only if there is no text filter, or if header pages are enabled. In my experience, output filters are rarely used. Section Output Filters describe them. There are only two arguments to an output filter:

  `filter-name` -w*width* -l*length*
  which are identical to the text filters `-w` and `-l` arguments.

Filters should also exit with the following exit status:

exit 0
: If the filter printed the file successfully.

exit 1
: If the filter failed to print the file but wants LPD to try to print the file again. LPD will restart a filter if it exits with this status.

exit 2
: If the filter failed to print the file and does not want LPD to try again. LPD will throw out the file.

The text filter that comes with the FreeBSD release, `/usr/libexec/lpr/lpf` , takes advantage of the page width and length arguments to determine when to send a form feed and how to account for printer usage. It uses the login, host, and accounting file arguments to make the accounting entries.

If you are shopping for filters, see if they are LPD-compatible. If they are, they must support the argument lists described above. If you plan on writing filters for general use, then have them support the same argument lists and exit codes.

9.4.1.2. Accommodating Plain Text Jobs on PostScript® Printers

If you are the only user of your computer and PostScript® (or other language-based) printer, and you promise to never send plain text to your printer and to never use features of various programs that will want to send plain text to your printer, then you do not need to worry about this section at all.

But, if you would like to send both PostScript® and plain text jobs to the printer, then you are urged to augment your printer setup. To do so, we have the text filter detect if the arriving job is plain text or PostScript®. All PostScript® jobs must start with `%!` (for other printer languages, see your printer documentation). If those are the first two characters in the job, we have PostScript®, and can pass the rest of the job directly. If those are not the first two characters in the file, then the filter will convert the text into PostScript® and print the result.

How do we do this?

If you have got a serial printer, a great way to do it is to install `lprps`. `lprps` is a PostScript® printer filter which performs two-way communication with the printer. It updates the printer's status file with verbose information from the printer, so users and administrators can see exactly what the state of the printer is (such as toner low or paper jam). But more importantly, it includes a program called `psif` which detects whether the incoming job is plain text and calls `textps` (another program that comes with `lprps`) to convert it to PostScript®. It then uses `lprps` to send the job to the printer.

`lprps` is part of the FreeBSD Ports Collection (see The Ports Collection). You can fetch, build and install it yourself, of course. After installing `lprps`, just specify the pathname to the `psif` program that is part of `lprps`. If you installed `lprps` from the Ports Collection, use the following in the serial PostScript® printer's entry in `/etc/printcap`:

```
:if=/usr/local/libexec/psif:
```

You should also specify the `rw` capability; that tells LPD to open the printer in read-write mode.

If you have a parallel PostScript® printer (and therefore cannot use two-way communication with the printer, which `lprps` needs), you can use the following shell script as the text filter:

```
#!/bin/sh
#
#  psif - Print PostScript or plain text on a PostScript printer
#  Script version; NOT the version that comes with lprps
#  Installed in /usr/local/libexec/psif
#
```

```
IFS="" read -r first_line
first_two_chars=`expr "$first_line" : '\(..\)'`

if [ "$first_two_chars" = "%!" -]; then
    #
    #  PostScript job, print it.
    #
    echo "$first_line" && cat && printf "\004" && exit 0
    exit 2
else
    #
    #  Plain text, convert it, then print it.
    #
    ( echo "$first_line"; cat ) | /usr/local/bin/textps && printf "\004" && exit 0
    exit 2
fi
```

In the above script, `textps` is a program we installed separately to convert plain text to PostScript®. You can use any text-to-PostScript® program you wish. The FreeBSD Ports Collection (see The Ports Collection) includes a full featured text-to-PostScript® program called `a2ps` that you might want to investigate.

9.4.1.3. Simulating PostScript® on Non PostScript® Printers

PostScript® is the de facto standard for high quality typesetting and printing. PostScript® is, however, an expensive standard. Thankfully, Aladdin Enterprises has a free PostScript® work-alike called Ghostscript that runs with FreeBSD. Ghostscript can read most PostScript® files and can render their pages onto a variety of devices, including many brands of non-PostScript printers. By installing Ghostscript and using a special text filter for your printer, you can make your non PostScript® printer act like a real PostScript® printer.

Ghostscript is in the FreeBSD Ports Collection, if you would like to install it from there. You can fetch, build, and install it quite easily yourself, as well.

To simulate PostScript®, we have the text filter detect if it is printing a PostScript® file. If it is not, then the filter will pass the file directly to the printer; otherwise, it will use Ghostscript to first convert the file into a format the printer will understand.

Here is an example: the following script is a text filter for Hewlett Packard DeskJet 500 printers. For other printers, substitute the `-sDEVICE` argument to the `gs` (Ghostscript) command. (Type `gs -h` to get a list of devices the current installation of Ghostscript supports.)

```
#!/bin/sh
#
#  ifhp - Print Ghostscript-simulated PostScript on a DeskJet 500
#  Installed in /usr/local/libexec/ifhp

#
#  Treat LF as CR+LF (to avoid the "staircase effect" on HP/PCL
#  printers):
#
printf "\033&k2G" || exit 2

#
#  Read first two characters of the file
#
IFS="" read -r first_line
first_two_chars=`expr "$first_line" : '\(..\)'`

if [ "$first_two_chars" = "%!" -]; then
    #
    #  It is PostScript; use Ghostscript to scan-convert and print it.
    #
    /usr/local/bin/gs -dSAFER -dNOPAUSE -q -sDEVICE=djet500 \
```

```
      -sOutputFile=- - && exit 0
else
    #
    #  Plain text or HP/PCL, so just print it directly; print a form feed
    #  at the end to eject the last page.
    #
    echo "$first_line" && cat && printf "\033&l0H" &&
exit 0
fi

exit 2
```

Finally, you need to notify LPD of the filter via the `if` capability:

```
:if=/usr/local/libexec/ifhp:
```

That is it. You can type `lpr plain.text` and `lpr whatever.ps` and both should print successfully.

9.4.1.4. Conversion Filters

After completing the simple setup described in Simple Printer Setup, the first thing you will probably want to do is install conversion filters for your favorite file formats (besides plain ASCII text).

9.4.1.4.1. Why Install Conversion Filters?

Conversion filters make printing various kinds of files easy. As an example, suppose we do a lot of work with the TeX typesetting system, and we have a PostScript® printer. Every time we generate a DVI file from TeX, we cannot print it directly until we convert the DVI file into PostScript®. The command sequence goes like this:

```
% dvips seaweed-analysis.dvi
% lpr seaweed-analysis.ps
```

By installing a conversion filter for DVI files, we can skip the hand conversion step each time by having LPD do it for us. Now, each time we get a DVI file, we are just one step away from printing it:

```
% lpr -d seaweed-analysis.dvi
```

We got LPD to do the DVI file conversion for us by specifying the `-d` option. Section Formatting and Conversion Options lists the conversion options.

For each of the conversion options you want a printer to support, install a conversion filter and specify its pathname in `/etc/printcap` . A conversion filter is like the text filter for the simple printer setup (see section Installing the Text Filter) except that instead of printing plain text, the filter converts the file into a format the printer can understand.

9.4.1.4.2. Which Conversion Filters Should I Install?

You should install the conversion filters you expect to use. If you print a lot of DVI data, then a DVI conversion filter is in order. If you have got plenty of troff to print out, then you probably want a troff filter.

The following table summarizes the filters that LPD works with, their capability entries for the `/etc/printcap` file, and how to invoke them with the `lpr` command:

File type	**/etc/printcap** capability	**lpr** option
cifplot	`cf`	`-c`
DVI	`df`	`-d`
plot	`gf`	`-g`
ditroff	`nf`	`-n`

File type	**/etc/printcap** capability	**lpr** option
FORTRAN text	rf	-f
troff	tf	-f
raster	vf	-v
plain text	if	none, -p, or -l

In our example, using `lpr -d` means the printer needs a `df` capability in its entry in `/etc/printcap`.

Despite what others might contend, formats like FORTRAN text and plot are probably obsolete. At your site, you can give new meanings to these or any of the formatting options just by installing custom filters. For example, suppose you would like to directly print Printerleaf files (files from the Interleaf desktop publishing program), but will never print plot files. You could install a Printerleaf conversion filter under the `gf` capability and then educate your users that `lpr -g` mean "print Printerleaf files."

9.4.1.4.3. Installing Conversion Filters

Since conversion filters are programs you install outside of the base FreeBSD installation, they should probably go under `/usr/local`. The directory `/usr/local/libexec` is a popular location, since they are specialized programs that only LPD will run; regular users should not ever need to run them.

To enable a conversion filter, specify its pathname under the appropriate capability for the destination printer in `/etc/printcap`.

In our example, we will add the DVI conversion filter to the entry for the printer named `bamboo`. Here is the example `/etc/printcap` file again, with the new `df` capability for the printer `bamboo`.

```
#
#  /etc/printcap for host rose - added df filter for bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

The DVI filter is a shell script named `/usr/local/libexec/psdf`. Here is that script:

```
#!/bin/sh
#
#  psdf - DVI to PostScript printer filter
#  Installed in /usr/local/libexec/psdf
#
# Invoked by lpd when user runs lpr -d
#
exec /usr/local/bin/dvips -f | /usr/local/libexec/lprps "$@"
```

This script runs `dvips` in filter mode (the `-f` argument) on standard input, which is the job to print. It then starts the PostScript® printer filter `lprps` (see section Accommodating Plain Text Jobs on PostScript® Printers) with the arguments LPD passed to this script. `lprps` will use those arguments to account for the pages printed.

9.4.1.4.4. More Conversion Filter Examples

Since there is no fixed set of steps to install conversion filters, let me instead provide more examples. Use these as guidance to making your own filters. Use them directly, if appropriate.

This example script is a raster (well, GIF file, actually) conversion filter for a Hewlett Packard LaserJet III-Si printer:

```
#!/bin/sh
#
#  hpvf - Convert GIF files into HP/PCL, then print
#  Installed in /usr/local/libexec/hpvf

PATH=/usr/X11R6/bin:$PATH; export PATH
giftopnm | ppmtopgm | pgmtopbm | pbmtolj -resolution 300 \
    && exit 0 \
    || exit 2
```

It works by converting the GIF file into a portable anymap, converting that into a portable graymap, converting that into a portable bitmap, and converting that into LaserJet/PCL-compatible data.

Here is the `/etc/printcap` file with an entry for a printer using the above filter:

```
#
#  /etc/printcap for host orchid
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sh:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/hpif:\
        :vf=/usr/local/libexec/hpvf:
```

The following script is a conversion filter for troff data from the groff typesetting system for the PostScript® printer named `bamboo`:

```
#!/bin/sh
#
#  pstf - Convert groff's troff data into PS, then print.
#  Installed in /usr/local/libexec/pstf
#
exec grops | /usr/local/libexec/lprps "$@"
```

The above script makes use of `lprps` again to handle the communication with the printer. If the printer were on a parallel port, we would use this script instead:

```
#!/bin/sh
#
#  pstf - Convert groff's troff data into PS, then print.
#  Installed in /usr/local/libexec/pstf
#
exec grops
```

That is it. Here is the entry we need to add to `/etc/printcap` to enable the filter:

```
:tf=/usr/local/libexec/pstf:
```

Here is an example that might make old hands at FORTRAN blush. It is a FORTRAN-text filter for any printer that can directly print plain text. We will install it for the printer `teak`:

```
#!/bin/sh
#
# hprf - FORTRAN text filter for LaserJet 3si:
# Installed in /usr/local/libexec/hprf
#

printf "\033&k2G" && fpr && printf "\033&l0H" &&
 exit 0
exit 2
```

And we will add this line to the `/etc/printcap` for the printer `teak` to enable this filter:

```
:rf=/usr/local/libexec/hprf:
```

Here is one final, somewhat complex example. We will add a DVI filter to the LaserJet printer `teak` introduced earlier. First, the easy part: updating `/etc/printcap` with the location of the DVI filter:

```
:df=/usr/local/libexec/hpdf:
```

Now, for the hard part: making the filter. For that, we need a DVI-to-LaserJet/PCL conversion program. The FreeBSD Ports Collection (see The Ports Collection) has one: `dvi2xx` is the name of the package. Installing this package gives us the program we need, `dvilj2p`, which converts DVI into LaserJet IIp, LaserJet III, and LaserJet 2000 compatible codes.

`dvilj2p` makes the filter `hpdf` quite complex since `dvilj2p` cannot read from standard input. It wants to work with a filename. What is worse, the filename has to end in `.dvi` so using `/dev/fd/0` for standard input is problematic. We can get around that problem by linking (symbolically) a temporary file name (one that ends in `.dvi`) to `/dev/fd/0`, thereby forcing `dvilj2p` to read from standard input.

The only other fly in the ointment is the fact that we cannot use `/tmp` for the temporary link. Symbolic links are owned by user and group `bin`. The filter runs as user `daemon`. And the `/tmp` directory has the sticky bit set. The filter can create the link, but it will not be able clean up when done and remove it since the link will belong to a different user.

Instead, the filter will make the symbolic link in the current working directory, which is the spooling directory (specified by the `sd` capability in `/etc/printcap`). This is a perfect place for filters to do their work, especially since there is (sometimes) more free disk space in the spooling directory than under `/tmp`.

Here, finally, is the filter:

```
#!/bin/sh
#
#  hpdf - Print DVI data on HP/PCL printer
#  Installed in /usr/local/libexec/hpdf

PATH=/usr/local/bin:$PATH; export PATH

#
#  Define a function to clean up our temporary files.  These exist
#  in the current directory, which will be the spooling directory
#  for the printer.
#
cleanup() {
   rm -f hpdf$$.dvi
}

#
#  Define a function to handle fatal errors: print the given message
#  and exit 2.  Exiting with 2 tells LPD to do not try to reprint the
#  job.
#
fatal() {
    echo "$@" 1>&2
    cleanup
    exit 2
}

#
#  If user removes the job, LPD will send SIGINT, so trap SIGINT
#  (and a few other signals) to clean up after ourselves.
#
trap cleanup 1 2 15

#
#  Make sure we are not colliding with any existing files.
#
cleanup
```

```
#
#  Link the DVI input file to standard input (the file to print).
#
ln -s /dev/fd/0 hpdf$$.dvi || fatal "Cannot symlink /dev/fd/0"

#
#  Make LF = CR+LF
#
printf "\033&k2G" || fatal "Cannot initialize printer"

#
#  Convert and print.  Return value from dvilj2p does not seem to be
#  reliable, so we ignore it.
#
dvilj2p -M1 -q -e- dfhp$$.dvi

#
#  Clean up and exit
#
cleanup
exit 0
```

9.4.1.4.5. Automated Conversion: an Alternative to Conversion Filters

All these conversion filters accomplish a lot for your printing environment, but at the cost forcing the user to specify (on the lpr(1) command line) which one to use. If your users are not particularly computer literate, having to specify a filter option will become annoying. What is worse, though, is that an incorrectly specified filter option may run a filter on the wrong type of file and cause your printer to spew out hundreds of sheets of paper.

Rather than install conversion filters at all, you might want to try having the text filter (since it is the default filter) detect the type of file it has been asked to print and then automatically run the right conversion filter. Tools such as `file` can be of help here. Of course, it will be hard to determine the differences between some file types—— and, of course, you can still provide conversion filters just for them.

The FreeBSD Ports Collection has a text filter that performs automatic conversion called `apsfilter`. It can detect plain text, PostScript®, and DVI files, run the proper conversions, and print.

9.4.1.5. Output Filters

The LPD spooling system supports one other type of filter that we have not yet explored: an output filter. An output filter is intended for printing plain text only, like the text filter, but with many simplifications. If you are using an output filter but no text filter, then:

- LPD starts an output filter once for the entire job instead of once for each file in the job.
- LPD does not make any provision to identify the start or the end of files within the job for the output filter.
- LPD does not pass the user's login or host to the filter, so it is not intended to do accounting. In fact, it gets only two arguments:

  `filter-name` -w*`width`* -l*`length`*

  Where *`width`* is from the `pw` capability and *`length`* is from the `pl` capability for the printer in question.

Do not be seduced by an output filter's simplicity. If you would like each file in a job to start on a different page an output filter will not work. Use a text filter (also known as an input filter); see section Installing the Text Filter. Furthermore, an output filter is actually more complex in that it has to examine the byte stream being sent to it for special flag characters and must send signals to itself on behalf of LPD.

However, an output filter is necessary if you want header pages and need to send escape sequences or other initialization strings to be able to print the header page. (But it is also futile if you want to charge header pages to the requesting user's account, since LPD does not give any user or host information to the output filter.)

On a single printer, LPD allows both an output filter and text or other filters. In such cases, LPD will start the output filter to print the header page (see section Header Pages) only. LPD then expects the output filter to stop itself by sending two bytes to the filter: ASCII 031 followed by ASCII 001. When an output filter sees these two bytes (031, 001), it should stop by sending `SIGSTOP` to itself. When LPD's done running other filters, it will restart the output filter by sending `SIGCONT` to it.

If there is an output filter but no text filter and LPD is working on a plain text job, LPD uses the output filter to do the job. As stated before, the output filter will print each file of the job in sequence with no intervening form feeds or other paper advancement, and this is probably not what you want. In almost all cases, you need a text filter.

The program `lpf`, which we introduced earlier as a text filter, can also run as an output filter. If you need a quick-and-dirty output filter but do not want to write the byte detection and signal sending code, try `lpf`. You can also wrap `lpf` in a shell script to handle any initialization codes the printer might require.

9.4.1.6. `lpf`: a Text Filter

The program `/usr/libexec/lpr/lpf` that comes with FreeBSD binary distribution is a text filter (input filter) that can indent output (job submitted with `lpr -i`), allow literal characters to pass (job submitted with `lpr -l`), adjust the printing position for backspaces and tabs in the job, and account for pages printed. It can also act like an output filter.

`lpf` is suitable for many printing environments. And although it has no capability to send initialization sequences to a printer, it is easy to write a shell script to do the needed initialization and then execute `lpf`.

In order for `lpf` to do page accounting correctly, it needs correct values filled in for the `pw` and `pl` capabilities in the `/etc/printcap` file. It uses these values to determine how much text can fit on a page and how many pages were in a user's job. For more information on printer accounting, see Accounting for Printer Usage.

9.4.2. Header Pages

If you have lots of users, all of them using various printers, then you probably want to consider header pages as a necessary evil.

Header pages, also known as banner or burst pages identify to whom jobs belong after they are printed. They are usually printed in large, bold letters, perhaps with decorative borders, so that in a stack of printouts they stand out from the real documents that comprise users' jobs. They enable users to locate their jobs quickly. The obvious drawback to a header page is that it is yet one more sheet that has to be printed for every job, their ephemeral usefulness lasting not more than a few minutes, ultimately finding themselves in a recycling bin or rubbish heap. (Note that header pages go with each job, not each file in a job, so the paper waste might not be that bad.)

The LPD system can provide header pages automatically for your printouts if your printer can directly print plain text. If you have a PostScript® printer, you will need an external program to generate the header page; see Header Pages on PostScript® Printers.

9.4.2.1. Enabling Header Pages

In the Simple Printer Setup section, we turned off header pages by specifying `sh` (meaning “suppress header”) in the `/etc/printcap` file. To enable header pages for a printer, just remove the `sh` capability.

Sounds too easy, right?

You are right. You might have to provide an output filter to send initialization strings to the printer. Here is an example output filter for Hewlett Packard PCL-compatible printers:

```
#!/bin/sh
#
#  hpof - Output filter for Hewlett Packard PCL-compatible printers
#  Installed in /usr/local/libexec/hpof
```

```
printf "\033&k2G" || exit 2
exec /usr/libexec/lpr/lpf
```

Specify the path to the output filter in the `of` capability. See the Output Filters section for more information.

Here is an example `/etc/printcap` file for the printer `teak` that we introduced earlier; we enabled header pages and added the above output filter:

```
#
#  /etc/printcap for host orchid
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/hpif:\
        :vf=/usr/local/libexec/hpvf:\
        :of=/usr/local/libexec/hpof:
```

Now, when users print jobs to `teak`, they get a header page with each job. If users want to spend time searching for their printouts, they can suppress header pages by submitting the job with `lpr -h`; see the Header Page Options section for more lpr(1) options.

注意

LPD prints a form feed character after the header page. If your printer uses a different character or sequence of characters to eject a page, specify them with the `ff` capability in `/etc/printcap` .

9.4.2.2. Controlling Header Pages

By enabling header pages, LPD will produce a long header, a full page of large letters identifying the user, host, and job. Here is an example (kelly printed the job named outline from host `rose`):

```
      k                   ll       ll
      k                    l        l
      k                    l        l
      k   k     eeee       l        l     y    y
      k  k     e    e      l        l     y    y
      k k      eeeeee      l        l     y    y
      kk k     e           l        l     y    y
      k   k    e    e      l        l     y   yy
      k    k    eeee      lll      lll     yyy y
                                             y
                                            y    y
                                             yyyy


                                  ll
                        t         l        i
                        t         l
       oooo    u    u   ttttt     l       ii     n nnn     eeee
      o    o   u    u     t       l        i     nn   n   e    e
      o    o   u    u     t       l        i     n    n   eeeeee
      o    o   u    u     t       l        i     n    n   e
      o    o   u   uu     t  t     l        i     n    n   e    e
       oooo     uuu u      tt      lll      iii    n    n    eeee
```

```
     r rrr     oooo     ssss     eeee
     rr   r   o    o   s    s   e    e
     r        o    o    ss      eeeeee
     r        o    o      ss    e
     r        o    o   s    s   e    e
     r         oooo     ssss     eeee




                                          Job:  outline
                                          Date: Sun Sep 17 11:04:58 1995
```

LPD appends a form feed after this text so the job starts on a new page (unless you have `sf` (suppress form feeds) in the destination printer's entry in `/etc/printcap`).

If you prefer, LPD can make a short header; specify `sb` (short banner) in the `/etc/printcap` file. The header page will look like this:

```
rose:kelly  Job: outline  Date: Sun Sep 17 11:07:51 1995
```

Also by default, LPD prints the header page first, then the job. To reverse that, specify `hl` (header last) in `/etc/printcap`.

9.4.2.3. Accounting for Header Pages

Using LPD's built-in header pages enforces a particular paradigm when it comes to printer accounting: header pages must be free of charge.

Why?

Because the output filter is the only external program that will have control when the header page is printed that could do accounting, and it is not provided with any user or host information or an accounting file, so it has no idea whom to charge for printer use. It is also not enough to just “add one page” to the text filter or any of the conversion filters (which do have user and host information) since users can suppress header pages with `lpr -h`. They could still be charged for header pages they did not print. Basically, `lpr -h` will be the preferred option of environmentally-minded users, but you cannot offer any incentive to use it.

It is still not enough to have each of the filters generate their own header pages (thereby being able to charge for them). If users wanted the option of suppressing the header pages with `lpr -h`, they will still get them and be charged for them since LPD does not pass any knowledge of the `-h` option to any of the filters.

So, what are your options?

You can:

- Accept LPD's paradigm and make header pages free.
- Install an alternative to LPD, such as LPRng. Section Alternatives to the Standard Spooler tells more about other spooling software you can substitute for LPD.
- Write a smart output filter. Normally, an output filter is not meant to do anything more than initialize a printer or do some simple character conversion. It is suited for header pages and plain text jobs (when there is no text (input) filter). But, if there is a text filter for the plain text jobs, then LPD will start the output filter only for the header pages. And the output filter can parse the header page text that LPD generates to determine what user and host to charge for the header page. The only other problem with this method is that the output filter still

does not know what accounting file to use (it is not passed the name of the file from the `af` capability), but if you have a well-known accounting file, you can hard-code that into the output filter. To facilitate the parsing step, use the `sh` (short header) capability in `/etc/printcap` . Then again, all that might be too much trouble, and users will certainly appreciate the more generous system administrator who makes header pages free.

9.4.2.4. Header Pages on PostScript® Printers

As described above, LPD can generate a plain text header page suitable for many printers. Of course, PostScript® cannot directly print plain text, so the header page feature of LPD is useless——or mostly so.

One obvious way to get header pages is to have every conversion filter and the text filter generate the header page. The filters should use the user and host arguments to generate a suitable header page. The drawback of this method is that users will always get a header page, even if they submit jobs with `lpr -h`.

Let us explore this method. The following script takes three arguments (user login name, host name, and job name) and makes a simple PostScript® header page:

```
#!/bin/sh
#
#  make-ps-header - make a PostScript header page on stdout
#  Installed in /usr/local/libexec/make-ps-header
#

#
#  These are PostScript units (72 to the inch).  Modify for A4 or
#  whatever size paper you are using:
#
page_width=612
page_height=792
border=72

#
#  Check arguments
#
if [ $# -ne 3 -]; then
    echo "Usage: `basename $0` <user> <host> <job>" 1>&2
    exit 1
fi

#
#  Save these, mostly for readability in the PostScript, below.
#
user=$1
host=$2
job=$3
date=`date`

#
#  Send the PostScript code to stdout.
#
exec cat <<EOF
%!PS

%
%  Make sure we do not interfere with user's job that will follow
%
save

%
%  Make a thick, unpleasant border around the edge of the paper.
%
$border $border moveto
$page_width $border 2 mul sub 0 rlineto
0 $page_height $border 2 mul sub rlineto
currentscreen 3 -1 roll pop 100 3 1 roll setscreen
```

```
$border 2 mul $page_width sub 0 rlineto closepath
0.8 setgray 10 setlinewidth stroke 0 setgray

%
%  Display user's login name, nice and large and prominent
%
/Helvetica-Bold findfont 64 scalefont setfont
$page_width ($user) stringwidth pop sub 2 div $page_height 200 sub moveto
($user) show

%
%  Now show the boring particulars
%
/Helvetica findfont 14 scalefont setfont
/y 200 def
[ (Job:) (Host:) (Date:) -] {
200 y moveto show /y y 18 sub def }
forall

/Helvetica-Bold findfont 14 scalefont setfont
/y 200 def
[ ($job) ($host) ($date) -] {
        270 y moveto show /y y 18 sub def
} forall

%
% That is it
%
restore
showpage
EOF
```

Now, each of the conversion filters and the text filter can call this script to first generate the header page, and then print the user's job. Here is the DVI conversion filter from earlier in this document, modified to make a header page:

```
#!/bin/sh
#
#  psdf - DVI to PostScript printer filter
#  Installed in /usr/local/libexec/psdf
#
#  Invoked by lpd when user runs lpr -d
#

orig_args="$@"

fail() {
    echo "$@" 1>&2
    exit 2
}

while getopts "x:y:n:h:" option; do
    case $option in
        x|y)  -;; # Ignore
        n)    login=$OPTARG -;;
        h)    host=$OPTARG -;;
        *)    echo "LPD started `basename $0` wrong." 1>&2
              exit 2
              -;;
    esac
done

[ "$login" -] || fail "No login name"
[ "$host" -] || fail "No host name"

( /usr/local/libexec/make-ps-header $login $host "DVI File"
  /usr/local/bin/dvips -f ) | eval /usr/local/libexec/lprps $orig_args
```

Notice how the filter has to parse the argument list in order to determine the user and host name. The parsing for the other conversion filters is identical. The text filter takes a slightly different set of arguments, though (see section How Filters Work).

As we have mentioned before, the above scheme, though fairly simple, disables the “suppress header page” option (the `-h` option) to `lpr`. If users wanted to save a tree (or a few pennies, if you charge for header pages), they would not be able to do so, since every filter's going to print a header page with every job.

To allow users to shut off header pages on a per-job basis, you will need to use the trick introduced in section Accounting for Header Pages: write an output filter that parses the LPD-generated header page and produces a PostScript® version. If the user submits the job with `lpr -h`, then LPD will not generate a header page, and neither will your output filter. Otherwise, your output filter will read the text from LPD and send the appropriate header page PostScript® code to the printer.

If you have a PostScript® printer on a serial line, you can make use of `lprps`, which comes with an output filter, `psof`, which does the above. Note that `psof` does not charge for header pages.

9.4.3. Networked Printing

FreeBSD supports networked printing: sending jobs to remote printers. Networked printing generally refers to two different things:

- Accessing a printer attached to a remote host. You install a printer that has a conventional serial or parallel interface on one host. Then, you set up LPD to enable access to the printer from other hosts on the network. Section Printers Installed on Remote Hosts tells how to do this.
- Accessing a printer attached directly to a network. The printer has a network interface in addition (or in place of) a more conventional serial or parallel interface. Such a printer might work as follows:
  - It might understand the LPD protocol and can even queue jobs from remote hosts. In this case, it acts just like a regular host running LPD. Follow the same procedure in section Printers Installed on Remote Hosts to set up such a printer.
  - It might support a data stream network connection. In this case, you “attach” the printer to one host on the network by making that host responsible for spooling jobs and sending them to the printer. Section Printers with Networked Data Stream Interfaces gives some suggestions on installing such printers.

9.4.3.1. Printers Installed on Remote Hosts

The LPD spooling system has built-in support for sending jobs to other hosts also running LPD (or are compatible with LPD). This feature enables you to install a printer on one host and make it accessible from other hosts. It also works with printers that have network interfaces that understand the LPD protocol.

To enable this kind of remote printing, first install a printer on one host, the printer host, using the simple printer setup described in the Simple Printer Setup section. Do any advanced setup in Advanced Printer Setup that you need. Make sure to test the printer and see if it works with the features of LPD you have enabled. Also ensure that the local host has authorization to use the LPD service in the remote host (see Restricting Jobs from Remote Printers).

If you are using a printer with a network interface that is compatible with LPD, then the printer host in the discussion below is the printer itself, and the printer name is the name you configured for the printer. See the documentation that accompanied your printer and/or printer-network interface.

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If you are using a Hewlett Packard Laserjet then the printer name `text` will automatically perform the LF to CRLF conversion for you, so you will not require the `hpif` script.

Then, on the other hosts you want to have access to the printer, make an entry in their `/etc/printcap` files with the following:

1. Name the entry anything you want. For simplicity, though, you probably want to use the same name and aliases as on the printer host.

2. Leave the `lp` capability blank, explicitly (`:lp=:`).

3. Make a spooling directory and specify its location in the `sd` capability. LPD will store jobs here before they get sent to the printer host.

4. Place the name of the printer host in the `rm` capability.

5. Place the printer name on the printer host in the `rp` capability.

That is it. You do not need to list conversion filters, page dimensions, or anything else in the `/etc/printcap` file.

Here is an example. The host `rose` has two printers, `bamboo` and `rattan`. We will enable users on the host `orchid` to print to those printers. Here is the `/etc/printcap` file for `orchid` (back from section Enabling Header Pages). It already had the entry for the printer `teak`; we have added entries for the two printers on the host `rose`:

```
#
#  /etc/printcap for host orchid - added (remote) printers on rose
#

#
#  teak is local; it is connected directly to orchid:
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/ifhp:\
        :vf=/usr/local/libexec/vfhp:\
        :of=/usr/local/libexec/ofhp:

#
#  rattan is connected to rose; send jobs for rattan to rose:
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :lp=:rm=rose:rp=rattan:sd=/var/spool/lpd/rattan:

#
#  bamboo is connected to rose as well:
#
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :lp=:rm=rose:rp=bamboo:sd=/var/spool/lpd/bamboo:
```

Then, we just need to make spooling directories on `orchid`:

```
# mkdir -p /var/spool/lpd/rattan /var/spool/lpd/bamboo
# chmod 770 /var/spool/lpd/rattan /var/spool/lpd/bamboo
```

```
# chown daemon:daemon /var/spool/lpd/rattan /var/spool/lpd/bamboo
```

Now, users on `orchid` can print to `rattan` and `bamboo`. If, for example, a user on `orchid` typed

```
% lpr -P bamboo -d sushi-review.dvi
```

the LPD system on `orchid` would copy the job to the spooling directory `/var/spool/lpd/bamboo` and note that it was a DVI job. As soon as the host `rose` has room in its `bamboo` spooling directory, the two LPDs would transfer the file to `rose`. The file would wait in `rose`'s queue until it was finally printed. It would be converted from DVI to PostScript® (since `bamboo` is a PostScript® printer) on `rose`.

9.4.3.2. Printers with Networked Data Stream Interfaces

Often, when you buy a network interface card for a printer, you can get two versions: one which emulates a spooler (the more expensive version), or one which just lets you send data to it as if you were using a serial or parallel port (the cheaper version). This section tells how to use the cheaper version. For the more expensive one, see the previous section Printers Installed on Remote Hosts.

The format of the `/etc/printcap` file lets you specify what serial or parallel interface to use, and (if you are using a serial interface), what baud rate, whether to use flow control, delays for tabs, conversion of newlines, and more. But there is no way to specify a connection to a printer that is listening on a TCP/IP or other network port.

To send data to a networked printer, you need to develop a communications program that can be called by the text and conversion filters. Here is one such example: the script `netprint` takes all data on standard input and sends it to a network-attached printer. We specify the hostname of the printer as the first argument and the port number to which to connect as the second argument to `netprint`. Note that this supports one-way communication only (FreeBSD to printer); many network printers support two-way communication, and you might want to take advantage of that (to get printer status, perform accounting, etc.).

```
#!/usr/bin/perl
#
#  netprint - Text filter for printer attached to network
#  Installed in /usr/local/libexec/netprint
#
$#ARGV eq 1 || die "Usage: $0 <printer-hostname> <port-number>";

$printer_host = $ARGV[0];
$printer_port = $ARGV[1];

require 'sys/socket.ph';

($ignore, $ignore, $protocol) = getprotobyname('tcp');
($ignore, $ignore, $ignore, $ignore, $address)
    = gethostbyname($printer_host);

$sockaddr = pack('S n a4 x8', &AF_INET, $printer_port, $address);

socket(PRINTER, &PF_INET, &SOCK_STREAM, $protocol)
    || die "Can't create TCP/IP stream socket: $!";
connect(PRINTER, $sockaddr) || die "Can't contact $printer_host: $!";
while (<STDIN>) { print PRINTER; }
exit 0;
```

We can then use this script in various filters. Suppose we had a Diablo 750-N line printer connected to the network. The printer accepts data to print on port number 5100. The host name of the printer is scrivener. Here is the text filter for the printer:

```
#!/bin/sh
#
#  diablo-if-net - Text filter for Diablo printer `scrivener' listening
#  on port 5100.   Installed in /usr/local/libexec/diablo-if-net
#
exec /usr/libexec/lpr/lpf "$@" | /usr/local/libexec/netprint scrivener 5100
```

9.4.4. Restricting Printer Usage

This section gives information on restricting printer usage. The LPD system lets you control who can access a printer, both locally or remotely, whether they can print multiple copies, how large their jobs can be, and how large the printer queues can get.

9.4.4.1. Restricting Multiple Copies

The LPD system makes it easy for users to print multiple copies of a file. Users can print jobs with `lpr -#5` (for example) and get five copies of each file in the job. Whether this is a good thing is up to you.

If you feel multiple copies cause unnecessary wear and tear on your printers, you can disable the `-#` option to lpr(1) by adding the `sc` capability to the `/etc/printcap` file. When users submit jobs with the `-#` option, they will see:

```
lpr: multiple copies are not allowed
```

Note that if you have set up access to a printer remotely (see section Printers Installed on Remote Hosts), you need the `sc` capability on the remote `/etc/printcap` files as well, or else users will still be able to submit multiple-copy jobs by using another host.

Here is an example. This is the `/etc/printcap` file for the host `rose`. The printer `rattan` is quite hearty, so we will allow multiple copies, but the laser printer `bamboo` is a bit more delicate, so we will disable multiple copies by adding the `sc` capability:

```
#
#  /etc/printcap for host rose - restrict multiple copies on bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Now, we also need to add the `sc` capability on the host `orchid`'s `/etc/printcap` (and while we are at it, let us disable multiple copies for the printer `teak`):

```
#
#  /etc/printcap for host orchid - no multiple copies for local
#  printer teak or remote printer bamboo
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:sc:\
        :if=/usr/local/libexec/ifhp:\
        :vf=/usr/local/libexec/vfhp:\
        :of=/usr/local/libexec/ofhp:

rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :lp=:rm=rose:rp=rattan:sd=/var/spool/lpd/rattan:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :lp=:rm=rose:rp=bamboo:sd=/var/spool/lpd/bamboo:sc:
```

By using the `sc` capability, we prevent the use of `lpr -#`, but that still does not prevent users from running lpr(1) multiple times, or from submitting the same file multiple times in one job like this:

```
% lpr forsale.sign forsale.sign forsale.sign forsale.sign forsale.sign
```

There are many ways to prevent this abuse (including ignoring it) which you are free to explore.

9.4.4.2. Restricting Access to Printers

You can control who can print to what printers by using the UNIX® group mechanism and the `rg` capability in `/etc/printcap` . Just place the users you want to have access to a printer in a certain group, and then name that group in the `rg` capability.

Users outside the group (including `root`) will be greeted with lpr: Not a member of the restricted group if they try to print to the controlled printer.

As with the `sc` (suppress multiple copies) capability, you need to specify `rg` on remote hosts that also have access to your printers, if you feel it is appropriate (see section Printers Installed on Remote Hosts).

For example, we will let anyone access the printer `rattan`, but only those in group `artists` can use `bamboo`. Here is the familiar `/etc/printcap` for host `rose`:

```
#
#  /etc/printcap for host rose - restricted group for bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Let us leave the other example `/etc/printcap` file (for the host `orchid`) alone. Of course, anyone on `orchid` can print to `bamboo`. It might be the case that we only allow certain logins on `orchid` anyway, and want them to have access to the printer. Or not.

注意

There can be only one restricted group per printer.

9.4.4.3. Controlling Sizes of Jobs Submitted

If you have many users accessing the printers, you probably need to put an upper limit on the sizes of the files users can submit to print. After all, there is only so much free space on the filesystem that houses the spooling directories, and you also need to make sure there is room for the jobs of other users.

LPD enables you to limit the maximum byte size a file in a job can be with the `mx` capability. The units are in `BUFSIZ` blocks, which are 1024 bytes. If you put a zero for this capability, there will be no limit on file size; however, if no `mx` capability is specified, then a default limit of 1000 blocks will be used.

注意

The limit applies to files in a job, and not the total job size.

LPD will not refuse a file that is larger than the limit you place on a printer. Instead, it will queue as much of the file up to the limit, which will then get printed. The rest will be discarded. Whether this is correct behavior is up for debate.

Let us add limits to our example printers `rattan` and `bamboo`. Since those artists' PostScript® files tend to be large, we will limit them to five megabytes. We will put no limit on the plain text line printer:

```
#
#  /etc/printcap for host rose
#

#
#  No limit on job size:
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:mx#0:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

#
#  Limit of five megabytes:
#
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:mx#5000:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Again, the limits apply to the local users only. If you have set up access to your printers remotely, remote users will not get those limits. You will need to specify the `mx` capability in the remote `/etc/printcap` files as well. See section Printers Installed on Remote Hosts for more information on remote printing.

There is another specialized way to limit job sizes from remote printers; see section Restricting Jobs from Remote Printers.

9.4.4.4. Restricting Jobs from Remote Printers

The LPD spooling system provides several ways to restrict print jobs submitted from remote hosts:

Host restrictions
: You can control from which remote hosts a local LPD accepts requests with the files `/etc/hosts.equiv` and `/etc/hosts.lpd`. LPD checks to see if an incoming request is from a host listed in either one of these files. If not, LPD refuses the request.

  The format of these files is simple: one host name per line. Note that the file `/etc/hosts.equiv` is also used by the ruserok(3) protocol, and affects programs like rsh(1) and rcp(1), so be careful.

  For example, here is the `/etc/hosts.lpd` file on the host `rose`:

  ```
  orchid
  violet
  madrigal.fishbaum.de
  ```

  This means `rose` will accept requests from the hosts `orchid`, `violet`, and `madrigal.fishbaum.de`. If any other host tries to access `rose`'s LPD, the job will be refused.

Size restrictions
: You can control how much free space there needs to remain on the filesystem where a spooling directory resides. Make a file called `minfree` in the spooling directory for the local printer. Insert in that file a number representing how many disk blocks (512 bytes) of free space there has to be for a remote job to be accepted.

This lets you insure that remote users will not fill your filesystem. You can also use it to give a certain priority to local users: they will be able to queue jobs long after the free disk space has fallen below the amount specified in the `minfree` file.

For example, let us add a `minfree` file for the printer `bamboo`. We examine `/etc/printcap` to find the spooling directory for this printer; here is `bamboo`'s entry:

```
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:mx#5000:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:mx#5000:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

The spooling directory is given in the `sd` capability. We will make three megabytes (which is 6144 disk blocks) the amount of free disk space that must exist on the filesystem for LPD to accept remote jobs:

```
# echo 6144 > /var/spool/lpd/bamboo/minfree
```

User restrictions

You can control which remote users can print to local printers by specifying the `rs` capability in `/etc/printcap`. When `rs` appears in the entry for a locally-attached printer, LPD will accept jobs from remote hosts if the user submitting the job also has an account of the same login name on the local host. Otherwise, LPD refuses the job.

This capability is particularly useful in an environment where there are (for example) different departments sharing a network, and some users transcend departmental boundaries. By giving them accounts on your systems, they can use your printers from their own departmental systems. If you would rather allow them to use only your printers and not your computer resources, you can give them “token” accounts, with no home directory and a useless shell like `/usr/bin/false` .

9.4.5. Accounting for Printer Usage

So, you need to charge for printouts. And why not? Paper and ink cost money. And then there are maintenance costs——printers are loaded with moving parts and tend to break down. You have examined your printers, usage patterns, and maintenance fees and have come up with a per-page (or per-foot, per-meter, or per-whatever) cost. Now, how do you actually start accounting for printouts?

Well, the bad news is the LPD spooling system does not provide much help in this department. Accounting is highly dependent on the kind of printer in use, the formats being printed, and your requirements in charging for printer usage.

To implement accounting, you have to modify a printer's text filter (to charge for plain text jobs) and the conversion filters (to charge for other file formats), to count pages or query the printer for pages printed. You cannot get away with using the simple output filter, since it cannot do accounting. See section Filters.

Generally, there are two ways to do accounting:

- Periodic accounting is the more common way, possibly because it is easier. Whenever someone prints a job, the filter logs the user, host, and number of pages to an accounting file. Every month, semester, year, or whatever time period you prefer, you collect the accounting files for the various printers, tally up the pages printed by users, and charge for usage. Then you truncate all the logging files, starting with a clean slate for the next period.
- Timely accounting is less common, probably because it is more difficult. This method has the filters charge users for printouts as soon as they use the printers. Like disk quotas, the accounting is immediate. You can prevent users from printing when their account goes in the red, and might provide a way for users to check and adjust their “print quotas.” But this method requires some database code to track users and their quotas.

The LPD spooling system supports both methods easily: since you have to provide the filters (well, most of the time), you also have to provide the accounting code. But there is a bright side: you have enormous flexibility in

your accounting methods. For example, you choose whether to use periodic or timely accounting. You choose what information to log: user names, host names, job types, pages printed, square footage of paper used, how long the job took to print, and so forth. And you do so by modifying the filters to save this information.

9.4.5.1. Quick and Dirty Printer Accounting

FreeBSD comes with two programs that can get you set up with simple periodic accounting right away. They are the text filter `lpf`, described in section lpf: a Text Filter, and pac(8), a program to gather and total entries from printer accounting files.

As mentioned in the section on filters (Filters), LPD starts the text and the conversion filters with the name of the accounting file to use on the filter command line. The filters can use this argument to know where to write an accounting file entry. The name of this file comes from the `af` capability in `/etc/printcap` , and if not specified as an absolute path, is relative to the spooling directory.

LPD starts `lpf` with page width and length arguments (from the `pw` and `pl` capabilities). `lpf` uses these arguments to determine how much paper will be used. After sending the file to the printer, it then writes an accounting entry in the accounting file. The entries look like this:

```
2.00 rose:andy
3.00 rose:kelly
3.00 orchid:mary
5.00 orchid:mary
2.00 orchid:zhang
```

You should use a separate accounting file for each printer, as `lpf` has no file locking logic built into it, and two `lpf`s might corrupt each other's entries if they were to write to the same file at the same time. An easy way to insure a separate accounting file for each printer is to use `af=acct` in `/etc/printcap` . Then, each accounting file will be in the spooling directory for a printer, in a file named `acct`.

When you are ready to charge users for printouts, run the pac(8) program. Just change to the spooling directory for the printer you want to collect on and type `pac`. You will get a dollar-centric summary like the following:

```
  Login               pages/feet   runs    price
orchid:kelly               5.00    1   $  0.10
orchid:mary               31.00    3   $  0.62
orchid:zhang               9.00    1   $  0.18
rose:andy                  2.00    1   $  0.04
rose:kelly               177.00  104   $  3.54
rose:mary                 87.00   32   $  1.74
rose:root                 26.00   12   $  0.52

total                    337.00  154   $  6.74
```

These are the arguments pac(8) expects:

`-P`*`printer`*
: Which *`printer`* to summarize. This option works only if there is an absolute path in the `af` capability in `/etc/printcap` .

`-c`
: Sort the output by cost instead of alphabetically by user name.

`-m`
: Ignore host name in the accounting files. With this option, user `smith` on host `alpha` is the same user `smith` on host `gamma`. Without, they are different users.

`-p`*`price`*
: Compute charges with *`price`* dollars per page or per foot instead of the price from the `pc` capability in `/etc/printcap` , or two cents (the default). You can specify *`price`* as a floating point number.

`-r`
: Reverse the sort order.

`-s`
: Make an accounting summary file and truncate the accounting file.

`name` …
: Print accounting information for the given user *`names`* only.

In the default summary that pac(8) produces, you see the number of pages printed by each user from various hosts. If, at your site, host does not matter (because users can use any host), run `pac -m`, to produce the following summary:

```
  Login               pages/feet   runs    price
andy                        2.00    1   $  0.04
kelly                     182.00  105   $  3.64
mary                      118.00   35   $  2.36
root                       26.00   12   $  0.52
zhang                       9.00    1   $  0.18

total                     337.00  154   $  6.74
```

To compute the dollar amount due, pac(8) uses the `pc` capability in the `/etc/printcap` file (default of 200, or 2 cents per page). Specify, in hundredths of cents, the price per page or per foot you want to charge for printouts in this capability. You can override this value when you run pac(8) with the `-p` option. The units for the `-p` option are in dollars, though, not hundredths of cents. For example,

```
# pac -p1.50
```

makes each page cost one dollar and fifty cents. You can really rake in the profits by using this option.

Finally, running `pac -s` will save the summary information in a summary accounting file, which is named the same as the printer's accounting file, but with `_sum` appended to the name. It then truncates the accounting file. When you run pac(8) again, it rereads the summary file to get starting totals, then adds information from the regular accounting file.

9.4.5.2. How Can You Count Pages Printed?

In order to perform even remotely accurate accounting, you need to be able to determine how much paper a job uses. This is the essential problem of printer accounting.

For plain text jobs, the problem is not that hard to solve: you count how many lines are in a job and compare it to how many lines per page your printer supports. Do not forget to take into account backspaces in the file which overprint lines, or long logical lines that wrap onto one or more additional physical lines.

The text filter `lpf` (introduced in lpf: a Text Filter) takes into account these things when it does accounting. If you are writing a text filter which needs to do accounting, you might want to examine `lpf`'s source code.

How do you handle other file formats, though?

Well, for DVI-to-LaserJet or DVI-to-PostScript® conversion, you can have your filter parse the diagnostic output of `dvilj` or `dvips` and look to see how many pages were converted. You might be able to do similar things with other file formats and conversion programs.

But these methods suffer from the fact that the printer may not actually print all those pages. For example, it could jam, run out of toner, or explode——and the user would still get charged.

So, what can you do?

There is only one sure way to do accurate accounting. Get a printer that can tell you how much paper it uses, and attach it via a serial line or a network connection. Nearly all PostScript® printers support this notion. Other makes and models do as well (networked Imagen laser printers, for example). Modify the filters for these printers to get the page usage after they print each job and have them log accounting information based on that value only. There is no line counting nor error-prone file examination required.

Of course, you can always be generous and make all printouts free.

9.5. Using Printers

This section tells you how to use printers you have set up with FreeBSD. Here is an overview of the user-level commands:

lpr(1)
: Print jobs

lpq(1)
: Check printer queues

lprm(1)
: Remove jobs from a printer's queue

There is also an administrative command, lpc(8), described in the section Administering Printers, used to control printers and their queues.

All three of the commands lpr(1), lprm(1), and lpq(1) accept an option `-P` *`printer-name`* to specify on which printer/queue to operate, as listed in the `/etc/printcap` file. This enables you to submit, remove, and check on jobs for various printers. If you do not use the `-P` option, then these commands use the printer specified in the `PRINTER` environment variable. Finally, if you do not have a `PRINTER` environment variable, these commands default to the printer named `lp`.

Hereafter, the terminology default printer means the printer named in the `PRINTER` environment variable, or the printer named `lp` when there is no `PRINTER` environment variable.

9.5.1. Printing Jobs

To print files, type:

```
% lpr filename ...
```

This prints each of the listed files to the default printer. If you list no files, lpr(1) reads data to print from standard input. For example, this command prints some important system files:

```
% lpr /etc/host.conf /etc/hosts.equiv
```

To select a specific printer, type:

```
% lpr -P printer-name filename ...
```

This example prints a long listing of the current directory to the printer named `rattan`:

```
% ls -l | lpr -P rattan
```

Because no files were listed for the lpr(1) command, `lpr` read the data to print from standard input, which was the output of the `ls -l` command.

The lpr(1) command can also accept a wide variety of options to control formatting, apply file conversions, generate multiple copies, and so forth. For more information, see the section Printing Options.

9.5.2. Checking Jobs

When you print with lpr(1), the data you wish to print is put together in a package called a "print job", which is sent to the LPD spooling system. Each printer has a queue of jobs, and your job waits in that queue along with other jobs from yourself and from other users. The printer prints those jobs in a first-come, first-served order.

To display the queue for the default printer, type lpq(1). For a specific printer, use the `-P` option. For example, the command

```
% lpq -P bamboo
```

shows the queue for the printer named `bamboo`. Here is an example of the output of the `lpq` command:

```
bamboo is ready and printing
Rank   Owner    Job  Files                              Total Size
active kelly    9    /etc/host.conf, /etc/hosts.equiv   88 bytes
2nd    kelly    10   (standard input)                   1635 bytes
3rd    mary     11   ...                                78519 bytes
```

This shows three jobs in the queue for `bamboo`. The first job, submitted by user kelly, got assigned "job number" 9. Every job for a printer gets a unique job number. Most of the time you can ignore the job number, but you will need it if you want to cancel the job; see section Removing Jobs for details.

Job number nine consists of two files; multiple files given on the lpr(1) command line are treated as part of a single job. It is the currently active job (note the word `active` under the "Rank" column), which means the printer should be currently printing that job. The second job consists of data passed as the standard input to the lpr(1) command. The third job came from user `mary`; it is a much larger job. The pathname of the file she is trying to print is too long to fit, so the lpq(1) command just shows three dots.

The very first line of the output from lpq(1) is also useful: it tells what the printer is currently doing (or at least what LPD thinks the printer is doing).

The lpq(1) command also support a `-l` option to generate a detailed long listing. Here is an example of `lpq -l`:

```
waiting for bamboo to become ready (offline ?)
kelly: 1st     [job 009rose]
       /etc/host.conf                   73 bytes
       /etc/hosts.equiv                 15 bytes

kelly: 2nd     [job 010rose]
       (standard input)                 1635 bytes

mary: 3rd                               [job 011rose]
      /home/orchid/mary/research/venus/alpha-regio/mapping 78519 bytes
```

9.5.3. Removing Jobs

If you change your mind about printing a job, you can remove the job from the queue with the lprm(1) command. Often, you can even use lprm(1) to remove an active job, but some or all of the job might still get printed.

To remove a job from the default printer, first use lpq(1) to find the job number. Then type:

```
% lprm job-number
```

To remove the job from a specific printer, add the `-P` option. The following command removes job number 10 from the queue for the printer `bamboo`:

```
% lprm -P bamboo 10
```

The lprm(1) command has a few shortcuts:

lprm -
: Removes all jobs (for the default printer) belonging to you.

lprm *user*
: Removes all jobs (for the default printer) belonging to *user*. The superuser can remove other users' jobs; you can remove only your own jobs.

lprm
: With no job number, user name, or `-` appearing on the command line, lprm(1) removes the currently active job on the default printer, if it belongs to you. The superuser can remove any active job.

Just use the `-P` option with the above shortcuts to operate on a specific printer instead of the default. For example, the following command removes all jobs for the current user in the queue for the printer named `rattan`:

```
% lprm -P rattan -
```

注意

If you are working in a networked environment, lprm(1) will let you remove jobs only from the host from which the jobs were submitted, even if the same printer is available from other hosts. The following command sequence demonstrates this:

```
% lpr -P rattan myfile
% rlogin orchid
% lpq -P rattan
Rank   Owner   Job  Files                                 Total Size
active seeyan   12 ...                                   49123 bytes
2nd    kelly      13   myfile                                12 bytes
% lprm -P rattan 13
rose: Permission denied
% logout
% lprm -P rattan 13
dfA013rose dequeued
cfA013rose dequeued
```

9.5.4. Beyond Plain Text: Printing Options

The lpr(1) command supports a number of options that control formatting text, converting graphic and other file formats, producing multiple copies, handling of the job, and more. This section describes the options.

9.5.4.1. Formatting and Conversion Options

The following lpr(1) options control formatting of the files in the job. Use these options if the job does not contain plain text or if you want plain text formatted through the pr(1) utility.

For example, the following command prints a DVI file (from the TeX typesetting system) named `fish-report.dvi` to the printer named `bamboo`:

```
% lpr -P bamboo -d fish-report.dvi
```

These options apply to every file in the job, so you cannot mix (say) DVI and ditroff files together in a job. Instead, submit the files as separate jobs, using a different conversion option for each job.

注意

All of these options except `-p` and `-T` require conversion filters installed for the destination printer. For example, the `-d` option requires the DVI conversion filter. Section Conversion Filters gives details.

`-c`
Print cifplot files.

`-d`
Print DVI files.

`-f`
Print FORTRAN text files.

`-g`
Print plot data.

`-i` *`number`*
Indent the output by *`number`* columns; if you omit *`number`*, indent by 8 columns. This option works only with certain conversion filters.

注意

Do not put any space between the `-i` and the number.

`-l`
Print literal text data, including control characters.

`-n`
Print ditroff (device independent troff) data.

-p
Format plain text with pr(1) before printing. See pr(1) for more information.

`-T` *`title`*
Use *`title`* on the pr(1) header instead of the file name. This option has effect only when used with the `-p` option.

`-t`
Print troff data.

`-v`
Print raster data.

Here is an example: this command prints a nicely formatted version of the ls(1) manual page on the default printer:

```
% zcat /usr/share/man/man1/ls.1.gz | troff -t -man | lpr -t
```

The zcat(1) command uncompresses the source of the ls(1) manual page and passes it to the troff(1) command, which formats that source and makes GNU troff output and passes it to lpr(1), which submits the job to the LPD

spooler. Because we used the `-t` option to lpr(1), the spooler will convert the GNU troff output into a format the default printer can understand when it prints the job.

9.5.4.2. Job Handling Options

The following options to lpr(1) tell LPD to handle the job specially:

-# *`copies`*
: Produce a number of *`copies`* of each file in the job instead of just one copy. An administrator may disable this option to reduce printer wear-and-tear and encourage photocopier usage. See section Restricting Multiple Copies.

  This example prints three copies of `parser.c` followed by three copies of `parser.h` to the default printer:

```
% lpr -#3 parser.c parser.h
```

-m
: Send mail after completing the print job. With this option, the LPD system will send mail to your account when it finishes handling your job. In its message, it will tell you if the job completed successfully or if there was an error, and (often) what the error was.

-s
: Do not copy the files to the spooling directory, but make symbolic links to them instead.

  If you are printing a large job, you probably want to use this option. It saves space in the spooling directory (your job might overflow the free space on the filesystem where the spooling directory resides). It saves time as well since LPD will not have to copy each and every byte of your job to the spooling directory.

  There is a drawback, though: since LPD will refer to the original files directly, you cannot modify or remove them until they have been printed.

> **注意**
>
> If you are printing to a remote printer, LPD will eventually have to copy files from the local host to the remote host, so the `-s` option will save space only on the local spooling directory, not the remote. It is still useful, though.

-r
: Remove the files in the job after copying them to the spooling directory, or after printing them with the `-s` option. Be careful with this option!

9.5.4.3. Header Page Options

These options to lpr(1) adjust the text that normally appears on a job's header page. If header pages are suppressed for the destination printer, these options have no effect. See section Header Pages for information about setting up header pages.

-C *`text`*
: Replace the hostname on the header page with *`text`*. The hostname is normally the name of the host from which the job was submitted.

-J *`text`*
: Replace the job name on the header page with *`text`*. The job name is normally the name of the first file of the job, or `stdin` if you are printing standard input.

-h
: Do not print any header page.

注意

At some sites, this option may have no effect due to the way header pages are generated. See Header Pages for details.

9.5.5. Administering Printers

As an administrator for your printers, you have had to install, set up, and test them. Using the lpc(8) command, you can interact with your printers in yet more ways. With lpc(8), you can

- Start and stop the printers
- Enable and disable their queues
- Rearrange the order of the jobs in each queue.

First, a note about terminology: if a printer is stopped, it will not print anything in its queue. Users can still submit jobs, which will wait in the queue until the printer is started or the queue is cleared.

If a queue is disabled, no user (except `root`) can submit jobs for the printer. An enabled queue allows jobs to be submitted. A printer can be started for a disabled queue, in which case it will continue to print jobs in the queue until the queue is empty.

In general, you have to have `root` privileges to use the lpc(8) command. Ordinary users can use the lpc(8) command to get printer status and to restart a hung printer only.

Here is a summary of the lpc(8) commands. Most of the commands take a *`printer-name`* argument to tell on which printer to operate. You can use `all` for the *`printer-name`* to mean all printers listed in `/etc/printcap`.

`abort printer-name`
: Cancel the current job and stop the printer. Users can still submit jobs if the queue is enabled.

`clean printer-name`
: Remove old files from the printer's spooling directory. Occasionally, the files that make up a job are not properly removed by LPD, particularly if there have been errors during printing or a lot of administrative activity. This command finds files that do not belong in the spooling directory and removes them.

`disable printer-name`
: Disable queuing of new jobs. If the printer is running, it will continue to print any jobs remaining in the queue. The superuser (`root`) can always submit jobs, even to a disabled queue.

  This command is useful while you are testing a new printer or filter installation: disable the queue and submit jobs as `root`. Other users will not be able to submit jobs until you complete your testing and re-enable the queue with the `enable` command.

`down printer-name message`
: Take a printer down. Equivalent to `disable` followed by `stop`. The *`message`* appears as the printer's status whenever a user checks the printer's queue with lpq(1) or status with `lpc status`.

`enable printer-name`
: Enable the queue for a printer. Users can submit jobs but the printer will not print anything until it is started.

`help command-name`
: Print help on the command *`command-name`*. With no *`command-name`*, print a summary of the commands available.

`restart printer-name`
: Start the printer. Ordinary users can use this command if some extraordinary circumstance hangs LPD, but they cannot start a printer stopped with either the `stop` or `down` commands. The `restart` command is equivalent to `abort` followed by `start`.

`start printer-name`
: Start the printer. The printer will print jobs in its queue.

`stop printer-name`
: Stop the printer. The printer will finish the current job and will not print anything else in its queue. Even though the printer is stopped, users can still submit jobs to an enabled queue.

`topq printer-name job-or-username`
: Rearrange the queue for *`printer-name`* by placing the jobs with the listed *`job`* numbers or the jobs belonging to *`username`* at the top of the queue. For this command, you cannot use `all` as the *`printer-name`*.

`up printer-name`
: Bring a printer up; the opposite of the `down` command. Equivalent to `start` followed by `enable`.

lpc(8) accepts the above commands on the command line. If you do not enter any commands, lpc(8) enters an interactive mode, where you can enter commands until you type `exit`, `quit`, or end-of-file.

9.6. Alternatives to the Standard Spooler

If you have been reading straight through this manual, by now you have learned just about everything there is to know about the LPD spooling system that comes with FreeBSD. You can probably appreciate many of its shortcomings, which naturally leads to the question: "What other spooling systems are out there (and work with FreeBSD)?"

LPRng

LPRng, which purportedly means "LPR: the Next Generation" is a complete rewrite of PLP. Patrick Powell and Justin Mason (the principal maintainer of PLP) collaborated to make LPRng. The main site for LPRng is `http://www.lprng.org/` .

CUPS

CUPS, the Common UNIX Printing System, provides a portable printing layer for UNIX®-based operating systems. It has been developed by Easy Software Products to promote a standard printing solution for all UNIX® vendors and users.

CUPS uses the Internet Printing Protocol (IPP) as the basis for managing print jobs and queues. The Line Printer Daemon (LPD), Server Message Block (SMB), and AppSocket (a.k.a. JetDirect) protocols are also supported with reduced functionality. CUPS adds network printer browsing and PostScript Printer Description (PPD) based printing options to support real-world printing under UNIX®.

The main site for CUPS is `http://www.cups.org/` .

9.7. Troubleshooting

After performing the simple test with lptest(1), you might have gotten one of the following results instead of the correct printout:

It worked, after awhile; or, it did not eject a full sheet.
: The printer printed the above, but it sat for awhile and did nothing. In fact, you might have needed to press a PRINT REMAINING or FORM FEED button on the printer to get any results to appear.

If this is the case, the printer was probably waiting to see if there was any more data for your job before it printed anything. To fix this problem, you can have the text filter send a FORM FEED character (or whatever is necessary) to the printer. This is usually sufficient to have the printer immediately print any text remaining in its internal buffer. It is also useful to make sure each print job ends on a full sheet, so the next job does not start somewhere on the middle of the last page of the previous job.

The following replacement for the shell script `/usr/local/libexec/if-simple` prints a form feed after it sends the job to the printer:

```
#!/bin/sh
#
# if-simple - Simple text input filter for lpd
# Installed in /usr/local/libexec/if-simple
#
# Simply copies stdin to stdout.  Ignores all filter arguments.
# Writes a form feed character (\f) after printing job.

/bin/cat && printf "\f" && exit 0
exit 2
```

It produced the “staircase effect.”

You got the following on paper:

```
!"#$%&'()*+,-./01234
               "#$%&'()*+,-./012345
                              #$%&'()*+,-./0123456
```

You have become another victim of the staircase effect, caused by conflicting interpretations of what characters should indicate a new line. UNIX® style operating systems use a single character: ASCII code 10, the line feed (LF). MS-DOS®, OS/2®, and others uses a pair of characters, ASCII code 10 and ASCII code 13 (the carriage return or CR). Many printers use the MS-DOS® convention for representing new-lines.

When you print with FreeBSD, your text used just the line feed character. The printer, upon seeing a line feed character, advanced the paper one line, but maintained the same horizontal position on the page for the next character to print. That is what the carriage return is for: to move the location of the next character to print to the left edge of the paper.

Here is what FreeBSD wants your printer to do:

Printer received CR	Printer prints CR
Printer received LF	Printer prints CR + LF

Here are some ways to achieve this:

- Use the printer's configuration switches or control panel to alter its interpretation of these characters. Check your printer's manual to find out how to do this.

注意

If you boot your system into other operating systems besides FreeBSD, you may have to reconfigure the printer to use a an interpretation for CR and LF characters that those other operating systems use. You might prefer one of the other solutions, below.

- Have FreeBSD's serial line driver automatically convert LF to CR+LF. Of course, this works with printers on serial ports only. To enable this feature, use the `ms#` capability and set the `onlcr` mode in the `/etc/printcap` file for the printer.

- Send an escape code to the printer to have it temporarily treat LF characters differently. Consult your printer's manual for escape codes that your printer might support. When you find the proper escape code, modify the text filter to send the code first, then send the print job.

  Here is an example text filter for printers that understand the Hewlett-Packard PCL escape codes. This filter makes the printer treat LF characters as a LF and CR; then it sends the job; then it sends a form feed to eject the last page of the job. It should work with nearly all Hewlett Packard printers.

  ```
  #!/bin/sh
  #
  # hpif - Simple text input filter for lpd for HP-PCL based printers
  # Installed in /usr/local/libexec/hpif
  #
  # Simply copies stdin to stdout.  Ignores all filter arguments.
  # Tells printer to treat LF as CR+LF.  Ejects the page when done.

  printf "\033&k2G" && cat && printf "\033&l0H" && exit 0
  exit 2
  ```

  Here is an example `/etc/printcap` from a host called `orchid`. It has a single printer attached to its first parallel port, a Hewlett Packard LaserJet 3Si named `teak`. It is using the above script as its text filter:

  ```
  #
  #  /etc/printcap for host orchid
  #
  teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
          :lp=/dev/lpt0:sh:sd=/var/spool/lpd/teak:mx#0:\
          :if=/usr/local/libexec/hpif:
  ```

It overprinted each line.
: The printer never advanced a line. All of the lines of text were printed on top of each other on one line.

  This problem is the "opposite" of the staircase effect, described above, and is much rarer. Somewhere, the LF characters that FreeBSD uses to end a line are being treated as CR characters to return the print location to the left edge of the paper, but not also down a line.

  Use the printer's configuration switches or control panel to enforce the following interpretation of LF and CR characters:

Printer receives	Printer prints
CR	CR
LF	CR + LF

The printer lost characters.
: While printing, the printer did not print a few characters in each line. The problem might have gotten worse as the printer ran, losing more and more characters.

  The problem is that the printer cannot keep up with the speed at which the computer sends data over a serial line (this problem should not occur with printers on parallel ports). There are two ways to overcome the problem:

  - If the printer supports XON/XOFF flow control, have FreeBSD use it by specifying the `ixon` mode in the `ms#` capability.

  - If the printer supports carrier flow control, specify the `crtscts` mode in the `ms#` capability. Make sure the cable connecting the printer to the computer is correctly wired for carrier flow control.

It printed garbage.
: The printer printed what appeared to be random garbage, but not the desired text.

This is usually another symptom of incorrect communications parameters with a serial printer. Double-check the bps rate in the `br` capability, and the parity setting in the `ms#` capability; make sure the printer is using the same settings as specified in the `/etc/printcap` file.

Nothing happened.

If nothing happened, the problem is probably within FreeBSD and not the hardware. Add the log file (`lf`) capability to the entry for the printer you are debugging in the `/etc/printcap` file. For example, here is the entry for `rattan`, with the `lf` capability:

```
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:\
        :lf=/var/log/rattan.log
```

Then, try printing again. Check the log file (in our example, `/var/log/rattan.log`) to see any error messages that might appear. Based on the messages you see, try to correct the problem.

If you do not specify a `lf` capability, LPD uses `/dev/console` as a default.

章 10. Linux® 二進位檔的相容性

Restructured and parts updated by Jim Mock.
Originally contributed by Brian N. Handy 且 Rich Murphey.

10.1. 概述

FreeBSD 提供和32位元 Linux® 二進位檔的相容性，允許使用者在 FreeBSD不需要修改就可以安裝和執行大部份32位元 Linux® 二進位檔。 曾經有人指出，在某些情況下，32位元 Linux®二進位檔在 FreeBSD 的表現比在 Linux®好。

然而，某些However, some Linux®作業系統的特色在 FreeBSD 並未支援。 例如，如果 Linux® 二進位檔過度使用i386™特定的呼叫，像是啓動虛擬8086模式，將無法在 FreeBSD 執行。此外，64位元 Linux® 二進位檔目前也尚未支援。

讀完本章後，您將了解：

- 如何在FreeBSD系統啓用 Linux® 相容模式 FreeBSD。
- 如何安裝額外的 Linux® 共享程式庫。
- 如何在FreeBSD系統安裝 Linux® 應用程式。
- The implementation details of Linux® compatibility in FreeBSD.

在閱讀這章之前，您應當了解：

- 知道如何安裝 額外的第3方軟體。

10.2. 設置 Linux® 二進位檔相容性

Linux® 程式庫並未預設安裝，而且 Linux® 二進位檔相容性並未啓用。 Linux® 程式庫可以手動安裝或是從 FreeBSD Ports 安裝。

編譯 port 前，要載入 Linux® 核心模組，否則編譯會失敗：

```
# kldload linux
```

確認模組已載入：

```
% kldstat
     Id Refs Address    Size     Name
     1    2 0xc0100000 16bdb8   kernel
     7    1 0xc24db000 d000     linux.ko
```

在 FreeBSD 安裝基本的 Linux® 程式庫和二進位檔最簡單的方式是安裝 emulators/linux_base-c6 套件或是 port 。安裝 port：

```
# printf "compat.linux.osrelease=2.6.18\n" >> /etc/sysctl.conf
# sysctl compat.linux.osrelease=2.6.18
# pkg install emulators/linux_base-c6
```

要讓 Linux® 相容性在開機時就啓用，可以加入這行到 /etc/rc.conf：

```
linux_enable="YES"
```

想要靜態連結 Linux® 二進位檔相容性到自訂核心的使用者應該增加 `options COMPAT_LINUX` 到他們自訂核心設定檔。 編譯和安裝新核心的方法，如 章 8, 設定 FreeBSD Kernel所述。

10.2.1. 手動安裝額外的程式庫

如果一個 Linux® 應用程式在設定 Linux®二進位檔相容性後表示缺少共享程式庫， 看看這個Linux® 二進位檔需要哪個共享程式庫，手動安裝他。

Linux® 系統中， `ldd` 可以用來決定應用程式需要哪個。 例如，檢查 `linuxdoom` 需要哪個共享程式庫，從安裝 Doom的 Linux® 系統中執行這個指令：

```
% ldd linuxdoom
libXt.so.3 (DLL Jump 3.1) => /usr/X11/lib/libXt.so.3.1.0
libX11.so.3 (DLL Jump 3.1) => /usr/X11/lib/libX11.so.3.1.0
libc.so.4 (DLL Jump 4.5pl26) => /lib/libc.so.4.6.29
```

然後，複製所有 Linux® 系統輸出最後一欄的檔案到 FreeBSD系統的 `/compat/linux` 。 複製完後，建立符號連結到剛剛輸出第一欄的名字。這個例子會在 FreeBSD 系統產生以下檔案：

```
/compat/linux/usr/X11/lib/libXt.so.3.1.0
/compat/linux/usr/X11/lib/libXt.so.3 -> libXt.so.3.1.0
/compat/linux/usr/X11/lib/libX11.so.3.1.0
/compat/linux/usr/X11/lib/libX11.so.3 -> libX11.so.3.1.0
/compat/linux/lib/libc.so.4.6.29
/compat/linux/lib/libc.so.4 -> libc.so.4.6.29
```

If a Linux® shared library already exists with a matching major revision number to the first column of the `ldd` output, it does not need to be copied to the file named in the last column, as the existing library should work. It is advisable to copy the shared library if it is a newer version, though. The old one can be removed, as long as the symbolic link points to the new one.

For example, these libraries already exist on the FreeBSD system:

```
/compat/linux/lib/libc.so.4.6.27
/compat/linux/lib/libc.so.4 -> libc.so.4.6.27
```

and `ldd` indicates that a binary requires a later version:

```
libc.so.4 (DLL Jump 4.5pl26) -> libc.so.4.6.29
```

Since the existing library is only one or two versions out of date in the last digit, the program should still work with the slightly older version. However, it is safe to replace the existing `libc.so` with the newer version:

```
/compat/linux/lib/libc.so.4.6.29
/compat/linux/lib/libc.so.4 -> libc.so.4.6.29
```

Generally, one will need to look for the shared libraries that Linux® binaries depend on only the first few times that a Linux® program is installed on FreeBSD. After a while, there will be a sufficient set of Linux® shared libraries on the system to be able to run newly installed Linux® binaries without any extra work.

10.2.2. 安裝 Linux® ELF 二進位檔

ELF 二進位等有時候需要額外的步驟。當執行未標記的 ELF 二進位檔，會產生錯誤訊息：

```
% ./my-linux-elf-binary
ELF binary type not known
Abort
```

為了幫 FreeBSD 核心辨識 FreeBSD ELF 二進位檔和 Linux® 二進位檔，使用 brandelf(1)：

```
% brandelf -t Linux my-linux-elf-binary
```

因為GNU工具鏈會自動放置適當的標記資訊進 ELF 二進位檔，通常就不需要這個步驟。

10.2.3. 安裝 Linux® RPM 基礎的應用程式

要安裝 Linux® RPM 基礎的應用程式，先安裝 archivers/rpm 套件或 port。 安裝後， root 可以使用這個指令來安裝.rpm檔：

```
# cd /compat/linux
# rpm2cpio < /path/to/linux.archive.rpm | cpio -id
```

如果需要， brandelf 已安裝的 ELF二進位檔。注意，這將會無法乾淨地解除安裝。

10.2.4. 設定主機名稱解析器（Hostname Resolver）

如果 DNS 有問題或是出現這個錯誤：

```
resolv+: "bind" is an invalid keyword resolv+:
"hosts" is an invalid keyword
```

將 /compat/linux/etc/host.conf 設定如下：

```
order hosts, bind
multi on
```

這指定先搜尋 /etc/hosts ， DNS 次之。 當 /compat/linux/etc/host.conf 不存在， Linux® 應用程式會使用 /etc/host.conf 並會抱怨不相容的 FreeBSD 語法。 如果名稱伺服器未設定使用/etc/resolv.conf 的話，移除 bind 。

10.3. 進階主題

本節描述 Linux® 二進位檔如何運作，以 Terry Lambert <tlambert@primenet.com > 寫給FreeBSD chat 郵遞論壇的電子郵件為基礎(Message ID: <199906020108.SAA07001@usr09.primenet.com>)。

FreeBSD has an abstraction called an “execution class loader”. This is a wedge into the execve(2) system call.

歷史上， UNIX® 載入器檢查魔術數字（通常是檔案的頭四或八個位元組）來看它是否是系統已知的二進位檔，如果是，就調用二進位檔載入器。

如果不是系統的二進位檔類型， execve(2) 呼叫會回報失敗，shell會嘗試當作 shell 指令來執行。 The assumption was a default of “whatever the current shell is”.

後來， sh(1) 做了hack來檢查頭兩字元，如果他們是 :\n ，就改調用 csh(1) shell 。

FreeBSD 有一系列的載入器取代單一載入器，其中有with a fallback to the #! 載入器來執行 shell 解譯器或是 shell 腳本。

對於 Linux® ABI 支援， FreeBSD 將魔術數字看待為 ELF 二進位檔。 ELF載入器尋找專門的 brand，這是 ELF 影像的註解部份，並未存在於 SVR4/Solaris™ ELF 二進位檔。

For Linux® binaries to function, they must be branded as type Linux using brandelf(1):

```
# brandelf -t Linux file
```

When the ELF loader sees the Linux brand, the loader replaces a pointer in the proc structure. All system calls are indexed through this pointer. In addition, the process is flagged for special handling of the trap vector for the signal trampoline code, and several other (minor) fix-ups that are handled by the Linux® kernel module.

The Linux® system call vector contains, among other things, a list of `sysent[]` entries whose addresses reside in the kernel module.

When a system call is called by the Linux® binary, the trap code dereferences the system call function pointer off the `proc` structure, and gets the Linux®, not the FreeBSD, system call entry points.

Linux® mode dynamically reroots lookups. This is, in effect, equivalent to the `union` option to file system mounts. First, an attempt is made to lookup the file in `/compat/linux/` *`original-path`* . If that fails, the lookup is done in */original-path* . This makes sure that binaries that require other binaries can run. For example, the Linux® toolchain can all run under Linux® ABI support. It also means that the Linux® binaries can load and execute FreeBSD binaries, if there are no corresponding Linux® binaries present, and that a uname(1) command can be placed in the `/compat/linux` directory tree to ensure that the Linux® binaries can not tell they are not running on Linux®.

In effect, there is a Linux® kernel in the FreeBSD kernel. The various underlying functions that implement all of the services provided by the kernel are identical to both the FreeBSD system call table entries, and the Linux® system call table entries: file system operations, virtual memory operations, signal delivery, and System V IPC. The only difference is that FreeBSD binaries get the FreeBSD glue functions, and Linux® binaries get the Linux® glue functions. The FreeBSD glue functions are statically linked into the kernel, and the Linux® glue functions can be statically linked, or they can be accessed via a kernel module.

Technically, this is not really emulation, it is an ABI implementation. It is sometimes called “Linux® emulation” because the implementation was done at a time when there was no other word to describe what was going on. Saying that FreeBSD ran Linux® binaries was not true, since the code was not compiled in.

部 III. 系統管理

FreeBSD 使用手冊剩下的這些章節涵蓋了全方位的 FreeBSD 系統管理。 每個章節的開頭會先描述在該您讀完該章節後您會學到什麼，也會詳述在您在看這些資料時應該要有的一些背景知識。

這些章節是讓您在需要查資料的時候翻閱用的。 您不需要依照特定的順序來讀，也不需要將這些章節全部過讀之後才開始用 FreeBSD。

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章 11. 設定與效能調校(Tuning)

Written by Chern Lee.
Based on a tutorial written by Mike Smith.
Also based on tuning(7) written by Matt Dillon.

11.1. 概述

在 FreeBSD 使用過程中，相當重要的環節之一就是系統設定部分。 正確的系統設定，可以讓你減輕日後升級的頭痛壓力。 本章著重於介紹 FreeBSD 的相關重要設定上，包括一些可以調整 FreeBSD 效能的參數設定。

讀完這章，您將了解：

- 如何有效運用檔案系統以及 swap 分割區。
- `rc.conf` 的設定與 `/usr/local/etc/rc.d` 的啓動架構。
- 如何設定、測試網路卡。
- 如何設定 virtual `hosts`。
- 如何設定 `/etc` 內的各種設定檔。
- 如何以 `sysctl` 來調整 FreeBSD 的系統效能。
- 如何調整硬碟效能，以及更改 kernel 限制。

在開始閱讀這章之前，您需要：

- 瞭解 UNIX® 及 FreeBSD 相關基本概念(章 3, UNIX 基礎概念)。
- 要有設定、編譯 kernel 的基礎概念(章 8, 設定 FreeBSD Kernel)。

11.2. 最主要的設定檔

The principal location for system configuration information is within `/etc/rc.conf` . This file contains a wide range of configuration information, principally used at system startup to configure the system. Its name directly implies this; it is configuration information for the `rc*` files.

An administrator should make entries in the `rc.conf` file to override the default settings from `/etc/defaults/rc.conf` . The defaults file should not be copied verbatim to `/etc` - it contains default values, not examples. All system-specific changes should be made in the `rc.conf` file itself.

A number of strategies may be applied in clustered applications to separate site-wide configuration from system-specific configuration in order to keep administration overhead down. The recommended approach is to place site-wide configuration into another file, such as `/etc/rc.conf.site` , and then include this file into `/etc/rc.conf` , which will contain only system-specific information.

As `rc.conf` is read by sh(1) it is trivial to achieve this. For example:

- rc.conf:

```
. /etc/rc.conf.site
hostname="node15.example.com"
network_interfaces="fxp0 lo0"
```

```
ifconfig_fxp0="inet 10.1.1.1"
```

- rc.conf.site:

```
defaultrouter="10.1.1.254"
saver="daemon"
blanktime="100"
```

The `rc.conf.site` file can then be distributed to every system using `rsync` or a similar program, while the `rc.conf` file remains unique.

Upgrading the system using sysinstall(8) or `make world` will not overwrite the `rc.conf` file, so system configuration information will not be lost.

11.3. 各式應用程式的設定檔

原則上，安裝的軟體都會有其自有的設定檔，也會有自己的格式及語法。 因此，將其與系統分開獨立是件非常重要的事情。如此一來，套件管理工具將可以 很輕易的找出這些設定檔並管理這些設定檔。

原則上，設定檔會被放置在 `/usr/local/etc` 。 若某軟體的設定檔為數衆多，那將會其下建立一個目錄以供放置

通常，當一個 port 或 package 被安裝的同時，一些基本的設定範例 也會一併被安裝至此。這些範例通常會被用 `.default` 做為副檔名。 若安裝時沒有自行撰寫的軟體設定檔，那麼將會複製一份 `.default` 設定做為預設設定檔

舉個例子，我們來看看 `/usr/local/etc/apache` ：

```
-rw-r--r--  1 root  wheel   2184 May 20  1998 access.conf
-rw-r--r--  1 root  wheel   2184 May 20  1998 access.conf.default
-rw-r--r--  1 root  wheel   9555 May 20  1998 httpd.conf
-rw-r--r--  1 root  wheel   9555 May 20  1998 httpd.conf.default
-rw-r--r--  1 root  wheel  12205 May 20  1998 magic
-rw-r--r--  1 root  wheel  12205 May 20  1998 magic.default
-rw-r--r--  1 root  wheel   2700 May 20  1998 mime.types
-rw-r--r--  1 root  wheel   2700 May 20  1998 mime.types.default
-rw-r--r--  1 root  wheel   7980 May 20  1998 srm.conf
-rw-r--r--  1 root  wheel   7933 May 20  1998 srm.conf.default
```

`srm.conf` 的檔案被修改過了，爾後 Apache 的更新 將不會對這個已修改過的設定檔做任何變動。

11.4. 各種 Services 的啓動方式

Contributed by Tom Rhodes.

Many users choose to install third party software on FreeBSD from the Ports Collection. In many of these situations it may be necessary to configure the software in a manner which will allow it to be started upon system initialization. Services, such as mail/postfix or www/apache13 are just two of the many software packages which may be started during system initialization. This section explains the procedures available for starting third party software.

In FreeBSD, most included services, such as cron(8), are started through the system start up scripts. These scripts may differ depending on FreeBSD or vendor version; however, the most important aspect to consider is that their start up configuration can be handled through simple startup scripts.

Before the advent of `rc.d`, applications would drop a simple start up script into the `/usr/local/etc/rc.d` directory which would be read by the system initialization scripts. These scripts would then be executed during the latter stages of system start up.

While many individuals have spent hours trying to merge the old configuration style into the new system, the fact remains that some third party utilities still require a script simply dropped into the aforementioned directory. The subtle differences in the scripts depend whether or not `rc.d` is being used. Prior to FreeBSD 5.1 the old configuration style is used and in almost all cases a new style script would do just fine.

While every script must meet some minimal requirements, most of the time these requirements are FreeBSD version agnostic. Each script must have a `.sh` extension appended to the end and every script must be executable by the system. The latter may be achieved by using the `chmod` command and setting the unique permissions of `755`. There should also be, at minimal, an option to `start` the application and an option to `stop` the application.

The simplest start up script would probably look a little bit like this one:

```
#!/bin/sh
echo -n ' utility'

case "$1" in
start)
        /usr/local/bin/utility
        -;;
stop)
        kill -9 `cat /var/run/utility.pid`
        -;;
*)
        echo "Usage: `basename $0` {start|stop}" >&2
        exit 64
        -;;
esac

exit 0
```

This script provides for a `stop` and `start` option for the application hereto referred simply as `utility`.

Could be started manually with:

```
# /usr/local/etc/rc.d/utility.sh start
```

While not all third party software requires the line in `rc.conf`, almost every day a new port will be modified to accept this configuration. Check the final output of the installation for more information on a specific application. Some third party software will provide start up scripts which permit the application to be used with `rc.d`; although, this will be discussed in the next section.

11.4.1. Extended Application Configuration

Now that FreeBSD includes `rc.d`, configuration of application startup has become easier, and more featureful. Using the key words discussed in the rc.d section, applications may now be set to start after certain other services for example DNS; may permit extra flags to be passed through `rc.conf` in place of hard coded flags in the start up script, etc. A basic script may look similar to the following:

```
#!/bin/sh
#
# PROVIDE: utility
# REQUIRE: DAEMON
# KEYWORD: shutdown

. /etc/rc.subr

name=utility
rcvar=utility_pidfile

command="/usr/local/sbin/utility"

load_rc_config $name
```

```
#
# DO NOT CHANGE THESE DEFAULT VALUES HERE
# SET THEM IN THE /etc/rc.conf FILE
#
utility_enable=${utility_enable-"NO"}
pidfile=${utility_pidfile-"/var/run/utility.pid"}

run_rc_command "$1"
```

This script will ensure that the provided utility will be started after the `daemon` service. It also provides a method for setting and tracking the PID, or process ID file.

This application could then have the following line placed in `/etc/rc.conf`:

```
utility_enable="YES"
```

This new method also allows for easier manipulation of the command line arguments, inclusion of the default functions provided in `/etc/rc.subr`, compatibility with the rcorder(8) utility and provides for easier configuration via the `rc.conf` file.

11.4.2. 以 Services 來啓動各式 Services

Other services, such as POP3 server daemons, IMAP, etc. could be started using the inetd(8). This involves installing the service utility from the Ports Collection with a configuration line appended to the `/etc/inetd.conf` file, or uncommenting one of the current configuration lines. Working with inetd and its configuration is described in depth in the inetd section.

In some cases, it may be more plausible to use the cron(8) daemon to start system services. This approach has a number of advantages because `cron` runs these processes as the `crontab`'s file owner. This allows regular users to start and maintain some applications.

The `cron` utility provides a unique feature, `@reboot`, which may be used in place of the time specification. This will cause the job to be run when cron(8) is started, normally during system initialization.

11.5. 設定 cron

Contributed by Tom Rhodes.

FreeBSD 最好用的工具之一就是 cron(8)。 `cron` 會在背景下運作，並不斷檢查 `/etc/crontab` 檔以及 `/var/cron/tabs` 目錄，來搜尋是否有新 `crontab` 檔案。 這些 `crontab` 檔會存放一些排程工作的設定，來給 `cron` 執行。

`cron` 程式，可同時採用兩種不同類型的設定檔：系統本身的 crontab 及使用者本身的 `crontab`。而兩種格式唯一差別在於第六欄的不同；In the system crontab, the sixth field is the name of a user for the command to run as. This gives the system crontab the ability to run commands as any user. In a user crontab, the sixth field is the command to run, and all commands run as the user who created the crontab; this is an important security feature.

注意

User crontabs allow individual users to schedule tasks without the need for `root` privileges. Commands in a user's crontab run with the permissions of the user who owns the crontab.

The `root` user can have a user crontab just like any other user. This one is different from `/etc/crontab` (the system crontab). Because of the system crontab, there is usually no need to create a user crontab for `root`.

Let us take a look at the `/etc/crontab` file (the system crontab):

```
# /etc/crontab - root's crontab for FreeBSD
#
# $FreeBSD: src/etc/crontab,v 1.32 2002/11/22 16:13:39 tom Exp $
# ❶
#
SHELL=/bin/sh
PATH=/etc:/bin:/sbin:/usr/bin:/usr/sbin ❷
HOME=/var/log
#
#
#minute hour mday month wday who command ❸
#
#
*/5 * * * * root /usr/libexec/atrun ❹
```

❶ Like most FreeBSD configuration files, the # character represents a comment. A comment can be placed in the file as a reminder of what and why a desired action is performed. Comments cannot be on the same line as a command or else they will be interpreted as part of the command; they must be on a new line. Blank lines are ignored.

❷ First, the environment must be defined. The equals (=) character is used to define any environment settings, as with this example where it is used for the `SHELL`, `PATH`, and `HOME` options. If the shell line is omitted, `cron` will use the default, which is `sh`. If the `PATH` variable is omitted, no default will be used and file locations will need to be absolute. If `HOME` is omitted, `cron` will use the invoking users home directory.

❸ This line defines a total of seven fields. Listed here are the values `minute`, `hour`, `mday`, `month`, `wday`, `who`, and `command`. These are almost all self explanatory. `minute` is the time in minutes the command will be run. `hour` is similar to the `minute` option, just in hours. `mday` stands for day of the month. `month` is similar to `hour` and `minute`, as it designates the month. The `wday` option stands for day of the week. All these fields must be numeric values, and follow the twenty-four hour clock. The `who` field is special, and only exists in the `/etc/crontab` file. This field specifies which user the command should be run as. When a user installs his or her `crontab` file, they will not have this option. Finally, the `command` option is listed. This is the last field, so naturally it should designate the command to be executed.

❹ This last line will define the values discussed above. Notice here we have a `*/5` listing, followed by several more * characters. These * characters mean “first-last”, and can be interpreted as every time. So, judging by this line, it is apparent that the `atrun` command is to be invoked by `root` every five minutes regardless of what day or month it is. For more information on the `atrun` command, see the atrun(8) manual page.

Commands can have any number of flags passed to them; however, commands which extend to multiple lines need to be broken with the backslash “\” continuation character.

This is the basic set up for every `crontab` file, although there is one thing different about this one. Field number six, where we specified the username, only exists in the system `/etc/crontab` file. This field should be omitted for individual user `crontab` files.

11.5.1. 工作排程(Crontab)的排定與管理

重要

You must not use the procedure described here to edit/install the system crontab. Simply use your favorite editor: the `cron` utility will notice that the file has changed and immediately begin using the updated version. See this FAQ entry for more information.

To install a freshly written user `crontab`, first use your favorite editor to create a file in the proper format, and then use the `crontab` utility. The most common usage is:

```
% crontab crontab-file
```

In this example, `crontab-file` is the filename of a `crontab` that was previously created.

There is also an option to list installed `crontab` files: just pass the `-l` option to `crontab` and look over the output.

For users who wish to begin their own crontab file from scratch, without the use of a template, the `crontab -e` option is available. This will invoke the selected editor with an empty file. When the file is saved, it will be automatically installed by the `crontab` command.

If you later want to remove your user `crontab` completely, use `crontab` with the `-r` option.

11.6. 在 FreeBSD 使用 rc

Contributed by Tom Rhodes.

從 2002 年起，FreeBSD 整合了 NetBSD 的 `rc.d` 機制來作為系統服務啓動機制。 可以到 `/etc/rc.d` 目錄下去看，很多檔案都是基本服務，可以用 `start`, `stop` 及 `restart` 作為使用時的選項。 舉個例子，可以用下列指令來重新啓動 sshd(8)：

```
# /etc/rc.d/sshd restart
```

其他服務也是類似作法。當然， 服務通常只要在 rc.conf(5) 內有指定的話，都會在開機時就自動啓動。舉例來說，若要開機時啓動 NAT(Network Address Translation) daemon 的話，只要在 `/etc/rc.conf` 內加上下列這行即可：

```
natd_enable="YES"
```

若原本寫的是 `natd_enable="NO"` 那麼只要把 `NO` 改為 `YES` 就好了。`rc` scripts 會在下次重開機時，自動載入相關(有相依)的服務，以下我們會講到這部分。

Since the `rc.d` system is primarily intended to start/stop services at system startup/shutdown time, the standard `start`, `stop` and `restart` options will only perform their action if the appropriate `/etc/rc.conf` variables are set. For instance the above `sshd restart` command will only work if `sshd_enable` is set to `YES` in `/etc/rc.conf`. To `start`, `stop` or `restart` a service regardless of the settings in `/etc/rc.conf`, the commands should be prefixed with "force". For instance to restart `sshd` regardless of the current `/etc/rc.conf` setting, execute the following command:

```
# /etc/rc.d/sshd forcerestart
```

It is easy to check if a service is enabled in `/etc/rc.conf` by running the appropriate `rc.d` script with the option `rcvar`. Thus, an administrator can check that `sshd` is in fact enabled in `/etc/rc.conf` by running:

```
# /etc/rc.d/sshd rcvar
# sshd
$sshd_enable=YES
```

注意

The second line (`# sshd`) is the output from the `sshd` command, not a `root` console.

若要檢查服務是否有在運作，可以用 `status` 選項來查詢。比如：若要確認 `sshd` 是否真的有啓動的話，那麼打：

```
# /etc/rc.d/sshd status
sshd is running as pid 433.
```

In some cases it is also possible to `reload` a service. This will attempt to send a signal to an individual service, forcing the service to reload its configuration files. In most cases this means sending the service a `SIGHUP` signal. Support for this feature is not included for every service.

The `rc.d` system is not only used for network services, it also contributes to most of the system initialization. For instance, consider the `bgfsck` file. When this script is executed, it will print out the following message:

```
Starting background file system checks in 60 seconds.
```

Therefore this file is used for background file system checks, which are done only during system initialization.

Many system services depend on other services to function properly. For example, NIS and other RPC-based services may fail to start until after the `rpcbind` (portmapper) service has started. To resolve this issue, information about dependencies and other meta-data is included in the comments at the top of each startup script. The rcorder(8) program is then used to parse these comments during system initialization to determine the order in which system services should be invoked to satisfy the dependencies. The following words may be included at the top of each startup file:

- `PROVIDE`: Specifies the services this file provides.
- `REQUIRE`: Lists services which are required for this service. This file will run after the specified services.
- `BEFORE`: Lists services which depend on this service. This file will run before the specified services.

By using this method, an administrator can easily control system services without the hassle of “runlevels” like some other UNIX® operating systems.

Additional information about the `rc.d` system can be found in the rc(8) and rc.subr(8) manual pages.

11.7. 設定網路卡

Contributed by Marc Fonvieille.

Nowadays we can not think about a computer without thinking about a network connection. Adding and configuring a network card is a common task for any FreeBSD administrator.

11.7.1. 選擇正確、可用的驅動程式(Driver)

Before you begin, you should know the model of the card you have, the chip it uses, and whether it is a PCI or ISA card. FreeBSD supports a wide variety of both PCI and ISA cards. Check the Hardware Compatibility List for your release to see if your card is supported.

Once you are sure your card is supported, you need to determine the proper driver for the card. `/usr/src/sys/conf/NOTES` and `/usr/src/sys/arch/conf/NOTES` will give you the list of network interface drivers with some information about the supported chipsets/cards. If you have doubts about which driver is the correct one, read the manual page of the driver. The manual page will give you more information about the supported hardware and even the possible problems that could occur.

If you own a common card, most of the time you will not have to look very hard for a driver. Drivers for common network cards are present in the `GENERIC` kernel, so your card should show up during boot, like so:

```
dc0: <82c169 PNIC 10/100BaseTX> port 0xa000-0xa0ff mem 0xd3800000-0xd38
000ff irq 15 at device 11.0 on pci0
dc0: Ethernet address: 00:a0:cc:da:da:da
miibus0: <MII bus> on dc0
ukphy0: <Generic IEEE 802.3u media interface> on miibus0
ukphy0:  10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
dc1: <82c169 PNIC 10/100BaseTX> port 0x9800-0x98ff mem 0xd3000000-0xd30
000ff irq 11 at device 12.0 on pci0
dc1: Ethernet address: 00:a0:cc:da:da:db
miibus1: <MII bus> on dc1
ukphy1: <Generic IEEE 802.3u media interface> on miibus1
ukphy1:  10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
```

In this example, we see that two cards using the dc(4) driver are present on the system.

If the driver for your NIC is not present in `GENERIC`, you will need to load the proper driver to use your NIC. This may be accomplished in one of two ways:

- The easiest way is to simply load a kernel module for your network card with kldload(8), or automatically at boot time by adding the appropriate line to the file `/boot/loader.conf`. Not all NIC drivers are available as modules; notable examples of devices for which modules do not exist are ISA cards.

- Alternatively, you may statically compile the support for your card into your kernel. Check `/usr/src/sys/conf/NOTES`, `/usr/src/sys/arch/conf/NOTES` and the manual page of the driver to know what to add in your kernel configuration file. For more information about recompiling your kernel, please see 章 8, 設定 FreeBSD Kernel. If your card was detected at boot by your kernel (`GENERIC`) you do not have to build a new kernel.

11.7.1.1. Using Windows® NDIS Drivers

Unfortunately, there are still many vendors that do not provide schematics for their drivers to the open source community because they regard such information as trade secrets. Consequently, the developers of FreeBSD and other operating systems are left two choices: develop the drivers by a long and pain-staking process of reverse engineering or using the existing driver binaries available for the Microsoft® Windows® platforms. Most developers, including those involved with FreeBSD, have taken the latter approach.

Thanks to the contributions of Bill Paul (wpaul), as of FreeBSD 5.3-RELEASE there is “native” support for the Network Driver Interface Specification (NDIS). The FreeBSD NDISulator (otherwise known as Project Evil) takes a Windows® driver binary and basically tricks it into thinking it is running on Windows®. Because the ndis(4) driver is using a Windows® binary, it is only usable on i386™ and amd64 systems.

注意

The ndis(4) driver is designed to support mainly PCI, CardBus and PCMCIA devices, USB devices are not yet supported.

In order to use the NDISulator, you need three things:

1. Kernel sources

2. Windows® XP driver binary (`.SYS` extension)

3. Windows® XP driver configuration file (`.INF` extension)

Locate the files for your specific card. Generally, they can be found on the included CDs or at the vendors' websites. In the following examples, we will use `W32DRIVER.SYS` and `W32DRIVER.INF`.

注意

You can not use a Windows®/i386 driver with FreeBSD/amd64, you must get a Windows®/amd64 driver to make it work properly.

The next step is to compile the driver binary into a loadable kernel module. To accomplish this, as `root`, use ndisgen(8):

```
# ndisgen /path/to/W32DRIVER.INF /path/to/W32DRIVER.SYS
```

The ndisgen(8) utility is interactive and will prompt for any extra information it requires; it will produce a kernel module in the current directory which can be loaded as follows:

```
# kldload ./W32DRIVER.ko
```

In addition to the generated kernel module, you must load the `ndis.ko` and `if_ndis.ko` modules. This should be automatically done when you load any module that depends on ndis(4). If you want to load them manually, use the following commands:

```
# kldload ndis
# kldload if_ndis
```

The first command loads the NDIS miniport driver wrapper, the second loads the actual network interface.

Now, check dmesg(8) to see if there were any errors loading. If all went well, you should get output resembling the following:

```
ndis0: <Wireless-G PCI Adapter> mem 0xf4100000-0xf4101fff irq 3 at device 8.0 on pci1
ndis0: NDIS API version: 5.0
ndis0: Ethernet address: 0a:b1:2c:d3:4e:f5
ndis0: 11b rates: 1Mbps 2Mbps 5.5Mbps 11Mbps
ndis0: 11g rates: 6Mbps 9Mbps 12Mbps 18Mbps 36Mbps 48Mbps 54Mbps
```

From here you can treat the `ndis0` device like any other network interface (e.g., `dc0`).

You can configure the system to load the NDIS modules at boot time in the same way as with any other module. First, copy the generated module, `W32DRIVER.ko` , to the `/boot/modules` directory. Then, add the following line to `/boot/loader.conf` :

```
W32DRIVER_load="YES"
```

11.7.2. 設定網路卡

Once the right driver is loaded for the network card, the card needs to be configured. As with many other things, the network card may have been configured at installation time by sysinstall.

To display the configuration for the network interfaces on your system, enter the following command:

```
% ifconfig
dc0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 192.168.1.3 netmask 0xffffff00 broadcast 192.168.1.255
        ether 00:a0:cc:da:da:da
        media: Ethernet autoselect (100baseTX <full-duplex>)
        status: active
dc1: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 10.0.0.1 netmask 0xffffff00 broadcast 10.0.0.255
        ether 00:a0:cc:da:da:db
        media: Ethernet 10baseT/UTP
```

```
        status: no carrier
lp0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet 127.0.0.1 netmask 0xff000000
tun0: flags=8010<POINTOPOINT,MULTICAST> mtu 1500
```

注意

Old versions of FreeBSD may require the `-a` option following ifconfig(8), for more details about the correct syntax of ifconfig(8), please refer to the manual page. Note also that entries concerning IPv6 (`inet6` etc.) were omitted in this example.

In this example, the following devices were displayed:

- `dc0`: The first Ethernet interface
- `dc1`: The second Ethernet interface
- `lp0`: The parallel port interface
- `lo0`: The loopback device
- `tun0`: The tunnel device used by ppp

FreeBSD uses the driver name followed by the order in which one the card is detected at the kernel boot to name the network card. For example `sis2` would be the third network card on the system using the sis(4) driver.

In this example, the `dc0` device is up and running. The key indicators are:

1. `UP` means that the card is configured and ready.
2. The card has an Internet (`inet`) address (in this case `192.168.1.3`).
3. It has a valid subnet mask (`netmask`; `0xffffff00` is the same as `255.255.255.0`).
4. It has a valid broadcast address (in this case, `192.168.1.255`).
5. The MAC address of the card (`ether`) is `00:a0:cc:da:da:da`
6. The physical media selection is on autoselection mode (`media: Ethernet autoselect (100baseTX <full-duplex>)`). We see that `dc1` was configured to run with `10baseT/UTP` media. For more information on available media types for a driver, please refer to its manual page.
7. The status of the link (`status`) is `active`, i.e. the carrier is detected. For `dc1`, we see `status: no carrier`. This is normal when an Ethernet cable is not plugged into the card.

If the ifconfig(8) output had shown something similar to:

```
dc0: flags=8843<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
        ether 00:a0:cc:da:da:da
```

it would indicate the card has not been configured.

To configure your card, you need `root` privileges. The network card configuration can be done from the command line with ifconfig(8) but you would have to do it after each reboot of the system. The file `/etc/rc.conf` is where to add the network card's configuration.

Open `/etc/rc.conf` in your favorite editor. You need to add a line for each network card present on the system, for example in our case, we added these lines:

```
ifconfig_dc0="inet 192.168.1.3 netmask 255.255.255.0"
ifconfig_dc1="inet 10.0.0.1 netmask 255.255.255.0 media 10baseT/UTP"
```

You have to replace `dc0`, `dc1`, and so on, with the correct device for your cards, and the addresses with the proper ones. You should read the card driver and ifconfig(8) manual pages for more details about the allowed options and also rc.conf(5) manual page for more information on the syntax of `/etc/rc.conf` .

If you configured the network during installation, some lines about the network card(s) may be already present. Double check `/etc/rc.conf` before adding any lines.

You will also have to edit the file `/etc/hosts` to add the names and the IP addresses of various machines of the LAN, if they are not already there. For more information please refer to hosts(5) and to `/usr/share/examples/etc/hosts` .

11.7.3. 測試與疑難排除

Once you have made the necessary changes in `/etc/rc.conf` , you should reboot your system. This will allow the change(s) to the interface(s) to be applied, and verify that the system restarts without any configuration errors.

Once the system has been rebooted, you should test the network interfaces.

11.7.3.1. 測試乙太網路卡(Ethernet Card)

To verify that an Ethernet card is configured correctly, you have to try two things. First, ping the interface itself, and then ping another machine on the LAN.

First test the local interface:

```
% ping -c5 192.168.1.3
PING 192.168.1.3 (192.168.1.3): 56 data bytes
64 bytes from 192.168.1.3: icmp_seq=0 ttl=64 time=0.082 ms
64 bytes from 192.168.1.3: icmp_seq=1 ttl=64 time=0.074 ms
64 bytes from 192.168.1.3: icmp_seq=2 ttl=64 time=0.076 ms
64 bytes from 192.168.1.3: icmp_seq=3 ttl=64 time=0.108 ms
64 bytes from 192.168.1.3: icmp_seq=4 ttl=64 time=0.076 ms

--- 192.168.1.3 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.074/0.083/0.108/0.013 ms
```

Now we have to ping another machine on the LAN:

```
% ping -c5 192.168.1.2
PING 192.168.1.2 (192.168.1.2): 56 data bytes
64 bytes from 192.168.1.2: icmp_seq=0 ttl=64 time=0.726 ms
64 bytes from 192.168.1.2: icmp_seq=1 ttl=64 time=0.766 ms
64 bytes from 192.168.1.2: icmp_seq=2 ttl=64 time=0.700 ms
64 bytes from 192.168.1.2: icmp_seq=3 ttl=64 time=0.747 ms
64 bytes from 192.168.1.2: icmp_seq=4 ttl=64 time=0.704 ms

--- 192.168.1.2 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.700/0.729/0.766/0.025 ms
```

You could also use the machine name instead of `192.168.1.2` if you have set up the `/etc/hosts` file.

11.7.3.2. 疑難排除

Troubleshooting hardware and software configurations is always a pain, and a pain which can be alleviated by checking the simple things first. Is your network cable plugged in? Have you properly configured the network services? Did you configure the firewall correctly? Is the card you are using supported by FreeBSD? Always check the hardware notes before sending off a bug report. Update your version of FreeBSD to the latest STABLE version. Check the mailing list archives, or perhaps search the Internet.

If the card works, yet performance is poor, it would be worthwhile to read over the tuning(7) manual page. You can also check the network configuration as incorrect network settings can cause slow connections.

Some users experience one or two device timeout messages, which is normal for some cards. If they continue, or are bothersome, you may wish to be sure the device is not conflicting with another device. Double check the cable connections. Perhaps you may just need to get another card.

At times, users see a few watchdog timeout errors. The first thing to do here is to check your network cable. Many cards require a PCI slot which supports Bus Mastering. On some old motherboards, only one PCI slot allows it (usually slot 0). Check the network card and the motherboard documentation to determine if that may be the problem.

No route to host messages occur if the system is unable to route a packet to the destination host. This can happen if no default route is specified, or if a cable is unplugged. Check the output of `netstat -rn` and make sure there is a valid route to the host you are trying to reach. If there is not, read on to 章 30, 網路進階練功房.

ping: sendto: Permission denied error messages are often caused by a misconfigured firewall. If `ipfw` is enabled in the kernel but no rules have been defined, then the default policy is to deny all traffic, even ping requests! Read on to 章 29, 防火牆 for more information.

Sometimes performance of the card is poor, or below average. In these cases it is best to set the media selection mode from `autoselect` to the correct media selection. While this usually works for most hardware, it may not resolve this issue for everyone. Again, check all the network settings, and read over the tuning(7) manual page.

11.8. 虛擬主機(Virtual Hosts)

A very common use of FreeBSD is virtual site hosting, where one server appears to the network as many servers. This is achieved by assigning multiple network addresses to a single interface.

A given network interface has one “real” address, and may have any number of “alias” addresses. These aliases are normally added by placing alias entries in `/etc/rc.conf` .

An alias entry for the interface `fxp0` looks like:

```
ifconfig_fxp0_alias0="inet xxx.xxx.xxx.xxx netmask xxx.xxx.xxx.xxx"
```

Note that alias entries must start with `alias0` and proceed upwards in order, (for example, `_alias1`, `_alias2` , and so on). The configuration process will stop at the first missing number.

The calculation of alias netmasks is important, but fortunately quite simple. For a given interface, there must be one address which correctly represents the network's netmask. Any other addresses which fall within this network must have a netmask of all `1`s (expressed as either `255.255.255.255` or `0xffffffff`).

For example, consider the case where the `fxp0` interface is connected to two networks, the `10.1.1.0` network with a netmask of `255.255.255.0` and the `202.0.75.16` network with a netmask of `255.255.255.240` . We want the system to appear at `10.1.1.1` through `10.1.1.5` and at `202.0.75.17` through `202.0.75.20` . As noted above, only the first address in a given network range (in this case, `10.0.1.1` and `202.0.75.17`) should have a real netmask; all the rest (`10.1.1.2` through `10.1.1.5` and `202.0.75.18` through `202.0.75.20`) must be configured with a netmask of `255.255.255.255` .

The following `/etc/rc.conf` entries configure the adapter correctly for this arrangement:

```
ifconfig_fxp0="inet 10.1.1.1 netmask 255.255.255.0"
ifconfig_fxp0_alias0="inet 10.1.1.2 netmask 255.255.255.255"
ifconfig_fxp0_alias1="inet 10.1.1.3 netmask 255.255.255.255"
ifconfig_fxp0_alias2="inet 10.1.1.4 netmask 255.255.255.255"
ifconfig_fxp0_alias3="inet 10.1.1.5 netmask 255.255.255.255"
ifconfig_fxp0_alias4="inet 202.0.75.17 netmask 255.255.255.240"
```

```
ifconfig_fxp0_alias5="inet 202.0.75.18 netmask 255.255.255.255"
ifconfig_fxp0_alias6="inet 202.0.75.19 netmask 255.255.255.255"
ifconfig_fxp0_alias7="inet 202.0.75.20 netmask 255.255.255.255"
```

11.9. 還有哪些主要設定檔呢？

11.9.1. /etc Layout

There are a number of directories in which configuration information is kept. These include:

/etc	Generic system configuration information; data here is system-specific.
/etc/defaults	Default versions of system configuration files.
/etc/mail	Extra sendmail(8) configuration, other MTA configuration files.
/etc/ppp	Configuration for both user- and kernel-ppp programs.
/etc/namedb	Default location for named(8) data. Normally named.conf and zone files are stored here.
/usr/local/etc	Configuration files for installed applications. May contain per-application subdirectories.
/usr/local/etc/rc.d	Start/stop scripts for installed applications.
/var/db	Automatically generated system-specific database files, such as the package database, the locate database, and so on

11.9.2. Hostnames

11.9.2.1. /etc/resolv.conf

/etc/resolv.conf dictates how FreeBSD's resolver accesses the Internet Domain Name System (DNS).

The most common entries to resolv.conf are:

nameserver	The IP address of a name server the resolver should query. The servers are queried in the order listed with a maximum of three.
search	Search list for hostname lookup. This is normally determined by the domain of the local hostname.
domain	The local domain name.

A typical resolv.conf :

```
search example.com
nameserver 147.11.1.11
nameserver 147.11.100.30
```

注意

Only one of the search and domain options should be used.

If you are using DHCP, dhclient(8) usually rewrites resolv.conf with information received from the DHCP server.

11.9.2.2. /etc/hosts

`/etc/hosts` is a simple text database reminiscent of the old Internet. It works in conjunction with DNS and NIS providing name to IP address mappings. Local computers connected via a LAN can be placed in here for simplistic naming purposes instead of setting up a named(8) server. Additionally, `/etc/hosts` can be used to provide a local record of Internet names, reducing the need to query externally for commonly accessed names.

```
# $FreeBSD$
#
# Host Database
# This file should contain the addresses and aliases
# for local hosts that share this file.
# In the presence of the domain name service or NIS, this file may
# not be consulted at all; see /etc/nsswitch.conf for the resolution order.
#
#
::1                     localhost localhost.my.domain myname.my.domain
127.0.0.1               localhost localhost.my.domain myname.my.domain

#
# Imaginary network.
#10.0.0.2               myname.my.domain myname
#10.0.0.3               myfriend.my.domain myfriend
#
# According to RFC 1918, you can use the following IP networks for
# private nets which will never be connected to the Internet:
#
#       10.0.0.0        -   10.255.255.255
#       172.16.0.0      -   172.31.255.255
#       192.168.0.0     -   192.168.255.255
#
# In case you want to be able to connect to the Internet, you need
# real official assigned numbers.  PLEASE PLEASE PLEASE do not try
# to invent your own network numbers but instead get one from your
# network provider (if any) or from the Internet Registry (ftp to
# rs.internic.net, directory `/templates').
#
```

`/etc/hosts` takes on the simple format of:

```
[Internet address] [official hostname] [alias1] [alias2] ...
```

For example:

```
10.0.0.1 myRealHostname.example.com myRealHostname foobar1 foobar2
```

Consult hosts(5) for more information.

11.9.3. Log File Configuration

11.9.3.1. `syslog.conf`

`syslog.conf` is the configuration file for the syslogd(8) program. It indicates which types of `syslog` messages are logged to particular log files.

```
# $FreeBSD$
#
#       Spaces ARE valid field separators in this file. However,
#       other *nix-like systems still insist on using tabs as field
#       separators. If you are sharing this file between systems, you
#       may want to use only tabs as field separators here.
#       Consult the syslog.conf(5) manual page.
*.err;kern.debug;auth.notice;mail.crit          /dev/console
*.notice;kern.debug;lpr.info;mail.crit;news.err /var/log/messages
security.*                                      /var/log/security
mail.info                                       /var/log/maillog
lpr.info                                        /var/log/lpd-errs
```

```
cron.*                                          /var/log/cron
*.err                                           root
*.notice;news.err                               root
*.alert                                         root
*.emerg                                         *
# uncomment this to log all writes to /dev/console to /var/log/console.log
#console.info                                  /var/log/console.log
# uncomment this to enable logging of all log messages to /var/log/all.log
#*.*                                           /var/log/all.log
# uncomment this to enable logging to a remote log host named loghost
#*.*                                           @loghost
# uncomment these if you're running inn
# news.crit                                     /var/log/news/news.crit
# news.err                                      /var/log/news/news.err
# news.notice                                   /var/log/news/news.notice
!startslip
*.*                                             /var/log/slip.log
!ppp
*.*                                             /var/log/ppp.log
```

Consult the syslog.conf(5) manual page for more information.

11.9.3.2. `newsyslog.conf`

`newsyslog.conf` is the configuration file for newsyslog(8), a program that is normally scheduled to run by cron(8). newsyslog(8) determines when log files require archiving or rearranging. `logfile` is moved to `logfile.0`, `logfile.0` is moved to `logfile.1`, and so on. Alternatively, the log files may be archived in gzip(1) format causing them to be named: `logfile.0.gz`, `logfile.1.gz`, and so on.

`newsyslog.conf` indicates which log files are to be managed, how many are to be kept, and when they are to be touched. Log files can be rearranged and/or archived when they have either reached a certain size, or at a certain periodic time/date.

```
# configuration file for newsyslog
# $FreeBSD$
#
# filename          [owner:group]    mode count size when [ZB] [/pid_file] [sig_num]
/var/log/cron                         600  3     100  *     Z
/var/log/amd.log                      644  7     100  *     Z
/var/log/kerberos.log                 644  7     100  *     Z
/var/log/lpd-errs                     644  7     100  *     Z
/var/log/maillog                      644  7     *    @T00  Z
/var/log/sendmail.st                  644  10    *    168   B
/var/log/messages                     644  5     100  *     Z
/var/log/all.log                      600  7     *    @T00  Z
/var/log/slip.log                     600  3     100  *     Z
/var/log/ppp.log                      600  3     100  *     Z
/var/log/security                     600  10    100  *     Z
/var/log/wtmp                         644  3     *    @01T05 B
/var/log/daily.log                    640  7     *    @T00  Z
/var/log/weekly.log                   640  5     1    $W6D0 Z
/var/log/monthly.log                  640  12    *    $M1D0 Z
/var/log/console.log                  640  5     100  *     Z
```

Consult the newsyslog(8) manual page for more information.

11.9.4. `sysctl.conf`

`sysctl.conf` looks much like `rc.conf`. Values are set in a `variable=value` form. The specified values are set after the system goes into multi-user mode. Not all variables are settable in this mode.

A sample `sysctl.conf` turning off logging of fatal signal exits and letting Linux programs know they are really running under FreeBSD:

```
kern.logsigexit=0       # Do not log fatal signal exits (e.g. sig 11)
compat.linux.osname=FreeBSD
compat.linux.osrelease=4.3-STABLE
```

11.10. Tuning with sysctl

sysctl(8) is an interface that allows you to make changes to a running FreeBSD system. This includes many advanced options of the TCP/IP stack and virtual memory system that can dramatically improve performance for an experienced system administrator. Over five hundred system variables can be read and set using sysctl(8).

At its core, sysctl(8) serves two functions: to read and to modify system settings.

To view all readable variables:

```
% sysctl -a
```

To read a particular variable, for example, `kern.maxproc` :

```
% sysctl kern.maxproc
kern.maxproc: 1044
```

To set a particular variable, use the intuitive *`variable`*=*`value`* syntax:

```
# sysctl kern.maxfiles=5000
kern.maxfiles: 2088 -> 5000
```

Settings of sysctl variables are usually either strings, numbers, or booleans (a boolean being `1` for yes or a `0` for no).

If you want to set automatically some variables each time the machine boots, add them to the `/etc/sysctl.conf` file. For more information see the sysctl.conf(5) manual page and the 節 11.9.4, “`sysctl.conf`”.

11.10.1. sysctl(8) Read-only

Contributed by Tom Rhodes.

In some cases it may be desirable to modify read-only sysctl(8) values. While this is sometimes unavoidable, it can only be done on (re)boot.

For instance on some laptop models the cardbus(4) device will not probe memory ranges, and fail with errors which look similar to:

```
cbb0: Could not map register memory
device_probe_and_attach: cbb0 attach returned 12
```

Cases like the one above usually require the modification of some default sysctl(8) settings which are set read only. To overcome these situations a user can put sysctl(8) “OIDs” in their local `/boot/loader.conf` . Default settings are located in the `/boot/defaults/loader.conf` file.

Fixing the problem mentioned above would require a user to set `hw.pci.allow_unsupported_io_range=1` in the aforementioned file. Now cardbus(4) will work properly.

11.11. Tuning Disks

11.11.1. Sysctl Variables

11.11.1.1. `vfs.vmiodirenable`

The `vfs.vmiodirenable` sysctl variable may be set to either 0 (off) or 1 (on); it is 1 by default. This variable controls how directories are cached by the system. Most directories are small, using just a single fragment (typically 1 K) in the file system and less (typically 512 bytes) in the buffer cache. With this variable turned off (to 0), the buffer cache will only cache a fixed number of directories even if you have a huge amount of memory. When turned on (to 1), this sysctl allows the buffer cache to use the VM Page Cache to cache the directories, making all the memory available for caching directories. However, the minimum in-core memory used to cache a directory is the physical page size (typically 4 K) rather than 512 bytes. We recommend keeping this option on if you are running any services which manipulate large numbers of files. Such services can include web caches, large mail systems, and news systems. Keeping this option on will generally not reduce performance even with the wasted memory but you should experiment to find out.

11.11.1.2. `vfs.write_behind`

The `vfs.write_behind` sysctl variable defaults to `1` (on). This tells the file system to issue media writes as full clusters are collected, which typically occurs when writing large sequential files. The idea is to avoid saturating the buffer cache with dirty buffers when it would not benefit I/O performance. However, this may stall processes and under certain circumstances you may wish to turn it off.

11.11.1.3. `vfs.hirunningspace`

The `vfs.hirunningspace` sysctl variable determines how much outstanding write I/O may be queued to disk controllers system-wide at any given instance. The default is usually sufficient but on machines with lots of disks you may want to bump it up to four or five megabytes. Note that setting too high a value (exceeding the buffer cache's write threshold) can lead to extremely bad clustering performance. Do not set this value arbitrarily high! Higher write values may add latency to reads occurring at the same time.

There are various other buffer-cache and VM page cache related sysctls. We do not recommend modifying these values, the VM system does an extremely good job of automatically tuning itself.

11.11.1.4. `vm.swap_idle_enabled`

The `vm.swap_idle_enabled` sysctl variable is useful in large multi-user systems where you have lots of users entering and leaving the system and lots of idle processes. Such systems tend to generate a great deal of continuous pressure on free memory reserves. Turning this feature on and tweaking the swapout hysteresis (in idle seconds) via `vm.swap_idle_threshold1` and `vm.swap_idle_threshold2` allows you to depress the priority of memory pages associated with idle processes more quickly then the normal pageout algorithm. This gives a helping hand to the pageout daemon. Do not turn this option on unless you need it, because the tradeoff you are making is essentially pre-page memory sooner rather than later; thus eating more swap and disk bandwidth. In a small system this option will have a determinable effect but in a large system that is already doing moderate paging this option allows the VM system to stage whole processes into and out of memory easily.

11.11.1.5. `hw.ata.wc`

FreeBSD 4.3 flirted with turning off IDE write caching. This reduced write bandwidth to IDE disks but was considered necessary due to serious data consistency issues introduced by hard drive vendors. The problem is that IDE drives lie about when a write completes. With IDE write caching turned on, IDE hard drives not only write data to disk out of order, but will sometimes delay writing some blocks indefinitely when under heavy disk loads. A crash or power failure may cause serious file system corruption. FreeBSD's default was changed to be safe. Unfortunately, the result was such a huge performance loss that we changed write caching back to on by default after the release. You should check the default on your system by observing the `hw.ata.wc` sysctl variable. If IDE write caching is turned off, you can turn it back on by setting the kernel variable back to 1. This must be done from the boot loader at boot time. Attempting to do it after the kernel boots will have no effect.

For more information, please see ata(4).

11.11.1.6. SCSI_DELAY (`kern.cam.scsi_delay`)

The `SCSI_DELAY` kernel config may be used to reduce system boot times. The defaults are fairly high and can be responsible for `15` seconds of delay in the boot process. Reducing it to `5` seconds usually works (especially with modern drives). Newer versions of FreeBSD (5.0 and higher) should use the `kern.cam.scsi_delay` boot time tunable. The tunable, and kernel config option accept values in terms of milliseconds and not seconds.

11.11.2. Soft Updates

The tunefs(8) program can be used to fine-tune a file system. This program has many different options, but for now we are only concerned with toggling Soft Updates on and off, which is done by:

```
# tunefs -n enable /filesystem
# tunefs -n disable /filesystem
```

A filesystem cannot be modified with tunefs(8) while it is mounted. A good time to enable Soft Updates is before any partitions have been mounted, in single-user mode.

Soft Updates drastically improves meta-data performance, mainly file creation and deletion, through the use of a memory cache. We recommend to use Soft Updates on all of your file systems. There are two downsides to Soft Updates that you should be aware of: First, Soft Updates guarantees filesystem consistency in the case of a crash but could very easily be several seconds (even a minute!) behind updating the physical disk. If your system crashes you may lose more work than otherwise. Secondly, Soft Updates delays the freeing of filesystem blocks. If you have a filesystem (such as the root filesystem) which is almost full, performing a major update, such as `make installworld` , can cause the filesystem to run out of space and the update to fail.

11.11.2.1. More Details about Soft Updates

There are two traditional approaches to writing a file systems meta-data back to disk. (Meta-data updates are updates to non-content data like inodes or directories.)

Historically, the default behavior was to write out meta-data updates synchronously. If a directory had been changed, the system waited until the change was actually written to disk. The file data buffers (file contents) were passed through the buffer cache and backed up to disk later on asynchronously. The advantage of this implementation is that it operates safely. If there is a failure during an update, the meta-data are always in a consistent state. A file is either created completely or not at all. If the data blocks of a file did not find their way out of the buffer cache onto the disk by the time of the crash, fsck(8) is able to recognize this and repair the filesystem by setting the file length to 0. Additionally, the implementation is clear and simple. The disadvantage is that meta-data changes are slow. An `rm -r`, for instance, touches all the files in a directory sequentially, but each directory change (deletion of a file) will be written synchronously to the disk. This includes updates to the directory itself, to the inode table, and possibly to indirect blocks allocated by the file. Similar considerations apply for unrolling large hierarchies (`tar -x`).

The second case is asynchronous meta-data updates. This is the default for Linux/ext2fs and `mount -o async` for *BSD ufs. All meta-data updates are simply being passed through the buffer cache too, that is, they will be intermixed with the updates of the file content data. The advantage of this implementation is there is no need to wait until each meta-data update has been written to disk, so all operations which cause huge amounts of meta-data updates work much faster than in the synchronous case. Also, the implementation is still clear and simple, so there is a low risk for bugs creeping into the code. The disadvantage is that there is no guarantee at all for a consistent state of the filesystem. If there is a failure during an operation that updated large amounts of meta-data (like a power failure, or someone pressing the reset button), the filesystem will be left in an unpredictable state. There is no opportunity to examine the state of the filesystem when the system comes up again; the data blocks of a file could already have been written to the disk while the updates of the inode table or the associated directory were not. It is actually impossible to implement a `fsck` which is able to clean up the resulting chaos (because the necessary information is not available on the disk). If the filesystem has been damaged beyond repair, the only choice is to use newfs(8) on it and restore it from backup.

The usual solution for this problem was to implement dirty region logging, which is also referred to as journaling, although that term is not used consistently and is occasionally applied to other forms of transaction logging as well. Meta-data updates are still written synchronously, but only into a small region of the disk. Later on they will be moved to their proper location. Because the logging area is a small, contiguous region on the disk, there are no long distances for the disk heads to move, even during heavy operations, so these operations are quicker than synchronous updates. Additionally the complexity of the implementation is fairly limited, so the risk of bugs being present is low. A disadvantage is that all meta-data are written twice (once into the logging region and once to the proper location) so for normal work, a performance "pessimization" might result. On the other hand, in case of a crash, all pending meta-data operations can be quickly either rolled-back or completed from the logging area after the system comes up again, resulting in a fast filesystem startup.

Kirk McKusick, the developer of Berkeley FFS, solved this problem with Soft Updates: all pending meta-data updates are kept in memory and written out to disk in a sorted sequence ("ordered meta-data updates"). This has the effect that, in case of heavy meta-data operations, later updates to an item "catch" the earlier ones if the earlier ones are still in memory and have not already been written to disk. So all operations on, say, a directory are generally performed in memory before the update is written to disk (the data blocks are sorted according to their position so that they will not be on the disk ahead of their meta-data). If the system crashes, this causes an implicit "log rewind": all operations which did not find their way to the disk appear as if they had never happened. A consistent filesystem state is maintained that appears to be the one of 30 to 60 seconds earlier. The algorithm used guarantees that all resources in use are marked as such in their appropriate bitmaps: blocks and inodes. After a crash, the only resource allocation error that occurs is that resources are marked as "used" which are actually "free". fsck(8) recognizes this situation, and frees the resources that are no longer used. It is safe to ignore the dirty state of the filesystem after a crash by forcibly mounting it with `mount -f`. In order to free resources that may be unused, fsck(8) needs to be run at a later time. This is the idea behind the background fsck: at system startup time, only a snapshot of the filesystem is recorded. The `fsck` can be run later on. All file systems can then be mounted "dirty", so the system startup proceeds in multiuser mode. Then, background `fsck`s will be scheduled for all file systems where this is required, to free resources that may be unused. (File systems that do not use Soft Updates still need the usual foreground `fsck` though.)

The advantage is that meta-data operations are nearly as fast as asynchronous updates (i.e. faster than with logging, which has to write the meta-data twice). The disadvantages are the complexity of the code (implying a higher risk for bugs in an area that is highly sensitive regarding loss of user data), and a higher memory consumption. Additionally there are some idiosyncrasies one has to get used to. After a crash, the state of the filesystem appears to be somewhat "older". In situations where the standard synchronous approach would have caused some zero-length files to remain after the `fsck`, these files do not exist at all with a Soft Updates filesystem because neither the meta-data nor the file contents have ever been written to disk. Disk space is not released until the updates have been written to disk, which may take place some time after running `rm`. This may cause problems when installing large amounts of data on a filesystem that does not have enough free space to hold all the files twice.

11.12. Tuning Kernel Limits

11.12.1. File/Process Limits

11.12.1.1. `kern.maxfiles`

`kern.maxfiles` can be raised or lowered based upon your system requirements. This variable indicates the maximum number of file descriptors on your system. When the file descriptor table is full, file: table is full will show up repeatedly in the system message buffer, which can be viewed with the `dmesg` command.

Each open file, socket, or fifo uses one file descriptor. A large-scale production server may easily require many thousands of file descriptors, depending on the kind and number of services running concurrently.

In older FreeBSD releases, `kern.maxfile` 's default value is derived from the `maxusers` option in your dictated by the `maxusers` option in your kernel configuration file. `kern.maxfiles` grows proportionally to

the value of `maxusers`. When compiling a custom kernel, it is a good idea to set this kernel configuration option according to the uses of your system. From this number, the kernel is given most of its pre-defined limits. Even though a production machine may not actually have 256 users connected at once, the resources needed may be similar to a high-scale web server.

As of FreeBSD 4.5, `kern.maxusers` is automatically sized at boot based on the amount of memory available in the system, and may be determined at run-time by inspecting the value of the read-only `kern.maxusers` sysctl. Some sites will require larger or smaller values of `kern.maxusers` and may set it as a loader tunable; values of 64, 128, and 256 are not uncommon. We do not recommend going above 256 unless you need a huge number of file descriptors; many of the tunable values set to their defaults by `kern.maxusers` may be individually overridden at boot-time or run-time in `/boot/loader.conf` (see the loader.conf(5) man page or the `/boot/defaults/loader.conf` file for some hints) or as described elsewhere in this document. Systems older than FreeBSD 4.4 must set this value via the kernel config(8) option `maxusers` instead.

The system will auto-tune `maxusers` for you if you explicitly set it to `0`[1]. When setting this option, you will want to set `maxusers` to at least 4, especially if you are using the X Window System or compiling software. The reason is that the most important table set by `maxusers` is the maximum number of processes, which is set to `20 + 16 * maxusers`, so if you set `maxusers` to 1, then you can only have 36 simultaneous processes, including the 18 or so that the system starts up at boot time and the 15 or so you will probably create when you start the X Window System. Even a simple task like reading a manual page will start up nine processes to filter, decompress, and view it. Setting `maxusers` to 64 will allow you to have up to 1044 simultaneous processes, which should be enough for nearly all uses. If, however, you see the dreaded proc table full error when trying to start another program, or are running a server with a large number of simultaneous users (like `ftp.FreeBSD.org`), you can always increase the number and rebuild.

注意

`maxusers` does not limit the number of users which can log into your machine. It simply sets various table sizes to reasonable values considering the maximum number of users you will likely have on your system and how many processes each of them will be running. One keyword which does limit the number of simultaneous remote logins and X terminal windows is `pseudo-device pty 16`. With FreeBSD 5.X, you do not have to worry about this number since the pty(4) driver is "auto-cloning"; you simply use the line `device pty` in your configuration file.

11.12.1.2. `kern.ipc.somaxconn`

The `kern.ipc.somaxconn` sysctl variable limits the size of the listen queue for accepting new TCP connections. The default value of `128` is typically too low for robust handling of new connections in a heavily loaded web server environment. For such environments, it is recommended to increase this value to `1024` or higher. The service daemon may itself limit the listen queue size (e.g. sendmail(8), or Apache) but will often have a directive in its configuration file to adjust the queue size. Large listen queues also do a better job of avoiding Denial of Service (DoS) attacks.

11.12.2. Network Limits

The `NMBCLUSTERS` kernel configuration option dictates the amount of network Mbufs available to the system. A heavily-trafficked server with a low number of Mbufs will hinder FreeBSD's ability. Each cluster represents approximately 2 K of memory, so a value of 1024 represents 2 megabytes of kernel memory reserved for network buffers. A simple calculation can be done to figure out how many are needed. If you have a web server which maxes out at 1000 simultaneous connections, and each connection eats a 16 K receive and 16 K send buffer, you need

[1]The auto-tuning algorithm sets `maxusers` equal to the amount of memory in the system, with a minimum of 32, and a maximum of 384.

approximately 32 MB worth of network buffers to cover the web server. A good rule of thumb is to multiply by 2, so 2x32 MB / 2 KB = 64 MB / 2 kB = 32768. We recommend values between 4096 and 32768 for machines with greater amounts of memory. Under no circumstances should you specify an arbitrarily high value for this parameter as it could lead to a boot time crash. The `-m` option to netstat(1) may be used to observe network cluster use.

`kern.ipc.nmbclusters` loader tunable should be used to tune this at boot time. Only older versions of FreeBSD will require you to use the `NMBCLUSTERS` kernel config(8) option.

For busy servers that make extensive use of the sendfile(2) system call, it may be necessary to increase the number of sendfile(2) buffers via the `NSFBUFS` kernel configuration option or by setting its value in `/boot/loader.conf` (see loader(8) for details). A common indicator that this parameter needs to be adjusted is when processes are seen in the `sfbufa` state. The sysctl variable `kern.ipc.nsfbufs` is a read-only glimpse at the kernel configured variable. This parameter nominally scales with `kern.maxusers` , however it may be necessary to tune accordingly.

重要

Even though a socket has been marked as non-blocking, calling sendfile(2) on the non-blocking socket may result in the sendfile(2) call blocking until enough `struct sf_buf` 's are made available.

11.12.2.1. `net.inet.ip.portrange.*`

The `net.inet.ip.portrange.*` sysctl variables control the port number ranges automatically bound to TCP and UDP sockets. There are three ranges: a low range, a default range, and a high range. Most network programs use the default range which is controlled by the `net.inet.ip.portrange.first` and `net.inet.ip.portrange.last` , which default to 1024 and 5000, respectively. Bound port ranges are used for outgoing connections, and it is possible to run the system out of ports under certain circumstances. This most commonly occurs when you are running a heavily loaded web proxy. The port range is not an issue when running servers which handle mainly incoming connections, such as a normal web server, or has a limited number of outgoing connections, such as a mail relay. For situations where you may run yourself out of ports, it is recommended to increase `net.inet.ip.portrange.last` modestly. A value of `10000`, `20000` or `30000` may be reasonable. You should also consider firewall effects when changing the port range. Some firewalls may block large ranges of ports (usually low-numbered ports) and expect systems to use higher ranges of ports for outgoing connections —— for this reason it is not recommended that `net.inet.ip.portrange.first` be lowered.

11.12.2.2. TCP Bandwidth Delay Product

The TCP Bandwidth Delay Product Limiting is similar to TCP/Vegas in NetBSD. It can be enabled by setting `net.inet.tcp.inflight.enable` sysctl variable to `1`. The system will attempt to calculate the bandwidth delay product for each connection and limit the amount of data queued to the network to just the amount required to maintain optimum throughput.

This feature is useful if you are serving data over modems, Gigabit Ethernet, or even high speed WAN links (or any other link with a high bandwidth delay product), especially if you are also using window scaling or have configured a large send window. If you enable this option, you should also be sure to set `net.inet.tcp.inflight.debug` to `0` (disable debugging), and for production use setting `net.inet.tcp.inflight.min` to at least `6144` may be beneficial. However, note that setting high minimums may effectively disable bandwidth limiting depending on the link. The limiting feature reduces the amount of data built up in intermediate route and switch packet queues as well as reduces the amount of data built up in the local host's interface queue. With fewer packets queued up, interactive connections, especially over slow modems, will also be able to operate with lower Round Trip Times. However, note that this feature only effects data transmission (uploading / server side). It has no effect on data reception (downloading).

Adjusting `net.inet.tcp.inflight.stab` is not recommended. This parameter defaults to 20, representing 2 maximal packets added to the bandwidth delay product window calculation. The additional window is required to stabilize the algorithm and improve responsiveness to changing conditions, but it can also result in higher ping times over slow links (though still much lower than you would get without the inflight algorithm). In such cases, you may wish to try reducing this parameter to 15, 10, or 5; and may also have to reduce `net.inet.tcp.inflight.min` (for example, to 3500) to get the desired effect. Reducing these parameters should be done as a last resort only.

11.12.3. Virtual Memory

11.12.3.1. `kern.maxvnodes`

A vnode is the internal representation of a file or directory. So increasing the number of vnodes available to the operating system cuts down on disk I/O. Normally this is handled by the operating system and does not need to be changed. In some cases where disk I/O is a bottleneck and the system is running out of vnodes, this setting will need to be increased. The amount of inactive and free RAM will need to be taken into account.

To see the current number of vnodes in use:

```
# sysctl vfs.numvnodes
vfs.numvnodes: 91349
```

To see the maximum vnodes:

```
# sysctl kern.maxvnodes
kern.maxvnodes: 100000
```

If the current vnode usage is near the maximum, increasing `kern.maxvnodes` by a value of 1,000 is probably a good idea. Keep an eye on the number of `vfs.numvnodes`. If it climbs up to the maximum again, `kern.maxvnodes` will need to be increased further. A shift in your memory usage as reported by top(1) should be visible. More memory should be active.

11.13. Adding Swap Space

No matter how well you plan, sometimes a system does not run as you expect. If you find you need more swap space, it is simple enough to add. You have three ways to increase swap space: adding a new hard drive, enabling swap over NFS, and creating a swap file on an existing partition.

For information on how to encrypt swap space, what options for this task exist and why it should be done, please refer to 節 17.14, “Encrypting Swap” of the Handbook.

11.13.1. Swap on a New Hard Drive

The best way to add swap, of course, is to use this as an excuse to add another hard drive. You can always use another hard drive, after all. If you can do this, go reread the discussion of swap space in 節 2.6.1, “Designing the Partition Layout” of the Handbook for some suggestions on how to best arrange your swap.

11.13.2. Swapping over NFS

Swapping over NFS is only recommended if you do not have a local hard disk to swap to; NFS swapping will be limited by the available network bandwidth and puts an additional burden on the NFS server.

11.13.3. Swapfiles

You can create a file of a specified size to use as a swap file. In our example here we will use a 64MB file called `/usr/swap0`. You can use any name you want, of course.

範例 11.1. Creating a Swapfile on FreeBSD

1. Be certain that your kernel configuration includes the memory disk driver (md(4)). It is default in `GENERIC` kernel.

```
device   md   # Memory "disks"
```

2. Create a swapfile (`/usr/swap0`):

```
# dd if=/dev/zero of=/usr/swap0 bs=1024k count=64
```

3. Set proper permissions on (`/usr/swap0`):

```
# chmod 0600 /usr/swap0
```

4. Enable the swap file in `/etc/rc.conf` :

```
swapfile="/usr/swap0"   # Set to name of swapfile if aux swapfile desired.
```

5. Reboot the machine or to enable the swap file immediately, type:

```
# mdconfig -a -t vnode -f /usr/swap0 -u 0 && swapon /dev/md0
```

11.14. Power and Resource Management

Written by Hiten Pandya # Tom Rhodes.

It is very important to utilize hardware resources in an efficient manner. Before ACPI was introduced, it was very difficult and inflexible for operating systems to manage the power usage and thermal properties of a system. The hardware was controlled by some sort of BIOS embedded interface, such as Plug and Play BIOS (PNPBIOS), or Advanced Power Management (APM) and so on. Power and Resource Management is one of the key components of a modern operating system. For example, you may want an operating system to monitor system limits (and possibly alert you) in case your system temperature increased unexpectedly.

In this section of the FreeBSD Handbook, we will provide comprehensive information about ACPI. References will be provided for further reading at the end.

11.14.1. What Is ACPI?

Advanced Configuration and Power Interface (ACPI) is a standard written by an alliance of vendors to provide a standard interface for hardware resources and power management (hence the name). It is a key element in Operating System-directed configuration and Power Management, i.e.: it provides more control and flexibility to the operating system (OS). Modern systems “stretched” the limits of the current Plug and Play interfaces prior to the introduction of ACPI. ACPI is the direct successor to APM (Advanced Power Management).

11.14.2. Shortcomings of Advanced Power Management (APM)

The Advanced Power Management (APM) facility controls the power usage of a system based on its activity. The APM BIOS is supplied by the (system) vendor and it is specific to the hardware platform. An APM driver in the OS mediates access to the APM Software Interface, which allows management of power levels.

There are four major problems in APM. Firstly, power management is done by the (vendor-specific) BIOS, and the OS does not have any knowledge of it. One example of this, is when the user sets idle-time values for a hard drive

in the APM BIOS, that when exceeded, it (BIOS) would spin down the hard drive, without the consent of the OS. Secondly, the APM logic is embedded in the BIOS, and it operates outside the scope of the OS. This means users can only fix problems in their APM BIOS by flashing a new one into the ROM; which is a very dangerous procedure with the potential to leave the system in an unrecoverable state if it fails. Thirdly, APM is a vendor-specific technology, which means that there is a lot of parity (duplication of efforts) and bugs found in one vendor's BIOS, may not be solved in others. Last but not the least, the APM BIOS did not have enough room to implement a sophisticated power policy, or one that can adapt very well to the purpose of the machine.

Plug and Play BIOS (PNPBIOS) was unreliable in many situations. PNPBIOS is 16-bit technology, so the OS has to use 16-bit emulation in order to “interface” with PNPBIOS methods.

The FreeBSD APM driver is documented in the apm(4) manual page.

11.14.3. Configuring ACPI

The `acpi.ko` driver is loaded by default at start up by the loader(8) and should not be compiled into the kernel. The reasoning behind this is that modules are easier to work with, say if switching to another `acpi.ko` without doing a kernel rebuild. This has the advantage of making testing easier. Another reason is that starting ACPI after a system has been brought up is not too useful, and in some cases can be fatal. In doubt, just disable ACPI all together. This driver should not and can not be unloaded because the system bus uses it for various hardware interactions. ACPI can be disabled with the acpiconf(8) utility. In fact most of the interaction with ACPI can be done via acpiconf(8). Basically this means, if anything about ACPI is in the dmesg(8) output, then most likely it is already running.

注意

ACPI and APM cannot coexist and should be used separately. The last one to load will terminate if the driver notices the other running.

In the simplest form, ACPI can be used to put the system into a sleep mode with acpiconf(8), the `-s` flag, and a `1-5` option. Most users will only need `1`. Option `5` will do a soft-off which is the same action as:

```
# halt -p
```

The other options are available. Check out the acpiconf(8) manual page for more information.

11.15. Using and Debugging FreeBSD ACPI

Written by Nate Lawson.
With contributions from Peter Schultz # Tom Rhodes.

ACPI is a fundamentally new way of discovering devices, managing power usage, and providing standardized access to various hardware previously managed by the BIOS. Progress is being made toward ACPI working on all systems, but bugs in some motherboards' ACPI Machine Language (AML) bytecode, incompleteness in FreeBSD's kernel subsystems, and bugs in the Intel® ACPI-CA interpreter continue to appear.

This document is intended to help you assist the FreeBSD ACPI maintainers in identifying the root cause of problems you observe and debugging and developing a solution. Thanks for reading this and we hope we can solve your system's problems.

11.15.1. Submitting Debugging Information

注意

Before submitting a problem, be sure you are running the latest BIOS version and, if available, embedded controller firmware version.

For those of you that want to submit a problem right away, please send the following information to freebsd-acpi@FreeBSD.org:

- Description of the buggy behavior, including system type and model and anything that causes the bug to appear. Also, please note as accurately as possible when the bug began occurring if it is new for you.
- The dmesg(8) output after `boot -v`, including any error messages generated by you exercising the bug.
- The dmesg(8) output from `boot -v` with ACPI disabled, if disabling it helps fix the problem.
- Output from `sysctl hw.acpi` . This is also a good way of figuring out what features your system offers.
- URL where your ACPI Source Language (ASL) can be found. Do not send the ASL directly to the list as it can be very large. Generate a copy of your ASL by running this command:

  ```
  # acpidump -t -d > name-system.asl
  ```

  (Substitute your login name for *`name`* and manufacturer/model for *`system`*. Example: `njl-FooCo6000.asl`)

Most of the developers watch the FreeBSD-CURRENT 郵遞論壇 but please submit problems to freebsd-acpi to be sure it is seen. Please be patient, all of us have full-time jobs elsewhere. If your bug is not immediately apparent, we will probably ask you to submit a PR via send-pr(1). When entering a PR, please include the same information as requested above. This will help us track the problem and resolve it. Do not send a PR without emailing freebsd-acpi first as we use PRs as reminders of existing problems, not a reporting mechanism. It is likely that your problem has been reported by someone before.

11.15.2. Background

ACPI is present in all modern computers that conform to the ia32 (x86), ia64 (Itanium), and amd64 (AMD) architectures. The full standard has many features including CPU performance management, power planes control, thermal zones, various battery systems, embedded controllers, and bus enumeration. Most systems implement less than the full standard. For instance, a desktop system usually only implements the bus enumeration parts while a laptop might have cooling and battery management support as well. Laptops also have suspend and resume, with their own associated complexity.

An ACPI-compliant system has various components. The BIOS and chipset vendors provide various fixed tables (e.g., FADT) in memory that specify things like the APIC map (used for SMP), config registers, and simple configuration values. Additionally, a table of bytecode (the Differentiated System Description Table DSDT) is provided that specifies a tree-like name space of devices and methods.

The ACPI driver must parse the fixed tables, implement an interpreter for the bytecode, and modify device drivers and the kernel to accept information from the ACPI subsystem. For FreeBSD, Intel® has provided an interpreter (ACPI-CA) that is shared with Linux and NetBSD. The path to the ACPI-CA source code is `src/sys/contrib/dev/acpica` . The glue code that allows ACPI-CA to work on FreeBSD is in `src/sys/dev/acpica/Osd` . Finally, drivers that implement various ACPI devices are found in `src/sys/dev/acpica` .

11.15.3. Common Problems

For ACPI to work correctly, all the parts have to work correctly. Here are some common problems, in order of frequency of appearance, and some possible workarounds or fixes.

11.15.3.1. Mouse Issues

In some cases, resuming from a suspend operation will cause the mouse to fail. A known work around is to add `hint.psm.0.flags="0x3000"` to the `/boot/loader.conf` file. If this does not work then please consider sending a bug report as described above.

11.15.3.2. Suspend/Resume

ACPI has three suspend to RAM (STR) states, `S1`-`S3`, and one suspend to disk state (`STD`), called `S4`. `S5` is "soft off" and is the normal state your system is in when plugged in but not powered up. `S4` can actually be implemented two separate ways. `S4`BIOS is a BIOS-assisted suspend to disk. `S4`OS is implemented entirely by the operating system.

Start by checking `sysctl hw.acpi` for the suspend-related items. Here are the results for a Thinkpad:

```
hw.acpi.supported_sleep_state: S3 S4 S5
hw.acpi.s4bios: 0
```

This means that we can use `acpiconf -s` to test `S3`, `S4`OS, and `S5`. If `s4bios` was one (`1`), we would have `S4`BIOS support instead of `S4` OS.

When testing suspend/resume, start with `S1`, if supported. This state is most likely to work since it does not require much driver support. No one has implemented `S2` but if you have it, it is similar to `S1`. The next thing to try is `S3`. This is the deepest STR state and requires a lot of driver support to properly reinitialize your hardware. If you have problems resuming, feel free to email the freebsd-acpi list but do not expect the problem to be resolved since there are a lot of drivers/hardware that need more testing and work.

To help isolate the problem, remove as many drivers from your kernel as possible. If it works, you can narrow down which driver is the problem by loading drivers until it fails again. Typically binary drivers like `nvidia.ko`, X11 display drivers, and USB will have the most problems while Ethernet interfaces usually work fine. If you can properly load/unload the drivers, you can automate this by putting the appropriate commands in `/etc/rc.suspend` and `/etc/rc.resume`. There is a commented-out example for unloading and loading a driver. Try setting `hw.acpi.reset_video` to zero (`0`) if your display is messed up after resume. Try setting longer or shorter values for `hw.acpi.sleep_delay` to see if that helps.

Another thing to try is load a recent Linux distribution with ACPI support and test their suspend/resume support on the same hardware. If it works on Linux, it is likely a FreeBSD driver problem and narrowing down which driver causes the problems will help us fix the problem. Note that the ACPI maintainers do not usually maintain other drivers (e.g sound, ATA, etc.) so any work done on tracking down a driver problem should probably eventually be posted to the freebsd-current list and mailed to the driver maintainer. If you are feeling adventurous, go ahead and start putting some debugging printf(3)s in a problematic driver to track down where in its resume function it hangs.

Finally, try disabling ACPI and enabling APM instead. If suspend/resume works with APM, you may be better off sticking with APM, especially on older hardware (pre-2000). It took vendors a while to get ACPI support correct and older hardware is more likely to have BIOS problems with ACPI.

11.15.3.3. System Hangs (temporary or permanent)

Most system hangs are a result of lost interrupts or an interrupt storm. Chipsets have a lot of problems based on how the BIOS configures interrupts before boot, correctness of the APIC (MADT) table, and routing of the System Control Interrupt (SCI).

Interrupt storms can be distinguished from lost interrupts by checking the output of `vmstat -i` and looking at the line that has `acpi0`. If the counter is increasing at more than a couple per second, you have an interrupt storm. If the system appears hung, try breaking to DDB (CTRL+ALT+ESC on console) and type `show interrupts`.

Your best hope when dealing with interrupt problems is to try disabling APIC support with `hint.apic.0.disabled="1"` in `loader.conf`.

11.15.3.4. Panics

Panics are relatively rare for ACPI and are the top priority to be fixed. The first step is to isolate the steps to reproduce the panic (if possible) and get a backtrace. Follow the advice for enabling `options DDB` and setting up a serial console (see 節 25.6.5.3, "Entering the DDB Debugger from the Serial Line") or setting up a dump(8) partition. You can get a backtrace in DDB with `tr`. If you have to handwrite the backtrace, be sure to at least get the lowest five (5) and top five (5) lines in the trace.

Then, try to isolate the problem by booting with ACPI disabled. If that works, you can isolate the ACPI subsystem by using various values of `debug.acpi.disable`. See the acpi(4) manual page for some examples.

11.15.3.5. System Powers Up After Suspend or Shutdown

First, try setting `hw.acpi.disable_on_poweroff="0"` in loader.conf(5). This keeps ACPI from disabling various events during the shutdown process. Some systems need this value set to `1` (the default) for the same reason. This usually fixes the problem of a system powering up spontaneously after a suspend or poweroff.

11.15.3.6. Other Problems

If you have other problems with ACPI (working with a docking station, devices not detected, etc.), please email a description to the mailing list as well; however, some of these issues may be related to unfinished parts of the ACPI subsystem so they might take a while to be implemented. Please be patient and prepared to test patches we may send you.

11.15.4. ASL, `acpidump`, and IASL

The most common problem is the BIOS vendors providing incorrect (or outright buggy!) bytecode. This is usually manifested by kernel console messages like this:

```
ACPI-1287: *** Error: Method execution failed [\\_SB_.PCI0.LPC0.FIGD._STA] \\
(Node 0xc3f6d160), AE_NOT_FOUND
```

Often, you can resolve these problems by updating your BIOS to the latest revision. Most console messages are harmless but if you have other problems like battery status not working, they are a good place to start looking for problems in the AML. The bytecode, known as AML, is compiled from a source language called ASL. The AML is found in the table known as the DSDT. To get a copy of your ASL, use acpidump(8). You should use both the `-t` (show contents of the fixed tables) and `-d` (disassemble AML to ASL) options. See the Submitting Debugging Information section for an example syntax.

The simplest first check you can do is to recompile your ASL to check for errors. Warnings can usually be ignored but errors are bugs that will usually prevent ACPI from working correctly. To recompile your ASL, issue the following command:

```
# iasl your.asl
```

11.15.5. Fixing Your ASL

In the long run, our goal is for almost everyone to have ACPI work without any user intervention. At this point, however, we are still developing workarounds for common mistakes made by the BIOS vendors. The Microsoft® interpreter (`acpi.sys` and `acpiec.sys`) does not strictly check for adherence to the standard, and thus many BIOS vendors who only test ACPI under Windows® never fix their ASL. We hope to continue to identify and document exactly what non-standard behavior is allowed by Microsoft®'s interpreter and replicate it so FreeBSD can work without forcing users to fix the ASL. As a workaround and to help us identify behavior, you can fix the

ASL manually. If this works for you, please send a diff(1) of the old and new ASL so we can possibly work around the buggy behavior in ACPI-CA and thus make your fix unnecessary.

Here is a list of common error messages, their cause, and how to fix them:

11.15.5.1. _OS dependencies

Some AML assumes the world consists of various Windows® versions. You can tell FreeBSD to claim it is any OS to see if this fixes problems you may have. An easy way to override this is to set `hw.acpi.osname="Windows 2001"` in `/boot/loader.conf` or other similar strings you find in the ASL.

11.15.5.2. Missing Return statements

Some methods do not explicitly return a value as the standard requires. While ACPI-CA does not handle this, FreeBSD has a workaround that allows it to return the value implicitly. You can also add explicit Return statements where required if you know what value should be returned. To force `iasl` to compile the ASL, use the `-f` flag.

11.15.5.3. Overriding the Default AML

After you customize `your.asl`, you will want to compile it, run:

```
# iasl your.asl
```

You can add the `-f` flag to force creation of the AML, even if there are errors during compilation. Remember that some errors (e.g., missing Return statements) are automatically worked around by the interpreter.

`DSDT.aml` is the default output filename for `iasl`. You can load this instead of your BIOS's buggy copy (which is still present in flash memory) by editing `/boot/loader.conf` as follows:

```
acpi_dsdt_load="YES"
acpi_dsdt_name="/boot/DSDT.aml"
```

Be sure to copy your `DSDT.aml` to the `/boot` directory.

11.15.6. Getting Debugging Output From ACPI

The ACPI driver has a very flexible debugging facility. It allows you to specify a set of subsystems as well as the level of verbosity. The subsystems you wish to debug are specified as "layers" and are broken down into ACPI-CA components (ACPI_ALL_COMPONENTS) and ACPI hardware support (ACPI_ALL_DRIVERS). The verbosity of debugging output is specified as the "level" and ranges from ACPI_LV_ERROR (just report errors) to ACPI_LV_VERBOSE (everything). The "level" is a bitmask so multiple options can be set at once, separated by spaces. In practice, you will want to use a serial console to log the output if it is so long it flushes the console message buffer. A full list of the individual layers and levels is found in the acpi(4) manual page.

Debugging output is not enabled by default. To enable it, add `options ACPI_DEBUG` to your kernel configuration file if ACPI is compiled into the kernel. You can add `ACPI_DEBUG=1` to your `/etc/make.conf` to enable it globally. If it is a module, you can recompile just your `acpi.ko` module as follows:

```
# cd /sys/modules/acpi/acpi
&& make clean &&
make ACPI_DEBUG=1
```

Install `acpi.ko` in `/boot/kernel` and add your desired level and layer to `loader.conf`. This example enables debug messages for all ACPI-CA components and all ACPI hardware drivers (CPU, LID, etc.) It will only output error messages, the least verbose level.

```
debug.acpi.layer="ACPI_ALL_COMPONENTS ACPI_ALL_DRIVERS"
debug.acpi.level="ACPI_LV_ERROR"
```

If the information you want is triggered by a specific event (say, a suspend and then resume), you can leave out changes to `loader.conf` and instead use `sysctl` to specify the layer and level after booting and preparing your system for the specific event. The `sysctl`s are named the same as the tunables in `loader.conf`.

11.15.7. References

More information about ACPI may be found in the following locations:

- The FreeBSD ACPI 郵遞論壇
- The ACPI Mailing List Archives `http://lists.freebsd.org/pipermail/freebsd-acpi/`
- The old ACPI Mailing List Archives `http://home.jp.FreeBSD.org/mail-list/acpi-jp/`
- The ACPI 2.0 Specification `http://acpi.info/spec.htm`
- FreeBSD Manual pages: acpi(4), acpi_thermal(4), acpidump(8), iasl(8), acpidb(8)
- DSDT debugging resource. (Uses Compaq as an example but generally useful.)

章 12. FreeBSD 開機流程篇

12.1. 概述

The process of starting a computer and loading the operating system is referred to as “the bootstrap process”, or simply “booting”. FreeBSD's boot process provides a great deal of flexibility in customizing what happens when you start the system, allowing you to select from different operating systems installed on the same computer, or even different versions of the same operating system or installed kernel.

This chapter details the configuration options you can set and how to customize the FreeBSD boot process. This includes everything that happens until the FreeBSD kernel has started, probed for devices, and started init(8). If you are not quite sure when this happens, it occurs when the text color changes from bright white to grey.

讀完這章，您將了解：

- What the components of the FreeBSD bootstrap system are, and how they interact.
- The options you can give to the components in the FreeBSD bootstrap to control the boot process.
- device.hints(5) 的基本概念。

x86 Only

This chapter only describes the boot process for FreeBSD running on Intel x86 systems.

12.2. Booting 問題

Turning on a computer and starting the operating system poses an interesting dilemma. By definition, the computer does not know how to do anything until the operating system is started. This includes running programs from the disk. So if the computer can not run a program from the disk without the operating system, and the operating system programs are on the disk, how is the operating system started?

This problem parallels one in the book The Adventures of Baron Munchausen. A character had fallen part way down a manhole, and pulled himself out by grabbing his bootstraps, and lifting. In the early days of computing the term bootstrap was applied to the mechanism used to load the operating system, which has become shortened to “booting”.

On x86 hardware the Basic Input/Output System (BIOS) is responsible for loading the operating system. To do this, the BIOS looks on the hard disk for the Master Boot Record (MBR), which must be located on a specific place on the disk. The BIOS has enough knowledge to load and run the MBR, and assumes that the MBR can then carry out the rest of the tasks involved in loading the operating system, possibly with the help of the BIOS.

The code within the MBR is usually referred to as a boot manager, especially when it interacts with the user. In this case the boot manager usually has more code in the first track of the disk or within some OS's file system. (A boot manager is sometimes also called a boot loader, but FreeBSD uses that term for a later stage of booting.) Popular boot managers include boot0 (a.k.a. Boot Easy, the standard FreeBSD boot manager), Grub, GAG, and LILO. (Only boot0 fits within the MBR.)

If you have only one operating system installed on your disks then a standard PC MBR will suffice. This MBR searches for the first bootable (a.k.a. active) slice on the disk, and then runs the code on that slice to load the

remainder of the operating system. The MBR installed by fdisk(8), by default, is such an MBR. It is based on `/boot/mbr`.

If you have installed multiple operating systems on your disks then you can install a different boot manager, one that can display a list of different operating systems, and allows you to choose the one to boot from. Two of these are discussed in the next subsection.

The remainder of the FreeBSD bootstrap system is divided into three stages. The first stage is run by the MBR, which knows just enough to get the computer into a specific state and run the second stage. The second stage can do a little bit more, before running the third stage. The third stage finishes the task of loading the operating system. The work is split into these three stages because the PC standards put limits on the size of the programs that can be run at stages one and two. Chaining the tasks together allows FreeBSD to provide a more flexible loader.

The kernel is then started and it begins to probe for devices and initialize them for use. Once the kernel boot process is finished, the kernel passes control to the user process init(8), which then makes sure the disks are in a usable state. init(8) then starts the user-level resource configuration which mounts file systems, sets up network cards to communicate on the network, and generally starts all the processes that usually are run on a FreeBSD system at startup.

12.3. The Boot Manager and Boot Stages

12.3.1. The Boot Manager

The code in the MBR or boot manager is sometimes referred to as stage zero of the boot process. This subsection discusses two of the boot managers previously mentioned: boot0 and LILO.

The boot0 Boot Manager: The MBR installed by FreeBSD's installer or boot0cfg(8), by default, is based on `/boot/boot0`. (The boot0 program is very simple, since the program in the MBR can only be 446 bytes long because of the slice table and 0x55AA identifier at the end of the MBR.) If you have installed boot0 and multiple operating systems on your hard disks, then you will see a display similar to this one at boot time:

範例 12.1. **boot0** Screenshot

```
F1 DOS
F2 FreeBSD
F3 Linux
F4 ??
F5 Drive 1

Default: F2
```

Other operating systems, in particular Windows®, have been known to overwrite an existing MBR with their own. If this happens to you, or you want to replace your existing MBR with the FreeBSD MBR then use the following command:

```
# fdisk -B -b /boot/boot0 device
```

where *`device`* is the device that you boot from, such as `ad0` for the first IDE disk, `ad2` for the first IDE disk on a second IDE controller, `da0` for the first SCSI disk, and so on. Or, if you want a custom configuration of the MBR, use boot0cfg(8).

The LILO Boot Manager: To install this boot manager so it will also boot FreeBSD, first start Linux and add the following to your existing `/etc/lilo.conf` configuration file:

```
other=/dev/hdXY
table=/dev/hdX
loader=/boot/chain.b
label=FreeBSD
```

In the above, specify FreeBSD's primary partition and drive using Linux specifiers, replacing *X* with the Linux drive letter and *Y* with the Linux primary partition number. If you are using a SCSI drive, you will need to change */dev/hd* to read something similar to */dev/sd*. The `loader=/boot/chain.b` line can be omitted if you have both operating systems on the same drive. Now run `/sbin/lilo -v` to commit your new changes to the system; this should be verified by checking its screen messages.

12.3.2. Stage One, /boot/boot1, and Stage Two, /boot/boot2

Conceptually the first and second stages are part of the same program, on the same area of the disk. Because of space constraints they have been split into two, but you would always install them together. They are copied from the combined file `/boot/boot` by the installer or disklabel (see below).

They are located outside file systems, in the first track of the boot slice, starting with the first sector. This is where boot0, or any other boot manager, expects to find a program to run which will continue the boot process. The number of sectors used is easily determined from the size of `/boot/boot` .

`boot1` is very simple, since it can only be 512 bytes in size, and knows just enough about the FreeBSD disklabel, which stores information about the slice, to find and execute `boot2`.

`boot2` is slightly more sophisticated, and understands the FreeBSD file system enough to find files on it, and can provide a simple interface to choose the kernel or loader to run.

Since the loader is much more sophisticated, and provides a nice easy-to-use boot configuration, `boot2` usually runs it, but previously it was tasked to run the kernel directly.

範例 12.2. **boot2** Screenshot

```
>> FreeBSD/i386 BOOT
Default: 0:ad(0,a)/kernel
boot:
```

If you ever need to replace the installed `boot1` and `boot2` use disklabel(8):

```
# disklabel -B diskslice
```

where *diskslice* is the disk and slice you boot from, such as `ad0s1` for the first slice on the first IDE disk.

Dangerously Dedicated Mode

If you use just the disk name, such as `ad0`, in the disklabel(8) command you will create a dangerously dedicated disk, without slices. This is almost certainly not what you want to do, so make sure you double check the disklabel(8) command before you press Return.

12.3.3. Stage Three, /boot/loader

The loader is the final stage of the three-stage bootstrap, and is located on the file system, usually as `/boot/loader`.

The loader is intended as a user-friendly method for configuration, using an easy-to-use built-in command set, backed up by a more powerful interpreter, with a more complex command set.

12.3.3.1. Loader Program Flow

During initialization, the loader will probe for a console and for disks, and figure out what disk it is booting from. It will set variables accordingly, and an interpreter is started where user commands can be passed from a script or interactively.

The loader will then read `/boot/loader.rc`, which by default reads in `/boot/defaults/loader.conf` which sets reasonable defaults for variables and reads `/boot/loader.conf` for local changes to those variables. `loader.rc` then acts on these variables, loading whichever modules and kernel are selected.

Finally, by default, the loader issues a 10 second wait for key presses, and boots the kernel if it is not interrupted. If interrupted, the user is presented with a prompt which understands the easy-to-use command set, where the user may adjust variables, unload all modules, load modules, and then finally boot or reboot.

12.3.3.2. Loader Built-In Commands

These are the most commonly used loader commands. For a complete discussion of all available commands, please see loader(8).

autoboot *`seconds`*
: Proceeds to boot the kernel if not interrupted within the time span given, in seconds. It displays a countdown, and the default time span is 10 seconds.

boot [-options] [kernelname]
: Immediately proceeds to boot the kernel, with the given options, if any, and with the kernel name given, if it is.

boot-conf
: Goes through the same automatic configuration of modules based on variables as what happens at boot. This only makes sense if you use `unload` first, and change some variables, most commonly `kernel`.

help [topic]
: Shows help messages read from `/boot/loader.help`. If the topic given is `index`, then the list of available topics is given.

include *`filename`* ...
: Processes the file with the given filename. The file is read in, and interpreted line by line. An error immediately stops the include command.

load [-t type] *`filename`*
: Loads the kernel, kernel module, or file of the type given, with the filename given. Any arguments after filename are passed to the file.

ls [-l] [path]
: Displays a listing of files in the given path, or the root directory, if the path is not specified. If `-l` is specified, file sizes will be shown too.

lsdev [-v]
: Lists all of the devices from which it may be possible to load modules. If `-v` is specified, more details are printed.

lsmod [-v]
: Displays loaded modules. If `-v` is specified, more details are shown.

more *`filename`*
: Displays the files specified, with a pause at each `LINES` displayed.

reboot
: Immediately reboots the system.

set *variable* , set *variable* =*value*
: Sets the loader's environment variables.

unload
: Removes all loaded modules.

12.3.3.3. Loader Examples

Here are some practical examples of loader usage:

- To simply boot your usual kernel, but in single-user mode:

```
boot -s
```

- To unload your usual kernel and modules, and then load just your old (or another) kernel:

```
unload
load kernel.old
```

You can use `kernel.GENERIC` to refer to the generic kernel that comes on the install disk, or `kernel.old` to refer to your previously installed kernel (when you have upgraded or configured your own kernel, for example).

注意

Use the following to load your usual modules with another kernel:

```
unload
set kernel="kernel.old"
boot-conf
```

- To load a kernel configuration script (an automated script which does the things you would normally do in the kernel boot-time configurator):

```
load -t userconfig_script /boot/kernel.conf
```

12.4. Kernel Interaction During Boot

Once the kernel is loaded by either loader (as usual) or boot2 (bypassing the loader), it examines its boot flags, if any, and adjusts its behavior as necessary.

12.4.1. Kernel Boot Flags

Here are the more common boot flags:

`-a`
: during kernel initialization, ask for the device to mount as the root file system.

`-C`
: boot from CDROM.

`-c`
run UserConfig, the boot-time kernel configurator

`-s`
boot into single-user mode

`-v`
be more verbose during kernel startup

注意

There are other boot flags, read boot(8) for more information on them.

12.5. Device Hints

Contributed by Tom Rhodes.

注意

This is a FreeBSD 5.0 and later feature which does not exist in earlier versions.

During initial system startup, the boot loader(8) will read the device.hints(5) file. This file stores kernel boot information known as variables, sometimes referred to as "device hints". These "device hints" are used by device drivers for device configuration.

Device hints may also be specified at the Stage 3 boot loader prompt. Variables can be added using `set`, removed with `unset`, and viewed with the `show` commands. Variables set in the `/boot/device.hints` file can be overridden here also. Device hints entered at the boot loader are not permanent and will be forgotten on the next reboot.

Once the system is booted, the kenv(1) command can be used to dump all of the variables.

The syntax for the `/boot/device.hints` file is one variable per line, using the standard hash "#" as comment markers. Lines are constructed as follows:

```
hint.driver.unit.keyword="value"
```

The syntax for the Stage 3 boot loader is:

```
set hint.driver.unit.keyword=value
```

`driver` is the device driver name, `unit` is the device driver unit number, and `keyword` is the hint keyword. The keyword may consist of the following options:

- `at`: specifies the bus which the device is attached to.
- `port`: specifies the start address of the I/O to be used.
- `irq`: specifies the interrupt request number to be used.
- `drq`: specifies the DMA channel number.

- `maddr`: specifies the physical memory address occupied by the device.
- `flags`: sets various flag bits for the device.
- `disabled`: if set to `1` the device is disabled.

Device drivers may accept (or require) more hints not listed here, viewing their manual page is recommended. For more information, consult the device.hints(5), kenv(1), loader.conf(5), and loader(8) manual pages.

12.6. Init: Process Control Initialization

Once the kernel has finished booting, it passes control to the user process init(8), which is located at `/sbin/init`, or the program path specified in the `init_path` variable in `loader`.

12.6.1. Automatic Reboot Sequence

The automatic reboot sequence makes sure that the file systems available on the system are consistent. If they are not, and fsck(8) cannot fix the inconsistencies, init(8) drops the system into single-user mode for the system administrator to take care of the problems directly.

12.6.2. Single-User Mode

This mode can be reached through the automatic reboot sequence, or by the user booting with the `-s` option or setting the `boot_single` variable in `loader`.

It can also be reached by calling shutdown(8) without the reboot (`-r`) or halt (`-h`) options, from multi-user mode.

If the system `console` is set to `insecure` in `/etc/ttys`, then the system prompts for the `root` password before initiating single-user mode.

範例 12.3. An Insecure Console in **/etc/ttys**

```
# name  getty                           type    status          comments
#
# If console is marked "insecure", then init will ask for the root password
# when going to single-user mode.
console none                            unknown off insecure
```

注意

An `insecure` console means that you consider your physical security to the console to be insecure, and want to make sure only someone who knows the `root` password may use single-user mode, and it does not mean that you want to run your console insecurely. Thus, if you want security, choose `insecure`, not `secure`.

12.6.3. Multi-User Mode

If init(8) finds your file systems to be in order, or once the user has finished in single-user mode, the system enters multi-user mode, in which it starts the resource configuration of the system.

12.6.3.1. Resource Configuration (rc)

The resource configuration system reads in configuration defaults from `/etc/defaults/rc.conf` , and system-specific details from `/etc/rc.conf` , and then proceeds to mount the system file systems mentioned in `/etc/fstab` , start up networking services, start up miscellaneous system daemons, and finally runs the startup scripts of locally installed packages.

The rc(8) manual page is a good reference to the resource configuration system, as is examining the scripts themselves.

12.7. Shutdown Sequence

Upon controlled shutdown, via shutdown(8), init(8) will attempt to run the script `/etc/rc.shutdown` , and then proceed to send all processes the `TERM` signal, and subsequently the `KILL` signal to any that do not terminate timely.

To power down a FreeBSD machine on architectures and systems that support power management, simply use the command `shutdown -p now` to turn the power off immediately. To just reboot a FreeBSD system, just use `shutdown -r now` . You need to be `root` or a member of `operator` group to run shutdown(8). The halt(8) and reboot(8) commands can also be used, please refer to their manual pages and to shutdown(8)'s one for more information.

注意

Power management requires acpi(4) support in the kernel or loaded as module for FreeBSD 5.X and apm(4) support for FreeBSD 4.X.

章 13. 系統安全

Rewritten by Tom Rhodes.

13.1. 概述

這一章將對系統安全的基本概念進行介紹，除此之外，還將介紹一些好的習慣，以及 FreeBSD 下的一些更深入的話題。這章的許多內容對於一般的系統和 Internet 安全也適用。如今，Internet 已經不再像以前那樣是個人人都願意與您作好鄰居的『友善場所』。 必須讓系統更安全，才能去保護您的資料、智慧財產、寶貴時間以及其他很多東西， 而不至於被入侵者或心存惡意的人所竊取。

FreeBSD 提供了一系列工具和相關機制，來確保系統和網路的完整、安全。

讀完這章，您將了解：

- FreeBSD 系統的基本安全概念。
- FreeBSD 中許多可用的加密機制，例如 DES 及 MD5。
- 如何建立一次性(one-time)密碼驗證機制。
- 如何設定 TCP Wrappers 以便與 `inetd` 配合使用。
- 如何在 FreeBSD 5.0. 之前的版本上設定 KerberosIV。
- 如何在 FreeBSD 5.0（含之後版本）上設定 Kerberos5。
- 如何設定 IPsec 以及在 FreeBSD/Windows® 上建立 VPN 網路。
- 如何設定、運用 OpenSSH，以及 FreeBSD 的 SSH 實作方式(implementation)
- 了解檔案系統的 ACLs 機制為何，以及如何運用。
- 如何使用 Portaudit 工具來檢驗(audit) 從 Ports Collection 安裝的軟體安全性。
- 如何善用 FreeBSD 安全公告(Security Advisories)，並採取相應措施。
- 瞭解 Process Accounting 機制及如何在 FreeBSD 上啓動。

在開始閱讀這章之前，您需要：

- 瞭解 FreeBSD 及 Internet 的基本概念。

本書中其他章節，也有介紹安全方面的其他話題。例如： 在 章 15, Mandatory Access Control 有談到 Mandatory Access Control， Internet Firewalls 則在 章 29, 防火牆。

13.2. Introduction

Security is everyone's responsibility. A weak entry point in any system could allow intruders to gain access to critical information and cause havoc on an entire network. One of the core principles of information security is the CIA triad, which stands for the Confidentiality, Integrity, and Availability of information systems.

The CIA triad is a bedrock concept of computer security as customers and users expect their data to be protected. For example, a customer expects that their credit card information is securely stored (confidentiality), that their orders are not changed behind the scenes (integrity), and that they have access to their order information at all times (availablility).

To provide CIA, security professionals apply a defense in depth strategy. The idea of defense in depth is to add several layers of security to prevent one single layer failing and the entire security system collapsing. For example,

a system administrator cannot simply turn on a firewall and consider the network or system secure. One must also audit accounts, check the integrity of binaries, and ensure malicious tools are not installed. To implement an effective security strategy, one must understand threats and how to defend against them.

What is a threat as it pertains to computer security? Threats are not limited to remote attackers who attempt to access a system without permission from a remote location. Threats also include employees, malicious software, unauthorized network devices, natural disasters, security vulnerabilities, and even competing corporations.

Systems and networks can be accessed without permission, sometimes by accident, or by remote attackers, and in some cases, via corporate espionage or former employees. As a user, it is important to prepare for and admit when a mistake has lead to a security breach and report possible issues to the security team. As an administrator, it is important to know of the threats and be prepared to mitigate them.

When applying security to systems, it is recommended to start by securing the basic accounts and system configuration, and then to secure the network layer so that it adheres to the system policy and the organization's security procedures. Many organizations already have a security policy that covers the configuration of technology devices. The policy should include the security configuration of workstations, desktops, mobile devices, phones, production servers, and development servers. In many cases, standard operating procedures (SOPs) already exist. When in doubt, ask the security team.

The rest of this introduction describes how some of these basic security configurations are performed on a FreeBSD system. The rest of this chapter describes some specific tools which can be used when implementing a security policy on a FreeBSD system.

13.2.1. Preventing Logins

In securing a system, a good starting point is an audit of accounts. Ensure that `root` has a strong password and that this password is not shared. Disable any accounts that do not need login access.

To deny login access to accounts, two methods exist. The first is to lock the account. This example locks the `toor` account:

```
# pw lock toor
```

The second method is to prevent login access by changing the shell to `/sbin/nologin` . Only the superuser can change the shell for other users:

```
# chsh -s /usr/sbin/nologin  toor
```

The `/usr/sbin/nologin` shell prevents the system from assigning a shell to the user when they attempt to login.

13.2.2. Permitted Account Escalation

In some cases, system administration needs to be shared with other users. FreeBSD has two methods to handle this. The first one, which is not recommended, is a shared root password used by members of the `wheel` group. With this method, a user types `su` and enters the password for `wheel` whenever superuser access is needed. The user should then type `exit` to leave privileged access after finishing the commands that required administrative access. To add a user to this group, edit `/etc/group` and add the user to the end of the `wheel` entry. The user must be separated by a comma character with no space.

The second, and recommended, method to permit privilege escalation is to install the security/sudo package or port. This software provides additional auditing, more fine-grained user control, and can be configured to lock users into running only the specified privileged commands.

After installation, use `visudo` to edit `/usr/local/etc/sudoers` . This example creates a new `webadmin` group, adds the `trhodes` account to that group, and configures that group access to restart apache24:

```
# pw groupadd webadmin -M trhodes -g 6000
```

```
# visudo
%webadmin ALL=(ALL) /usr/sbin/service apache24 *
```

13.2.3. Password Hashes

Passwords are a necessary evil of technology. When they must be used, they should be complex and a powerful hash mechanism should be used to encrypt the version that is stored in the password database. FreeBSD supports the DES, MD5, SHA256, SHA512, and Blowfish hash algorithms in its `crypt()` library. The default of SHA512 should not be changed to a less secure hashing algorithm, but can be changed to the more secure Blowfish algorithm.

注意

Blowfish is not part of AES and is not considered compliant with any Federal Information Processing Standards (FIPS). Its use may not be permitted in some environments.

To determine which hash algorithm is used to encrypt a user's password, the superuser can view the hash for the user in the FreeBSD password database. Each hash starts with a symbol which indicates the type of hash mechanism used to encrypt the password. If DES is used, there is no beginning symbol. For MD5, the symbol is `$`. For SHA256 and SHA512, the symbol is `$6$`. For Blowfish, the symbol is `$2a$`. In this example, the password for `dru` is hashed using the default SHA512 algorithm as the hash starts with `$6$`. Note that the encrypted hash, not the password itself, is stored in the password database:

```
# grep dru /etc/master.passwd
dru:$6$pzIjSvCAn.PBYQBA
$PXpSeWPx3g5kscj3IMiM7tUEUSPmGexxta.8Lt9TGSi2lNQqYGKszsBPuGME0:1001:1001::0:0:dru:/usr/
home/dru:/bin/csh
```

The hash mechanism is set in the user's login class. For this example, the user is in the `default` login class and the hash algorithm is set with this line in `/etc/login.conf` :

```
        :passwd_format=sha512:\
```

To change the algorithm to Blowfish, modify that line to look like this:

```
        :passwd_format=blf:\
```

Then run `cap_mkdb /etc/login.conf` as described in 節 13.13.1, “Configuring Login Classes”. Note that this change will not affect any existing password hashes. This means that all passwords should be re-hashed by asking users to run `passwd` in order to change their password.

For remote logins, two-factor authentication should be used. An example of two-factor authentication is “something you have”, such as a key, and “something you know”, such as the passphrase for that key. Since OpenSSH is part of the FreeBSD base system, all network logins should be over an encrypted connection and use key-based authentication instead of passwords. For more information, refer to 節 13.8, “OpenSSH”. Kerberos users may need to make additional changes to implement OpenSSH in their network. These changes are described in 節 13.5, “Kerberos”.

13.2.4. Password Policy Enforcement

Enforcing a strong password policy for local accounts is a fundamental aspect of system security. In FreeBSD, password length, password strength, and password complexity can be implemented using built-in Pluggable Authentication Modules (PAM).

This section demonstrates how to configure the minimum and maximum password length and the enforcement of mixed characters using the `pam_passwdqc.so` module. This module is enforced when a user changes their password.

To configure this module, become the superuser and uncomment the line containing `pam_passwdqc.so` in `/etc/pam.d/passwd`. Then, edit that line to match the password policy:

```
password        requisite       pam_passwdqc.so
  min=disabled,disabled,disabled,12,10 similar=deny retry=3    enforce=users
```

This example sets several requirements for new passwords. The `min` setting controls the minimum password length. It has five values because this module defines five different types of passwords based on their complexity. Complexity is defined by the type of characters that must exist in a password, such as letters, numbers, symbols, and case. The types of passwords are described in pam_passwdqc(8). In this example, the first three types of passwords are disabled, meaning that passwords that meet those complexity requirements will not be accepted, regardless of their length. The `12` sets a minimum password policy of at least twelve characters, if the password also contains characters with three types of complexity. The `10` sets the password policy to also allow passwords of at least ten characters, if the password contains characters with four types of complexity.

The `similar` setting denies passwords that are similar to the user's previous password. The `retry` setting provides a user with three opportunities to enter a new password.

Once this file is saved, a user changing their password will see a message similar to the following:

```
% passwd
Changing local password for trhodes
Old Password:

You can now choose the new password.
A valid password should be a mix of upper and lower case letters,
digits and other characters.  You can use a 12 character long
password with characters from at least 3 of these 4 classes, or
a 10 character long password containing characters from all the
classes.  Characters that form a common pattern are discarded by
the check.
Alternatively, if noone else can see your terminal now, you can
pick this as your password: "trait-useful&knob".
Enter new password:
```

If a password that does not match the policy is entered, it will be rejected with a warning and the user will have an opportunity to try again, up to the configured number of retries.

Most password policies require passwords to expire after so many days. To set a password age time in FreeBSD, set `passwordtime` for the user's login class in `/etc/login.conf`. The `default` login class contains an example:

```
#       :passwordtime=90d:\
```

So, to set an expiry of 90 days for this login class, remove the comment symbol (#), save the edit, and run `cap_mkdb /etc/login.conf`.

To set the expiration on individual users, pass an expiration date or the number of days to expiry and a username to `pw`:

```
# pw usermod -p 30-apr-2015 -n trhodes
```

As seen here, an expiration date is set in the form of day, month, and year. For more information, see pw(8).

13.2.5. Detecting Rootkits

A rootkit is any unauthorized software that attempts to gain `root` access to a system. Once installed, this malicious software will normally open up another avenue of entry for an attacker. Realistically, once a system has been compromised by a rootkit and an investigation has been performed, the system should be reinstalled from scratch. There is tremendous risk that even the most prudent security or systems engineer will miss something an attacker left behind.

A rootkit does do one thing usefulfor administrators: once detected, it is a sign that a compromise happened at some point. But, these types of applications tend to be very well hidden. This section demonstrates a tool that can be used to detect rootkits, security/rkhunter.

After installation of this package or port, the system may be checked using the following command. It will produce a lot of information and will require some manual pressing of ENTER:

```
# rkhunter -c
```

After the process completes, a status message will be printed to the screen. This message will include the amount of files checked, suspect files, possible rootkits, and more. During the check, some generic security warnings may be produced about hidden files, the OpenSSH protocol selection, and known vulnerable versions of installed software. These can be handled now or after a more detailed analysis has been performed.

Every administrator should know what is running on the systems they are responsible for. Third-party tools like rkhunter and sysutils/lsof, and native commands such as `netstat` and `ps`, can show a great deal of information on the system. Take notes on what is normal, ask questions when something seems out of place, and be paranoid. While preventing a compromise is ideal, detecting a compromise is a must.

13.2.6. Binary Verification

Verification of system files and binaries is important because it provides the system administration and security teams information about system changes. A software application that monitors the system for changes is called an Intrusion Detection System (IDS).

FreeBSD provides native support for a basic IDS system. While the nightly security emails will notify an administrator of changes, the information is stored locally and there is a chance that a malicious user could modify this information in order to hide their changes to the system. As such, it is recommended to create a separate set of binary signatures and store them on a read-only, root-owned directory or, preferably, on a removable USB disk or remote rsync server.

The built-in `mtree` utility can be used to generate a specification of the contents of a directory. A seed, or a numeric constant, is used to generate the specification and is required to check that the specification has not changed. This makes it possible to determine if a file or binary has been modified. Since the seed value is unknown by an attacker, faking or checking the checksum values of files will be difficult to impossible. The following example generates a set of SHA256 hashes, one for each system binary in `/bin`, and saves those values to a hidden file in `root`'s home directory, `/root/.bin_chksum_mtree` :

```
# mtree -s 3483151339707503 -c -K cksum,sha256digest -p /bin > /root/.↺
bin_chksum_mtree
# mtree: /bin checksum: 3427012225
```

The *3483151339707503* represents the seed. This value should be remembered, but not shared.

Viewing `/root/.bin_cksum_mtree` should yield output similar to the following:

```
#          user: root
#       machine: dreadnaught
#          tree: /bin
#          date: Mon Feb  3 10:19:53 2014

# .
/set type=file uid=0 gid=0 mode=0555 nlink=1 flags=none
.               type=dir mode=0755 nlink=2 size=1024 \
                time=1380277977.000000000
    \133        nlink=2 size=11704 time=1380277977.000000000 \
                cksum=484492447 \
                ↺
sha256digest=6207490fbdb5ed1904441fbfa941279055c3e24d3a4049aeb45094596400662a
    cat         size=12096 time=1380277975.000000000 cksum=3909216944 \
```

```
                ↺
sha256digest=65ea347b9418760b247ab10244f47a7ca2a569c9836d77f074e7a306900c1e69
    chflags     size=8168 time=1380277975.000000000 cksum=3949425175 \
                ↺
sha256digest=c99eb6fc1c92cac335c08be004a0a5b4c24a0c0ef3712017b12c89a978b2dac3
    chio        size=18520 time=1380277975.000000000 cksum=2208263309 \
                ↺
sha256digest=ddf7c8cb92a58750a675328345560d8cc7fe14fb3ccd3690c34954cbe69fc964
    chmod       size=8640 time=1380277975.000000000 cksum=2214429708 \
                ↺
sha256digest=a435972263bf814ad8df082c0752aa2a7bdd8b74ff01431ccbd52ed1e490bbe7
```

The machine's hostname, the date and time the specification was created, and the name of the user who created the specification are included in this report. There is a checksum, size, time, and SHA256 digest for each binary in the directory.

To verify that the binary signatures have not changed, compare the current contents of the directory to the previously generated specification, and save the results to a file. This command requires the seed that was used to generate the original specification:

```
# mtree -s 3483151339707503  -p /bin < /root/.bin_chksum_mtree  >> /
root/.bin_chksum_output
# mtree: /bin checksum: 3427012225
```

This should produce the same checksum for `/bin` that was produced when the specification was created. If no changes have occurred to the binaries in this directory, the `/root/.bin_chksum_output` output file will be empty. To simulate a change, change the date on `/bin/cat` using `touch` and run the verification command again:

```
# touch /bin/cat
# mtree -s 3483151339707503  -p /bin < /root/.bin_chksum_mtree  >> /
root/.bin_chksum_output
# more /root/.bin_chksum_output
cat changed
 modification time expected Fri Sep 27 06:32:55 2013 found Mon Feb  3 10:28:43 2014
```

It is recommended to create specifications for the directories which contain binaries and configuration files, as well as any directories containing sensitive data. Typically, specifications are created for `/bin`, `/sbin`, `/usr/bin`, `/usr/sbin`, `/usr/local/bin`, `/etc`, and `/usr/local/etc`.

More advanced IDS systems exist, such as security/aide. In most cases, `mtree` provides the functionality administrators need. It is important to keep the seed value and the checksum output hidden from malicious users. More information about `mtree` can be found in mtree(8).

13.2.7. System Tuning for Security

In FreeBSD, many system features can be tuned using `sysctl`. A few of the security features which can be tuned to prevent Denial of Service (DoS) attacks will be covered in this section. More information about using `sysctl`, including how to temporarily change values and how to make the changes permanent after testing, can be found in 節 11.10, “Tuning with sysctl”.

注意

Any time a setting is changed with `sysctl`, the chance to cause undesired harm is increased, affecting the availability of the system. All changes should be monitored and, if possible, tried on a testing system before being used on a production system.

By default, the FreeBSD kernel boots with a security level of `-1`. This is called "insecure mode" because immutable file flags may be turned off and all devices may be read from or written to. The security level will remain at `-1` unless it is altered through `sysctl` or by a setting in the startup scripts. The security level may be increased during system startup by setting `kern_securelevel_enable` to `YES` in `/etc/rc.conf`, and the value of `kern_securelevel` to the desired security level. See security(7) and init(8) for more information on these settings and the available security levels.

警告

Increasing the `securelevel` can break Xorg and cause other issues. Be prepared to do some debugging.

The `net.inet.tcp.blackhole` and `net.inet.udp.blackhole` settings can be used to drop incoming SYN packets on closed ports without sending a return RST response. The default behavior is to return an RST to show a port is closed. Changing the default provides some level of protection against ports scans, which are used to determine which applications are running on a system. Set `net.inet.tcp.blackhole` to `2` and `net.inet.udp.blackhole` to `1`. Refer to blackhole(4) for more information about these settings.

The `net.inet.icmp.drop_redirect` and `net.inet.ip.redirect` settings help prevent against redirect attacks. A redirect attack is a type of DoS which sends mass numbers of ICMP type 5 packets. Since these packets are not required, set `net.inet.icmp.drop_redirect` to `1` and set `net.inet.ip.redirect` to `0`.

Source routing is a method for detecting and accessing non-routable addresses on the internal network. This should be disabled as non-routable addresses are normally not routable on purpose. To disable this feature, set `net.inet.ip.sourceroute` and `net.inet.ip.accept_sourceroute` to `0`.

When a machine on the network needs to send messages to all hosts on a subnet, an ICMP echo request message is sent to the broadcast address. However, there is no reason for an external host to perform such an action. To reject all external broadcast requests, set `net.inet.icmp.bmcastecho` to `0`.

Some additional settings are documented in security(7).

13.3. One-time Passwords

By default, FreeBSD includes support for One-time Passwords In Everything (OPIE). OPIE is designed to prevent replay attacks, in which an attacker discovers a user's password and uses it to access a system. Since a password is only used once in OPIE, a discovered password is of little use to an attacker. OPIE uses a secure hash and a challenge/response system to manage passwords. The FreeBSD implementation uses the MD5 hash by default.

OPIE uses three different types of passwords. The first is the usual UNIX® or Kerberos password. The second is the one-time password which is generated by `opiekey`. The third type of password is the "secret password" which is used to generate one-time passwords. The secret password has nothing to do with, and should be different from, the UNIX® password.

There are two other pieces of data that are important to OPIE. One is the "seed" or "key", consisting of two letters and five digits. The other is the "iteration count", a number between 1 and 100. OPIE creates the one-time password by concatenating the seed and the secret password, applying the MD5 hash as many times as specified by the iteration count, and turning the result into six short English words which represent the one-time password. The authentication system keeps track of the last one-time password used, and the user is authenticated if the hash of the user-provided password is equal to the previous password. Because a one-way hash is used, it is impossible to generate future one-time passwords if a successfully used password is captured. The iteration count is decremented

after each successful login to keep the user and the login program in sync. When the iteration count gets down to `1`, OPIE must be reinitialized.

There are a few programs involved in this process. A one-time password, or a consecutive list of one-time passwords, is generated by passing an iteration count, a seed, and a secret password to opiekey(1). In addition to initializing OPIE, opiepasswd(1) is used to change passwords, iteration counts, or seeds. The relevant credential files in `/etc/opiekeys` are examined by opieinfo(1) which prints out the invoking user's current iteration count and seed.

This section describes four different sorts of operations. The first is how to set up one-time-passwords for the first time over a secure connection. The second is how to use `opiepasswd` over an insecure connection. The third is how to log in over an insecure connection. The fourth is how to generate a number of keys which can be written down or printed out to use at insecure locations.

13.3.1. Initializing OPIE

To initialize OPIE for the first time, run this command from a secure location:

```
% opiepasswd -c
[grimreaper] ~ $ opiepasswd -f -c
Adding unfurl:
Only use this method from the console; NEVER from remote. If you are using
telnet, xterm, or a dial-in, type ^C now or exit with no password.
Then run opiepasswd without the -c parameter.
Using MD5 to compute responses.
Enter new secret pass phrase:
Again new secret pass phrase:

ID unfurl OTP key is 499 to4268
MOS MALL GOAT ARM AVID COED
```

The `-c` sets console mode which assumes that the command is being run from a secure location, such as a computer under the user's control or a SSH session to a computer under the user's control.

When prompted, enter the secret password which will be used to generate the one-time login keys. This password should be difficult to guess and should be different than the password which is associated with the user's login account. It must be between 10 and 127 characters long. Remember this password.

The `ID` line lists the login name (`unfurl`), default iteration count (`499`), and default seed (`to4268`). When logging in, the system will remember these parameters and display them, meaning that they do not have to be memorized. The last line lists the generated one-time password which corresponds to those parameters and the secret password. At the next login, use this one-time password.

13.3.2. Insecure Connection Initialization

To initialize or change the secret password on an insecure system, a secure connection is needed to some place where `opiekey` can be run. This might be a shell prompt on a trusted machine. An iteration count is needed, where 100 is probably a good value, and the seed can either be specified or the randomly-generated one used. On the insecure connection, the machine being initialized, use opiepasswd(1):

```
% opiepasswd

Updating unfurl:
You need the response from an OTP generator.
Old secret pass phrase:
 otp-md5 498 to4268 ext
 Response: GAME GAG WELT OUT DOWN CHAT
New secret pass phrase:
 otp-md5 499 to4269
 Response: LINE PAP MILK NELL BUOY TROY

ID mark OTP key is 499 gr4269
```

```
LINE PAP MILK NELL BUOY TROY
```

To accept the default seed, press Return. Before entering an access password, move over to the secure connection and give it the same parameters:

```
% opiekey 498 to4268
Using the MD5 algorithm to compute response.
Reminder: Do not use opiekey from telnet or dial-in sessions.
Enter secret pass phrase:
GAME GAG WELT OUT DOWN CHAT
```

Switch back over to the insecure connection, and copy the generated one-time password over to the relevant program.

13.3.3. Generating a Single One-time Password

After initializing OPIE and logging in, a prompt like this will be displayed:

```
% telnet example.com
Trying 10.0.0.1...
Connected to example.com
Escape character is '^]'.

FreeBSD/i386 (example.com) (ttypa)

login: <username>
otp-md5 498 gr4269 ext
Password:
```

The OPIE prompts provides a useful feature. If Return is pressed at the password prompt, the prompt will turn echo on and display what is typed. This can be useful when attempting to type in a password by hand from a printout.

At this point, generate the one-time password to answer this login prompt. This must be done on a trusted system where it is safe to run opiekey(1). There are versions of this command for Windows®, Mac OS® and FreeBSD. This command needs the iteration count and the seed as command line options. Use cut-and-paste from the login prompt on the machine being logged in to.

On the trusted system:

```
% opiekey 498 to4268
Using the MD5 algorithm to compute response.
Reminder: Do not use opiekey from telnet or dial-in sessions.
Enter secret pass phrase:
GAME GAG WELT OUT DOWN CHAT
```

Once the one-time password is generated, continue to log in.

13.3.4. Generating Multiple One-time Passwords

Sometimes there is no access to a trusted machine or secure connection. In this case, it is possible to use opiekey(1) to generate a number of one-time passwords beforehand. For example:

```
% opiekey -n 5 30 zz99999
Using the MD5 algorithm to compute response.
Reminder: Do not use opiekey from telnet or dial-in sessions.
Enter secret pass phrase: <secret password>
26: JOAN BORE FOSS DES NAY QUIT
27: LATE BIAS SLAY FOLK MUCH TRIG
28: SALT TIN ANTI LOON NEAL USE
29: RIO ODIN GO BYE FURY TIC
30: GREW JIVE SAN GIRD BOIL PHI
```

The `-n 5` requests five keys in sequence, and `30` specifies what the last iteration number should be. Note that these are printed out in reverse order of use. The really paranoid might want to write the results down by hand;

otherwise, print the list. Each line shows both the iteration count and the one-time password. Scratch off the passwords as they are used.

13.3.5. Restricting Use of UNIX® Passwords

OPIE can restrict the use of UNIX® passwords based on the IP address of a login session. The relevant file is `/etc/opieaccess`, which is present by default. Refer to opieaccess(5) for more information on this file and which security considerations to be aware of when using it.

Here is a sample `opieaccess`:

```
permit 192.168.0.0 255.255.0.0
```

This line allows users whose IP source address (which is vulnerable to spoofing) matches the specified value and mask, to use UNIX® passwords at any time.

If no rules in `opieaccess` are matched, the default is to deny non-OPIE logins.

13.4. TCP Wrapper

Written by Tom Rhodes.

每個熟 inetd(8) 的人幾乎都會聽過 TCP Wrappers 這個東西，但很少人能完全瞭解它在網路環境上的好用在哪。 大多數的人都會裝防火牆來保護網路，雖然，防火牆用途非常廣泛，但並非萬能。 例如：若打算回傳一段文字給連線來源者等之類的。而 TCP 軟體卻可以做到這點，還有其他更多事情。在以下段落內，我們將繼續介紹 TCP Wrappers 提供的功能，以及一些實際運用的例子。

TCP Wrappers 可以讓 `inetd` 所管理的每個 server daemon ，都會在 TCP Wrappers 的掌握之下。透過 TCP Wrappers 這種方式可以支援連線紀錄(logging) 、回傳一段文字給連線來源者、可以讓 daemon 只接受內部連線等等。 雖然其中部份功能用防火牆也可以做到，但 TCP Wrappers 不只是增加了一層保護，還提供了防火牆所辦不到的事情。

然而， 由 TCP Wrappers 所提供的這些額外安全功能， 不應該視為優秀防火牆的替代方案。應該結合 TCP Wrappers 及防火牆、其他加强安全措施來一併運用才對，這樣才可以為系統提供多層安全防護。

由於這些設定是主要針對 `inetd` 所提供的，所以我們建議您先參閱 inetd 設定 一節。

注意

雖然 inetd(8) 所啓動的程式並非全部都是真正的『daemons』，但一般來講，我們都還是會稱呼為『daemons』， 下面我們仍將使用這字眼來表達。

13.4.1. Initial Configuration

若要在 FreeBSD 中使用 TCP Wrappers 的話，只要確定 `inetd` 在啓動時，有在 `/etc/rc.conf` 加上 `-Ww` 的參數即可，這個設定在系統預設就有了。 當然還需要適當修改 `/etc/hosts.allow` 設定檔，但 syslogd(8) 仍會在系統 log 檔內，紀錄相關資料下來。

注意

FreeBSD 的 TCP Wrappers 實作方式與其他作業系統上的 TCP Wrappers 不太一樣，目前 FreeBSD 已經廢棄不用 `/etc/hosts.deny` ，而一律改用 `/etc/hosts.allow` 。

最簡單的設定方式是，每個對 daemon 的連線都由 `/etc/hosts.allow` 來決定是否允許或拒絕。 The default configuration in FreeBSD is to allow a connection to every daemon started with `inetd`. Changing this will be discussed only after the basic configuration is covered.

Basic configuration usually takes the form of `daemon : address : action` . Where `daemon` is the daemon name which `inetd` started. The `address` can be a valid hostname, an IP address or an IPv6 address enclosed in brackets ([ ]). The action field can be either allow or deny to grant or deny access appropriately. Keep in mind that configuration works off a first rule match semantic, meaning that the configuration file is scanned in ascending order for a matching rule. When a match is found the rule is applied and the search process will halt.

Several other options exist but they will be explained in a later section. A simple configuration line may easily be constructed from that information alone. For example, to allow POP3 connections via the mail/qpopper daemon, the following lines should be appended to `hosts.allow` :

```
# This line is required for POP3 connections:
qpopper : ALL : allow
```

加上上面這行之後，必須重新啓動 `inetd`。重新啓動的方式可以用 kill(1) 指令，或打『 `/etc/rc.d/inetd restart` 』來完成。

13.4.2. Advanced Configuration

TCP Wrappers has advanced options too; they will allow for more control over the way connections are handled. In some cases it may be a good idea to return a comment to certain hosts or daemon connections. In other cases, perhaps a log file should be recorded or an email sent to the administrator. Other situations may require the use of a service for local connections only. This is all possible through the use of configuration options known as `wildcards` , expansion characters and external command execution. The next two sections are written to cover these situations.

13.4.2.1. External Commands

Suppose that a situation occurs where a connection should be denied yet a reason should be sent to the individual who attempted to establish that connection. How could it be done? That action can be made possible by using the `twist` option. When a connection attempt is made, `twist` will be called to execute a shell command or script. An example already exists in the `hosts.allow` file:

```
# The rest of the daemons are protected.
ALL : ALL \
        : severity auth.info \
        : twist /bin/echo "You are not welcome to use %d from %h."
```

This example shows that the message, “You are not allowed to use `daemon` from `hostname` .” will be returned for any daemon not previously configured in the access file. This is extremely useful for sending a reply back to the connection initiator right after the established connection is dropped. Note that any message returned must be wrapped in quote " characters; there are no exceptions to this rule.

警告

It may be possible to launch a denial of service attack on the server if an attacker, or group of attackers could flood these daemons with connection requests.

Another possibility is to use the `spawn` option in these cases. Like `twist`, the `spawn` implicitly denies the connection and may be used to run external shell commands or scripts. Unlike `twist`, `spawn` will not send a reply back to the individual who established the connection. For an example, consider the following configuration line:

```
# We do not allow connections from example.com:
ALL : .example.com \
```

```
: spawn (/bin/echo %a from %h attempted to access %d >> \
  /var/log/connections.log) \
: deny
```

This will deny all connection attempts from the `*.example.com` domain; simultaneously logging the hostname, IP address and the daemon which they attempted to access in the `/var/log/connections.log` file.

Aside from the already explained substitution characters above, e.g. %a, a few others exist. See the hosts_access(5) manual page for the complete list.

13.4.2.2. Wildcard Options

Thus far the `ALL` example has been used continuously throughout the examples. Other options exist which could extend the functionality a bit further. For instance, `ALL` may be used to match every instance of either a daemon, domain or an IP address. Another wildcard available is `PARANOID` which may be used to match any host which provides an IP address that may be forged. In other words, `paranoid` may be used to define an action to be taken whenever a connection is made from an IP address that differs from its hostname. The following example may shed some more light on this discussion:

```
# Block possibly spoofed requests to sendmail:
sendmail : PARANOID : deny
```

In that example all connection requests to `sendmail` which have an IP address that varies from its hostname will be denied.

注意

Using the `PARANOID` may severely cripple servers if the client or server has a broken DNS setup. Administrator discretion is advised.

To learn more about wildcards and their associated functionality, see the hosts_access(5) manual page.

Before any of the specific configuration lines above will work, the first configuration line should be commented out in `hosts.allow` . This was noted at the beginning of this section.

13.5. Kerberos

Contributed by Tillman Hodgson.
Based on a contribution by Mark Murray.

Kerberos is a network authentication protocol which was originally created by the Massachusetts Institute of Technology (MIT) as a way to securely provide authentication across a potentially hostile network. The Kerberos protocol uses strong cryptography so that both a client and server can prove their identity without sending any unencrypted secrets over the network. Kerberos can be described as an identity-verifying proxy system and as a trusted third-party authentication system. After a user authenticates with Kerberos, their communications can be encrypted to assure privacy and data integrity.

The only function of Kerberos is to provide the secure authentication of users and servers on the network. It does not provide authorization or auditing functions. It is recommended that Kerberos be used with other security methods which provide authorization and audit services.

The current version of the protocol is version 5, described in RFC 4120. Several free implementations of this protocol are available, covering a wide range of operating systems. MIT continues to develop their Kerberos package. It is commonly used in the US as a cryptography product, and has historically been subject to US export regulations. In FreeBSD, MIT Kerberos is available as the security/krb5 package or port. The Heimdal Kerberos implementation

was explicitly developed outside of the US to avoid export regulations. The Heimdal Kerberos distribution is included in the base FreeBSD installation, and another distribution with more configurable options is available as security/heimdal in the Ports Collection.

In Kerberos users and services are identified as “principals” which are contained within an administrative grouping, called a “realm”. A typical user principal would be of the form *`user@REALM`* (realms are traditionally uppercase).

This section provides a guide on how to set up Kerberos using the Heimdal distribution included in FreeBSD.

For purposes of demonstrating a Kerberos installation, the name spaces will be as follows:

- The DNS domain (zone) will be `example.org` .
- The Kerberos realm will be `EXAMPLE.ORG` .

注意

Use real domain names when setting up Kerberos, even if it will run internally. This avoids DNS problems and assures inter-operation with other Kerberos realms.

13.5.1. Setting up a Heimdal KDC

The Key Distribution Center (KDC) is the centralized authentication service that Kerberos provides, the “trusted third party” of the system. It is the computer that issues Kerberos tickets, which are used for clients to authenticate to servers. Because the KDC is considered trusted by all other computers in the Kerberos realm, it has heightened security concerns. Direct access to the KDC should be limited.

While running a KDC requires few computing resources, a dedicated machine acting only as a KDC is recommended for security reasons.

To begin setting up a KDC, add these lines to `/etc/rc.conf` :

```
kerberos5_server_enable="YES"
kadmind5_server_enable="YES"
```

Next, edit `/etc/krb5.conf` as follows:

```
[libdefaults]
    default_realm = EXAMPLE.ORG
[realms]
    EXAMPLE.ORG  = {
 kdc = kerberos.example.org
 admin_server = kerberos.example.org
    }
[domain_realm]
    .example.org  = EXAMPLE.ORG
```

In this example, the KDC will use the fully-qualified hostname `kerberos.example.org` . The hostname of the KDC must be resolvable in the DNS.

Kerberos can also use the DNS to locate KDCs, instead of a `[realms]` section in `/etc/krb5.conf` . For large organizations that have their own DNS servers, the above example could be trimmed to:

```
[libdefaults]
      default_realm = EXAMPLE.ORG
[domain_realm]
    .example.org  = EXAMPLE.ORG
```

With the following lines being included in the `example.org` zone file:

```
_kerberos._udp      IN  SRV     01 00 88 kerberos.example.org .
_kerberos._tcp      IN  SRV     01 00 88 kerberos.example.org .
_kpasswd._udp       IN  SRV     01 00 464 kerberos.example.org .
_kerberos-adm._tcp  IN  SRV     01 00 749 kerberos.example.org .
_kerberos           IN  TXT     EXAMPLE.ORG
```

注意

In order for clients to be able to find the Kerberos services, they must have either a fully configured `/etc/krb5.conf` or a minimally configured `/etc/krb5.conf` and a properly configured DNS server.

Next, create the Kerberos database which contains the keys of all principals (users and hosts) encrypted with a master password. It is not required to remember this password as it will be stored in `/var/heimdal/m-key` ; it would be reasonable to use a 45-character random password for this purpose. To create the master key, run `kstash` and enter a password:

```
# kstash
Master key: xxxxxxxxxxxxxxxxxxxxxxx
Verifying password - Master key: xxxxxxxxxxxxxxxxxxxxxxx
```

Once the master key has been created, the database should be initialized. The Kerberos administrative tool kadmin(8) can be used on the KDC in a mode that operates directly on the database, without using the kadmind(8) network service, as `kadmin -l` . This resolves the chicken-and-egg problem of trying to connect to the database before it is created. At the `kadmin` prompt, use `init` to create the realm's initial database:

```
# kadmin -l
kadmin> init EXAMPLE.ORG
Realm max ticket life [unlimited]:
```

Lastly, while still in `kadmin` , create the first principal using `add` . Stick to the default options for the principal for now, as these can be changed later with `modify` . Type `?` at the prompt to see the available options.

```
kadmin> add tillman
Max ticket life [unlimited]:
Max renewable life [unlimited]:
Attributes []:
Password: xxxxxxxx
Verifying password - Password: xxxxxxxx
```

Next, start the KDC services by running `service kerberos start` and `service kadmind start` . While there will not be any kerberized daemons running at this point, it is possible to confirm that the KDC is functioning by obtaining a ticket for the principal that was just created:

```
% kinit tillman
tillman@EXAMPLE.ORG's Password:
```

Confirm that a ticket was successfully obtained using `klist` :

```
% klist
Credentials cache: FILE:/tmp/krb5cc_1001
 Principal: tillman@EXAMPLE.ORG

  Issued                Expires               Principal
Aug 27 15:37:58 2013  Aug 28 01:37:58 2013  krbtgt/EXAMPLE.ORG@EXAMPLE.ORG
```

The temporary ticket can be destroyed when the test is finished:

```
% kdestroy
```

13.5.2. Configuring a Server to Use Kerberos

The first step in configuring a server to use Kerberos authentication is to ensure that it has the correct configuration in `/etc/krb5.conf`. The version from the KDC can be used as-is, or it can be regenerated on the new system.

Next, create `/etc/krb5.keytab` on the server. This is the main part of "Kerberizing" a service —— it corresponds to generating a secret shared between the service and the KDC. The secret is a cryptographic key, stored in a "keytab". The keytab contains the server's host key, which allows it and the KDC to verify each others' identity. It must be transmitted to the server in a secure fashion, as the security of the server can be broken if the key is made public. Typically, the `keytab` is generated on an administrator's trusted machine using `kadmin`, then securely transferred to the server, e.g., with scp(1); it can also be created directly on the server if that is consistent with the desired security policy. It is very important that the keytab is transmitted to the server in a secure fashion: if the key is known by some other party, that party can impersonate any user to the server! Using `kadmin` on the server directly is convenient, because the entry for the host principal in the KDC database is also created using `kadmin`.

Of course, `kadmin` is a kerberized service; a Kerberos ticket is needed to authenticate to the network service, but to ensure that the user running `kadmin` is actually present (and their session has not been hijacked), `kadmin` will prompt for the password to get a fresh ticket. The principal authenticating to the kadmin service must be permitted to use the `kadmin` interface, as specified in `kadmind.acl`. See the section titled "Remote administration" in `info heimdal` for details on designing access control lists. Instead of enabling remote `kadmin` access, the administrator could securely connect to the KDC via the local console or ssh(1), and perform administration locally using `kadmin -l`.

After installing `/etc/krb5.conf`, use `add --random-key` in `kadmin`. This adds the server's host principal to the database, but does not extract a copy of the host principal key to a keytab. To generate the keytab, use `ext` to extract the server's host principal key to its own keytab:

```
# kadmin
kadmin> add --random-key host/myserver.example.org
Max ticket life [unlimited]:
Max renewable life [unlimited]:
Principal expiration time [never]:
Password expiration time [never]:
Attributes []:
kadmin> ext_keytab host/myserver.example.org
kadmin> exit
```

Note that `ext_keytab` stores the extracted key in `/etc/krb5.keytab` by default. This is good when being run on the server being kerberized, but the `--keytab path/to/file` argument should be used when the keytab is being extracted elsewhere:

```
# kadmin
kadmin> ext_keytab --keytab=/tmp/example.keytab host/myserver.example.org
kadmin> exit
```

The keytab can then be securely copied to the server using scp(1) or a removable media. Be sure to specify a non-default keytab name to avoid inserting unneeded keys into the system's keytab.

At this point, the server can read encrypted messages from the KDC using its shared key, stored in `krb5.keytab`. It is now ready for the Kerberos-using services to be enabled. One of the most common such services is sshd(8), which supports Kerberos via the GSS-API. In `/etc/ssh/sshd_config`, add the line:

```
GSSAPIAuthentication yes
```

After making this change, sshd(8) must be restared for the new configuration to take effect: `service sshd restart`.

13.5.3. Configuring a Client to Use Kerberos

As it was for the server, the client requires configuration in `/etc/krb5.conf`. Copy the file in place (securely) or re-enter it as needed.

Test the client by using `kinit`, `klist`, and `kdestroy` from the client to obtain, show, and then delete a ticket for an existing principal. Kerberos applications should also be able to connect to Kerberos enabled servers. If that does not work but obtaining a ticket does, the problem is likely with the server and not with the client or the KDC. In the case of kerberized ssh(1), GSS-API is disabled by default, so test using `ssh -o GSSAPIAuthentication=yes` *`hostname`*.

When testing a Kerberized application, try using a packet sniffer such as `tcpdump` to confirm that no sensitive information is sent in the clear.

Various Kerberos client applications are available. With the advent of a bridge so that applications using SASL for authentication can use GSS-API mechanisms as well, large classes of client applications can use Kerberos for authentication, from Jabber clients to IMAP clients.

Users within a realm typically have their Kerberos principal mapped to a local user account. Occasionally, one needs to grant access to a local user account to someone who does not have a matching Kerberos principal. For example, `tillman@EXAMPLE.ORG` may need access to the local user account `webdevelopers`. Other principals may also need access to that local account.

The `.k5login` and `.k5users` files, placed in a user's home directory, can be used to solve this problem. For example, if the following `.k5login` is placed in the home directory of `webdevelopers`, both principals listed will have access to that account without requiring a shared password.:

```
tillman@example.org
jdoe@example.org
```

Refer to ksu(1) for more information about `.k5users`.

13.5.4. MIT Differences

The major difference between the MIT and Heimdal implementations is that `kadmin` has a different, but equivalent, set of commands and uses a different protocol. If the KDC is MIT, the Heimdal version of `kadmin` cannot be used to administer the KDC remotely, and vice versa.

Client applications may also use slightly different command line options to accomplish the same tasks. Following the instructions at http://web.mit.edu/Kerberos/www/ is recommended. Be careful of path issues: the MIT port installs into `/usr/local/` by default, and the FreeBSD system applications run instead of the MIT versions if `PATH` lists the system directories first.

When using MIT Kerberos as a KDC on FreeBSD, the following edits should also be made to `rc.conf`:

```
kerberos5_server="/usr/local/sbin/krb5kdc"
kadmind5_server="/usr/local/sbin/kadmind"
kerberos5_server_flags=""
kerberos5_server_enable="YES"
kadmind5_server_enable="YES"
```

13.5.5. Kerberos Tips, Tricks, and Troubleshooting

When configuring and troubleshooting Kerberos, keep the following points in mind:

- When using either Heimdal or MIT Kerberos from ports, ensure that the `PATH` lists the port's versions of the client applications before the system versions.
- If all the computers in the realm do not have synchronized time settings, authentication may fail. 節 28.11, "Clock Synchronization with NTP" describes how to synchronize clocks using NTP.
- If the hostname is changed, the `host/` principal must be changed and the keytab updated. This also applies to special keytab entries like the `HTTP/` principal used for Apache's www/mod_auth_kerb.
- All hosts in the realm must be both forward and reverse resolvable in DNS or, at a minimum, exist in `/etc/hosts`. CNAMEs will work, but the A and PTR records must be correct and in place. The error message for unresolvable hosts is not intuitive: Kerberos5 refuses authentication because Read req failed: Key table entry not found.
- Some operating systems that act as clients to the KDC do not set the permissions for `ksu` to be setuid `root`. This means that `ksu` does not work. This is a permissions problem, not a KDC error.
- With MIT Kerberos, to allow a principal to have a ticket life longer than the default lifetime of ten hours, use `modify_principal` at the kadmin(8) prompt to change the `maxlife` of both the principal in question and the `krbtgt` principal. The principal can then use `kinit -l` to request a ticket with a longer lifetime.
- When running a packet sniffer on the KDC to aid in troubleshooting while running `kinit` from a workstation, the Ticket Granting Ticket (TGT) is sent immediately, even before the password is typed. This is because the Kerberos server freely transmits a TGT to any unauthorized request. However, every TGT is encrypted in a key derived from the user's password. When a user types their password, it is not sent to the KDC, it is instead used to decrypt the TGT that `kinit` already obtained. If the decryption process results in a valid ticket with a valid time stamp, the user has valid Kerberos credentials. These credentials include a session key for establishing secure communications with the Kerberos server in the future, as well as the actual TGT, which is encrypted with the Kerberos server's own key. This second layer of encryption allows the Kerberos server to verify the authenticity of each TGT.
- Host principals can have a longer ticket lifetime. If the user principal has a lifetime of a week but the host being connected to has a lifetime of nine hours, the user cache will have an expired host principal and the ticket cache will not work as expected.
- When setting up `krb5.dict` to prevent specific bad passwords from being used as described in kadmind(8), remember that it only applies to principals that have a password policy assigned to them. The format used in `krb5.dict` is one string per line. Creating a symbolic link to `/usr/share/dict/words` might be useful.

13.5.6. Mitigating Kerberos Limitations

Since Kerberos is an all or nothing approach, every service enabled on the network must either be modified to work with Kerberos or be otherwise secured against network attacks. This is to prevent user credentials from being stolen and re-used. An example is when Kerberos is enabled on all remote shells but the non-Kerberized POP3 mail server sends passwords in plain text.

The KDC is a single point of failure. By design, the KDC must be as secure as its master password database. The KDC should have absolutely no other services running on it and should be physically secure. The danger is high because Kerberos stores all passwords encrypted with the same master key which is stored as a file on the KDC.

A compromised master key is not quite as bad as one might fear. The master key is only used to encrypt the Kerberos database and as a seed for the random number generator. As long as access to the KDC is secure, an attacker cannot do much with the master key.

If the KDC is unavailable, network services are unusable as authentication cannot be performed. This can be alleviated with a single master KDC and one or more slaves, and with careful implementation of secondary or fall-back authentication using PAM.

Kerberos allows users, hosts and services to authenticate between themselves. It does not have a mechanism to authenticate the KDC to the users, hosts, or services. This means that a trojanned `kinit` could record all user names and passwords. File system integrity checking tools like security/tripwire can alleviate this.

13.5.7. Resources and Further Information

- The Kerberos FAQ
- Designing an Authentication System: a Dialog in Four Scenes
- RFC 4120, The Kerberos Network Authentication Service (V5)
- MIT Kerberos home page
- Heimdal Kerberos home page

13.6. OpenSSL

Written by Tom Rhodes.

OpenSSL is an open source implementation of the SSL and TLS protocols. It provides an encryption transport layer on top of the normal communications layer, allowing it to be intertwined with many network applications and services.

The version of OpenSSL included in FreeBSD supports the Secure Sockets Layer v2/v3 (SSLv2/SSLv3) and Transport Layer Security v1 (TLSv1) network security protocols and can be used as a general cryptographic library.

OpenSSL is often used to encrypt authentication of mail clients and to secure web based transactions such as credit card payments. Some ports, such as www/apache24 and databases/postgresql91-server, include a compile option for building with OpenSSL.

FreeBSD provides two versions of OpenSSL: one in the base system and one in the Ports Collection. Users can choose which version to use by default for other ports using the following knobs:

- WITH_OPENSSL_PORT: when set, the port will use OpenSSL from the security/openssl port, even if the version in the base system is up to date or newer.
- WITH_OPENSSL_BASE: when set, the port will compile against OpenSSL provided by the base system.

Another common use of OpenSSL is to provide certificates for use with software applications. Certificates can be used to verify the credentials of a company or individual. If a certificate has not been signed by an external Certificate Authority (CA), such as http://www.verisign.com, the application that uses the certificate will produce a warning. There is a cost associated with obtaining a signed certificate and using a signed certificate is not mandatory as certificates can be self-signed. However, using an external authority will prevent warnings and can put users at ease.

This section demonstrates how to create and use certificates on a FreeBSD system. Refer to 節 28.5.2, “Configuring an LDAP Server” for an example of how to create a CA for signing one's own certificates.

13.6.1. Generating Certificates

To generate a certificate that will be signed by an external CA, issue the following command and input the information requested at the prompts. This input information will be written to the certificate. At the `Common Name` prompt, input the fully qualified name for the system that will use the certificate. If this name does not match the server, the application verifying the certificate will issue a warning to the user, rendering the verification provided by the certificate as useless.

```
# openssl req -new -nodes -out req.pem -keyout cert.pem
Generating a 1024 bit RSA private key
..............++++++
.....................................++++++
writing new private key to 'cert.pem'
-----
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:US
State or Province Name (full name) [Some-State]:PA
Locality Name (eg, city) []:Pittsburgh
Organization Name (eg, company) [Internet Widgits Pty Ltd]:My Company
Organizational Unit Name (eg, section) []:Systems Administrator
Common Name (eg, YOUR name) []:localhost.example.org
Email Address []:trhodes@FreeBSD.org

Please enter the following 'extra' attributes
to be sent with your certificate request
A challenge password []:SOME PASSWORD
An optional company name []:Another Name
```

Other options, such as the expire time and alternate encryption algorithms, are available when creating a certificate. A complete list of options is described in openssl(1).

This command will create two files in the current directory. The certificate request, `req.pem`, can be sent to a CA who will validate the entered credentials, sign the request, and return the signed certificate. The second file, `cert.pem`, is the private key for the certificate and should be stored in a secure location. If this falls in the hands of others, it can be used to impersonate the user or the server.

Alternately, if a signature from a CA is not required, a self-signed certificate can be created. First, generate the RSA key:

```
# openssl dsaparam -rand -genkey -out myRSA.key 1024
0 semi-random bytes loaded
Generating DSA parameters, 1024 bit long prime
This could take some time
.............+........+...........+...+....+........+.....++++++++++++++++++++++++++++++
++++++++++++++++++*
..........+.+...........+....+........+................+.++++++++++++++++++++++++++++++
++++++++++++++++++*
```

Next, generate the CA key. When prompted, enter a passphrase between 4 to 1023 characters. Remember this passphrase as it is needed whenever the key is used to sign a certificate.

```
# openssl gendsa -des3 -out myca.key myRSA.key
Generating DSA key, 1024 bits
Enter PEM pass phrase:
Verifying - Enter PEM pass phrase:
```

Use this key to create a self-signed certificate. When prompted, enter the passphrase. Then follow the usual prompts for creating a certificate:

```
# openssl req -new -x509 -days 365 -key myca.key -out new.crt
Enter pass phrase for myca.key:
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
```

```
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:US
State or Province Name (full name) [Some-State]:PA
Locality Name (eg, city) []:Pittsburgh
Organization Name (eg, company) [Internet Widgits Pty Ltd]:My Company
Organizational Unit Name (eg, section) []:Systems Administrator
Common Name (e.g. server FQDN or YOUR name) []:localhost.example.org
Email Address []:trhodes@FreeBSD.org
```

This will create two new files in the current directory: a certificate authority signature file, `myca.key`, and the certificate itself, `new.crt`. These should be placed in a directory, preferably under `/etc`, which is readable only by `root`. Permissions of `0700` are appropriate for these files and can be set using `chmod`.

13.6.2. Using Certificates

One use for a certificate is to encrypt connections to the Sendmail mail server in order to prevent the use of clear text authentication.

注意

Some mail clients will display an error if the user has not installed a local copy of the certificate. Refer to the documentation included with the software for more information on certificate installation.

In FreeBSD 10.0-RELEASE and above, it is possible to create a self-signed certificate for Sendmail automatically. To enable this, add the following lines to `/etc/rc.conf`:

```
sendmail_enable="YES"
sendmail_cert_create="YES"
sendmail_cert_cn="localhost.example.org "
```

This will automatically create a self-signed certificate, `/etc/mail/certs/host.cert`, a signing key, `/etc/mail/certs/host.key`, and a CA certificate, `/etc/mail/certs/cacert.pem`. The certificate will use the `Common Name` specified in `sendmail_cert_cn`. After saving the edits, restart Sendmail:

```
# service sendmail restart
```

If all went well, there will be no error messages in `/var/log/maillog`. For a simple test, connect to the mail server's listening port using `telnet`:

```
# telnet example.com 25
Trying 192.0.34.166...
Connected to example.com.
Escape character is '^]'.
220 example.com ESMTP Sendmail 8.14.7/8.14.7; Fri, 18 Apr 2014 11:50:32 -0400 (EDT)
ehlo example.com
250-example.com Hello example.com [192.0.34.166], pleased to meet you
250-ENHANCEDSTATUSCODES
250-PIPELINING
250-8BITMIME
250-SIZE
250-DSN
250-ETRN
250-AUTH LOGIN PLAIN
```

```
250-STARTTLS
250-DELIVERBY
250 HELP
quit
221 2.0.0 example.com closing connection
Connection closed by foreign host.
```

If the STARTTLS line appears in the output, everything is working correctly.

13.7. VPN over IPsec

Written by Nik Clayton.
Written by Hiten M. Pandya.

Internet Protocol Security (IPsec) is a set of protocols which sit on top of the Internet Protocol (IP) layer. It allows two or more hosts to communicate in a secure manner by authenticating and encrypting each IP packet of a communication session. The FreeBSD IPsec network stack is based on the http://www.kame.net/ implementation and supports both IPv4 and IPv6 sessions.

IPsec is comprised of the following sub-protocols:

- Encapsulated Security Payload (ESP): this protocol protects the IP packet data from third party interference by encrypting the contents using symmetric cryptography algorithms such as Blowfish and 3DES.
- Authentication Header (AH)): this protocol protects the IP packet header from third party interference and spoofing by computing a cryptographic checksum and hashing the IP packet header fields with a secure hashing function. This is then followed by an additional header that contains the hash, to allow the information in the packet to be authenticated.
- IP Payload Compression Protocol (IPComp): this protocol tries to increase communication performance by compressing the IP payload in order ro reduce the amount of data sent.

These protocols can either be used together or separately, depending on the environment.

IPsec supports two modes of operation. The first mode, Transport Mode, protects communications between two hosts. The second mode, Tunnel Mode, is used to build virtual tunnels, commonly known as Virtual Private Networks (VPNs). Consult ipsec(4) for detailed information on the IPsec subsystem in FreeBSD.

To add IPsec support to the kernel, add the following options to the custom kernel configuration file and rebuild the kernel using the instructions in 章 8, 設定 FreeBSD Kernel:

```
options   IPSEC        #IP security
device    crypto
```

If IPsec debugging support is desired, the following kernel option should also be added:

```
options   IPSEC_DEBUG  #debug for IP security
```

This rest of this chapter demonstrates the process of setting up an IPsec VPN between a home network and a corporate network. In the example scenario:

- Both sites are connected to the Internet through a gateway that is running FreeBSD.
- The gateway on each network has at least one external IP address. In this example, the corporate LAN's external IP address is `172.16.5.4` and the home LAN's external IP address is `192.168.1.12` .
- The internal addresses of the two networks can be either public or private IP addresses. However, the address space must not collide. For example, both networks cannot use `192.168.1.x` . In this example, the corporate LAN's internal IP address is `10.246.38.1` and the home LAN's internal IP address is `10.0.0.5` .

13.7.1. Configuring a VPN on FreeBSD

Written by Tom Rhodes.

To begin, security/ipsec-tools must be installed from the Ports Collection. This software provides a number of applications which support the configuration.

The next requirement is to create two gif(4) pseudo-devices which will be used to tunnel packets and allow both networks to communicate properly. As `root`, run the following commands, replacing *`internal`* and *`external`* with the real IP addresses of the internal and external interfaces of the two gateways:

```
# ifconfig gif0 create
# ifconfig gif0 internal1 internal2
# ifconfig gif0 tunnel external1 external2
```

Verify the setup on each gateway, using `ifconfig`. Here is the output from Gateway 1:

```
gif0: flags=8051 mtu 1280
tunnel inet 172.16.5.4 --> 192.168.1.12
inet6 fe80::2e0:81ff:fe02:5881%gif0 prefixlen 64 scopeid 0x6
inet 10.246.38.1 --> 10.0.0.5 netmask 0xffffff00
```

Here is the output from Gateway 2:

```
gif0: flags=8051 mtu 1280
tunnel inet 192.168.1.12 --> 172.16.5.4
inet 10.0.0.5 --> 10.246.38.1 netmask 0xffffff00
inet6 fe80::250:bfff:fe3a:c1f%gif0 prefixlen 64 scopeid 0x4
```

Once complete, both internal IP addresses should be reachable using ping(8):

```
priv-net# ping 10.0.0.5
PING 10.0.0.5 (10.0.0.5): 56 data bytes
64 bytes from 10.0.0.5: icmp_seq=0 ttl=64 time=42.786 ms
64 bytes from 10.0.0.5: icmp_seq=1 ttl=64 time=19.255 ms
64 bytes from 10.0.0.5: icmp_seq=2 ttl=64 time=20.440 ms
64 bytes from 10.0.0.5: icmp_seq=3 ttl=64 time=21.036 ms
--- 10.0.0.5 ping statistics ---
4 packets transmitted, 4 packets received, 0% packet loss
round-trip min/avg/max/stddev = 19.255/25.879/42.786/9.782 ms

corp-net# ping 10.246.38.1
PING 10.246.38.1 (10.246.38.1): 56 data bytes
64 bytes from 10.246.38.1: icmp_seq=0 ttl=64 time=28.106 ms
64 bytes from 10.246.38.1: icmp_seq=1 ttl=64 time=42.917 ms
64 bytes from 10.246.38.1: icmp_seq=2 ttl=64 time=127.525 ms
64 bytes from 10.246.38.1: icmp_seq=3 ttl=64 time=119.896 ms
64 bytes from 10.246.38.1: icmp_seq=4 ttl=64 time=154.524 ms
--- 10.246.38.1 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 28.106/94.594/154.524/49.814 ms
```

As expected, both sides have the ability to send and receive ICMP packets from the privately configured addresses. Next, both gateways must be told how to route packets in order to correctly send traffic from either network. The following commands will achieve this goal:

```
# corp-net# route add 10.0.0.0 10.0.0.5 255.255.255.0
# corp-net# route add net 10.0.0.0: gateway 10.0.0.5
# priv-net# route add 10.246.38.0 10.246.38.1 255.255.255.0
# priv-net# route add host 10.246.38.0: gateway 10.246.38.1
```

At this point, internal machines should be reachable from each gateway as well as from machines behind the gateways. Again, use ping(8) to confirm:

```
corp-net# ping 10.0.0.8
PING 10.0.0.8 (10.0.0.8): 56 data bytes
64 bytes from 10.0.0.8: icmp_seq=0 ttl=63 time=92.391 ms
64 bytes from 10.0.0.8: icmp_seq=1 ttl=63 time=21.870 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=63 time=198.022 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=63 time=22.241 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=63 time=174.705 ms
--- 10.0.0.8 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 21.870/101.846/198.022/74.001 ms

priv-net# ping 10.246.38.107
PING 10.246.38.1 (10.246.38.107): 56 data bytes
64 bytes from 10.246.38.107: icmp_seq=0 ttl=64 time=53.491 ms
64 bytes from 10.246.38.107: icmp_seq=1 ttl=64 time=23.395 ms
64 bytes from 10.246.38.107: icmp_seq=2 ttl=64 time=23.865 ms
64 bytes from 10.246.38.107: icmp_seq=3 ttl=64 time=21.145 ms
64 bytes from 10.246.38.107: icmp_seq=4 ttl=64 time=36.708 ms
--- 10.246.38.107 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 21.145/31.721/53.491/12.179 ms
```

Setting up the tunnels is the easy part. Configuring a secure link is a more in depth process. The following configuration uses pre-shared (PSK) RSA keys. Other than the IP addresses, the `/usr/local/etc/racoon/racoon.conf` on both gateways will be identical and look similar to:

```
path    pre_shared_key  "/usr/local/etc/racoon/psk.txt"; #location of pre-shared key file
log     debug; #log verbosity setting: set to 'notify' when testing and debugging is ↺
complete

padding # options are not to be changed
{
        maximum_length  20;
        randomize       off;
        strict_check    off;
        exclusive_tail  off;
}

timer # timing options. change as needed
{
        counter         5;
        interval        20 sec;
        persend         1;
#       natt_keepalive  15 sec;
        phase1          30 sec;
        phase2          15 sec;
}

listen # address [port] that racoon will listen on
{
        isakmp          172.16.5.4 [500];
        isakmp_natt     172.16.5.4 [4500];
}

remote  192.168.1.12 [500]
{
        exchange_mode   main,aggressive;
        doi             ipsec_doi;
        situation       identity_only;
        my_identifier   address 172.16.5.4;
        peers_identifier        address 192.168.1.12;
        lifetime        time 8 hour;
        passive         off;
        proposal_check  obey;
#       nat_traversal   off;
        generate_policy off;
```

```
                        proposal {
                                encryption_algorithm    blowfish;
                                hash_algorithm          md5;
                                authentication_method   pre_shared_key;
                                lifetime time           30 sec;
                                dh_group                1;
                        }
}

sainfo  (address 10.246.38.0/24 any address 10.0.0.0/24 any) # address $network/
$netmask $type address $network/$netmask $type ( $type being any or esp)
{        # $network must be the two internal networks you are joining.
        pfs_group       1;
        lifetime        time    36000 sec;
        encryption_algorithm    blowfish,3des,des;
        authentication_algorithm        hmac_md5,hmac_sha1;
        compression_algorithm   deflate;
}
```

For descriptions of each available option, refer to the manual page for `racoon.conf` .

The Security Policy Database (SPD) needs to be configured so that FreeBSD and racoon are able to encrypt and decrypt network traffic between the hosts.

This can be achieved with a shell script, similar to the following, on the corporate gateway. This file will be used during system initialization and should be saved as `/usr/local/etc/racoon/setkey.conf` .

```
flush;
spdflush;
# To the home network
spdadd 10.246.38.0/24 10.0.0.0/24 any -P out ipsec esp/tunnel/172.16.5.4-192.168.1.12/
use;
spdadd 10.0.0.0/24 10.246.38.0/24 any -P in ipsec esp/tunnel/192.168.1.12-172.16.5.4/use;
```

Once in place, racoon may be started on both gateways using the following command:

```
# /usr/local/sbin/racoon -F -f /usr/local/etc/racoon/racoon.conf -l /
var/log/racoon.log
```

The output should be similar to the following:

```
corp-net# /usr/local/sbin/racoon -F -f /usr/local/etc/racoon/racoon.conf
Foreground mode.
2006-01-30 01:35:47: INFO: begin Identity Protection mode.
2006-01-30 01:35:48: INFO: received Vendor ID: KAME/racoon
2006-01-30 01:35:55: INFO: received Vendor ID: KAME/racoon
2006-01-30 01:36:04: INFO: ISAKMP-SA established 172.16.5.4[500]-192.168.1.12[500] ↺
spi:623b9b3bd2492452:7deab82d54ff704a
2006-01-30 01:36:05: INFO: initiate new phase 2 negotiation: 172.16.5.4[0]192.168.1.12[0]
2006-01-30 01:36:09: INFO: IPsec-SA established: ESP/Tunnel 192.168.1.12[0]-
>172.16.5.4[0] spi=28496098(0x1b2d0e2)
2006-01-30 01:36:09: INFO: IPsec-SA established: ESP/Tunnel 172.16.5.4[0]-
>192.168.1.12[0] spi=47784998(0x2d92426)
2006-01-30 01:36:13: INFO: respond new phase 2 negotiation: 172.16.5.4[0]192.168.1.12[0]
2006-01-30 01:36:18: INFO: IPsec-SA established: ESP/Tunnel 192.168.1.12[0]-
>172.16.5.4[0] spi=124397467(0x76a279b)
2006-01-30 01:36:18: INFO: IPsec-SA established: ESP/Tunnel 172.16.5.4[0]-
>192.168.1.12[0] spi=175852902(0xa7b4d66)
```

To ensure the tunnel is working properly, switch to another console and use tcpdump(1) to view network traffic using the following command. Replace `em0` with the network interface card as required:

```
# tcpdump -i em0 host  172.16.5.4 and dst 192.168.1.12
```

Data similar to the following should appear on the console. If not, there is an issue and debugging the returned data will be required.

```
01:47:32.021683 IP corporatenetwork.com > 192.168.1.12.privatenetwork.com: ESP↺
(spi=0x02acbf9f,seq=0xa)
01:47:33.022442 IP corporatenetwork.com > 192.168.1.12.privatenetwork.com: ESP↺
(spi=0x02acbf9f,seq=0xb)
01:47:34.024218 IP corporatenetwork.com > 192.168.1.12.privatenetwork.com: ESP↺
(spi=0x02acbf9f,seq=0xc)
```

At this point, both networks should be available and seem to be part of the same network. Most likely both networks are protected by a firewall. To allow traffic to flow between them, rules need to be added to pass packets. For the ipfw(8) firewall, add the following lines to the firewall configuration file:

```
ipfw add 00201 allow log esp from any to any
ipfw add 00202 allow log ah from any to any
ipfw add 00203 allow log ipencap from any to any
ipfw add 00204 allow log udp from any 500 to any
```

注意

The rule numbers may need to be altered depending on the current host configuration.

For users of pf(4) or ipf(8), the following rules should do the trick:

```
pass in quick proto esp from any to any
pass in quick proto ah from any to any
pass in quick proto ipencap from any to any
pass in quick proto udp from any port = 500 to any port = 500
pass in quick on gif0 from any to any
pass out quick proto esp from any to any
pass out quick proto ah from any to any
pass out quick proto ipencap from any to any
pass out quick proto udp from any port = 500 to any port = 500
pass out quick on gif0 from any to any
```

Finally, to allow the machine to start support for the VPN during system initialization, add the following lines to `/etc/rc.conf` :

```
ipsec_enable="YES"
ipsec_program="/usr/local/sbin/setkey"
ipsec_file="/usr/local/etc/racoon/setkey.conf" # allows setting up spd policies on boot
racoon_enable="yes"
```

13.8. OpenSSH

Contributed by Chern Lee.

OpenSSH is a set of network connectivity tools used to provide secure access to remote machines. Additionally, TCP/IP connections can be tunneled or forwarded securely through SSH connections. OpenSSH encrypts all traffic to effectively eliminate eavesdropping, connection hijacking, and other network-level attacks.

OpenSSH is maintained by the OpenBSD project and is installed by default in FreeBSD. It is compatible with both SSH version 1 and 2 protocols.

When data is sent over the network in an unencrypted form, network sniffers anywhere in between the client and server can steal user/password information or data transferred during the session. OpenSSH offers a variety

of authentication and encryption methods to prevent this from happening. More information about OpenSSH is available from http://www.openssh.com/.

This section provides an overview of the built-in client utilities to securely access other systems and securely transfer files from a FreeBSD system. It then describes how to configure a SSH server on a FreeBSD system. More information is available in the man pages mentioned in this chapter.

13.8.1. Using the SSH Client Utilities

To log into a SSH server, use `ssh` and specify a username that exists on that server and the IP address or hostname of the server. If this is the first time a connection has been made to the specified server, the user will be prompted to first verify the server's fingerprint:

```
# ssh user@example.com
The authenticity of host 'example.com (10.0.0.1)' can't be established.
ECDSA key fingerprint is 25:cc:73:b5:b3:96:75:3d:56:19:49:d2:5c:1f:91:3b.
Are you sure you want to continue connecting (yes/no)? yes
Permanently added 'example.com' (ECDSA) to the list of known hosts.
Password for user@example.com: user_password
```

SSH utilizes a key fingerprint system to verify the authenticity of the server when the client connects. When the user accepts the key's fingerprint by typing `yes` when connecting for the first time, a copy of the key is saved to `.ssh/known_hosts` in the user's home directory. Future attempts to login are verified against the saved key and `ssh` will display an alert if the server's key does not match the saved key. If this occurs, the user should first verify why the key has changed before continuing with the connection.

By default, recent versions of OpenSSH only accept SSHv2 connections. By default, the client will use version 2 if possible and will fall back to version 1 if the server does not support version 2. To force `ssh` to only use the specified protocol, include `-1` or `-2`. Additional options are described in ssh(1).

Use scp(1) to securely copy a file to or from a remote machine. This example copies `COPYRIGHT` on the remote system to a file of the same name in the current directory of the local system:

```
# scp user@example.com:/COPYRIGHT COPYRIGHT
Password for user@example.com: *******
COPYRIGHT            100% |***************************|  4735
00:00
#
```

Since the fingerprint was already verified for this host, the server's key is automatically checked before prompting for the user's password.

The arguments passed to `scp` are similar to `cp`. The file or files to copy is the first argument and the destination to copy to is the second. Since the file is fetched over the network, one or more of the file arguments takes the form `user@host:<path_to_remote_file>` . Be aware when copying directories recursively that `scp` uses `-r`, whereas `cp` uses `-R`.

To open an interactive session for copying files, use `sftp`. Refer to sftp(1) for a list of available commands while in an `sftp` session.

13.8.1.1. Key-based Authentication

Instead of using passwords, a client can be configured to connect to the remote machine using keys. To generate DSA or RSA authentication keys, use `ssh-keygen` . To generate a public and private key pair, specify the type of key and follow the prompts. It is recommended to protect the keys with a memorable, but hard to guess passphrase.

```
% ssh-keygen -t dsa
Generating public/private dsa key pair.
```

```
Enter file in which to save the key (/home/user/.ssh/id_dsa):
Created directory '/home/user/.ssh'.
Enter passphrase (empty for no passphrase): type some passphrase here which can ↺
contain spaces
Enter same passphrase again: type some passphrase here which can contain ↺
spaces
Your identification has been saved in /home/user/.ssh/id_dsa.
Your public key has been saved in /home/user/.ssh/id_dsa.pub.
The key fingerprint is:
bb:48:db:f2:93:57:80:b6:aa:bc:f5:d5:ba:8f:79:17 user@host.example.com
```

Depending upon the specified protocol, the private key is stored in `~/.ssh/id_dsa` (or `~/.ssh/id_rsa`), and the public key is stored in `~/.ssh/id_dsa.pub` (or `~/.ssh/id_rsa.pub`). The public key must be first copied to `~/.ssh/authorized_keys` on the remote machine in order for key-based authentication to work.

警告

Many users believe that keys are secure by design and will use a key without a passphrase. This is dangerous behavior. An administrator can verify that a key pair is protected by a passphrase by viewing the private key manually. If the private key file contains the word `ENCRYPTED`, the key owner is using a passphrase. In addition, to better secure end users, `from` may be placed in the public key file. For example, adding `from="192.168.10.5"` in the front of `ssh-rsa` or `rsa-dsa` prefix will only allow that specific user to login from that IP address.

The various options and files can be different according to the OpenSSH version. To avoid problems, consult ssh-keygen(1).

If a passphrase is used, the user will be prompted for the passphrase each time a connection is made to the server. To load SSH keys into memory, without needing to type the passphrase each time, use ssh-agent(1) and ssh-add(1).

Authentication is handled by `ssh-agent`, using the private key(s) that are loaded into it. Then, `ssh-agent` should be used to launch another application such as a shell or a window manager.

To use `ssh-agent` in a shell, start it with a shell as an argument. Next, add the identity by running `ssh-add` and providing it the passphrase for the private key. Once these steps have been completed, the user will be able to `ssh` to any host that has the corresponding public key installed. For example:

```
% ssh-agent csh
% ssh-add
Enter passphrase for key '/usr/home/user/.ssh/id_dsa': type passphrase here
Identity added: /usr/home/user/.ssh/id_dsa (/usr/home/user/.ssh/id_dsa)
%
```

To use `ssh-agent` in Xorg, add an entry for it in `~/.xinitrc`. This provides the `ssh-agent` services to all programs launched in Xorg. An example `~/.xinitrc` might look like this:

```
exec ssh-agent startxfce4
```

This launches `ssh-agent`, which in turn launches XFCE, every time Xorg starts. Once Xorg has been restarted so that the changes can take effect, run `ssh-add` to load all of the SSH keys.

13.8.1.2. SSH Tunneling

OpenSSH has the ability to create a tunnel to encapsulate another protocol in an encrypted session.

The following command tells `ssh` to create a tunnel for telnet:

```
% ssh -2 -N -f -L 5023:localhost:23 user@foo.example.com
%
```

This example uses the following options:

`-2`
: Forces `ssh` to use version 2 to connect to the server.

`-N`
: Indicates no command, or tunnel only. If omitted, `ssh` initiates a normal session.

`-f`
: Forces `ssh` to run in the background.

`-L`
: Indicates a local tunnel in *`localport:remotehost:remoteport`* format.

`user@foo.example.com`
: The login name to use on the specified remote SSH server.

An SSH tunnel works by creating a listen socket on `localhost` on the specified `localport`. It then forwards any connections received on `localport` via the SSH connection to the specified `remotehost:remoteport`. In the example, port `5023` on the client is forwarded to port `23` on the remote machine. Since port 23 is used by telnet, this creates an encrypted telnet session through an SSH tunnel.

This method can be used to wrap any number of insecure TCP protocols such as SMTP, POP3, and FTP, as seen in the following examples.

範例 13.1. Create a Secure Tunnel for SMTP

```
% ssh -2 -N -f -L 5025:localhost:25 user@mailserver.example.com
user@mailserver.example.com's password: *****
% telnet localhost 5025
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
220 mailserver.example.com ESMTP
```

This can be used in conjunction with `ssh-keygen` and additional user accounts to create a more seamless SSH tunneling environment. Keys can be used in place of typing a password, and the tunnels can be run as a separate user.

範例 13.2. Secure Access of a POP3 Server

In this example, there is an SSH server that accepts connections from the outside. On the same network resides a mail server running a POP3 server. To check email in a secure manner, create an SSH connection to the SSH server and tunnel through to the mail server:

```
% ssh -2 -N -f -L 2110:mail.example.com:110 user@ssh-server.↺
example.com
user@ssh-server.example.com's password: ******
```

Once the tunnel is up and running, point the email client to send POP3 requests to `localhost` on port 2110. This connection will be forwarded securely across the tunnel to `mail.example.com` .

範例 13.3. Bypassing a Firewall

Some firewalls filter both incoming and outgoing connections. For example, a firewall might limit access from remote machines to ports 22 and 80 to only allow SSH and web surfing. This prevents access to any other service which uses a port other than 22 or 80.

The solution is to create an SSH connection to a machine outside of the network's firewall and use it to tunnel to the desired service:

```
% ssh -2 -N -f -L 8888:music.example.com:8000 user@unfirewalled-system.example.org
user@unfirewalled-system.example.org's password: *******
```

In this example, a streaming Ogg Vorbis client can now be pointed to `localhost` port 8888, which will be forwarded over to `music.example.com` on port 8000, successfully bypassing the firewall.

13.8.2. Enabling the SSH Server

In addition to providing built-in SSH client utilities, a FreeBSD system can be configured as an SSH server, accepting connections from other SSH clients.

To see if sshd is enabled, check `/etc/rc.conf` for this line and add it if it is missing:

```
sshd_enable="YES"
```

This will start sshd, the daemon program for OpenSSH, the next time the system boots. To start it now:

```
# service sshd start
```

The first time sshd starts on a FreeBSD system, the system's host keys will be automatically created and the fingerprint will be displayed on the console. Provide users with the fingerprint so that they can verify it the first time they connect to the server.

Refer to sshd(8) for the list of available options when starting sshd and a more complete discussion about authentication, the login process, and the various configuration files.

It is a good idea to limit which users can log into the SSH server and from where using the `AllowUsers` keyword in the OpenSSH server configuration file. For example, to only allow `root` to log in from `192.168.1.32` , add this line to `/etc/ssh/sshd_config` :

```
AllowUsers root@192.168.1.32
```

To allow `admin` to log in from anywhere, list that user without specifying an IP address:

```
AllowUsers admin
```

Multiple users should be listed on the same line, like so:

```
AllowUsers root@192.168.1.32 admin
```

After making changes to `/etc/ssh/sshd_config` , tell sshd to reload its configuration file by running:

```
# service sshd reload
```

注意

When this keyword is used, it is important to list each user that needs to log into this machine. Any user that is not specified in that line will be locked out. Also, the keywords used in the OpenSSH server configuration file are case-sensitive. If the keyword is not spelled correctly, including its case, it will be ignored. Always test changes to this file to make sure that the edits are working as expected. Refer to sshd_config(5) to verify the spelling and use of the available keywords.

提示

Do not confuse `/etc/ssh/sshd_config` with `/etc/ssh/ssh_config` (note the extra `d` in the first filename). The first file configures the server and the second file configures the client. Refer to ssh_config(5) for a listing of the available client settings,.

13.9. Access Control Lists

Contributed by Tom Rhodes.

Access Control Lists (ACLs) extend the standard UNIX® permission model in a POSIX®.1e compatible way. This permits an administrator to take advantage of a more fine-grained permissions model.

The FreeBSD `GENERIC` kernel provides ACL support for UFS file systems. Users who prefer to compile a custom kernel must include the following option in their custom kernel configuration file:

```
options UFS_ACL
```

If this option is not compiled in, a warning message will be displayed when attempting to mount a file system with ACL support. ACLs rely on extended attributes which are natively supported in UFS2.

This chapter describes how to enable ACL support and provides some usage examples.

13.9.1. Enabling ACL Support

ACLs are enabled by the mount-time administrative flag, `acls`, which may be added to `/etc/fstab`. The mount-time flag can also be automatically set in a persistent manner using tunefs(8) to modify a superblock ACLs flag in the file system header. In general, it is preferred to use the superblock flag for several reasons:

- The superblock flag cannot be changed by a remount using `mount -u` as it requires a complete `umount` and fresh `mount`. This means that ACLs cannot be enabled on the root file system after boot. It also means that ACL support on a file system cannot be changed while the system is in use.
- Setting the superblock flag causes the file system to always be mounted with ACLs enabled, even if there is not an `fstab` entry or if the devices re-order. This prevents accidental mounting of the file system without ACL support.

注意

It is desirable to discourage accidental mounting without ACLs enabled because nasty things can happen if ACLs are enabled, then disabled, then re-enabled without flushing the extended

attributes. In general, once ACLs are enabled on a file system, they should not be disabled, as the resulting file protections may not be compatible with those intended by the users of the system, and re-enabling ACLs may re-attach the previous ACLs to files that have since had their permissions changed, resulting in unpredictable behavior.

File systems with ACLs enabled will show a plus (+) sign in their permission settings:

```
drwx------  2 robert  robert  512 Dec 27 11:54 private
drwxrwx---+ 2 robert  robert  512 Dec 23 10:57 directory1
drwxrwx---+ 2 robert  robert  512 Dec 22 10:20 directory2
drwxrwx---+ 2 robert  robert  512 Dec 27 11:57 directory3
drwxr-xr-x  2 robert  robert  512 Nov 10 11:54 public_html
```

In this example, `directory1` , `directory2` , and `directory3` are all taking advantage of ACLs, whereas `public_html` is not.

13.9.2. Using ACLs

File system ACLs can be viewed using `getfacl` . For instance, to view the ACL settings on `test`:

```
% getfacl test
 #file:test
 #owner:1001
 #group:1001
 user::rw-
 group::r--
 other::r--
```

To change the ACL settings on this file, use `setfacl` . To remove all of the currently defined ACLs from a file or file system, include `-k`. However, the preferred method is to use `-b` as it leaves the basic fields required for ACLs to work.

```
% setfacl -k test
```

To modify the default ACL entries, use `-m`:

```
% setfacl -m u:trhodes:rwx,group:web:r--,o::--- test
```

In this example, there were no pre-defined entries, as they were removed by the previous command. This command restores the default options and assigns the options listed. If a user or group is added which does not exist on the system, an Invalid argument error will be displayed.

Refer to getfacl(1) and setfacl(1) for more information about the options available for these commands.

13.10. Monitoring Third Party Security Issues

Contributed by Tom Rhodes.

In recent years, the security world has made many improvements to how vulnerability assessment is handled. The threat of system intrusion increases as third party utilities are installed and configured for virtually any operating system available today.

Vulnerability assessment is a key factor in security. While FreeBSD releases advisories for the base system, doing so for every third party utility is beyond the FreeBSD Project's capability. There is a way to mitigate third party vulnerabilities and warn administrators of known security issues. A FreeBSD add on utility known as portaudit exists solely for this purpose.

The ports-mgmt/portaudit port polls a database, which is updated and maintained by the FreeBSD Security Team and ports developers, for known security issues.

To install portaudit from the Ports Collection:

```
# cd /usr/ports/ports-mgmt/portaudit && make install clean
```

During the installation, the configuration files for periodic(8) will be updated, permitting portaudit output in the daily security runs. Ensure that the daily security run emails, which are sent to `root`'s email account, are being read. No other configuration is required.

After installation, an administrator can update the database and view known vulnerabilities in installed packages by invoking the following command:

```
# portaudit -Fda
```

注意

The database is automatically updated during the periodic(8) run. The above command is optional and can be used to manually update the database now.

To audit the third party utilities installed as part of the Ports Collection at anytime, an administrator can run the following command:

```
# portaudit -a
```

portaudit will display messages for any installed vulnerable packages:

```
Affected package: cups-base-1.1.22.0_1
Type of problem: cups-base -- HPGL buffer overflow vulnerability.
Reference: <http://www.FreeBSD.org/ports/portaudit/40a3bca2-6809-11d9-a9e7-0001020eed82.↺
html>

1 problem(s) in your installed packages found.

You are advised to update or deinstall the affected package(s) immediately.
```

By pointing a web browser to the displayed URL, an administrator may obtain more information about the vulnerability. This will include the versions affected, by FreeBSD port version, along with other web sites which may contain security advisories.

portaudit is a powerful utility and is extremely useful when coupled with the portmaster port.

13.11. FreeBSD Security Advisories

Contributed by Tom Rhodes.

Like many producers of quality operating systems, the FreeBSD Project has a security team which is responsible for determining the End-of-Life (EoL) date for each FreeBSD release and to provide security updates for supported releases which have not yet reached their EoL. More information about the FreeBSD security team and the supported releases is available on the FreeBSD security page.

One task of the security team is to respond to reported security vulnerabilities in the FreeBSD operating system. Once a vulnerability is confirmed, the security team verifies the steps necessary to fix the vulnerability and updates the source code with the fix. It then publishes the details as a "Security Advisory". Security advisories are published on the FreeBSD website and mailed to the freebsd-security-notifications, freebsd-security, and freebsd-announce mailing lists.

This section describes the format of a FreeBSD security advisory.

13.11.1. Format of a Security Advisory

Here is an example of a FreeBSD security advisory:

```
=============================================================================
-----BEGIN PGP SIGNED MESSAGE-----
Hash: SHA512

=============================================================================
FreeBSD-SA-14:04.bind                                        Security Advisory
                                                          The FreeBSD Project

Topic:          BIND remote denial of service vulnerability

Category:       contrib
Module:         bind
Announced:      2014-01-14
Credits:        ISC
Affects:        FreeBSD 8.x and FreeBSD 9.x
Corrected:      2014-01-14 19:38:37 UTC (stable/9, 9.2-STABLE)
                2014-01-14 19:42:28 UTC (releng/9.2, 9.2-RELEASE-p3)
                2014-01-14 19:42:28 UTC (releng/9.1, 9.1-RELEASE-p10)
                2014-01-14 19:38:37 UTC (stable/8, 8.4-STABLE)
                2014-01-14 19:42:28 UTC (releng/8.4, 8.4-RELEASE-p7)
                2014-01-14 19:42:28 UTC (releng/8.3, 8.3-RELEASE-p14)
CVE Name:       CVE-2014-0591

For general information regarding FreeBSD Security Advisories,
including descriptions of the fields above, security branches, and the
following sections, please visit <URL:http://security.FreeBSD.org/>.

I.   Background

BIND 9 is an implementation of the Domain Name System (DNS) protocols.
The named(8) daemon is an Internet Domain Name Server.

II.  Problem Description

Because of a defect in handling queries for NSEC3-signed zones, BIND can
crash with an "INSIST" failure in name.c when processing queries possessing
certain properties.  This issue only affects authoritative nameservers with
at least one NSEC3-signed zone.  Recursive-only servers are not at risk.

III. Impact

An attacker who can send a specially crafted query could cause named(8)
to crash, resulting in a denial of service.

IV.  Workaround

No workaround is available, but systems not running authoritative DNS service
with at least one NSEC3-signed zone using named(8) are not vulnerable.

V.   Solution

Perform one of the following:

1) Upgrade your vulnerable system to a supported FreeBSD stable or
release / security branch (releng) dated after the correction date.

2) To update your vulnerable system via a source code patch:

The following patches have been verified to apply to the applicable
FreeBSD release branches.
```

```
a) Download the relevant patch from the location below, and verify the
detached PGP signature using your PGP utility.

[FreeBSD 8.3, 8.4, 9.1, 9.2-RELEASE and 8.4-STABLE]
# fetch http://security.FreeBSD.org/patches/SA-14:04/bind-release.patch
# fetch http://security.FreeBSD.org/patches/SA-14:04/bind-release.patch.asc
# gpg --verify bind-release.patch.asc

[FreeBSD 9.2-STABLE]
# fetch http://security.FreeBSD.org/patches/SA-14:04/bind-stable-9.patch
# fetch http://security.FreeBSD.org/patches/SA-14:04/bind-stable-9.patch.asc
# gpg --verify bind-stable-9.patch.asc

b) Execute the following commands as root:

# cd /usr/src
# patch < /path/to/patch

Recompile the operating system using buildworld and installworld as
described in <URL:http://www.FreeBSD.org/handbook/makeworld.html>.

Restart the applicable daemons, or reboot the system.

3) To update your vulnerable system via a binary patch:

Systems running a RELEASE version of FreeBSD on the i386 or amd64
platforms can be updated via the freebsd-update(8) utility:

# freebsd-update fetch
# freebsd-update install

VI.  Correction details

The following list contains the correction revision numbers for each
affected branch.

Branch/path                                                      Revision
- -------------------------------------------------------------------------
stable/8/                                                         r260646
releng/8.3/                                                       r260647
releng/8.4/                                                       r260647
stable/9/                                                         r260646
releng/9.1/                                                       r260647
releng/9.2/                                                       r260647
- -------------------------------------------------------------------------

To see which files were modified by a particular revision, run the
following command, replacing NNNNNN with the revision number, on a
machine with Subversion installed:

# svn diff -cNNNNNN --summarize svn://svn.freebsd.org/base

Or visit the following URL, replacing NNNNNN with the revision number:

<URL:http://svnweb.freebsd.org/base?view=revision&revision=NNNNNN>

VII. References

<URL:https://kb.isc.org/article/AA-01078>

<URL:http://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2014-0591>

The latest revision of this advisory is available at
<URL:http://security.FreeBSD.org/advisories/FreeBSD-SA-14:04.bind.asc>
-----BEGIN PGP SIGNATURE-----
```

```
iQIcBAEBCgAGBQJS1ZTYAAoJEO1n7NZdz2rnOvQP/2/68/s9Cu35PmqNtSZVVxVG
ZSQP5EGWx/lramNf9566iKxOrLRMq/h3XWcC4goVd+gZFrvITJSVOWSa7ntDQ7TO
XcinfRZ/iyiJbs/Rg2wLHc/t5oVSyeouyccqODYFbOwOlk35JjOTMUG1YcX+Zasg
ax8RV+7Zt1QSBkMlOz/myBLXUjlTZ3Xg2FXVsfFQW5/g2CjuHpRSFx1bVNX6ysoG
9DT58EQcYxIS8WfkHRbbXKh9I1nSfZ7/Hky/kTafRdRMrjAgbqFgHkYTYsBZeav5
fYWKGQRJulYfeZQ90yMTvlpF42DjCC3uJYamJnwDIu8OhS1WRBI8fQfr9DRzmRua
OK3BK9hUiScDZOJB6OqeVzUTfe7MAA4/UwrDtTYQ+PqAenv1PK8DZqwXyxA9ThHb
zKO3OwuKOVHJnKvpOcr+eNwo7jbnHlis0oBksj/mrq2P9m2ueF9gzCiq5Ri5Syag
Wssb1HUoMGwqU0roS8+pRpNC8YgsWpsttvUWSZ8u6Vj/FLeHpiV3mYXPVMaKRhVm
067BA2uj4Th1JKtGleox+Em0R7OFbCc/9aWC67wiqI6KRyit9pYiF3npph+7D5Eq
7zPsUdDd+qc+UTiLp3liCRp5w6484wWdhZO6wRtmUgxGjNkxFoNnX8CitzF8AaqO
UWWemqWuz3lAZuORQ9KX
=OQzQ
-----END PGP SIGNATURE-----
```

Every security advisory uses the following format:

- Each security advisory is signed by the PGP key of the Security Officer. The public key for the Security Officer can be verified at 附錄 D, PGP Keys.
- The name of the security advisory always begins with `FreeBSD-SA-` (for FreeBSD Security Advisory), followed by the year in two digit format (`14:`), followed by the advisory number for that year (`04.`), followed by the name of the affected application or subsystem (`bind`). The advisory shown here is the fourth advisory for 2014 and it affects BIND.
- The `Topic` field summarizes the vulnerability.
- The `Category` refers to the affected part of the system which may be one of `core`, `contrib`, or `ports`. The `core` category means that the vulnerability affects a core component of the FreeBSD operating system. The `contrib` category means that the vulnerability affects software included with FreeBSD, such as BIND. The `ports` category indicates that the vulnerability affects software available through the Ports Collection.
- The `Module` field refers to the component location. In this example, the `bind` module is affected; therefore, this vulnerability affects an application installed with the operating system.
- The `Announced` field reflects the date the security advisory was published. This means that the security team has verified that the problem exists and that a patch has been committed to the FreeBSD source code repository.
- The `Credits` field gives credit to the individual or organization who noticed the vulnerability and reported it.
- The `Affects` field explains which releases of FreeBSD are affected by this vulnerability.
- The `Corrected` field indicates the date, time, time offset, and releases that were corrected. The section in parentheses shows each branch for which the fix has been merged, and the version number of the corresponding release from that branch. The release identifier itself includes the version number and, if appropriate, the patch level. The patch level is the letter `p` followed by a number, indicating the sequence number of the patch, allowing users to track which patches have already been applied to the system.
- The `CVE Name` field lists the advisory number, if one exists, in the public cve.mitre.org security vulnerabilities database.
- The `Background` field provides a description of the affected module.
- The `Problem Description` field explains the vulnerability. This can include information about the flawed code and how the utility could be maliciously used.
- The `Impact` field describes what type of impact the problem could have on a system.
- The `Workaround` field indicates if a workaround is available to system administrators who cannot immediately patch the system .

- The `Solution` field provides the instructions for patching the affected system. This is a step by step tested and verified method for getting a system patched and working securely.
- The `Correction Details` field displays each affected Subversion branch with the revision number that contains the corrected code.
- The `References` field offers sources of additional information regarding the vulnerability.

13.12. Process Accounting

Contributed by Tom Rhodes.

Process accounting is a security method in which an administrator may keep track of system resources used and their allocation among users, provide for system monitoring, and minimally track a user's commands.

Process accounting has both positive and negative points. One of the positives is that an intrusion may be narrowed down to the point of entry. A negative is the amount of logs generated by process accounting, and the disk space they may require. This section walks an administrator through the basics of process accounting.

注意

If more fine-grained accounting is needed, refer to 章 16, Security Event Auditing.

13.12.1. Enabling and Utilizing Process Accounting

Before using process accounting, it must be enabled using the following commands:

```
# touch /var/account/acct
# chmod 600 /var/account/acct
# accton /var/account/acct
# echo 'accounting_enable="YES"' >> /etc/rc.conf
```

Once enabled, accounting will begin to track information such as CPU statistics and executed commands. All accounting logs are in a non-human readable format which can be viewed using `sa`. If issued without any options, `sa` prints information relating to the number of per-user calls, the total elapsed time in minutes, total CPU and user time in minutes, and the average number of I/O operations. Refer to sa(8) for the list of available options which control the output.

To display the commands issued by users, use `lastcomm`. For example, this command prints out all usage of `ls` by `trhodes` on the `ttyp1` terminal:

```
# lastcomm ls trhodes ttyp1
```

Many other useful options exist and are explained in lastcomm(1), acct(5), and sa(8).

13.13. Resource Limits

Contributed by Tom Rhodes.

FreeBSD provides several methods for an administrator to limit the amount of system resources an individual may use. Disk quotas limit the amount of disk space available to users. Quotas are discussed in 節 17.12, “磁碟空間配額(Quota)”.

Limits to other resources, such as CPU and memory, can be set using either a flat file or a command to configure a resource limits database. The traditional method defines login classes by editing `/etc/login.conf` . While this method is still supported, any changes require a multi-step process of editing this file, rebuilding the resource database, making necessary changes to `/etc/master.passwd` , and rebuilding the password database. This can become time consuming, depending upon the number of users to configure.

Beginning with FreeBSD 9.0-RELEASE, `rctl` can be used to provide a more fine-grained method for controlling resource limits. This command supports more than user limits as it can also be used to set resource constraints on processes and jails.

This section demonstrates both methods for controlling resources, beginning with the traditional method.

13.13.1. Configuring Login Classes

In the traditional method, login classes and the resource limits to apply to a login class are defined in `/etc/login.conf` . Each user account can be assigned to a login class, where `default` is the default login class. Each login class has a set of login capabilities associated with it. A login capability is a *`name=value`* pair, where *`name`* is a well-known identifier and *`value`* is an arbitrary string which is processed accordingly depending on the *`name`*.

注意

Whenever `/etc/login.conf` is edited, the `/etc/login.conf.db` must be updated by executing the following command:

```
# cap_mkdb /etc/login.conf
```

Resource limits differ from the default login capabilities in two ways. First, for every limit, there is a soft and hard limit. A soft limit may be adjusted by the user or application, but may not be set higher than the hard limit. The hard limit may be lowered by the user, but can only be raised by the superuser. Second, most resource limits apply per process to a specific user.

表格 13.1, “Login Class Resource Limits” lists the most commonly used resource limits. All of the available resource limits and capabilities are described in detail in login.conf(5).

表格 13.1. Login Class Resource Limits

Resource Limit	Description
coredumpsize	The limit on the size of a core file generated by a program is subordinate to other limits on disk usage, such as `filesize` or disk quotas. This limit is often used as a less severe method of controlling disk space consumption. Since users do not generate core files and often do not delete them, this setting may save them from running out of disk space should a large program crash.
cputime	The maximum amount of CPU time a user's process may consume. Offending processes will be killed by the kernel. This is a limit on CPU time consumed, not the percentage of the CPU as displayed in some of the fields generated by `top` and `ps`.
filesize	The maximum size of a file the user may own. Unlike disk quotas (節 17.12, “磁碟空間配額(Quota)”), this limit is

Resource Limit	Description
	enforced on individual files, not the set of all files a user owns.
maxproc	The maximum number of foreground and background processes a user can run. This limit may not be larger than the system limit specified by `kern.maxproc`. Setting this limit too small may hinder a user's productivity as some tasks, such as compiling a large program, start lots of processes.
memorylocked	The maximum amount of memory a process may request to be locked into main memory using mlock(2). Some system-critical programs, such as amd(8), lock into main memory so that if the system begins to swap, they do not contribute to disk thrashing.
memoryuse	The maximum amount of memory a process may consume at any given time. It includes both core memory and swap usage. This is not a catch-all limit for restricting memory consumption, but is a good start.
openfiles	The maximum number of files a process may have open. In FreeBSD, files are used to represent sockets and IPC channels, so be careful not to set this too low. The system-wide limit for this is defined by `kern.maxfiles`.
sbsize	The limit on the amount of network memory a user may consume. This can be generally used to limit network communications.
stacksize	The maximum size of a process stack. This alone is not sufficient to limit the amount of memory a program may use, so it should be used in conjunction with other limits.

There are a few other things to remember when setting resource limits:

- Processes started at system startup by `/etc/rc` are assigned to the `daemon` login class.
- Although the default `/etc/login.conf` is a good source of reasonable values for most limits, they may not be appropriate for every system. Setting a limit too high may open the system up to abuse, while setting it too low may put a strain on productivity.
- Xorg takes a lot of resources and encourages users to run more programs simultaneously.
- Many limits apply to individual processes, not the user as a whole. For example, setting `openfiles` to `50` means that each process the user runs may open up to `50` files. The total amount of files a user may open is the value of `openfiles` multiplied by the value of `maxproc`. This also applies to memory consumption.

For further information on resource limits and login classes and capabilities in general, refer to cap_mkdb(1), getrlimit(2), and login.conf(5).

13.13.2. Enabling and Configuring Resource Limits

By default, kernel support for `rctl` is not built-in, meaning that the kernel will first need to be recompiled using the instructions in 章 8, 設定 FreeBSD Kernel. Add these lines to either `GENERIC` or a custom kernel configuration file, then rebuild the kernel:

```
options         RACCT
```

```
options         RCTL
```

Once the system has rebooted into the new kernel, `rctl` may be used to set rules for the system.

Rule syntax is controlled through the use of a subject, subject-id, resource, and action, as seen in this example rule:

```
user:trhodes:maxproc:deny=10/user
```

In this rule, the subject is `user`, the subject-id is `trhodes`, the resource, `maxproc`, is the maximum number of processes, and the action is `deny`, which blocks any new processes from being created. This means that the user, `trhodes`, will be constrained to no greater than `10` processes. Other possible actions include logging to the console, passing a notification to devd(8), or sending a sigterm to the process.

Some care must be taken when adding rules. Since this user is constrained to `10` processes, this example will prevent the user from performing other tasks after logging in and executing a `screen` session. Once a resource limit has been hit, an error will be printed, as in this example:

```
% man test
    /usr/bin/man: Cannot fork: Resource temporarily unavailable
eval: Cannot fork: Resource temporarily unavailable
```

As another example, a jail can be prevented from exceeding a memory limit. This rule could be written as:

```
# rctl -a jail:httpd:memoryuse:deny=2G/jail
```

Rules will persist across reboots if they have been added to `/etc/rctl.conf`. The format is a rule, without the preceding command. For example, the previous rule could be added as:

```
# Block jail from using more than 2G memory:
jail:httpd:memoryuse:deny=2G/jail
```

To remove a rule, use `rctl` to remove it from the list:

```
# rctl -r user:trhodes:maxproc:deny=10/user
```

A method for removing all rules is documented in rctl(8). However, if removing all rules for a single user is required, this command may be issued:

```
# rctl -r user:trhodes
```

Many other resources exist which can be used to exert additional control over various `subjects`. See rctl(8) to learn about them.

章 14. Jails

Contributed by Matteo Riondato.

14.1. 概述

本章將介紹 FreeBSD jail 為何，以及如何運用之法。 Jails 有時也常被認為是 chroot 環境 的加强型替代品之一，它對系統管理者而言是非常好用的工具， 此外，它的一些基本用法對進階使用者而言，也是相當有用。

讀完這章，您將了解：

- jail 是什麼，以及它在 FreeBSD 上可以發揮的作用。
- 如何編譯、啓動、停止 `jail`。
- jail 管理的基本概念：包括從 jail 內部或主機本身。

其他有用的 jail 相關資源還有：

- jail(8) 線上說明。 這是有關 `jail` 的完整說明 —— FreeBSD 內的啓動、停止、控制 FreeBSD jail 相關管理工具。
- 郵遞論壇(mailing lists)及舊信檔案館(`archives`)。 FreeBSD list server 所提供的 FreeBSD general questions 郵遞論壇 及其他郵遞論壇的舊信 ，已有包括一堆 jail 的有用資料。 通常，搜尋舊信或者在 freebsd-questions 上發問，也相當有效。

14.2. Jail 相關術語

為協助更容易理解 FreeBSD 系統的 jail 相關部分， 以及它們與 FreeBSD 其他部分的相互作用關係， 以下列出本章將使用的術語：

chroot(2) (指令)
: FreeBSD 的 system call 之一，其作用為改變 process 及其衍生 process 所能運用的根目錄 (/ `dir`)。

chroot(2) (環境)
: 指在 “chroot” 中運行的 process 環境。 這包括了類似檔案系統的可見部分、可用的 `UID`、`GID`、網路卡及其他 IPC 機制等資源。

jail(8) (command)
: 允許程式在 jail 環境下執行的系統管理工具。

host (系統、`process`、帳號等等)
: jail 環境的控制系統。 host 系統可以使用全部可用的硬體資源， 並能控制 jail 環境內外的 `process`。 host 系統與 jail 最大的差別在於 ：在 host 系統中的 superuser processes 並不像在 jail 環境那樣處處受到一堆限制。

hosted (系統、`process`、帳號等等)
: 可用資源受到 FreeBSD jail 限制的 `process`、帳號、或其他設備資源 。

14.3. 背景故事

由於系統管理是困難又繁瑣的工作，因此人們開發許多好用工具， 以讓管理工作更加簡單輕鬆。 這些改善通常是讓系統能夠以更簡單的方式安裝、 設定、維護，而有些改善目標則是系統安全的正確設定，使其能真正發揮原本用途， 而非陷入安全風險之中。

FreeBSD 系統所提供的一種用於强化安全的工具就是 jail 。 Jail 是由 Poul-Henning Kamp 於 FreeBSD 4.X 開始導入，而在 FreeBSD 5.X 受到許多重大改良而集大成，成為强大而靈活的子系統，目前仍在持續開發、 以提高其可用性、效能與安全。

14.3.1. 何爲 Jail

BSD-like 作業系統自 4.2BSD 起即提供 chroot(2)。 chroot(8) 可用來變更一組 process 的根目錄位置， 藉此建立與實體系統中相隔離的安全環境。 處於 chrooted 環境的 process 會無法存取世外的檔案或資源。 由於此因素， 故即使攻擊者攻破某個處於 chroot 環境的 `service`，也不能攻破整個系統。 chroot(8) 對於那些不太需要彈性或複雜又高級的簡單應用而言相當好用。 另外，在引入 chroot 概念的過程中，曾經發現許多可脫逃 chroot 環境的方式， 儘管這些問題在較新版本的 FreeBSD kernel 均已修正，但很明顯地 chroot(2) 絶非用於强化安全的理想解決方案。 因此， 勢必得實作新的子系統來解決這些問題。

這就是為何要開發 jail 的最主要原因。

Jail 在各種方式分進合擊，改進傳統 chroot(2) 環境的概念。 在傳統的 chroot(2) 環境中，只限制 process 對於檔案系統的存取部分， 而系統資源的其他部分(例如系統帳號、執行中的 `process`、網路子系統)則是由 chroot process 與 host 系統的其他 process 一起共享。 Jail 以『虛擬化』來擴展這模型，不單只有檔案系統的存取，還延伸到 系統帳號、FreeBSD kernel 的網路子系統及其他系統資源的虛擬化。 關於這些 jail 環境存取的細微調控，請參閱 節 14.5, “微調與管理” 。

jail 具有下列四項特色：

- 目錄子樹(directory subtree) —— 也就是進入 jail 的起點。 一旦進入 jail 之後，`process` 就不再被允許跳到 subtree 以外。 &傳統會影響到 chroot(2) 最初設計的安全問題，就不會再影響 FreeBSD `jail`。
- 主機名稱(hostname) —— 用於 jail 的 `hostname`。 由於 jail 主要用於網路服務，因此若各 jail 皆有名稱， 對於系統管理工作的簡化會相當有效。
- IP address —— 是用來給 jail 使用， 並且在 jail 生命週期內都無法變更。 通常 jail 的 IP address 是現有網卡的 alias `address`，但這並不是必須的。
- 指令(Command) —— 準備在 jail 內執行的完整路徑。 這指令是相對於 jail 環境的根目錄，視 jail 環境的類型不同，而有所差異。

除了上述之外，`jail` 也可擁有自己的帳號及 `root` 帳號。 當然，這裡的`root` 權力會受制於 jail 環境內。 並且從 host 系統的角度來看，`jail` 的 `root` 並非無所不能的帳號。 此外 jail 的 `root` 並不能執行其對於 jail(8) 環境以外的一些關鍵性操作。 關於 `root` 的能力與限制，將於稍後的 節 14.5, “微調與管理” 介紹之。

14.4. 建立和控制 Jail

有些系統管理者把 jail 分為下列兩種： “`complete`(完全)” jail —— 通常包括完整的 FreeBSD 系統；另一種則為 “`service`(服務)” jail —— 專門只跑某單一可能要用特殊權限的程式或 `service`。 這只是一種概念上的區分 ，並不影響如何建立 jail 的過程。 至於如何建立 jail 在 jail(8) 內有更詳細的說明：

```
# setenv D /here/is/the/jail
# mkdir -p $D ❶
# cd /usr/src
# make world DESTDIR=$D ❷
# cd etc/ [1]
# make distribution DESTDIR=$D ❸
# mount -t devfs $D/dev ❹
```

❶ 首先就是先為 jail 找個家。 該路徑是在 host 系統中的 jail 實體位置。 習慣是放在 `/usr/jail/jailname`， *`jailname`* 請替換為該 jail 的 hostname 以便辨別。 通常 `/usr` 會有足夠空間來存放

[1] FreeBSD 6.0-(含) 之後就不需這步驟。

jail 檔案系統，對於 “complete” jail 而言，它通常包括了 FreeBSD 預設安裝 base system 所有檔案的拷貝檔。

❷ 該指令將會在 jail 目錄中安裝所需的 `binary`、`library`、`manual` 說明等 。 這些是以傳統的 FreeBSD 方式完成 —— 即首先先編譯所有檔案， 接著再裝到目的地。

❸ 使用 `distribution` 這個 make target 來裝所有會用到的設定檔。 簡單來說該動作就是把 `/usr/src/etc/` 複製到 jail 環境內的 `/etc`，也就是 `$D/etc/` 。

❹ 對於 jail 環境而言，devfs(8) 檔案系統的掛載並非必須， 但另一方面，幾乎所有應用程式都會需要存取至少一個設備(`device`)，這主要取決於該程式目的而定。 控制 jail 所能存取的設備非常重要，因為不正確的設定，會讓攻擊者對 jail 有機可趁。 至於如何透過 devfs(8) 來控制的規則，可以參閱 devfs(8) 及 devfs.conf(5) 說明。

裝好 jail 之後，就可以用 jail(8) 工具。 jail(8) 需要四項必填參數，這些參數在 節 14.3.1, “何為 Jail” 有介紹過。 除了這四個參數之外，還可以指定其他參數，像是以特定帳號在 jail 中執行 `process`。 *`command`* 參數取決於 jail 類型而定；對於 virtual `system`(虛擬系統)，那麼就選擇 `/etc/rc`，因為它會完成真正 FreeBSD 系統啓動所需的操作。 對於 `service`(服務) jail 而言，執行的指令取決於將在 jail 內執行的 service 或應用程式而定。

Jail 通常要在系統開機時啓動，因此 FreeBSD 的 `rc` 機制提供一些便利的方式來簡化這些工作：

1. 開機時要啓動的 jail 清單要加到 rc.conf(5) 設定檔：

```
jail_enable="YES"   # ### NO ######## jail
jail_list="www"     # #### jail #########
```

2. 對於每一筆在 `jail_list` 所列出的 `jail`， 也要在 rc.conf(5) 做出相對應的設定：

```
jail_www_rootdir="/usr/jail/www"      # jail ####
jail_www_hostname="www.example.org"  # jail # hostname
jail_www_ip="192.168.0.10"            # jail # IP address
jail_www_devfs_enable="YES"           # # jail # mount devfs
jail_www_devfs_ruleset="www_ruleset" # jail #### devfs ###
```

在 rc.conf(5) 所預設的 jail 啓動設定會跑 `/etc/rc` 內的 jail `script`，也就是說會假設 jail 是完整的虛擬系統。 若要用 service jail 類型，則要另外指定啓動指令， 方法是設定對應的 `jail_`*`jailname`*`_exec_start` 設定。

注意

若欲知道所有可用的選項清單，請參閱 rc.conf(5) 說明。

也可以透過手動執行 `/etc/rc.d/jail` script 來啓動或停止 `rc.conf` 所設定的 `jail`：

```
# /etc/rc.d/jail start www
# /etc/rc.d/jail stop www
```

目前尚無任何方法來很乾淨地關閉 jail(8)。 此乃因為正常用來關閉系統的指令，目前尚不能在 jail 中使用。 目前關閉 jail 最佳的方式，是在 jail 內執行下列指令，或者 jail 外面透過 jexec(8) 執行下列指令：

```
# sh /etc/rc.shutdown
```

詳情請參閱 jail(8) 說明。

14.5. 微調與管理

可以為 jail 設定許多不同選項，並讓 FreeBSD 的 host 系統與 jail 以各種不同方式組合搭配，以符合更多的應用用途。 本節要介紹的是：

- 用以微調 jail 行為與安全限制的選項。
- 可透過 FreeBSD Ports Collection 安裝的高階 jail 管理程式， 搭配這些程式可以達到一些 jail-based 解決方案。

14.5.1. FreeBSD 所提供的 jail tuning 工具

對於 jail 設定的微調，基本上都是透過設定 sysctl(8) 變數來完成。 系統提供一組 sysctl 的特殊子樹，全部相關的選項都在該子樹內，也就是 FreeBSD kernel 中的 `security.jail.*` 子樹。 下面則是與 jail 相關的主要 sysctl 設定及預設值，這些名稱都相當容易理解， 如欲更進一步的資訊，請參閱 jail(8) 與 sysctl(8) 說明：

- `security.jail.set_hostname_allowed: 1`
- `security.jail.socket_unixiproute_only: 1`
- `security.jail.sysvipc_allowed: 0`
- `security.jail.enforce_statfs: 2`
- `security.jail.allow_raw_sockets: 0`
- `security.jail.chflags_allowed: 0`
- `security.jail.jailed: 0`

系統管理者可在 host system 透過修改這些設定值來增加、取消 Jail 內 `root` 帳號的預設限制。 請注意：有些限制是不能取消，在 jail(8) 環境的 `root` 不能掛載或卸載檔案系統。 此外亦不能載入、 卸載 devfs(8) 規則、設定防火牆規則，或執行其他需修改 kernel 資料的管理作業，例如設定 kernel 的 `securelevel` 值。

FreeBSD base system 內附一些基本工具，可用來查閱目前使用中的 `jail`、 並接上(attach) jail 以執行管理指令。 jls(8) 及 jexec(8) 均屬於 FreeBSD base system 之一，可用來執行一些簡單工作：

- 列出有在使用的 jail 及其相對應的 jail identifier (`JID`)、`IP address`、 `hostname`、路徑。
- 接上(Attach)正在運作中的 `jail`，並在其中執行指令以進行管理工作。 這點在當 `root` 想乾淨關閉 jail 時相當有用， jexec(8) 也可用在 jail 中啓動 shell 以便對其進行管理， 比如：

```
# jexec 1 tcsh
```

14.5.2. FreeBSD Ports Collection 所提供的高階管理工具

在諸多 third-party 所提供的 jail 管理工具當中，sysutils/jailutils 是最完整也最好用的。 該套件是由一系列 jail(8) 管理小工具所組成的。 詳情請參閱其網站介紹 。

14.6. Jail 的應用

14.6.1. Service Jails

Contributed by Daniel Gerzo.

本節主要以 Simon L. B. Nielsen 寫的 `http://simon.nitro.dk/service-jails.html` 為主，加上 Ken Tom <`locals@gmail.com` > 所更新的文章。 本節介紹如何設定 FreeBSD 以 jail(8) 功能來增加額外的安全層面。 這部分假設您系統跑的是 RELENG_6_0 或更新的版本， 並且對本章先前部分均能理解。

14.6.1.1. Design

Jail 的主要問題之一在於如何對其進行更新、升級和管理。 由於每個 jail 都是從頭重新編譯，對於單一 jail 而言， 升級也許還不是很嚴重的問題，因為更新、升級並不會太麻煩。 但對於一堆 jail 而言，升級不僅會耗費太多時間，並相當枯燥乏味。

警告

這些設定的前提是您對 FreeBSD 使用、功能運用上有相當的經驗， 若下面的設定對您來說太過複雜，建議您該考慮用較簡易的系統，像是 sysutils/ezjail，其提供更簡單的 FreeBSD jail 管理方式。

基本的想法是在不同的 jail 中儘量以安全的方式來共用資源 —— 採用唯讀的 mount_nullfs(8) 掛載，來讓升級更簡單， 並把各個 service 放到不同的 jail 的作法會更加可行。 此外， 其也提供對於如何增加、刪除、升級 jail 的簡便方式。

注意

service 常見的例子包括： HTTP `server`、DNS `server`、SMTP server 等等。

本節介紹的設定目的在於：

- 建立簡易且容易理解的 jail 架構。 也就是說 不必為每個 jail 都執行完整的 installworld 。
- 讓 jail 的新增、移除更簡單。
- 讓 jail 的更新、升級更輕鬆。
- 可以跑自行打造的 FreeBSD 分支。
- 對安全有更偏執狂的追求，儘可能降低被攻陷的可能。
- 儘量節省空間與 `inode`。

如同先前所提到的，這設計主要是靠把唯讀的主要模版（也就是大家所熟知的 nullfs)掛載到每個 `jail`，並且讓每個 jail 有個可讀、寫的設備，這設備可以是獨立實體硬碟、 、分割區、或以 vnode 為後端的 md(4) 設備。 在本例當中， 我們採用可讀寫的 nullfs 掛載。

下面的表則介紹檔案系統的配置：

- 每個 jail 都會掛載到 `/home/j` 底下的其中一個目錄。
- `/home/j/mroot` 則是每個 jail 共用的模版，並對於所有 jail 而言都是唯讀。
- 每個 jail 在 `/home/j` 底下都有一個相對應的空目錄。
- 每個 jail 都會有 `/s` 目錄， 該目錄會連到系統的可讀寫部分。
- 每個 jail 都會在 `/home/j/skel` 目錄建立自屬的可讀寫空間 。
- 每個 jailspace（各 jail 可讀寫的部分）都建在 `/home/js` >。

注意

這邊假設所有 jail 都放在 /home 分割區。 當然， 也可以依自身需求更改，但接下來的例子中， 也要記得修改相對應的地方。

14.6.1.2. 建立模版

本節將逐步介紹如何建立 jail 要用的唯讀主模版。

建議先把 FreeBSD 系統升級到最新的 -RELEASE 分支，至於如何做請參閱 Handbook 的 相關章節。 當更新完成之後，就要進行 buildworld 程序，此外還要裝 sysutils/cpdup 套件。 我們將用 portsnap(8) 來下載 FreeBSD Ports Collection， 在 Handbook 中 過程 4.1, “Portsnap 方式” 有相關介紹，初學者可以看看。

1. 首先，先建立唯讀的目錄結構給 jail 放 FreeBSD binary， 接著到 FreeBSD source tree 目錄，並安裝 jail 模版：

```
# mkdir -p /home/j/mroot
# cd /usr/src
# make installworld DESTDIR=/home/j/mroot
```

2. 接著跟 FreeBSD source tree 一樣，也把 FreeBSD Ports Collection 放一份供 jail 使用，以備 mergemaster ：

```
# cd /home/j/mroot
# mkdir usr/ports
# portsnap -p /home/j/mroot/usr/ports fetch extract
# cpdup /usr/src /home/j/mroot/usr/src
```

3. 建立可讀寫部分的骨架：

```
# mkdir /home/j/skel /home/j/skel/home /home/j/skel/usr-X11R6 /home/
j/skel/distfiles
# mv etc /home/j/skel
# mv usr/local /home/j/skel/usr-local
# mv tmp /home/j/skel
# mv var /home/j/skel
# mv root /home/j/skel
```

4. 用 mergemaster 來裝漏掉的設定檔。 接下來刪除 mergemaster 所建立的多餘目錄：

```
# mergemaster -t /home/j/skel/var/tmp/temproot -D /home/j/skel -i
# cd /home/j/skel
# rm -R bin boot lib libexec mnt proc rescue sbin sys usr dev
```

5. 現在把可讀寫的檔案系統以 symlink 方式連到唯讀的檔案系統。 請確認 symbolic link 是否有正確連到 s/ 目錄，若目錄建立方式不對， 或指向位置不對，可能會導致安裝失敗。

```
# cd /home/j/mroot
# mkdir s
# ln -s s/etc etc
# ln -s s/home home
# ln -s s/root root
# ln -s ../s/usr-local usr/local
# ln -s ../s/usr-X11R6 usr/X11R6
# ln -s ../../s/distfiles usr/ports/distfiles
```

```
# ln -s s/tmp tmp
# ln -s s/var var
```

6. 最後則是新增 /home/j/skel/etc/make.conf ，並填入以下內容：

```
WRKDIRPREFIX?=  /s/portbuild
```

要設定 WRKDIRPREFIX 才可以讓各 jail 得以順利編譯 FreeBSD ports。請記住 ports 目錄是屬唯讀檔案系統。 而搭配自訂的 WRKDIRPREFIX 才可以讓各 jail 在可讀寫空間進行編譯。

14.6.1.3. 建立 Jail

現在已經有完整的 FreeBSD jail 模版，可以在 /etc/rc.conf 內做相關設定。 下面這例子則示範如何建立 3 個 jail：“NS”、“MAIL”、“WWW”。

1. 在 /etc/fstab 加上下列設定， 以便讓系統自動掛載各 jail 所需的唯讀模版與讀寫空間：

```
/home/j/mroot   /home/j/ns     nullfs  ro  0   0
/home/j/mroot   /home/j/mail   nullfs  ro  0   0
/home/j/mroot   /home/j/www    nullfs  ro  0   0
/home/js/ns     /home/j/ns/s   nullfs  rw  0   0
/home/js/mail   /home/j/mail/s nullfs  rw  0   0
/home/js/www    /home/j/www/s  nullfs  rw  0   0
```

注意

分割區的 pass number 標示為 0 就不會在開機時做 fsck(8) 檢查；而分割區的 dump number 標示為 0 則不會被 dump(8) 所備份。 我們並不希望 fsck 檢查 nullfs 的掛載，或者讓 dump 備份 jail 內唯讀的 nullfs 掛載。 這也就是為何上述 fstab 每行設定後面都有兩欄為 “0 0”。

2. 在 /etc/rc.conf 內設定 jail：

```
jail_enable="YES"
jail_set_hostname_allow="NO"
jail_list="ns mail www"
jail_ns_hostname="ns.example.org"
jail_ns_ip="192.168.3.17"
jail_ns_rootdir="/usr/home/j/ns"
jail_ns_devfs_enable="YES"
jail_mail_hostname="mail.example.org"
jail_mail_ip="192.168.3.18"
jail_mail_rootdir="/usr/home/j/mail"
jail_mail_devfs_enable="YES"
jail_www_hostname="www.example.org"
jail_www_ip="62.123.43.14"
jail_www_rootdir="/usr/home/j/www"
jail_www_devfs_enable="YES"
```

警告

之所以要把 jail_*name*_rootdir 從 /home 改為 /usr/home 的原因在於 FreeBSD 預設安裝的 /home 目錄其實只是指向 /usr/home 的 symbolic link。 而 jail_*name*_rootdir 變數須為 實體目錄 而非 symbolic link， 否則 jail 會拒絕

啓動。 可以用 realpath(1) 來決定該變數。 詳情請參閱 FreeBSD-SA-07:01.jail 安全通告。

3. 替每個 jail 建立必須的唯讀檔案系統掛載點：

```
# mkdir /home/j/ns /home/j/mail /home/j/www
```

4. 為每個 jail 安裝可讀寫的模版。 請注意這時要用 sysutils/cpdup ，它能確保每個目錄都有正確複製。

```
# mkdir /home/js
# cpdup /home/j/skel /home/js/ns
# cpdup /home/j/skel /home/js/mail
# cpdup /home/j/skel /home/js/www
```

5. 如此一來就已完成 jail 環境建立，可以準備好要用了。 請先為各 jail 掛載所須的檔案系統，再用 `/etc/rc.d/jail` script 來啓動：

```
# mount -a
# /etc/rc.d/jail start
```

現在 jail 應該就會啓動了。 若要檢查是否有正常啓動，可以用 jls(8) 指令來看，該指令的執行結果應該類似下面：

```
# jls
   JID  IP Address      Hostname                      Path
     3  192.168.3.17    ns.example.org                /home/j/ns
     2  192.168.3.18    mail.example.org              /home/j/mail
     1  62.123.43.14    www.example.org               /home/j/www
```

此時就可以登入各 jail 並新增帳號與設定相關 service 要用的 daemon 。 上面的 `JID` 欄代表正在運作中的 jail 編號。 可用下列指令以在 `JID` 編號 3 的 jail 執行管理工作：

```
# jexec 3 tcsh
```

14.6.1.4. 升級

有時由於安全問題或者 jail 內要用新功能，而需要把 FreeBSD 系統升級到更新。 這種安裝設計方式讓既有的 jail 升級變得更加容易。 jail 也可以把 service 停機時間(downtime)降到最低，因為 jail 只需在最後關鍵才需要重開。 此外，萬一新版有問題的話， 它也提供輕鬆回溯到舊版的功能。

1. 首先是照一般方式來升級 host `system`，再新增臨時的唯讀模版 `/home/j/mroot2` ：

```
# mkdir /home/j/mroot2
# cd /usr/src
# make installworld DESTDIR=/home/j/mroot2
# cd /home/j/mroot2
# cpdup /usr/src usr/src
# mkdir s
```

同樣地，在執行 `installworld` 時會建立一些用不著的目錄，請把這些砍掉：

```
# chflags -R 0 var
# rm -R etc var root usr/local tmp
```

2. 重新建立到主系統的可讀寫空間 `symlink`：

```
# ln -s s/etc etc
```

```
# ln -s s/root root
# ln -s s/home home
# ln -s ../s/usr-local usr/local
# ln -s ../s/usr-X11R6 usr/X11R6
# ln -s s/tmp tmp
# ln -s s/var var
```

3. 現在可以關閉 jail：

```
# /etc/rc.d/jail stop
```

4. 卸載原先的檔案系統：

```
# umount /home/j/ns/s
# umount /home/j/ns
# umount /home/j/mail/s
# umount /home/j/mail
# umount /home/j/www/s
# umount /home/j/www
```

注意

可讀寫空間(/s) 是掛載在唯讀檔案系統底下，故要先卸載。

5. 把舊的唯讀系統搬走，換成新的。 如此一來， 可同時保留先前系統的備份，以備萬一升級後有問題可回復。 這邊的命名方式採新唯讀檔案系統的建立時間，此外原先 FreeBSD Ports Collection 直接搬到新的檔案系統，以節省硬碟空間與 inode ：

```
# cd /home/j
# mv mroot mroot.20060601
# mv mroot2 mroot
# mv mroot.20060601/usr/ports mroot/usr
```

6. 現在新的唯讀模版準備好了，只剩下重新掛載以及啓動 jail：

```
# mount -a
# /etc/rc.d/jail start
```

最後以 jls(8) 來檢查 jail 是否均正常啓動。 別忘了要在各 jail 內執行 mergemaster，還有相關設定檔以及 rc.d scripts 均要更新。

章 15. Mandatory Access Control

Written by Tom Rhodes.

15.1. Synopsis

FreeBSD 5.X introduced new security extensions from the TrustedBSD project based on the POSIX®.1e draft. Two of the most significant new security mechanisms are file system Access Control Lists (ACLs) and Mandatory Access Control (MAC) facilities. Mandatory Access Control allows new access control modules to be loaded, implementing new security policies. Some provide protections of a narrow subset of the system, hardening a particular service, while others provide comprehensive labeled security across all subjects and objects. The mandatory part of the definition comes from the fact that the enforcement of the controls is done by administrators and the system, and is not left up to the discretion of users as is done with discretionary access control (DAC, the standard file and System V IPC permissions on FreeBSD).

This chapter will focus on the Mandatory Access Control Framework (MAC Framework), and a set of pluggable security policy modules enabling various security mechanisms.

After reading this chapter, you will know:

- What MAC security policy modules are currently included in FreeBSD and their associated mechanisms.
- What MAC security policy modules implement as well as the difference between a labeled and non-labeled policy.
- How to efficiently configure a system to use the MAC framework.
- How to configure the different security policy modules included with the MAC framework.
- How to implement a more secure environment using the MAC framework and the examples shown.
- How to test the MAC configuration to ensure the framework has been properly implemented.

Before reading this chapter, you should:

- Understand UNIX® and FreeBSD basics (章 3, UNIX 基礎概念).
- Be familiar with the basics of kernel configuration/compilation (章 8, 設定 FreeBSD Kernel).
- Have some familiarity with security and how it pertains to FreeBSD (章 13, 系統安全).

警告

The improper use of the information in this chapter may cause loss of system access, aggravation of users, or inability to access the features provided by X11. More importantly, MAC should not be relied upon to completely secure a system. The MAC framework only augments existing security policy; without sound security practices and regular security checks, the system will never be completely secure.

It should also be noted that the examples contained within this chapter are just that, examples. It is not recommended that these particular settings be rolled out on a production system. Implementing the various security policy modules takes a good deal of thought. One who does not fully understand exactly how everything works may find him or herself going back through the entire system and reconfiguring many files or directories.

15.1.1. What Will Not Be Covered

This chapter covers a broad range of security issues relating to the MAC framework; however, the development of new MAC security policy modules will not be covered. A number of security policy modules included with the MAC framework have specific characteristics which are provided for both testing and new module development. These include the mac_test(4), mac_stub(4) and mac_none(4). For more information on these security policy modules and the various mechanisms they provide, please review the manual pages.

15.2. Key Terms in this Chapter

Before reading this chapter, a few key terms must be explained. This will hopefully clear up any confusion that may occur and avoid the abrupt introduction of new terms and information.

- compartment: A compartment is a set of programs and data to be partitioned or separated, where users are given explicit access to specific components of a system. Also, a compartment represents a grouping, such as a work group, department, project, or topic. Using compartments, it is possible to implement a need-to-know security policy.

- integrity: Integrity, as a key concept, is the level of trust which can be placed on data. As the integrity of the data is elevated, so does the ability to trust that data.

- label: A label is a security attribute which can be applied to files, directories, or other items in the system. It could be considered a confidentiality stamp; when a label is placed on a file it describes the security properties for that specific file and will only permit access by files, users, resources, etc. with a similar security setting. The meaning and interpretation of label values depends on the policy configuration: while some policies might treat a label as representing the integrity or secrecy of an object, other policies might use labels to hold rules for access.

- level: The increased or decreased setting of a security attribute. As the level increases, its security is considered to elevate as well.

- multilabel: The `multilabel` property is a file system option which can be set in single user mode using the tunefs(8) utility, during the boot operation using the fstab(5) file, or during the creation of a new file system. This option will permit an administrator to apply different MAC labels on different objects. This option only applies to security policy modules which support labeling.

- object: An object or system object is an entity through which information flows under the direction of a subject. This includes directories, files, fields, screens, keyboards, memory, magnetic storage, printers or any other data storage/moving device. Basically, an object is a data container or a system resource; access to an object effectively means access to the data.

- policy: A collection of rules which defines how objectives are to be achieved. A policy usually documents how certain items are to be handled. This chapter will consider the term policy in this context as a security policy; i.e. a collection of rules which will control the flow of data and information and define whom will have access to that data and information.

- sensitivity: Usually used when discussing MLS. A sensitivity level is a term used to describe how important or secret the data should be. As the sensitivity level increases, so does the importance of the secrecy, or confidentiality of the data.

- single label: A single label is when the entire file system uses one label to enforce access control over the flow of data. When a file system has this set, which is any time when the `multilabel` option is not set, all files will conform to the same label setting.

- subject: a subject is any active entity that causes information to flow between objects; e.g. a user, user processor, system process, etc. On FreeBSD, this is almost always a thread acting in a process on behalf of a user.

15.3. Explanation of MAC

With all of these new terms in mind, consider how the MAC framework augments the security of the system as a whole. The various security policy modules provided by the MAC framework could be used to protect the network and file systems, block users from accessing certain ports and sockets, and more. Perhaps the best use of the policy modules is to blend them together, by loading several security policy modules at a time for a multi-layered security environment. In a multi-layered security environment, multiple policy modules are in effect to keep security in check. This is different to a hardening policy, which typically hardens elements of a system that is used only for specific purposes. The only downside is administrative overhead in cases of multiple file system labels, setting network access control user by user, etc.

These downsides are minimal when compared to the lasting effect of the framework; for instance, the ability to pick and choose which policies are required for a specific configuration keeps performance overhead down. The reduction of support for unneeded policies can increase the overall performance of the system as well as offer flexibility of choice. A good implementation would consider the overall security requirements and effectively implement the various security policy modules offered by the framework.

Thus a system utilizing MAC features should at least guarantee that a user will not be permitted to change security attributes at will; all user utilities, programs and scripts must work within the constraints of the access rules provided by the selected security policy modules; and that total control of the MAC access rules are in the hands of the system administrator.

It is the sole duty of the system administrator to carefully select the correct security policy modules. Some environments may need to limit access control over the network; in these cases, the mac_portacl(4), mac_ifoff(4) and even mac_biba(4) policy modules might make good starting points. In other cases, strict confidentiality of file system objects might be required. Policy modules such as mac_bsdextended(4) and mac_mls(4) exist for this purpose.

Policy decisions could be made based on network configuration. Perhaps only certain users should be permitted access to facilities provided by ssh(1) to access the network or the Internet. The mac_portacl(4) would be the policy module of choice for these situations. But what should be done in the case of file systems? Should all access to certain directories be severed from other groups or specific users? Or should we limit user or utility access to specific files by setting certain objects as classified?

In the file system case, access to objects might be considered confidential to some users, but not to others. For an example, a large development team might be broken off into smaller groups of individuals. Developers in project A might not be permitted to access objects written by developers in project B. Yet they might need to access objects created by developers in project C; that is quite a situation indeed. Using the different security policy modules provided by the MAC framework; users could be divided into these groups and then given access to the appropriate areas without fear of information leakage.

Thus, each security policy module has a unique way of dealing with the overall security of a system. Module selection should be based on a well thought out security policy. In many cases, the overall policy may need to be revised and reimplemented on the system. Understanding the different security policy modules offered by the MAC framework will help administrators choose the best policies for their situations.

The default FreeBSD kernel does not include the option for the MAC framework; thus the following kernel option must be added before trying any of the examples or information in this chapter:

```
options MAC
```

And the kernel will require a rebuild and a reinstall.

注意

While the various manual pages for MAC policy modules state that they may be built into the kernel, it is possible to lock the system out of the network and more. Implementing MAC is

much like implementing a firewall, care must be taken to prevent being completely locked out of the system. The ability to revert back to a previous configuration should be considered while the implementation of MAC remotely should be done with extreme caution.

15.4. Understanding MAC Labels

A MAC label is a security attribute which may be applied to subjects and objects throughout the system.

When setting a label, the user must be able to comprehend what it is, exactly, that is being done. The attributes available on an object depend on the policy module loaded, and that policy modules interpret their attributes in different ways. If improperly configured due to lack of comprehension, or the inability to understand the implications, the result will be the unexpected and perhaps, undesired, behavior of the system.

The security label on an object is used as a part of a security access control decision by a policy. With some policies, the label by itself contains all information necessary to make a decision; in other models, the labels may be processed as part of a larger rule set, etc.

For instance, setting the label of `biba/low` on a file will represent a label maintained by the Biba security policy module, with a value of "low".

A few policy modules which support the labeling feature in FreeBSD offer three specific predefined labels. These are the low, high, and equal labels. Although they enforce access control in a different manner with each policy module, you can be sure that the low label will be the lowest setting, the equal label will set the subject or object to be disabled or unaffected, and the high label will enforce the highest setting available in the Biba and MLS policy modules.

Within single label file system environments, only one label may be used on objects. This will enforce one set of access permissions across the entire system and in many environments may be all that is required. There are a few cases where multiple labels may be set on objects or subjects in the file system. For those cases, the `multilabel` option may be passed to tunefs(8).

In the case of Biba and MLS, a numeric label may be set to indicate the precise level of hierarchical control. This numeric level is used to partition or sort information into different groups of say, classification only permitting access to that group or a higher group level.

In most cases the administrator will only be setting up a single label to use throughout the file system.

Hey wait, this is similar to DAC! I thought MAC gave control strictly to the administrator. That statement still holds true, to some extent as `root` is the one in control and who configures the policies so that users are placed in the appropriate categories/access levels. Alas, many policy modules can restrict the `root` user as well. Basic control over objects will then be released to the group, but `root` may revoke or modify the settings at any time. This is the hierarchal/clearance model covered by policies such as Biba and MLS.

15.4.1. Label Configuration

Virtually all aspects of label policy module configuration will be performed using the base system utilities. These commands provide a simple interface for object or subject configuration or the manipulation and verification of the configuration.

All configuration may be done by use of the setfmac(8) and setpmac(8) utilities. The `setfmac` command is used to set MAC labels on system objects while the `setpmac` command is used to set the labels on system subjects. Observe:

```
# setfmac biba/high test
```

If no errors occurred with the command above, a prompt will be returned. The only time these commands are not quiescent is when an error occurred; similarly to the chmod(1) and chown(8) commands. In some cases this error may be a Permission denied and is usually obtained when the label is being set or modified on an object which is restricted.[1] The system administrator may use the following commands to overcome this:

```
# setfmac biba/high test
Permission denied
# setpmac biba/low setfmac biba/high test
# getfmac test
test: biba/high
```

As we see above, `setpmac` can be used to override the policy module's settings by assigning a different label to the invoked process. The `getpmac` utility is usually used with currently running processes, such as sendmail: although it takes a process ID in place of a command the logic is extremely similar. If users attempt to manipulate a file not in their access, subject to the rules of the loaded policy modules, the Operation not permitted error will be displayed by the `mac_set_link` function.

15.4.1.1. Common Label Types

For the mac_biba(4), mac_mls(4) and mac_lomac(4) policy modules, the ability to assign simple labels is provided. These take the form of high, equal and low, what follows is a brief description of what these labels provide:

- The `low` label is considered the lowest label setting an object or subject may have. Setting this on objects or subjects will block their access to objects or subjects marked high.
- The `equal` label should only be placed on objects considered to be exempt from the policy.
- The `high` label grants an object or subject the highest possible setting.

With respect to each policy module, each of those settings will instate a different information flow directive. Reading the proper manual pages will further explain the traits of these generic label configurations.

15.4.1.1.1. Advanced Label Configuration

Numeric grade numbers used for `comparison:compartment+compartment` ; thus the following:

```
biba/10:2+3+6(5:2+3-20:2+3+4+5+6)
```

May be interpreted as:

“Biba Policy Label”/“Grade 10” :“Compartments 2, 3 and 6”: (“grade 5 ...”)

In this example, the first grade would be considered the “effective grade” with “effective compartments”, the second grade is the low grade and the last one is the high grade. In most configurations these settings will not be used; indeed, they offered for more advanced configurations.

When applied to system objects, they will only have a current grade/compartments as opposed to system subjects as they reflect the range of available rights in the system, and network interfaces, where they are used for access control.

The grade and compartments in a subject and object pair are used to construct a relationship referred to as “dominance”, in which a subject dominates an object, the object dominates the subject, neither dominates the

[1]Other conditions may produce different failures. For instance, the file may not be owned by the user attempting to relabel the object, the object may not exist or may be read only. A mandatory policy will not allow the process to relabel the file, maybe because of a property of the file, a property of the process, or a property of the proposed new label value. For example: a user running at low integrity tries to change the label of a high integrity file. Or perhaps a user running at low integrity tries to change the label of a low integrity file to a high integrity label.

other, or both dominate each other. The “both dominate” case occurs when the two labels are equal. Due to the information flow nature of Biba, you have rights to a set of compartments, “need to know”, that might correspond to projects, but objects also have a set of compartments. Users may have to subset their rights using `su` or `setpmac` in order to access objects in a compartment from which they are not restricted.

15.4.1.2. Users and Label Settings

Users themselves are required to have labels so that their files and processes may properly interact with the security policy defined on the system. This is configured through the `login.conf` file by use of login classes. Every policy module that uses labels will implement the user class setting.

An example entry containing every policy module setting is displayed below:

```
default:\
 :copyright=/etc/COPYRIGHT:\
 :welcome=/etc/motd:\
 :setenv=MAIL=/var/mail/$,BLOCKSIZE=K:\
 :path=~/bin:/sbin:/bin:/usr/sbin:/usr/bin:/usr/local/sbin:/usr/local/bin:\
 :manpath=/usr/share/man /usr/local/man:\
 :nologin=/usr/sbin/nologin:\
 :cputime=1h30m:\
 :datasize=8M:\
 :vmemoryuse=100M:\
 :stacksize=2M:\
 :memorylocked=4M:\
 :memoryuse=8M:\
 :filesize=8M:\
 :coredumpsize=8M:\
 :openfiles=24:\
 :maxproc=32:\
 :priority=0:\
 :requirehome:\
 :passwordtime=91d:\
 :umask=022:\
 :ignoretime@:\
 :label=partition/13,mls/5,biba/10(5-15),lomac10[2]:
```

The `label` option is used to set the user class default label which will be enforced by MAC. Users will never be permitted to modify this value, thus it can be considered not optional in the user case. In a real configuration, however, the administrator will never wish to enable every policy module. It is recommended that the rest of this chapter be reviewed before any of this configuration is implemented.

注意

Users may change their label after the initial login; however, this change is subject constraints of the policy. The example above tells the Biba policy that a process's minimum integrity is 5, its maximum is 15, but the default effective label is 10. The process will run at 10 until it chooses to change label, perhaps due to the user using the setpmac command, which will be constrained by Biba to the range set at login.

In all cases, after a change to `login.conf` , the login class capability database must be rebuilt using `cap_mkdb` and this will be reflected throughout every forthcoming example or discussion.

It is useful to note that many sites may have a particularly large number of users requiring several different user classes. In depth planning is required as this may get extremely difficult to manage.

Future versions of FreeBSD will include a new way to deal with mapping users to labels; however, this will not be available until some time after FreeBSD 5.3.

15.4.1.3. Network Interfaces and Label Settings

Labels may also be set on network interfaces to help control the flow of data across the network. In all cases they function in the same way the policies function with respect to objects. Users at high settings in `biba`, for example, will not be permitted to access network interfaces with a label of low.

The `maclabel` may be passed to `ifconfig` when setting the MAC label on network interfaces. For example:

```
# ifconfig bge0 maclabel biba/equal
```

will set the MAC label of `biba/equal` on the bge(4) interface. When using a setting similar to `biba/high(low-high)` the entire label should be quoted; otherwise an error will be returned.

Each policy module which supports labeling has a tunable which may be used to disable the MAC label on network interfaces. Setting the label to `equal` will have a similar effect. Review the output from `sysctl`, the policy manual pages, or even the information found later in this chapter for those tunables.

15.4.2. Singlelabel or Multilabel?

By default the system will use the `singlelabel` option. But what does this mean to the administrator? There are several differences which, in their own right, offer pros and cons to the flexibility in the systems security model.

The `singlelabel` only permits for one label, for instance `biba/high` to be used for each subject or object. It provides for lower administration overhead but decreases the flexibility of policies which support labeling. Many administrators may want to use the `multilabel` option in their security policy.

The `multilabel` option will permit each subject or object to have its own independent MAC label in place of the standard `singlelabel` option which will allow only one label throughout the partition. The `multilabel` and `single` label options are only required for the policies which implement the labeling feature, including the Biba, Lomac, MLS and SEBSD policies.

In many cases, the `multilabel` may not need to be set at all. Consider the following situation and security model:

- FreeBSD web-server using the MAC framework and a mix of the various policies.
- This machine only requires one label, `biba/high`, for everything in the system. Here the file system would not require the `multilabel` option as a single label will always be in effect.
- But, this machine will be a web server and should have the web server run at `biba/low` to prevent write up capabilities. The Biba policy and how it works will be discussed later, so if the previous comment was difficult to interpret just continue reading and return. The server could use a separate partition set at `biba/low` for most if not all of its runtime state. Much is lacking from this example, for instance the restrictions on data, configuration and user settings; however, this is just a quick example to prove the aforementioned point.

If any of the non-labeling policies are to be used, then the `multilabel` option would never be required. These include the `seeotheruids`, `portacl` and `partition` policies.

It should also be noted that using `multilabel` with a partition and establishing a security model based on `multilabel` functionality could open the doors for higher administrative overhead as everything in the file system would have a label. This includes directories, files, and even device nodes.

The following command will set `multilabel` on the file systems to have multiple labels. This may only be done in single user mode:

```
# tunefs -l enable /
```

This is not a requirement for the swap file system.

注意

Some users have experienced problems with setting the `multilabel` flag on the root partition. If this is the case, please review the 節 15.16, “Troubleshooting the MAC Framework” of this chapter.

15.4.3. Controlling MAC with Tunables

Without any modules loaded, there are still some parts of MAC which may be configured using the `sysctl` interface. These tunables are described below and in all cases the number one (1) means enabled while the number zero (0) means disabled:

- `security.mac.enforce_fs` defaults to one (1) and enforces MAC file system policies on the file systems.
- `security.mac.enforce_kld` defaults to one (1) and enforces MAC kernel linking policies on the dynamic kernel linker (see kld(4)).
- `security.mac.enforce_network` defaults to one (1) and enforces MAC network policies.
- `security.mac.enforce_pipe` defaults to one (1) and enforces MAC policies on pipes.
- `security.mac.enforce_process` defaults to one (1) and enforces MAC policies on processes which utilize inter-process communication.
- `security.mac.enforce_socket` defaults to one (1) and enforces MAC policies on sockets (see the socket(2) manual page).
- `security.mac.enforce_system` defaults to one (1) and enforces MAC policies on system activities such as accounting and rebooting.
- `security.mac.enforce_vm` defaults to one (1) and enforces MAC policies on the virtual memory system.

注意

Every policy or MAC option supports tunables. These usually hang off of the `security.mac.<policyname>` tree. To view all of the tunables from MAC use the following command:

```
# sysctl -da | grep mac
```

This should be interpreted as all of the basic MAC policies are enforced by default. If the modules were built into the kernel the system would be extremely locked down and most likely unable to communicate with the local network or connect to the Internet, etc. This is why building the modules into the kernel is not completely recommended. Not because it limits the ability to disable features on the fly with `sysctl`, but it permits the administrator to instantly switch the policies of a system without the requirement of rebuilding and reinstalling a new system.

15.5. Module Configuration

Every module included with the MAC framework may be either compiled into the kernel as noted above or loaded as a run-time kernel module. The recommended method is to add the module name to the `/boot/loader.conf` file so that it will load during the initial boot operation.

The following sections will discuss the various MAC modules and cover their features. Implementing them into a specific environment will also be a consideration of this chapter. Some modules support the use of labeling, which is controlling access by enforcing a label such as “this is allowed and this is not”. A label configuration file may control how files may be accessed, network communication can be exchanged, and more. The previous section showed how the `multilabel` flag could be set on file systems to enable per-file or per-partition access control.

A single label configuration would enforce only one label across the system, that is why the `tunefs` option is called `multilabel` .

15.5.1. The MAC seeotheruids Module

Module name: `mac_seeotheruids.ko`

Kernel configuration line: `options MAC_SEEOTHERUIDS`

Boot option: `mac_seeotheruids_load="YES"`

The mac_seeotheruids(4) module mimics and extends the `security.bsd.see_other_uids` and `security.bsd.see_other_gids` `sysctl` tunables. This option does not require any labels to be set before configuration and can operate transparently with the other modules.

After loading the module, the following `sysctl` tunables may be used to control the features:

- `security.mac.seeotheruids.enabled` will enable the module's features and use the default settings. These default settings will deny users the ability to view processes and sockets owned by other users.
- `security.mac.seeotheruids.specificgid_enabled` will allow a certain group to be exempt from this policy. To exempt specific groups from this policy, use the `security.mac.seeotheruids.specificgid=XXX` `sysctl` tunable. In the above example, the *XXX* should be replaced with the numeric group ID to be exempted.
- `security.mac.seeotheruids.primarygroup_enabled` is used to exempt specific primary groups from this policy. When using this tunable, the `security.mac.seeotheruids.specificgid_enabled` may not be set.

15.6. The MAC bsdextended Module

Module name: `mac_bsdextended.ko`

Kernel configuration line: `options MAC_BSDEXTENDED`

Boot option: `mac_bsdextended_load="YES"`

The mac_bsdextended(4) module enforces the file system firewall. This module's policy provides an extension to the standard file system permissions model, permitting an administrator to create a firewall-like ruleset to protect files, utilities, and directories in the file system hierarchy.

The policy may be created using a utility, ugidfw(8), that has a syntax similar to that of ipfw(8). More tools can be written by using the functions in the libugidfw(3) library.

Extreme caution should be taken when working with this module; incorrect use could block access to certain parts of the file system.

15.6.1. Examples

After the mac_bsdextended(4) module has been loaded, the following command may be used to list the current rule configuration:

```
# ugidfw list
0 slots, 0 rules
```

As expected, there are no rules defined. This means that everything is still completely accessible. To create a rule which will block all access by users but leave `root` unaffected, simply run the following command:

```
# ugidfw add subject not uid root new object not uid root mode n
```

注意

In releases prior to FreeBSD 5.3, the *`add`* parameter did not exist. In those cases the *`set`* should be used instead. See below for a command example.

This is a very bad idea as it will block all users from issuing even the most simple commands, such as `ls`. A more patriotic list of rules might be:

```
# ugidfw set 2 subject uid user1 object uid user2 mode n
# ugidfw set 3 subject uid user1 object gid user2 mode n
```

This will block any and all access, including directory listings, to *`user2`*'s home directory from the username `user1`.

In place of `user1`, the `not uid` *`user2`* could be passed. This will enforce the same access restrictions above for all users in place of just one user.

注意

The `root` user will be unaffected by these changes.

This should give a general idea of how the mac_bsdextended(4) module may be used to help fortify a file system. For more information, see the mac_bsdextended(4) and the ugidfw(8) manual pages.

15.7. The MAC ifoff Module

Module name: `mac_ifoff.ko`

Kernel configuration line: `options MAC_IFOFF`

Boot option: `mac_ifoff_load="YES"`

The mac_ifoff(4) module exists solely to disable network interfaces on the fly and keep network interfaces from being brought up during the initial system boot. It does not require any labels to be set up on the system, nor does it have a dependency on other MAC modules.

Most of the control is done through the `sysctl` tunables listed below.

- `security.mac.ifoff.lo_enabled` will enable/disable all traffic on the loopback (lo(4)) interface.
- `security.mac.ifoff.bpfrecv_enabled` will enable/disable all traffic on the Berkeley Packet Filter interface (bpf(4))

- `security.mac.ifoff.other_enabled` will enable/disable traffic on all other interfaces.

One of the most common uses of mac_ifoff(4) is network monitoring in an environment where network traffic should not be permitted during the boot sequence. Another suggested use would be to write a script which uses security/aide to automatically block network traffic if it finds new or altered files in protected directories.

15.8. The MAC portacl Module

Module name: `mac_portacl.ko`

Kernel configuration line: `MAC_PORTACL`

Boot option: `mac_portacl_load="YES"`

The mac_portacl(4) module is used to limit binding to local TCP and UDP ports using a variety of `sysctl` variables. In essence mac_portacl(4) makes it possible to allow non-`root` users to bind to specified privileged ports, i.e. ports fewer than 1024.

Once loaded, this module will enable the MAC policy on all sockets. The following tunables are available:

- `security.mac.portacl.enabled` will enable/disable the policy completely.[2]
- `security.mac.portacl.port_high` will set the highest port number that mac_portacl(4) will enable protection for.
- `security.mac.portacl.suser_exempt` will, when set to a non-zero value, exempt the `root` user from this policy.
- `security.mac.portacl.rules` will specify the actual mac_portacl policy; see below.

The actual `mac_portacl` policy, as specified in the `security.mac.portacl.rules` sysctl, is a text string of the form: `rule[,rule,...]` with as many rules as needed. Each rule is of the form: `idtype:id:protocol:port` . The *`idtype`* parameter can be `uid` or `gid` and used to interpret the *`id`* parameter as either a user id or group id, respectively. The *`protocol`* parameter is used to determine if the rule should apply to TCP or UDP by setting the parameter to `tcp` or `udp`. The final *`port`* parameter is the port number to allow the specified user or group to bind to.

注意

Since the ruleset is interpreted directly by the kernel only numeric values can be used for the user ID, group ID, and port parameters. I.e. user, group, and port service names cannot be used.

By default, on UNIX®-like systems, ports fewer than 1024 can only be used by/bound to privileged processes, i.e. those run as `root`. For mac_portacl(4) to allow non-privileged processes to bind to ports below 1024 this standard UNIX® restriction has to be disabled. This can be accomplished by setting the sysctl(8) variables `net.inet.ip.portrange.reservedlow` and `net.inet.ip.portrange.reservedhigh` to zero.

See the examples below or review the mac_portacl(4) manual page for further information.

[2]Due to a bug the `security.mac.portacl.enabled` `sysctl` variable will not work on FreeBSD 5.2.1 or previous releases.

15.8.1. Examples

The following examples should illuminate the above discussion a little better:

```
# sysctl security.mac.portacl.port_high=1023
# sysctl net.inet.ip.portrange.reservedlow=0 net.inet.ip.portrange.ↄ
reservedhigh=0
```

First we set mac_portacl(4) to cover the standard privileged ports and disable the normal UNIX® bind restrictions.

```
# sysctl security.mac.portacl.suser_exempt=1
```

The `root` user should not be crippled by this policy, thus set the `security.mac.portacl.suser_exempt` to a non-zero value. The mac_portacl(4) module has now been set up to behave the same way UNIX®-like systems behave by default.

```
# sysctl security.mac.portacl.rules=uid:80:tcp:80
```

Allow the user with UID 80 (normally the `www` user) to bind to port 80. This can be used to allow the `www` user to run a web server without ever having `root` privilege.

```
# sysctl security.mac.portacl.rules=uid:1001:tcp:110,uid:1001:tcp:995
```

Permit the user with the UID of 1001 to bind to the TCP ports 110 (“pop3”) and 995 (“pop3s”). This will permit this user to start a server that accepts connections on ports 110 and 995.

15.9. MAC Policies with Labeling Features

The next few sections will discuss MAC policies which use labels.

From here on this chapter will focus on the features of mac_biba(4), mac_lomac(4), mac_partition(4), and mac_mls(4).

注意

This is an example configuration only and should not be considered for a production implementation. The goal is to document and show the syntax as well as examples for implementation and testing.

For these policies to work correctly several preparations must be made.

15.9.1. Preparation for Labeling Policies

The following changes are required in the `login.conf` file:

- An `insecure` class, or another class of similar type, must be added. The login class of `insecure` is not required and just used as an example here; different configurations may use another class name.
- The `insecure` class should have the following settings and definitions. Several of these can be altered but the line which defines the default label is a requirement and must remain.

```
insecure:\
 :copyright=/etc/COPYRIGHT:\
 :welcome=/etc/motd:\
 :setenv=MAIL=/var/mail/$,BLOCKSIZE=K:\
```

```
:path=~/bin:/sbin:/bin:/usr/sbin:/usr/bin:/usr/local/sbin:/usr/local/bin:\
:manpath=/usr/share/man /usr/local/man:\
:nologin=/usr/sbin/nologin:\
:cputime=1h30m:\
:datasize=8M:\
:vmemoryuse=100M:\
:stacksize=2M:\
:memorylocked=4M:\
:memoryuse=8M:\
:filesize=8M:\
:coredumpsize=8M:\
:openfiles=24:\
:maxproc=32:\
:priority=0:\
:requirehome:\
:passwordtime=91d:\
:umask=022:\
:ignoretime@:\
:label=partition/13,mls/5,biba/low:
```

The cap_mkdb(1) command needs to be ran on login.conf(5) before any of the users can be switched over to the new class.

The `root` username should also be placed into a login class; otherwise, almost every command executed by `root` will require the use of `setpmac`.

警告

Rebuilding the `login.conf` database may cause some errors later with the daemon class. Simply uncommenting the daemon account and rebuilding the database should alleviate these issues.

- Ensure that all partitions on which MAC labeling will be implemented support the `multilabel`. We must do this because many of the examples here contain different labels for testing purposes. Review the output from the `mount` command as a precautionary measure.
- Switch any users who will have the higher security mechanisms enforced over to the new user class. A quick run of pw(8) or vipw(8) should do the trick.

15.10. The MAC partition Module

Module name: `mac_partition.ko`

Kernel configuration line: `options MAC_PARTITION`

Boot option: `mac_partition_load="YES"`

The mac_partition(4) policy will drop processes into specific “partitions” based on their MAC label. Think of it as a special type of jail(8), though that is hardly a worthy comparison.

This is one module that should be added to the loader.conf(5) file so that it loads and enables the policy during the boot process.

Most configuration for this policy is done using the setpmac(8) utility which will be explained below. The following `sysctl` tunable is available for this policy:

- `security.mac.partition.enabled` will enable the enforcement of MAC process partitions.

When this policy is enabled, users will only be permitted to see their processes but will not be permitted to work with certain utilities. For instance, a user in the `insecure` class above will not be permitted to access the `top` command as well as many other commands that must spawn a process.

To set or drop utilities into a partition label, use the `setpmac` utility:

```
# setpmac partition/13 top
```

This will add the `top` command to the label set on users in the `insecure` class. Note that all processes spawned by users in the `insecure` class will stay in the `partition/13` label.

15.10.1. Examples

The following command will show you the partition label and the process list:

```
# ps Zax
```

This next command will allow the viewing of another user's process partition label and that user's currently running processes:

```
# ps -ZU trhodes
```

注意

Users can see processes in `root`'s label unless the mac_seeotheruids(4) policy is loaded.

A really crafty implementation could have all of the services disabled in `/etc/rc.conf` and started by a script that starts them with the proper labeling set.

注意

The following policies support integer settings in place of the three default labels offered. These options, including their limitations, are further explained in the module manual pages.

15.11. The MAC Multi-Level Security Module

Module name: `mac_mls.ko`

Kernel configuration line: `options MAC_MLS`

Boot option: `mac_mls_load="YES"`

The mac_mls(4) policy controls access between subjects and objects in the system by enforcing a strict information flow policy.

In MLS environments, a “clearance” level is set in each subject or objects label, along with compartments. Since these clearance or sensibility levels can reach numbers greater than six thousand; it would be a daunting task for any system administrator to thoroughly configure each subject or object. Thankfully, three “instant” labels are already included in this policy.

These labels are `mls/low`, `mls/equal` and `mls/high`. Since these labels are described in depth in the manual page, they will only get a brief description here:

- The `mls/low` label contains a low configuration which permits it to be dominated by all other objects. Anything labeled with `mls/low` will have a low clearance level and not be permitted to access information of a higher level. In addition, this label will prevent objects of a higher clearance level from writing or passing information on to them.
- The `mls/equal` label should be placed on objects considered to be exempt from the policy.
- The `mls/high` label is the highest level of clearance possible. Objects assigned this label will hold dominance over all other objects in the system; however, they will not permit the leaking of information to objects of a lower class.

MLS provides for:

- A hierarchical security level with a set of non hierarchical categories;
- Fixed rules: no read up, no write down (a subject can have read access to objects on its own level or below, but not above. Similarly, a subject can have write access to objects on its own level or above but not beneath.);
- Secrecy (preventing inappropriate disclosure of data);
- Basis for the design of systems that concurrently handle data at multiple sensitivity levels (without leaking information between secret and confidential).

The following `sysctl` tunables are available for the configuration of special services and interfaces:

- `security.mac.mls.enabled` is used to enable/disable the MLS policy.
- `security.mac.mls.ptys_equal` will label all pty(4) devices as `mls/equal` during creation.
- `security.mac.mls.revocation_enabled` is used to revoke access to objects after their label changes to a label of a lower grade.
- `security.mac.mls.max_compartments` is used to set the maximum number of compartment levels with objects; basically the maximum compartment number allowed on a system.

To manipulate the MLS labels, the setfmac(8) command has been provided. To assign a label to an object, issue the following command:

```
# setfmac mls/5 test
```

To get the MLS label for the file `test` issue the following command:

```
# getfmac test
```

This is a summary of the MLS policy's features. Another approach is to create a master policy file in `/etc` which specifies the MLS policy information and to feed that file into the `setfmac` command. This method will be explained after all policies are covered.

Observations: an object with lower clearance is unable to observe higher clearance processes. A basic policy would be to enforce `mls/high` on everything not to be read, even if it needs to be written. Enforce `mls/low` on everything not to be written, even if it needs to be read. And finally enforce `mls/equal` on the rest. All users marked `insecure` should be set at `mls/low`.

15.12. The MAC Biba Module

Module name: `mac_biba.ko`

Kernel configuration line: `options MAC_BIBA`

Boot option: `mac_biba_load="YES"`

The mac_biba(4) module loads the MAC Biba policy. This policy works much like that of the MLS policy with the exception that the rules for information flow are slightly reversed. This is said to prevent the downward flow of sensitive information whereas the MLS policy prevents the upward flow of sensitive information; thus, much of this section can apply to both policies.

In Biba environments, an "integrity" label is set on each subject or object. These labels are made up of hierarchal grades, and non-hierarchal components. As an object's or subject's grade ascends, so does its integrity.

Supported labels are `biba/low` , `biba/equal` , and `biba/high` ; as explained below:

- The `biba/low` label is considered the lowest integrity an object or subject may have. Setting this on objects or subjects will block their write access to objects or subjects marked high. They still have read access though.
- The `biba/equal` label should only be placed on objects considered to be exempt from the policy.
- The `biba/high` label will permit writing to objects set at a lower label, but not permit reading that object. It is recommended that this label be placed on objects that affect the integrity of the entire system.

Biba provides for:

- Hierarchical integrity level with a set of non hierarchical integrity categories;
- Fixed rules: no write up, no read down (opposite of MLS). A subject can have write access to objects on its own level or below, but not above. Similarly, a subject can have read access to objects on its own level or above, but not below;
- Integrity (preventing inappropriate modification of data);
- Integrity levels (instead of MLS sensitivity levels).

The following `sysctl` tunables can be used to manipulate the Biba policy.

- `security.mac.biba.enabled` may be used to enable/disable enforcement of the Biba policy on the target machine.
- `security.mac.biba.ptys_equal` may be used to disable the Biba policy on pty(4) devices.
- `security.mac.biba.revocation_enabled` will force the revocation of access to objects if the label is changed to dominate the subject.

To access the Biba policy setting on system objects, use the `setfmac` and `getfmac` commands:

```
# setfmac biba/low test
# getfmac test
test: biba/low
```

Observations: a lower integrity subject is unable to write to a higher integrity subject; a higher integrity subject cannot observe or read a lower integrity object.

15.13. The MAC LOMAC Module

Module name: `mac_lomac.ko`

Kernel configuration line: `options MAC_LOMAC`

Boot option: `mac_lomac_load="YES"`

Unlike the MAC Biba policy, the mac_lomac(4) policy permits access to lower integrity objects only after decreasing the integrity level to not disrupt any integrity rules.

The MAC version of the Low-watermark integrity policy, not to be confused with the older lomac(4) implementation, works almost identically to Biba, but with the exception of using floating labels to support subject demotion via an auxiliary grade compartment. This secondary compartment takes the form of `[auxgrade]`. When assigning a lomac policy with an auxiliary grade, it should look a little bit like: `lomac/10[2]` where the number two (2) is the auxiliary grade.

The MAC LOMAC policy relies on the ubiquitous labeling of all system objects with integrity labels, permitting subjects to read from low integrity objects and then downgrading the label on the subject to prevent future writes to high integrity objects. This is the `[auxgrade]` option discussed above, thus the policy may provide for greater compatibility and require less initial configuration than Biba.

15.13.1. Examples

Like the Biba and MLS policies; the `setfmac` and `setpmac` utilities may be used to place labels on system objects:

```
# setfmac /usr/home/trhodes lomac/high[low]
# getfmac /usr/home/trhodes  lomac/high[low]
```

Notice the auxiliary grade here is `low`, this is a feature provided only by the MAC LOMAC policy.

15.14. Implementing a Secure Environment with MAC

The following demonstration will implement a secure environment using various MAC modules with properly configured policies. This is only a test and should not be considered the complete answer to everyone's security woes. Just implementing a policy and ignoring it never works and could be disastrous in a production environment.

Before beginning this process, the `multilabel` option must be set on each file system as stated at the beginning of this chapter. Not doing so will result in errors.

15.14.1. Create an insecure User Class

Begin the procedure by adding the following user class to the `/etc/login.conf` file:

```
insecure:\
:copyright=/etc/COPYRIGHT:\
:welcome=/etc/motd:\
:setenv=MAIL=/var/mail/$,BLOCKSIZE=K:\
:path=~/bin:/sbin:/bin:/usr/sbin:/usr/bin:/usr/local/sbin:/usr/local/bin
:manpath=/usr/share/man /usr/local/man:\
:nologin=/usr/sbin/nologin:\
:cputime=1h30m:\
:datasize=8M:\
:vmemoryuse=100M:\
:stacksize=2M:\
:memorylocked=4M:\
:memoryuse=8M:\
:filesize=8M:\
:coredumpsize=8M:\
:openfiles=24:\
:maxproc=32:\
:priority=0:\
:requirehome:\
```

```
:passwordtime=91d:\
:umask=022:\
:ignoretime@:\
:label=partition/13,mls/5:
```

And adding the following line to the default user class:

```
:label=mls/equal,biba/equal,partition/15:
```

Once this is completed, the following command must be issued to rebuild the database:

```
# cap_mkdb /etc/login.conf
```

15.14.2. Boot with the Correct Modules

Add the following lines to `/boot/loader.conf` so the required modules will load during system initialization:

```
mac_biba_load="YES"
mac_mls_load="YES"
mac_seeotheruids_load="YES"
mac_partition_load="YES"
```

15.14.3. Set All Users to Insecure

All user accounts that are not `root` or system users will now require a login class. The login class is required otherwise users will be refused access to common commands such as vi(1). The following `sh` script should do the trick:

```
# for x in `awk -F: '($3 >= 1001) && ($3 != 65534) { print $1 }' \
 /etc/passwd`; do pw usermod $x -L insecure; done;
```

The `cap_mkdb` command will need to be run on `/etc/master.passwd` after this change.

15.14.4. Complete the Configuration

A contexts file should now be created; the following example was taken from Robert Watson's example policy and should be placed in `/etc/policy.contexts` .

```
# This is the default BIBA/MLS policy for this system.

.*                              biba/high,mls/high
/sbin/dhclient                  biba/high(low),mls/high(low)
/dev(/.*)?                      biba/equal,mls/equal
# This is not an exhaustive list of all "privileged" devices.
/dev/mdctl                      biba/high,mls/high
/dev/pci                        biba/high,mls/high
/dev/k?mem                      biba/high,mls/high
/dev/io                         biba/high,mls/high
/dev/agp.*                      biba/high,mls/high
(/var)?/tmp(/.*)?               biba/equal,mls/equal
/tmp/\.X11-unix                 biba/high(equal),mls/high(equal)
/tmp/\.X11-unix/.*              biba/equal,mls/equal
/proc(/.*)?                     biba/equal,mls/equal
/mnt.*                          biba/low,mls/low
(/usr)?/home                    biba/high(low),mls/high(low)
(/usr)?/home/.*                 biba/low,mls/low
/var/mail(/.*)?                 biba/low,mls/low
/var/spool/mqueue(/.*)?         biba/low,mls/low
(/mnt)?/cdrom(/.*)?             biba/high,mls/high
(/usr)?/home/(ftp|samba)(/.*)?  biba/high,mls/high
/var/log/sendmail\.st           biba/low,mls/low
/var/run/utmp                   biba/equal,mls/equal
/var/log/(lastlog|wtmp)         biba/equal,mls/equal
```

This policy will enforce security by setting restrictions on both the downward and upward flow of information with regards to the directories and utilities listed on the left.

This can now be read into our system by issuing the following command:

```
# setfsmac -ef /etc/policy.contexts /
# setfsmac -ef /etc/policy.contexts /usr
```

注意

The above file system layout may be different depending on environment.

The `/etc/mac.conf` file requires the following modifications in the main section:

```
default_labels file ?biba,?mls
default_labels ifnet ?biba,?mls
default_labels process ?biba,?mls,?partition
default_labels socket ?biba,?mls
```

15.14.5. Testing the Configuration

Add a user with the `adduser` command and place that user in the `insecure` class for these tests.

The examples below will show a mix of `root` and regular user tests; use the prompt to distinguish between the two.

15.14.5.1. Basic Labeling Tests

```
% getpmac
biba/15(15-15),mls/15(15-15),partition/15
# setpmac partition/15,mls/equal top
```

注意

The top process will be killed before we start another top process.

15.14.5.2. MAC Seeotheruids Tests

```
% ps Zax
biba/15(15-15),mls/15(15-15),partition/15  1096 #C:  S      0:00.03 -su (bash)
biba/15(15-15),mls/15(15-15),partition/15  1101 #C:  R+     0:00.01 ps Zax
```

We should not be permitted to see any processes owned by other users.

15.14.5.3. MAC Partition Test

Disable the MAC `seeotheruids` policy for the rest of these tests:

```
# sysctl security.mac.seeotheruids.enabled=0
% ps Zax
LABEL                                                PID  TT  STAT      TIME COMMAND
  biba/equal(low-high),mls/equal(low-high),partition/15  1122 #C:  S+     0:00.02 top
  biba/15(15-15),mls/15(15-15),partition/15              1096 #C:  S      0:00.05 -su ↺
(bash)
  biba/15(15-15),mls/15(15-15),partition/15              1123 #C:  R+     0:00.01 ps Zax
```

All users should be permitted to see every process in their partition.

15.14.5.4. Testing Biba and MLS Labels

```
# setpmac partition/15,mls/equal,biba/high\(high-high\) top
% ps Zax
LABEL                                                  PID  TT  STAT    TIME   COMMAND
  biba/high(high-high),mls/equal(low-high),partition/15   1251 #C:  S+     0:00.02 top
  biba/15(15-15),mls/15(15-15),partition/15               1096 #C:  S      0:00.06 -su ↺
(bash)
  biba/15(15-15),mls/15(15-15),partition/15               1157 #C:  R+     0:00.00 ps Zax
```

The Biba policy allows us to read higher-labeled objects.

```
# setpmac partition/15,mls/equal,biba/low top
% ps Zax
LABEL                                        PID  TT  STAT      TIME COMMAND
  biba/15(15-15),mls/15(15-15),partition/15  1096 #C:  S      0:00.07 -su (bash)
  biba/15(15-15),mls/15(15-15),partition/15  1226 #C:  R+     0:00.01 ps Zax
```

The Biba policy does not allow lower-labeled objects to be read; however, MLS does.

```
% ifconfig bge0 | grep maclabel
maclabel biba/low(low-low),mls/low(low-low)
% ping -c 1 192.0.34.166
PING 192.0.34.166 (192.0.34.166): 56 data bytes
ping: sendto: Permission denied
```

Users are unable to ping `example.com` , or any domain for that matter.

To prevent this error from occurring, run the following command:

```
# sysctl security.mac.biba.trust_all_interfaces=1
```

This sets the default interface label to insecure mode, so the default Biba policy label will not be enforced.

```
# ifconfig bge0 maclabel biba/equal\(low-high\),mls/equal\(low-high\)
% ping -c 1 192.0.34.166
PING 192.0.34.166 (192.0.34.166): 56 data bytes
64 bytes from 192.0.34.166: icmp_seq=0 ttl=50 time=204.455 ms
--- 192.0.34.166 ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max/stddev = 204.455/204.455/204.455/0.000 ms
```

By setting a more correct label, we can issue `ping` requests.

Now to create a few files for some read and write testing procedures:

```
# touch test1 test2 test3 test4 test5
# getfmac test1
test1: biba/equal,mls/equal
# setfmac biba/low test1 test2; setfmac biba/high test4 test5; \
  setfmac mls/low test1 test3; setfmac mls/high test2 test4
# setfmac mls/equal,biba/equal test3 && getfmac test?
test1: biba/low,mls/low
test2: biba/low,mls/high
test3: biba/equal,mls/equal
test4: biba/high,mls/high
test5: biba/high,mls/equal
# chown testuser:testuser test?
```

All of these files should now be owned by our `testuser` user. And now for some read tests:

```
% ls
test1   test2   test3   test4   test5
% ls test?
ls: test1: Permission denied
ls: test2: Permission denied
ls: test4: Permission denied
test3   test5
```

We should not be permitted to observe pairs; e.g.: `(biba/low,mls/low)` , `(biba/low,mls/high)` and `(biba/high,mls/high)` . And of course, read access should be denied. Now for some write tests:

```
% for i in `echo test*`; do echo 1 > $i; done
-su: test1: Permission denied
-su: test4: Permission denied
-su: test5: Permission denied
```

Like with the read tests, write access should not be permitted to write pairs; e.g.: `(biba/low,mls/high)` and `(biba/equal,mls/equal)` .

```
% cat test?
cat: test1: Permission denied
cat: test2: Permission denied
1
cat: test4: Permission denied
```

And now as `root`:

```
# cat test2
1
```

15.15. Another Example: Using MAC to Constrain a Web Server

A separate location for the web data which users must be capable of accessing will be appointed. This will permit `biba/high` processes access rights to the web data.

Begin by creating a directory to store the web data in:

```
# mkdir /usr/home/cvs
```

Now initialize it with `cvs`:

```
# cvs -d /usr/home/cvs init
```

The first goal is to enable the `biba` policy, thus the `mac_biba_enable="YES"` should be placed in `/boot/loader.conf` . This assumes that support for MAC has been enabled in the kernel.

From this point on everything in the system should be set at `biba/high` by default.

The following modification must be made to the `login.conf` file, under the default user class:

```
:ignoretime@:\
 :umask=022:\
 :label=biba/high:
```

Every user should now be placed in the default class; a command such as:

```
# for x in `awk -F: '($3 >= 1001) && ($3 != 65534) { print $1 }' \
 /etc/passwd`; do pw usermod $x -L default; done;
```

will accomplish this task in a few moments.

Now create another class, web, a copy of default, with the label setting of `biba/low`.

Create a user who will be used to work with the main web data stored in a cvs repository. This user must be placed in our new login class, `web`.

Since the default is `biba/high` everywhere, the repository will be the same. The web data must also be the same for users to have read/write access to it; however, since our web server will be serving data that `biba/high` users must access, we will need to downgrade the data as a whole.

The perfect tools for this are sh(1) and cron(8) and are already provided in FreeBSD. The following script should do everything we want:

```
PATH=/bin:/usr/bin:/usr/local/bin; export PATH;
CVSROOT=/home/repo; export CVSROOT;
cd /home/web;
cvs -qR checkout -P htdocs;
exit;
```

注意

In many cases the `cvs` Id tags must be placed into the web site data files.

This script may now be placed into `web`'s home directory and the following crontab(1) entry added:

```
# Check out the web data as biba/low every twelve hours:
0       */12       *       *       *       web    /home/web/checkout.sh
```

This will check out the HTML sources every twelve hours on the machine.

The default startup method for the web server must also be modified to start the process as `biba/low`. This can be done by making the following modification to the `/usr/local/etc/rc.d/apache.sh` script:

```
command="setpmac biba/low /usr/local/sbin/httpd"
```

The Apache configuration must be altered to work with the `biba/low` policy. In this case the software must be configured to append to the log files in a directory set at `biba/low` or else access denied errors will be returned.

注意

Following this example requires that the `docroot` directive be set to `/home/web/htdocs`; otherwise, Apache will fail when trying to locate the directory to serve documents from.

Other configuration variables must be altered as well, including the PID file, `Scoreboardfile`, `DocumentRoot`, log file locations, or any other variable which requires write access. When using `biba`, all write access will be denied to the server in areas not set at `biba/low`.

15.16. Troubleshooting the MAC Framework

During the development stage, a few users reported problems with normal configuration. Some of these problems are listed below:

15.16.1. The `multilabel` option cannot be enabled on `/`

The `multilabel` flag does not stay enabled on my root (`/`) partition!

It seems that one out of every fifty users has this problem, indeed, we had this problem during our initial configuration. Further observation of this so called "bug" has lead me to believe that it is a result of either incorrect documentation or misinterpretation of the documentation. Regardless of why it happened, the following steps may be taken to resolve it:

1. Edit `/etc/fstab` and set the root partition at `ro` for read-only.
2. Reboot into single user mode.
3. Run `tunefs -l enable` on `/`.
4. Reboot the system into normal mode.
5. Run `mount -urw /` and change the `ro` back to `rw` in `/etc/fstab` and reboot the system again.
6. Double-check the output from the `mount` to ensure that `multilabel` has been properly set on the root file system.

15.16.2. Cannot start a X11 server after MAC

After establishing a secure environment with MAC, I am no longer able to start X!

This could be caused by the MAC `partition` policy or by a mislabeling in one of the MAC labeling policies. To debug, try the following:

1. Check the error message; if the user is in the `insecure` class, the `partition` policy may be the culprit. Try setting the user's class back to the `default` class and rebuild the database with the `cap_mkdb` command. If this does not alleviate the problem, go to step two.
2. Double-check the label policies. Ensure that the policies are set correctly for the user in question, the X11 application, and the `/dev` entries.
3. If neither of these resolve the problem, send the error message and a description of your environment to the TrustedBSD discussion lists located at the TrustedBSD website or to the FreeBSD general questions 郵遞論壇 mailing list.

15.16.3. Error: _secure_path(3) cannot stat `.login_conf`

When I attempt to switch from the `root` to another user in the system, the error message _secure_path: unable to state .login_conf.

This message is usually shown when the user has a higher label setting then that of the user whom they are attempting to become. For instance a user on the system, `joe`, has a default label of `biba/low`. The `root` user, who has a label of `biba/high`, cannot view `joe`'s home directory. This will happen regardless if `root` has used the `su` command to become `joe`, or not. In this scenario, the Biba integrity model will not permit `root` to view objects set at a lower integrity level.

15.16.4. The `root` username is broken!

In normal or even single user mode, the `root` is not recognized. The `whoami` command returns 0 (zero) and `su` returns who are you?. What could be going on?

This can happen if a labeling policy has been disabled, either by a sysctl(8) or the policy module was unloaded. If the policy is being disabled or has been temporarily disabled, then the login capabilities database needs to

be reconfigured with the label option being removed. Double check the login.conf file to ensure that all label options have been removed and rebuild the database with the cap_mkdb command.

章 16. Security Event Auditing

Written by Tom Rhodes.

16.1. Synopsis

The FreeBSD 7-CURRENT development branch includes support for Event Auditing based on the POSIX®.1e draft and Sun's published BSM API and file format. Event auditing permits the selective logging of security-relevant system events for the purposes of post-mortem analysis, system monitoring, and intrusion detection. After some settling time in FreeBSD 7-CURRENT, this support will be merged to FreeBSD 6-STABLE and appear in subsequent releases.

警告

The audit facility in FreeBSD is considered experimental, and production deployment should occur only after careful consideration of the risks of deploying experimental software.

This chapter will focus mainly on the installation and configuration of Event Auditing. Explanation of audit policies, and an example configuration will be provided for the convenience of the reader.

After reading this chapter, you will know:

- What Event Auditing is and how it works.
- How to configure Event Auditing on FreeBSD for users and processes.

Before reading this chapter, you should:

- Understand UNIX® and FreeBSD basics (章 3, UNIX 基礎概念).
- Be familiar with the basics of kernel configuration/compilation (章 8, 設定 FreeBSD Kernel).
- Have some familiarity with security and how it pertains to FreeBSD (章 13, 系統安全).

警告

Event auditing can generate a great deal of log file data, exceeding gigabytes a week in some configurations. An administrator should read this chapter in its entirety to avoid possible self-inflicted DoS attacks due to improper configuration.

The implementation of Event Auditing in FreeBSD is similar to that of the Sun™ Basic Security Module, or BSM library. Thus, the configuration is almost completely interchangeable with Solaris™ and Mac OS X/Darwin operating systems.

16.2. Key Terms - Words to Know

Before reading this chapter, a few key terms must be explained. This is intended to clear up any confusion that may occur and to avoid the abrupt introduction of new terms and information.

- event: An auditable event is an event that can be logged using the audit subsystem. The administrator can configure which events will be audited. Examples of security-relevant events include the creation of a file, the building of a network connection, or the logging in of a user. Events are either “attributable”, meaning that they can be traced back to a user authentication, or “non-attributable”. Examples of non-attributable events are any events that occur before authentication has succeeded in the login process, such as failed authentication attempts.

- class: Events may be assigned to one or more classes, usually based on the general category of the events, such as “file creation”, “file access”, or “network”. Login and logout events are assigned to the `lo` class. The use of classes allows the administrator to specify high level auditing rules without having to specify whether each individual auditable operation will be logged.

- record: A record is a log entry describing a security event. Records typically have a record event type, information on the subject (user) associated with the event, time information, information on any objects, such as files, and information on whether the event corresponded to a successful operation.

- trail: An audit trail, or log file, consists of a series of audit records describing security events. Typically, trails are in roughly chronological order with respect to the time events completed. Only authorized processes are allowed to commit records to the audit trail.

- prefix: A prefix is considered to be the configuration element used to toggle auditing for success and failed events.

16.3. Installing Audit Support

Support for Event Auditing is installed with the normal `installworld` process. An administrator may confirm this by viewing the contents of `/etc/security` . Files beginning with the word audit should be present. For example, `audit_event` .

In-kernel support for the framework must also exist. This may be done by adding the following lines to the local kernel configuration file:

```
options AUDIT
```

Rebuild and reinstall the kernel via the normal process explained in 章 8, 設定 FreeBSD Kernel.

Once completed, enable the audit daemon by adding the following line to rc.conf(5):

```
auditd_enable="YES"
```

Functionality not provided by the default may be added here with the `auditd_flags` option.

16.4. Audit Configuration

All configuration files for security audit are found in `/etc/security` . The following files must be present before the audit daemon is started:

- `audit_class` - Contains the definitions of the audit classes.

- `audit_control` - Controls aspects of the audit subsystem, such as default audit classes, minimum disk space to leave on the audit log volume, etc.

- `audit_event` - Defines the kernel audit events. These map, mostly, to system calls.

- `audit_user` - The events to audit for individual users. Users not appearing here will be subject to the default configuration in the control configuration file.

- `audit_warn` - A shell script used by auditd to generate warning messages in exceptional situations, such as when space for audit records is running low.

16.4.1. Audit File Syntax

The configuration file syntax is rather arcane, albeit easy to work with. One thing an administrator must be leery about is overriding system defaults. This could create potential openings for audit data to not be collected properly.

The audit subsystem will accept both the short name and long name with regards to configuration syntax. A syntax map has been included below.

The following list contains all supported audit classes:

- `all` - `all` - All audit flags set.
- `ad` - `administrative` - Administrative actions performed on the system as a whole.
- `ap` - `application` - Application defined action.
- `cl` - `file_close` - Audit calls to the `close` system call.
- `ex` - `exec` - Audit program or utility execution.
- `fa` - `file_attr_acc` - Audit the access of object attributes such as stat(1), pathconf(2) and similar events.
- `fc` - `file_creation` - Audit events where a file is created as a result.
- `fd` - `file_deletion` - Audit events where file deletion occurs.
- `fm` - `file_attr_mod` - Audit events where file attribute modification occurs, such as chown(8), chflags(1), flock(2), etc.
- `fr` - `file_read` - Audit events in which data is read, files are opened for reading, etc.
- `fw` - `file_write` - Audit events in which data is written, files are written or modified, etc.
- `io` - `ioctl` - Audit use of the ioctl(2) system call.
- `ip` - `ipc` - Audit various forms of Inter-Process Communication, including POSIX pipes and System V IPC operations.
- `lo` - `login_logout` - Audit login(1) and logout(1) events occurring on the system.
- `na` - `non_attrib` - Audit non-attributable events.
- `no` - `no_class` - Null class used to disable event auditing.
- `nt` - `network` - Audit events related to network actions, such as connect(2) and accept(2).
- `ot` - `other` - Audit miscellaneous events.
- `pc` - `process` - Audit process operations, such as exec(3) and exit(3).

Following is a list of all supported audit prefixes:

- `none` - Audit both the success or failure of an event. For example, just listing a class will result in the auditing of both success and failure.
- `+` - Audit successful events only.

- `-` - Audit failed events only.

警告

Using the `all` class with either the positive or negative prefix can generate a large amount of data at an extremely rapid rate.

Extra prefixes used to modify the default configuration values:

- ^- - Disable auditing of failed events.
- ^+ - Enable auditing of successful events.
- ^ - Disable auditing of both successful and failed events.

16.4.2. Configuration Files

In most cases, administrators will need to modify only two files when configuring the audit system: `audit_control` and `audit_user`. The first controls system-wide audit paramaters and defaults for both attributable and non-attributable events. The second may be used to tune the level and nature of auditing for individual users.

16.4.2.1. The `audit_control` File

The `audit_control` file contains some basic defaults that the administrator may wish to modify. Perhaps even set some new ones. Viewing the contents of this file, we see the following:

```
dir:/var/audit
flags:lo
minfree:20
naflags:lo
```

The `dir` option is used to set the default directory where audit logs are stored. Audit is frequently configured so that audit logs are stored on a dedicated file system, so as to prevent interference between the audit subsystem and other subsystems when file systems become full.

The `flags` option is used to set the system-wide defaults. The current setting, `lo` configures the auditing of all login(1) and logout(1) actions. A more complex example, `lo,ad,-all,^-fa,^-fc,^-cl` audits all system login(1) and logout(1) actions, all administrator actions, all failed events in the system, and finally disables auditing of failed attempts for `fa`, `fc`, and `cl`. Even though the `-all` turned on the auditing of all failed attempts, the `^-` prefix will override that for the latter options.

Notice that the previous paragraph shows the file is read from left to right. As such, values further on the right side may override a previous value specified to its left.

The `minfree` option defines the minimum percentage of free space for audit file systems. This relates to the file system where audit logs are stored. For example, if the `dir` specifies `/var/audit` and `minfree` is set to twenty (20), warning messages will be generated when the `/var` file system grows to eighty (80) percent full.

The `naflags` option specifies audit classes to be audited for non-attributed events —— that is, events for which there is no authenticated user.

16.4.2.2. The `audit_user` File

The `audit_user` file permits the administrator to determine which classes of audit events should be logged for which system users.

The following is the defaults currently placed in the `audit_user` file:

```
root:lo:no
audit:fc:no
```

Notice how the default is to audit all cases of `login/logout` and disable auditing of all other actions for `root`. This configuration also audits all file creation and disables all other auditing for the `audit` user. While event auditing does not require a special user exist, some configurations, specifically environments making use of MAC, may require it.

16.5. Event Audit Administration

Events written by the kernel audit subsystem cannot be altered or read in plain text. Data is stored and accessed in a method similar to that of ktrace(1) and kdump(1), that is, they may only be viewed by dumping them using the `praudit` command; audit trails may be reduced using the `auditreduce` command, which selects records from an audit trail based on properties of interest, such as the user, time of the event, and type of operation.

For example, the `praudit` utility will dump the entire contents of a specified audit log in plain text. To dump an audit log in its entirety, use:

```
# praudit /var/audit/AUDITFILE
```

Where *`AUDITFILE`* is the audit log of viewing choice. Since audit logs may contain enormous amounts of data, an administrator may prefer to select records for specific users. This is made possible with the following command, where `trhodes` is the user of choice:

```
# auditreduce -e trhodes /var/audit/AUDITFILE | praudit
```

This will select all audit records produced by the user `trhodes` stored in the *`AUDITFILE`* file.

There are several other options available for reading audit records, see the aforementioned command's manual pages for a more in depth explanation.

16.5.1. Rotating Audit Log Files

Due to log reliability requirements, audit trails are written to only by the kernel, and managed only by `auditd`. Administrators should not attempt to use newsyslog.conf(5) or other tools to directly rotate audit logs. Instead, the `audit` management tool should be used to shut down auditing, reconfigure the audit system, and perform log rotation. The following command causes the audit daemon to create a new audit log and signal the kernel to switch to using the new log. The old log will be terminated and renamed, at which point it may then be manipulated by the administrator.

```
# audit -n
```

警告

If the `auditd` daemon is not currently running, the previous command will fail and an error message will be produced.

Adding the following line to `/etc/crontab` will force the rotation every twelve hours from cron(8):

```
*     */12      *       *       *       root    /usr/sbin/audit -n
```

The change will take effect once you have saved the new `/etc/crontab` .

16.5.2. Delegating Audit Review Rights

By default, only the root user has the right to read system audit logs. However, that right may be delegated to members of the `audit` group, as the audit directory and audit trail files are assigned to that group, and made group-readable. As the ability to track audit log contents provides significant insight into the behavior of users and processes, it is recommended that the delegation of audit review rights be performed with caution.

章 17. 儲存設備篇

17.1. 概述

本章涵蓋如何在 FreeBSD 下使用碟片裝置[1] 包含 memory-backed disk（用記憶體作為磁碟使用）、跨網路使用的磁碟、 標準 SCSI/IDE 磁碟、USB 介面的設備等。

閱讀本章後，您裝學會：

- FreeBSD 如何描述資料在磁碟上的劃分情形 (partition 和 slices)。
- 如何在系統上加入磁碟
- 如何設定 FreeBSD 來使用 USB 裝置。
- 如何設定虛擬檔案系統 (virtual file systems), 例如 memory disks（用記憶體作為磁碟使用）。
- 如何用 quota 來限制磁碟空間的使用。
- 如何對磁碟加密以應付攻擊。
- 如何在 FreeBSD 下建立、燒錄 CD 和 DVD。
- 各種不同的備份設備。
- 如何使用 FreeBSD 提供的備份工具。
- 如何備份到軟碟。
- 什麼是 snapshots ，且如何有效率地使用之。

在閱讀之前，您應該：

- 知道如何設定、安裝新的 FreeBSD kernel。 (章 8, 設定 FreeBSD Kernel).

17.2. 裝置名稱

下面是 FreeBSD 支援的儲存媒體列表，及它們對應的裝置名稱。

表格 17.1. 命名規則

裝置類型	裝置名稱
IDE 磁碟機	ad
IDE 光碟機	acd
SCSI 磁碟機和 USB 碟	da
SCSI 光碟機	cd
非標準規格光碟機	Mitsumi 光碟機用 mcd， Sony 光碟機用 scd。
軟碟機	fd
SCSI 碟帶機	sa
IDE 碟帶機	ast

[1]譯註：雖然有些設備沒有『碟片』，例如 USB 隨身碟， 不過在此仍把 Disk 譯為『碟片裝置』。此外，為方便起見， 後文所有的 Disk 都譯為『磁碟』。

裝置類型	裝置名稱
Flash 磁碟機	DiskOnChip® Flash 磁碟機用 `fla`
RAID 磁碟機	Adaptec® AdvancedRAID 用`aacd`， Mylex® 用 `mlxd` 和 `mlyd`， AMI MegaRAID® 用 `amrd`， Compaq Smart RAID 用 `idad`， 3ware® RAID 用 `twed`。

17.3. 新增磁碟

Originally contributed by David O'Brien.

假設我們想新增 SCSI 磁碟到一臺原先只有一顆磁碟的機器上， 首先將電腦關機，依製造商的指示將磁碟裝上去， 詳細的操作方式請參考製造商的說明文件。

安裝好磁碟後，用 `root` 登入系統， 看一下 `/var/run/dmesg.boot` 以確認系統是否抓到新磁碟。 繼續剛才的範例，新增的磁碟會是 `da1`， 假設我們想將它掛載到 `/1` 這個位置（如果您新增的是 IDE 磁碟的話，請用 `ad1`）。

FreeBSD 為了在 IBM-PC 相容電腦上執行， 必須配合 PC BIOS `partition`，因此和傳統的 BSD partition 有很大的不同。 在 PC 裡磁碟最多可以有四筆 BIOS partition 資訊(亦即最多可分割成四個 `partition`)。如果這個磁碟打算全部讓 FreeBSD 使用，可選擇 dedicated 模式， 不然的話 FreeBSD 必須置身於其中一個 PC BIOS partition 中。 在 FreeBSD 裡，`PC` BIOS partition 稱為 slice， 這是為了不要和傳統的 BSD partition 搞混了。[2] 不論是完全由 FreeBSD 使用的磁碟，還是安裝了其它作業系統的磁碟， 您都可以使用 `slice`。這樣的好處是，其它非 FreeBSD 作業系統的 `fdisk` 工具可以順利操作。

如果使用 `slice`，這個新增的磁碟會是 `/dev/da1s1e` 。可以這樣來解讀它：SCSI 磁碟、 unit number `1`(第二個 SCSI 磁碟)、`slice 1`(第一個 PC BIOS `partition`)、 及 `e` BSD `partition`。在 dedicated 模式的話， 新磁碟則是 `/dev/da1e` 。

因為 bsdlabel(8) 是用 32-bit 整數來儲存 `sector`(磁區) 數， 因此限制一個磁碟最大只能有 2^32-1 個 `sector`，亦即 2TB 的空間。 而 fdisk(8) 的格式容許起始 sector 編號不超過 `2^32-1`， 長度也不超過 `2^32-1`，因此 partition 最大空間是 `2TB`，而磁碟最大是 `4TB`。 sunlabel(8) 則限制 partition 最大是 `2TB`，磁碟最多可有 8 個 `partition`，因此最大是 `16TB`。 如果要使用更大的磁碟，請使用 gpt(8)。

17.3.1. 使用 sysinstall(8)

1. 操作 Sysinstall

   透過 `sysinstall` 的選單介面， 可以輕易為磁碟分割 BIOS partition(slice) 和 BSD `patition`。 必須以 root 身份使用 `sysinstall`， 要嘛用 root 登入，要嘛用 `su` 切換到 `root`。 執行 `sysinstall` 後，選 `Configure`，在 `FreeBSD Configuration Menu` 裡移到 `Fdisk` 選項。

2. fdisk Partition 編輯器

   在 fdisk 裡，按下 **`A`** 表示整個磁碟都給 FreeBSD 使用。 接著會提示您『是否要相容其它的作業系統』，回答 `YES`。 按 **`W`** 會將這些改變立即寫入磁碟，再按 **`q`** 可以離開 FDISK 編輯器。 接下來會問您要將 “Master Boot Record” 安裝於何處，由於現在是新增磁碟，表示作業系統已經裝在別的磁碟上了， 所以可以選 `None` 就行了。

3. Disk Label `Editor`(磁碟 Label 編輯器)

   接著請關閉 `sysinstall`，再重開一次。 照著上一節的指示，不過這次改選 `Label` 進入 `Disk Label Editor`，在此您可以編輯傳統的 BSD `partition`。 一個磁碟(或著一個 slice) 最多可切分成 8 個 BSD

[2]譯註：基於相同的理由， 現在 BSD partition 常稱為 BSD `label`，或簡稱 `label`。

partition，依序用 a-h 來表示。 有些字母有特別的意義，a partition 表示這是 root partition(根分割區，/)， 因此只有安裝系統的磁碟(例如用來開機的磁碟) 有 a partition。 b partition 表示這是 swap partitions(交換分割區)，每個磁碟上都可以有 swap。 c partition 用來表示整個磁碟(如果使用 dedicated mode 的話)或整個 slice。 其它的字母則用來表示普通的 BSD partition 。

sysinstall 的 Label editor(磁碟 Label 編輯器) 偏好用 e 來表示非 root、也非 swap 的分割區 [3] 在 Label editor 裡，按 C 可以新增一個檔案系統(BSD label)，它會問您這是一個 FS(file system ，檔案系統) 或是 swap(交換分割區)，選擇 FS 接著輸入要掛載的位置(例如 /mnt)。 如果系統安裝完後才新增磁碟，sysinstall 不會幫您把這筆掛載資料加入 /etc/fstab ， 所以掛載的位置不太重要。

當您準備好將新的 label 寫入磁碟、建立檔案系統，按 W 即可。如果出現在什麼錯誤， sysinstall 可能無法幫您掛載這個新分割區。 結束 Label Editor、結束 sysinstall 就行了。

4. 完成

最後要做的是編輯 /etc/fstab ， 加入您新增的分割區資訊。

17.3.2. 使用命令列工具

17.3.2.1. 使用 Slices(BIOS partitions)

這種模式能讓您的磁碟分割區與其它作業系統的 fdisk 工具和平共處，因此我們建議您使用 slice 模式。如果您一定要使用 dedicated 模式， 您得有個好理由！ [4]

```
# dd if=/dev/zero of=/dev/da1 bs=1k count=1
# fdisk -BI da1 # #######
# bsdlabel -B -w -r da1s1 auto  # ## bsdlabel#
# bsdlabel -e da1s1  # ## bsdlabel ### label#
# mkdir -p /1
# newfs /dev/da1s1e  # ######## label#### label #######
# mount /dev/da1s1e /1  # ##### label#
# vi /etc/fstab # # /etc/fstab ########
```

如果您新增的是 IDE 磁碟，將 da 改成 ad 即可 [5]。

17.3.2.2. Dedicated

如果您不打算將新磁碟用於其它的作業系統， 您可以使用 dedicated 模式。注意： Microsoft 的作業系統認不得這個模式，不過也不會去破壞它； 然而 IBM 的 OS/2® 就沒那麼好心了，它會去調整所有它不認得的分割區 [6]。

```
# dd if=/dev/zero of=/dev/da1 bs=1k count=1
# bsdlabel -Brw da1 auto
# bsdlabel -e da1    # ## `e' partition#
# newfs -d0 /dev/da1e
# mkdir -p /1
# vi /etc/fstab    # #### /dev/da1e ####
# mount /1
```

另一種方法：

[3]譯註：老實說我看不懂這句指的是什麼？原文是 sysinstall Label editor favors the e partition for non-root, non-swap partitions.

[4]譯註：如果您自始至終都不打算將這個磁碟用於 FreeBSD 之外的作業系統，那可以算是個好理由。不過就算如此， 用 slice 模式也沒什麼壞處就是了:–)。

[5]譯註：da 是 direct access (disk) 的縮寫； ad 是 ata disk 的縮寫。

[6]譯註：我對這句的意思沒什麼信心，原文是 IBM's OS/2® however, will “appropriate” any partition it finds which it does not understand.

```
# dd if=/dev/zero of=/dev/da1 count=2
# bsdlabel /dev/da1 | bsdlabel -BrR da1 /dev/stdin
# newfs /dev/da1e
# mkdir -p /1
# vi /etc/fstab     # #### /dev/da1e ####
# mount /1
```

17.4. Resizing and Growing Disks

Originally contributed by Allan Jude.

A disk's capacity can increase without any changes to the data already present. This happens commonly with virtual machines, when the virtual disk turns out to be too small and is enlarged. Sometimes a disk image is written to a USB memory stick, but does not use the full capacity. Here we describe how to resize or grow disk contents to take advantage of increased capacity.

Determine the device name of the disk to be resized by inspecting `/var/run/dmesg.boot` . In this example, there is only one SATA disk in the system, so the drive will appear as `ada0`.

List the partitions on the disk to see the current configuration:

```
# gpart show ada0
=>      34  83886013  ada0  GPT  (48G) [CORRUPT]
        34       128     1  freebsd-boot  (64k)
       162  79691648     2  freebsd-ufs  (38G)
  79691810   4194236     3  freebsd-swap  (2G)
  83886046         1        - free -  (512B)
```

注意

If the disk was formatted with the GPT partitioning scheme, it may show as "corrupted" because the GPT backup partition table is no longer at the end of the drive. Fix the backup partition table with `gpart`:

```
# gpart recover ada0
ada0 recovered
```

Now the additional space on the disk is available for use by a new partition, or an existing partition can be expanded:

```
# gpart show ada0
=>       34  102399933  ada0  GPT  (48G)
         34        128     1  freebsd-boot  (64k)
        162   79691648     2  freebsd-ufs  (38G)
   79691810    4194236     3  freebsd-swap  (2G)
   83886046   18513921        - free -  (8.8G)
```

Partitions can only be resized into contiguous free space. Here, the last partition on the disk is the swap partition, but the second partition is the one that needs to be resized. Swap partitions only contain temporary data, so it can safely be unmounted, deleted, and then recreated after resizing other partitions.

```
# swapoff /dev/ada0p3
# gpart delete -i 3 ada0
ada0p3 deleted
# gpart show ada0
=>       34  102399933  ada0  GPT  (48G)
         34        128     1  freebsd-boot  (64k)
```

```
       162   79691648     2  freebsd-ufs  (38G)
  79691810   22708157        - free -  (10G)
```

警告

There is risk of data loss when modifying the partition table of a mounted file system. It is best to perform the following steps on an unmounted file system while running from a live CD-ROM or USB device. However, if absolutely necessary, a mounted file system can be resized after disabling GEOM safety features:

```
# sysctl kern.geom.debugflags=16
```

Resize the partition, leaving room to recreate a swap partition of the desired size. This only modifies the size of the partition. The file system in the partition will be expanded in a separate step.

```
# gpart resize -i 2 -a 4k -s 47G ada0
ada0p2 resized
# gpart show ada0
=>       34  102399933  ada0  GPT  (48G)
         34        128     1  freebsd-boot  (64k)
        162   98566144     2  freebsd-ufs  (47G)
   98566306    3833661        - free -  (1.8G)
```

Recreate the swap partition:

```
# gpart add -t freebsd-swap -a 4k  ada0
ada0p3 added
# gpart show ada0
=>       34  102399933  ada0  GPT  (48G)
         34        128     1  freebsd-boot  (64k)
        162   98566144     2  freebsd-ufs  (47G)
   98566306    3833661     3  freebsd-swap  (1.8G)
# swapon /dev/ada0p3
```

Grow the UFS file system to use the new capacity of the resized partition:

注意

Growing a live UFS file system is only possible in FreeBSD 10.0-RELEASE and later. For earlier versions, the file system must not be mounted.

```
# growfs /dev/ada0p2
Device is mounted read-write; resizing will result in temporary write suspension for /.
It's strongly recommended to make a backup before growing the file system.
OK to grow file system on /dev/ada0p2, mounted on /, from 38GB to 47GB? [Yes/No] Yes
super-block backups (for fsck -b #) at:
 80781312, 82063552, 83345792, 84628032, 85910272, 87192512, 88474752,
 89756992, 91039232, 92321472, 93603712, 94885952, 96168192, 97450432
```

Both the partition and the file system on it have now been resized to use the newly-available disk space.

17.5. USB 儲存裝置

Contributed by Marc Fonvieille.

在現在，有許多外部儲存裝置採用 USB(Universal Serial Bus) 介面， 例如硬碟、USB 拇指碟、CD-R 燒錄機等。 FreeBSD 提供對這些裝置的支援。

17.5.1. 設定

USB mass 儲存裝置驅動程式(umass(4))提供 USB 儲存裝置的支援。 但如果是用 GENERIC kernel，就不需要做任何設定變動 。 若是自訂 kernel，請確認 kernel 設定檔含有下面這幾行：

```
device scbus
device da
device pass
device uhci
device ohci
device usb
device umass
```

umass(4) 驅動程式透過 SCSI 子系統存取 USB 儲存裝置， 您的 USB 裝置會被系統辨識成 SCSI 裝置。 依照您主機板上 USB 晶片型號， 您只需要 device uhci 或 device ohci 其中一個。 然而，將兩者都編進 kernel 也無妨。 只要別忘了在修改 kernel 設定後重新編譯及安裝新的 kernel 就行了。

注意

如果您的 USB 裝置是 CD-R 或 DVD 燒錄機，則 SCSI 光碟機驅動程式 cd(4) 必須寫入 kernel 設定檔，像這樣：

```
device cd
```

因為燒錄機會被當成 SCSI 裝置，所以 atapicam(4) 驅動程式不需要編入 kernel。

USB 2.0 控制器的支援由 FreeBSD; 提供，然而必須在 kernel 設定檔增加下面這行以提供 USB 2.0 支援：

```
device ehci
```

注意，如果您需要 USB 1.x 支援，您仍然需要將 uhci(4) 及 ohci(4) 驅動程式編入 kernel。

17.5.2. 測試設定

The configuration is ready to be tested: plug in your USB device, and in the system message buffer (dmesg(8)), the drive should appear as something like:

```
umass0: USB Solid state disk, rev 1.10/1.00, addr 2
GEOM: create disk da0 dp=0xc2d74850
da0 at umass-sim0 bus 0 target 0 lun 0
da0: <Generic Traveling Disk 1.11> Removable Direct Access SCSI-2 device
da0: 1.000MB/s transfers
da0: 126MB (258048 512 byte sectors: 64H 32S/T 126C)
```

Of course, the brand, the device node (da0) and other details can differ according to your configuration.

Since the USB device is seen as a SCSI one, the camcontrol command can be used to list the USB storage devices attached to the system:

```
# camcontrol devlist
<Generic Traveling Disk 1.11>      at scbus0 target 0 lun 0 (da0,pass0)
```

If the drive comes with a file system, you should be able to mount it. The 節 17.3, “新增磁碟” will help you to format and create partitions on the USB drive if needed.

If you unplug the device (the disk must be unmounted before), you should see, in the system message buffer, something like the following:

```
umass0: at uhub0 port 1 (addr 2) disconnected
(da0:umass-sim0:0:0:0): lost device
(da0:umass-sim0:0:0:0): removing device entry
GEOM: destroy disk da0 dp=0xc2d74850
umass0: detached
```

17.5.3. Further Reading

Beside the Adding Disks and Mounting and Unmounting File Systems sections, reading various manual pages may be also useful: umass(4), camcontrol(8), and usbdevs(8).

17.6. Creating and Using CD Media

Contributed by Mike Meyer.

Compact Disc (CD) media provide a number of features that differentiate them from conventional disks. They are designed so that they can be read continuously without delays to move the head between tracks. While CD media do have tracks, these refer to a section of data to be read continuously, and not a physical property of the disk. The ISO 9660 file system was designed to deal with these differences.

The FreeBSD Ports Collection provides several utilities for burning and duplicating audio and data CDs. This chapter demonstrates the use of several command line utilities. For CD burning software with a graphical utility, consider installing the sysutils/xcdroast or sysutils/k3b packages or ports.

17.6.1. Supported Devices

Contributed by Marc Fonvieille.

The `GENERIC` kernel provides support for SCSI, USB, and ATAPI CD readers and burners. If a custom kernel is used, the options that need to be present in the kernel configuration file vary by the type of device.

For a SCSI burner, make sure these options are present:

```
device scbus # SCSI bus (required for ATA/SCSI)
device da # Direct Access (disks)
device pass # Passthrough device (direct ATA/SCSI access)
device cd # needed for CD and DVD burners
```

For a USB burner, make sure these options are present:

```
device scbus # SCSI bus (required for ATA/SCSI)
device da # Direct Access (disks)
device pass # Passthrough device (direct ATA/SCSI access)
device cd # needed for CD and DVD burners
device uhci # provides USB 1.x support
device ohci # provides USB 1.x support
device ehci # provides USB 2.0 support
device xhci # provides USB 3.0 support
device usb # USB Bus (required)
device umass # Disks/Mass storage - Requires scbus and da
```

For an ATAPI burner, make sure these options are present:

```
device ata # Legacy ATA/SATA controllers
device scbus # SCSI bus (required for ATA/SCSI)
device pass # Passthrough device (direct ATA/SCSI access)
device cd # needed for CD and DVD burners
```

注意

On FreeBSD versions prior to 10.x, this line is also needed in the kernel configuration file if the burner is an ATAPI device:

```
device atapicam
```

Alternately, this driver can be loaded at boot time by adding the following line to `/boot/loader.conf`:

```
atapicam_load="YES"
```

This will require a reboot of the system as this driver can only be loaded at boot time.

To verify that FreeBSD recognizes the device, run `dmesg` and look for an entry for the device. On systems prior to 10.x, the device name in the first line of the output will be `acd0` instead of `cd0`.

```
% dmesg | grep cd
cd0 at ahcich1 bus 0 scbus1 target 0 lun 0
cd0: <HL-DT-ST DVDRAM GU70N LT20> Removable CD-ROM SCSI-0 device
cd0: Serial Number M3OD3S34152
cd0: 150.000MB/s transfers (SATA 1.x, UDMA6, ATAPI 12bytes, PIO 8192bytes)
cd0: Attempt to query device size failed: NOT READY, Medium not present - tray closed
```

17.6.2. Burning a CD

In FreeBSD, `cdrecord` can be used to burn CDs. This command is installed with the sysutils/cdrtools package or port.

注意

FreeBSD 8.x includes the built-in `burncd` utility for burning CDs using an ATAPI CD burner. Refer to the manual page for `burncd` for usage examples.

While `cdrecord` has many options, basic usage is simple. Specify the name of the ISO file to burn and, if the system has multiple burner devices, specify the name of the device to use:

```
# cdrecord dev=device imagefile.iso
```

To determine the device name of the burner, use `-scanbus` which might produce results like this:

```
# cdrecord -scanbus
ProDVD-ProBD-Clone 3.00 (amd64-unknown-freebsd10.0) Copyright (C) 1995-2010 Jörg ↺
Schilling
Using libscg version 'schily-0.9'
scsibus0:
        0,0,0     0) 'SEAGATE ' 'ST39236LW       ' '0004' Disk
        0,1,0     1) 'SEAGATE ' 'ST39173W        ' '5958' Disk
        0,2,0     2) *
        0,3,0     3) 'iomega  ' 'jaz 1GB         ' 'J.86' Removable Disk
        0,4,0     4) 'NEC     ' 'CD-ROM DRIVE:466' '1.26' Removable CD-ROM
        0,5,0     5) *
        0,6,0     6) *
        0,7,0     7) *
scsibus1:
```

```
        1,0,0   100) *
        1,1,0   101) *
        1,2,0   102) *
        1,3,0   103) *
        1,4,0   104) *
        1,5,0   105) 'YAMAHA  ' 'CRW4260         ' '1.0q' Removable CD-ROM
        1,6,0   106) 'ARTEC   ' 'AM12S           ' '1.06' Scanner
        1,7,0   107) *
```

Locate the entry for the CD burner and use the three numbers separated by commas as the value for `dev`. In this case, the Yamaha burner device is `1,5,0`, so the appropriate input to specify that device is `dev=1,5,0`. Refer to the manual page for `cdrecord` for other ways to specify this value and for information on writing audio tracks and controlling the write speed.

Alternately, run the following command to get the device address of the burner:

```
# camcontrol devlist
<MATSHITA CDRW/DVD UJDA740 1.00>   at scbus1 target 0 lun 0 (cd0,pass0)
```

Use the numeric values for `scbus`, `target`, and `lun`. For this example, `1,0,0` is the device name to use.

17.6.3. Writing Data to an ISO File System

In order to produce a data CD, the data files that are going to make up the tracks on the CD must be prepared before they can be burned to the CD. In FreeBSD, sysutils/cdrtools installs `mkisofs`, which can be used to produce an ISO 9660 file system that is an image of a directory tree within a UNIX® file system. The simplest usage is to specify the name of the ISO file to create and the path to the files to place into the ISO 9660 file system:

```
# mkisofs -o imagefile.iso /path/to/tree
```

This command maps the file names in the specified path to names that fit the limitations of the standard ISO 9660 file system, and will exclude files that do not meet the standard for ISO file systems.

A number of options are available to overcome the restrictions imposed by the standard. In particular, `-R` enables the Rock Ridge extensions common to UNIX® systems and `-J` enables Joliet extensions used by Microsoft® systems.

For CDs that are going to be used only on FreeBSD systems, `-U` can be used to disable all filename restrictions. When used with `-R`, it produces a file system image that is identical to the specified FreeBSD tree, even if it violates the ISO 9660 standard.

The last option of general use is `-b`. This is used to specify the location of a boot image for use in producing an "El Torito" bootable CD. This option takes an argument which is the path to a boot image from the top of the tree being written to the CD. By default, `mkisofs` creates an ISO image in "floppy disk emulation" mode, and thus expects the boot image to be exactly 1200, 1440 or 2880 KB in size. Some boot loaders, like the one used by the FreeBSD distribution media, do not use emulation mode. In this case, `-no-emul-boot` should be used. So, if `/tmp/myboot` holds a bootable FreeBSD system with the boot image in `/tmp/myboot/boot/cdboot`, this command would produce `/tmp/bootable.iso`:

```
# mkisofs -R -no-emul-boot -b boot/cdboot -o /tmp/bootable.iso /tmp/
myboot
```

The resulting ISO image can be mounted as a memory disk with:

```
# mdconfig -a -t vnode -f /tmp/bootable.iso -u 0
# mount -t cd9660 /dev/md0 /mnt
```

One can then verify that `/mnt` and `/tmp/myboot` are identical.

There are many other options available for `mkisofs` to fine-tune its behavior. Refer to mkisofs(8) for details.

注意

It is possible to copy a data CD to an image file that is functionally equivalent to the image file created with `mkisofs`. To do so, use `dd` with the device name as the input file and the name of the ISO to create as the output file:

```
# dd if=/dev/cd0 of=file.iso bs=2048
```

The resulting image file can be burned to CD as described in 節 17.6.2, “Burning a CD”.

17.6.4. Using Data CDs

Once an ISO has been burned to a CD, it can be mounted by specifying the file system type, the name of the device containing the CD, and an existing mount point:

```
# mount -t cd9660 /dev/cd0 /mnt
```

Since `mount` assumes that a file system is of type `ufs`, a Incorrect super block error will occur if `-t cd9660` is not included when mounting a data CD.

While any data CD can be mounted this way, disks with certain ISO 9660 extensions might behave oddly. For example, Joliet disks store all filenames in two-byte Unicode characters. If some non-English characters show up as question marks, specify the local charset with `-C`. For more information, refer to mount_cd9660(8).

注意

In order to do this character conversion with the help of `-C`, the kernel requires the `cd9660_iconv.ko` module to be loaded. This can be done either by adding this line to `loader.conf`:

```
cd9660_iconv_load="YES"
```

and then rebooting the machine, or by directly loading the module with `kldload`.

Occasionally, Device not configured will be displayed when trying to mount a data CD. This usually means that the CD drive thinks that there is no disk in the tray, or that the drive is not visible on the bus. It can take a couple of seconds for a CD drive to realize that a media is present, so be patient.

Sometimes, a SCSI CD drive may be missed because it did not have enough time to answer the bus reset. To resolve this, a custom kernel can be created which increases the default SCSI delay. Add the following option to the custom kernel configuration file and rebuild the kernel using the instructions in 節 8.4, “重新調配、編譯 kernel”:

```
options SCSI_DELAY=15000
```

This tells the SCSI bus to pause 15 seconds during boot, to give the CD drive every possible chance to answer the bus reset.

注意

It is possible to burn a file directly to CD, without creating an ISO 9660 file system. This is known as burning a raw data CD and some people do this for backup purposes.

This type of disk can not be mounted as a normal data CD. In order to retrieve the data burned to such a CD, the data must be read from the raw device node. For example, this command will extract a compressed tar file located on the second CD device into the current working directory:

```
# tar xzvf /dev/cd1
```

In order to mount a data CD, the data must be written using `mkisofs`.

17.6.5. Duplicating Audio CDs

To duplicate an audio CD, extract the audio data from the CD to a series of files, then write these files to a blank CD.

過程 17.1, "Duplicating an Audio CD" describes how to duplicate and burn an audio CD. If the FreeBSD version is less than 10.0 and the device is ATAPI, the `atapicam` module must be first loaded using the instructions in 節 17.6.1, "Supported Devices".

過程 17.1. Duplicating an Audio CD

1. The sysutils/cdrtools package or port installs `cdda2wav`. This command can be used to extract all of the audio tracks, with each track written to a separate WAV file in the current working directory:

   ```
   % cdda2wav -vall -B -Owav
   ```

   A device name does not need to be specified if there is only one CD device on the system. Refer to the `cdda2wav` manual page for instructions on how to specify a device and to learn more about the other options available for this command.

2. Use `cdrecord` to write the `.wav` files:

   ```
   % cdrecord -v dev=2,0 -dao -useinfo  *.wav
   ```

   Make sure that `2,0` is set appropriately, as described in 節 17.6.2, "Burning a CD".

17.7. Creating and Using DVD Media

Contributed by Marc Fonvieille.
With inputs from Andy Polyakov.

Compared to the CD, the DVD is the next generation of optical media storage technology. The DVD can hold more data than any CD and is the standard for video publishing.

Five physical recordable formats can be defined for a recordable DVD:

- DVD-R: This was the first DVD recordable format available. The DVD-R standard is defined by the DVD Forum. This format is write once.
- DVD-RW: This is the rewritable version of the DVD-R standard. A DVD-RW can be rewritten about 1000 times.
- DVD-RAM: This is a rewritable format which can be seen as a removable hard drive. However, this media is not compatible with most DVD-ROM drives and DVD-Video players as only a few DVD writers support the DVD-RAM format. Refer to 節 17.7.8, "Using a DVD-RAM" for more information on DVD-RAM use.
- DVD+RW: This is a rewritable format defined by the DVD+RW Alliance. A DVD+RW can be rewritten about 1000 times.

- DVD+R: This format is the write once variation of the DVD+RW format.

A single layer recordable DVD can hold up to 4,700,000,000 bytes which is actually 4.38 GB or 4485 MB as 1 kilobyte is 1024 bytes.

注意

A distinction must be made between the physical media and the application. For example, a DVD-Video is a specific file layout that can be written on any recordable DVD physical media such as DVD-R, DVD+R, or DVD-RW. Before choosing the type of media, ensure that both the burner and the DVD-Video player are compatible with the media under consideration.

17.7.1. Configuration

To perform DVD recording, use growisofs(1). This command is part of the sysutils/dvd+rw-tools utilities which support all DVD media types.

These tools use the SCSI subsystem to access the devices, therefore ATAPI/CAM support must be loaded or statically compiled into the kernel. This support is not needed if the burner uses the USB interface. Refer to 節 17.5, “USB 儲存裝置” for more details on USB device configuration.

DMA access must also be enabled for ATAPI devices, by adding the following line to `/boot/loader.conf` :

```
hw.ata.atapi_dma="1"
```

Before attempting to use dvd+rw-tools, consult the Hardware Compatibility Notes.

注意

For a graphical user interface, consider using sysutils/k3b which provides a user friendly interface to growisofs(1) and many other burning tools.

17.7.2. Burning Data DVDs

Since growisofs(1) is a front-end to mkisofs, it will invoke mkisofs(8) to create the file system layout and perform the write on the DVD. This means that an image of the data does not need to be created before the burning process.

To burn to a DVD+R or a DVD-R the data in `/path/to/data` , use the following command:

```
# growisofs -dvd-compat -Z  /dev/cd0  -J -R /path/to/data
```

In this example, `-J  -R` is passed to mkisofs(8) to create an ISO 9660 file system with Joliet and Rock Ridge extensions. Refer to mkisofs(8) for more details.

For the initial session recording, `-Z` is used for both single and multiple sessions. Replace */dev/cd0* , with the name of the DVD device. Using `-dvd-compat` indicates that the disk will be closed and that the recording will be unappendable. This should also provide better media compatibility with DVD-ROM drives.

To burn a pre-mastered image, such as *imagefile.iso* , use:

```
# growisofs -dvd-compat -Z  /dev/cd0=imagefile.iso
```

The write speed should be detected and automatically set according to the media and the drive being used. To force the write speed, use `-speed=` . Refer to growisofs(1) for example usage.

注意

In order to support working files larger than 4.38GB, an UDF/ISO-9660 hybrid file system must be created by passing `-udf -iso-level 3` to mkisofs(8) and all related programs, such as growisofs(1). This is required only when creating an ISO image file or when writing files directly to a disk. Since a disk created this way must be mounted as an UDF file system with mount_udf(8), it will be usable only on an UDF aware operating system. Otherwise it will look as if it contains corrupted files.

To create this type of ISO file:

```
% mkisofs -R -J -udf -iso-level 3 -o imagefile.iso /path/to/data
```

To burn files directly to a disk:

```
# growisofs -dvd-compat -udf -iso-level 3 -Z /dev/cd0 -J -R /path/to/data
```

When an ISO image already contains large files, no additional options are required for growisofs(1) to burn that image on a disk.

Be sure to use an up-to-date version of sysutils/cdrtools, which contains mkisofs(8), as an older version may not contain large files support. If the latest version does not work, install sysutils/cdrtools-devel and read its mkisofs(8).

17.7.3. Burning a DVD-Video

A DVD-Video is a specific file layout based on the ISO 9660 and micro-UDF (M-UDF) specifications. Since DVD-Video presents a specific data structure hierarchy, a particular program such as multimedia/dvdauthor is needed to author the DVD.

If an image of the DVD-Video file system already exists, it can be burned in the same way as any other image. If `dvdauthor` was used to make the DVD and the result is in `/path/to/video`, the following command should be used to burn the DVD-Video:

```
# growisofs -Z /dev/cd0 -dvd-video /path/to/video
```

`-dvd-video` is passed to mkisofs(8) to instruct it to create a DVD-Video file system layout. This option implies the `-dvd-compat` growisofs(1) option.

17.7.4. Using a DVD+RW

Unlike CD-RW, a virgin DVD+RW needs to be formatted before first use. It is recommended to let growisofs(1) take care of this automatically whenever appropriate. However, it is possible to use `dvd+rw-format` to format the DVD+RW:

```
# dvd+rw-format /dev/cd0
```

Only perform this operation once and keep in mind that only virgin DVD+RW medias need to be formatted. Once formatted, the DVD+RW can be burned as usual.

To burn a totally new file system and not just append some data onto a DVD+RW, the media does not need to be blanked first. Instead, write over the previous recording like this:

```
# growisofs -Z /dev/cd0 -J -R /path/to/newdata
```

The DVD+RW format supports appending data to a previous recording. This operation consists of merging a new session to the existing one as it is not considered to be multi-session writing. growisofs(1) will grow the ISO 9660 file system present on the media.

For example, to append data to a DVD+RW, use the following:

```
# growisofs -M /dev/cd0 -J -R /path/to/nextdata
```

The same mkisofs(8) options used to burn the initial session should be used during next writes.

注意

Use `-dvd-compat` for better media compatibility with DVD-ROM drives. When using DVD +RW, this option will not prevent the addition of data.

To blank the media, use:

```
# growisofs -Z /dev/cd0=/dev/zero
```

17.7.5. Using a DVD-RW

A DVD-RW accepts two disc formats: incremental sequential and restricted overwrite. By default, DVD-RW discs are in sequential format.

A virgin DVD-RW can be directly written without being formatted. However, a non-virgin DVD-RW in sequential format needs to be blanked before writing a new initial session.

To blank a DVD-RW in sequential mode:

```
# dvd+rw-format -blank=full /dev/cd0
```

注意

A full blanking using `-blank=full` will take about one hour on a 1x media. A fast blanking can be performed using `-blank`, if the DVD-RW will be recorded in Disk-At-Once (DAO) mode. To burn the DVD-RW in DAO mode, use the command:

```
# growisofs -use-the-force-luke=dao -Z /dev/
cd0=imagefile.iso
```

Since growisofs(1) automatically attempts to detect fast blanked media and engage DAO write, `-use-the-force-luke=dao` should not be required.

One should instead use restricted overwrite mode with any DVD-RW as this format is more flexible than the default of incremental sequential.

To write data on a sequential DVD-RW, use the same instructions as for the other DVD formats:

```
# growisofs -Z /dev/cd0 -J -R /path/to/data
```

To append some data to a previous recording, use `-M` with growisofs(1). However, if data is appended on a DVD-RW in incremental sequential mode, a new session will be created on the disc and the result will be a multi-session disc.

A DVD-RW in restricted overwrite format does not need to be blanked before a new initial session. Instead, overwrite the disc with `-Z`. It is also possible to grow an existing ISO 9660 file system written on the disc with `-M`. The result will be a one-session DVD.

To put a DVD-RW in restricted overwrite format, the following command must be used:

```
# dvd+rw-format /dev/cd0
```

To change back to sequential format, use:

```
# dvd+rw-format -blank=full /dev/cd0
```

17.7.6. Multi-Session

Few DVD-ROM drives support multi-session DVDs and most of the time only read the first session. DVD+R, DVD-R and DVD-RW in sequential format can accept multiple sessions. The notion of multiple sessions does not exist for the DVD+RW and the DVD-RW restricted overwrite formats.

Using the following command after an initial non-closed session on a DVD+R, DVD-R, or DVD-RW in sequential format, will add a new session to the disc:

```
# growisofs -M /dev/cd0 -J -R /path/to/nextdata
```

Using this command with a DVD+RW or a DVD-RW in restricted overwrite mode will append data while merging the new session to the existing one. The result will be a single-session disc. Use this method to add data after an initial write on these types of media.

注意

Since some space on the media is used between each session to mark the end and start of sessions, one should add sessions with a large amount of data to optimize media space. The number of sessions is limited to 154 for a DVD+R, about 2000 for a DVD-R, and 127 for a DVD +R Double Layer.

17.7.7. For More Information

To obtain more information about a DVD, use `dvd+rw-mediainfo /dev/cd0` while the disc in the specified drive.

More information about dvd+rw-tools can be found in growisofs(1), on the dvd+rw-tools web site, and in the cdwrite mailing list archives.

注意

When creating a problem report related to the use of dvd+rw-tools, always include the output of `dvd+rw-mediainfo` .

17.7.8. Using a DVD-RAM

DVD-RAM writers can use either a SCSI or ATAPI interface. For ATAPI devices, DMA access has to be enabled by adding the following line to `/boot/loader.conf` :

```
hw.ata.atapi_dma="1"
```

A DVD-RAM can be seen as a removable hard drive. Like any other hard drive, the DVD-RAM must be formatted before it can be used. In this example, the whole disk space will be formatted with a standard UFS2 file system:

```
# dd if=/dev/zero of=/dev/acd0 bs=2k count=1
# bsdlabel -Bw acd0
# newfs /dev/acd0
```

The DVD device, `acd0`, must be changed according to the configuration.

Once the DVD-RAM has been formatted, it can be mounted as a normal hard drive:

```
# mount /dev/acd0 /mnt
```

Once mounted, the DVD-RAM will be both readable and writeable.

17.8. Creating and Using Floppy Disks

This section explains how to format a 3.5 inch floppy disk in FreeBSD.

過程 17.2. Steps to Format a Floppy

A floppy disk needs to be low-level formatted before it can be used. This is usually done by the vendor, but formatting is a good way to check media integrity. To low-level format the floppy disk on FreeBSD, use fdformat(1). When using this utility, make note of any error messages, as these can help determine if the disk is good or bad.

1. To format the floppy, insert a new 3.5 inch floppy disk into the first floppy drive and issue:

   ```
   # /usr/sbin/fdformat -f 1440 /dev/fd0
   ```

2. After low-level formatting the disk, create a disk label as it is needed by the system to determine the size of the disk and its geometry. The supported geometry values are listed in `/etc/disktab` .

   To write the disk label, use bsdlabel(8):

   ```
   # /sbin/bsdlabel -B -w /dev/fd0 fd1440
   ```

3. The floppy is now ready to be high-level formatted with a file system. The floppy's file system can be either UFS or FAT, where FAT is generally a better choice for floppies.

   To format the floppy with FAT, issue:

   ```
   # /sbin/newfs_msdos /dev/fd0
   ```

The disk is now ready for use. To use the floppy, mount it with mount_msdosfs(8). One can also install and use emulators/mtools from the Ports Collection.

17.9. Backup Basics

Implementing a backup plan is essential in order to have the ability to recover from disk failure, accidental file deletion, random file corruption, or complete machine destruction, including destruction of on-site backups.

The backup type and schedule will vary, depending upon the importance of the data, the granularity needed for file restores, and the amount of acceptable downtime. Some possible backup techniques include:

- Archives of the whole system, backed up onto permanent, off-site media. This provides protection against all of the problems listed above, but is slow and inconvenient to restore from, especially for non-privileged users.

- File system snapshots, which are useful for restoring deleted files or previous versions of files.
- Copies of whole file systems or disks which are sychronized with another system on the network using a scheduled net/rsync.
- Hardware or software RAID, which minimizes or avoids downtime when a disk fails.

Typically, a mix of backup techniques is used. For example, one could create a schedule to automate a weekly, full system backup that is stored off-site and to supplement this backup with hourly ZFS snapshots. In addition, one could make a manual backup of individual directories or files before making file edits or deletions.

This section describes some of the utilities which can be used to create and manage backups on a FreeBSD system.

17.9.1. File System Backups

The traditional UNIX® programs for backing up a file system are dump(8), which creates the backup, and restore(8), which restores the backup. These utilities work at the disk block level, below the abstractions of the files, links, and directories that are created by file systems. Unlike other backup software, `dump` backs up an entire file system and is unable to backup only part of a file system or a directory tree that spans multiple file systems. Instead of writing files and directories, `dump` writes the raw data blocks that comprise files and directories.

注意

If `dump` is used on the root directory, it will not back up `/home`, `/usr` or many other directories since these are typically mount points for other file systems or symbolic links into those file systems.

When used to restore data, `restore` stores temporary files in `/tmp/` by default. When using a recovery disk with a small `/tmp`, set `TMPDIR` to a directory with more free space in order for the restore to succeed.

When using `dump`, be aware that some quirks remain from its early days in Version 6 of AT&T UNIX®,circa 1975. The default parameters assume a backup to a 9-track tape, rather than to another type of media or to the high-density tapes available today. These defaults must be overridden on the command line.

It is possible to backup a file system across the network to a another system or to a tape drive attached to another computer. While the rdump(8) and rrestore(8) utilities can be used for this purpose, they are not considered to be secure.

Instead, one can use `dump` and `restore` in a more secure fashion over an SSH connection. This example creates a full, compressed backup of `/usr` and sends the backup file to the specified host over a SSH connection.

範例 17.1. Using `dump` over ssh

```
# /sbin/dump -0uan -f - /usr | gzip -2 | ssh -c blowfish \
          targetuser@targetmachine.example.com dd of=/mybigfiles/
dump-usr-l0.gz
```

This example sets `RSH` in order to write the backup to a tape drive on a remote system over a SSH connection:

範例 17.2. Using **dump** over ssh with **RSH** Set

```
# env RSH=/usr/bin/ssh /sbin/dump -0uan -f ↺
targetuser@targetmachine.example.com:/dev/sa0 /usr
```

17.9.2. Directory Backups

Several built-in utilities are available for backing up and restoring specified files and directories as needed.

A good choice for making a backup of all of the files in a directory is tar(1). This utility dates back to Version 6 of AT&T UNIX® and by default assumes a recursive backup to a local tape device. Switches can be used to instead specify the name of a backup file.

This example creates a compressed backup of the current directory and saves it to `/tmp/mybackup.tgz` . When creating a backup file, make sure that the backup is not saved to the same directory that is being backed up.

範例 17.3. Backing Up the Current Directory with **tar**

```
# tar czvf /tmp/mybackup.tgz  .
```

To restore the entire backup, `cd` into the directory to restore into and specify the name of the backup. Note that this will overwrite any newer versions of files in the restore directory. When in doubt, restore to a temporary directory or specify the name of the file within the backup to restore.

範例 17.4. Restoring Up the Current Directory with **tar**

```
# tar xzvf /tmp/mybackup.tgz
```

There are dozens of available switches which are described in tar(1). This utility also supports the use of exclude patterns to specify which files should not be included when backing up the specified directory or restoring files from a backup.

To create a backup using a specified list of files and directories, cpio(1) is a good choice. Unlike `tar`, `cpio` does not know how to walk the directory tree and it must be provided the list of files to backup.

For example, a list of files can be created using `ls` or `find`. This example creates a recursive listing of the current directory which is then piped to `cpio` in order to create an output backup file named `/tmp/mybackup.cpio` .

範例 17.5. Using`ls` and `cpio` to Make a Recursive Backup of the Current Directory

```
# ls -R | cpio -ovF /tmp/mybackup.cpio
```

A backup utility which tries to bridge the features provided by `tar` and `cpio` is pax(1). Over the years, the various versions of `tar` and `cpio` became slightly incompatible. POSIX® created `pax` which attempts to read and write many of the various `cpio` and `tar` formats, plus new formats of its own.

The `pax` equivalent to the previous examples would be:

範例 17.6. Backing Up the Current Directory with `pax`

```
# pax -wf /tmp/mybackup.pax  .
```

17.9.3. Using Data Tapes for Backups

While tape technology has continued to evolve, modern backup systems tend to combine off-site backups with local removable media. FreeBSD supports any tape drive that uses SCSI, such as LTO or DAT. There is limited support for SATA and USB tape drives.

For SCSI tape devices, FreeBSD uses the sa(4) driver and the `/dev/sa0` , `/dev/nsa0` , and `/dev/esa0` devices. The physical device name is `/dev/sa0` . When `/dev/nsa0` is used, the backup application will not rewind the tape after writing a file, which allows writing more than one file to a tape. Using `/dev/esa0` ejects the tape after the device is closed.

In FreeBSD, `mt` is used to control operations of the tape drive, such as seeking through files on a tape or writing tape control marks to the tape. For example, the first three files on a tape can be preserved by skipping past them before writing a new file:

```
# mt -f /dev/nsa0 fsf 3
```

This utility supports many operations. Refer to mt(1) for details.

To write a single file to tape using `tar`, specify the name of the tape device and the file to backup:

```
# tar cvf /dev/sa0  file
```

To recover files from a `tar` archive on tape into the current directory:

```
# tar xvf /dev/sa0
```

To backup a UFS file system, use `dump`. This examples backs up `/usr` without rewinding the tape when finished:

```
# dump -0aL -b64 -f /dev/nsa0 /usr
```

To interactively restore files from a `dump` file on tape into the current directory:

```
# restore -i -f /dev/nsa0
```

17.9.4. Third-Party Backup Utilities

The FreeBSD Ports Collection provides many third-party utilities which can be used to schedule the creation of backups, simplify tape backup, and make backups easier and more convenient. Many of these applications are client/server based and can be used to automate the backups of a single system or all of the computers in a network.

Popular utilities include Amanda, Bacula, rsync, and duplicity.

17.9.5. Emergency Recovery

In addition to regular backups, it is recommended to perform the following steps as part of an emergency preparedness plan.

Create a print copy of the output of the following commands:

- `gpart show`
- `more /etc/fstab`
- `dmesg`

Store this printout and a copy of the installation media in a secure location. Should an emergency restore be needed, boot into the installation media and select `Live CD` to access a rescue shell. This rescue mode can be used to view the current state of the system, and if needed, to reformat disks and restore data from backups.

注意

The installation media for FreeBSD/i386 9.3-RELEASE does not include a rescue shell. For this version, instead download and burn a Livefs CD image from `ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/ISO-IMAGES/9.3/FreeBSD-9.3-RELEASE-i386-livefs.iso` .

Next, test the rescue shell and the backups. Make notes of the procedure. Store these notes with the media, the printouts, and the backups. These notes may prevent the inadvertent destruction of the backups while under the stress of performing an emergency recovery.

For an added measure of security, store the latest backup at a remote location which is physically separated from the computers and disk drives by a significant distance.

17.10. Memory Disks

Reorganized and enhanced by Marc Fonvieille.

In addition to physical disks, FreeBSD also supports the creation and use of memory disks. One possible use for a memory disk is to access the contents of an ISO file system without the overhead of first burning it to a CD or DVD, then mounting the CD/DVD media.

In FreeBSD, the md(4) driver is used to provide support for memory disks. The `GENERIC` kernel includes this driver. When using a custom kernel configuration file, ensure it includes this line:

```
device md
```

17.10.1. Attaching and Detaching Existing Images

To mount an existing file system image, use `mdconfig` to specify the name of the ISO file and a free unit number. Then, refer to that unit number to mount it on an existing mount point. Once mounted, the files in the ISO will appear in the mount point. This example attaches *`diskimage.iso`* to the memory device `/dev/md0` then mounts that memory device on `/mnt`:

```
# mdconfig -f diskimage.iso -u 0
# mount /dev/md0 /mnt
```

If a unit number is not specified with `-u`, `mdconfig` will automatically allocate an unused memory device and output the name of the allocated unit, such as `md4`. Refer to mdconfig(8) for more details about this command and its options.

When a memory disk is no longer in use, its resources should be released back to the system. First, unmount the file system, then use `mdconfig` to detach the disk from the system and release its resources. To continue this example:

```
# umount /mnt
# mdconfig -d -u 0
```

To determine if any memory disks are still attached to the system, type `mdconfig -l`.

17.10.2. Creating a File- or Memory-Backed Memory Disk

FreeBSD also supports memory disks where the storage to use is allocated from either a hard disk or an area of memory. The first method is commonly referred to as a file-backed file system and the second method as a memory-backed file system. Both types can be created using `mdconfig`.

To create a new memory-backed file system, specify a type of `swap` and the size of the memory disk to create. Then, format the memory disk with a file system and mount as usual. This example creates a 5M memory disk on unit `1`. That memory disk is then formatted with the UFS file system before it is mounted:

```
# mdconfig -a -t swap -s 5m -u 1
# newfs -U md1
/dev/md1: 5.0MB (10240 sectors) block size 16384, fragment size 2048
        using 4 cylinder groups of 1.27MB, 81 blks, 192 inodes.
        with soft updates
super-block backups (for fsck -b #) at:
 160, 2752, 5344, 7936
# mount /dev/md1 /mnt
# df /mnt
Filesystem 1K-blocks Used Avail Capacity  Mounted on
/dev/md1        4718    4  4338     0%    /mnt
```

To create a new file-backed memory disk, first allocate an area of disk to use. This example creates an empty 5K file named `newimage`:

```
# dd if=/dev/zero of=newimage bs=1k count=5k
5120+0 records in
5120+0 records out
```

Next, attach that file to a memory disk, label the memory disk and format it with the UFS file system, mount the memory disk, and verify the size of the file-backed disk:

```
# mdconfig -f newimage -u 0
# bsdlabel -w md0 auto
```

```
# newfs md0a
/dev/md0a: 5.0MB (10224 sectors) block size 16384, fragment size 2048
        using 4 cylinder groups of 1.25MB, 80 blks, 192 inodes.
super-block backups (for fsck -b #) at:
 160, 2720, 5280, 7840
# mount /dev/md0a /mnt
# df /mnt
Filesystem 1K-blocks Used Avail Capacity  Mounted on
/dev/md0a       4710    4  4330     0%    /mnt
```

It takes several commands to create a file- or memory-backed file system using `mdconfig`. FreeBSD also comes with `mdmfs` which automatically configures a memory disk, formats it with the UFS file system, and mounts it. For example, after creating *`newimage`* with `dd`, this one command is equivalent to running the `bsdlabel`, `newfs`, and `mount` commands shown above:

```
# mdmfs -F newimage -s 5m md0 /mnt
```

To instead create a new memory-based memory disk with `mdmfs`, use this one command:

```
# mdmfs -s 5m md1 /mnt
```

If the unit number is not specified, `mdmfs` will automatically select an unused memory device. For more details about `mdmfs`, refer to mdmfs(8).

17.11. File System Snapshots

Contributed by Tom Rhodes.

FreeBSD offers a feature in conjunction with Soft Updates: file system snapshots.

UFS snapshots allow a user to create images of specified file systems, and treat them as a file. Snapshot files must be created in the file system that the action is performed on, and a user may create no more than 20 snapshots per file system. Active snapshots are recorded in the superblock so they are persistent across unmount and remount operations along with system reboots. When a snapshot is no longer required, it can be removed using rm(1). While snapshots may be removed in any order, all the used space may not be acquired because another snapshot will possibly claim some of the released blocks.

The un-alterable `snapshot` file flag is set by mksnap_ffs(8) after initial creation of a snapshot file. unlink(1) makes an exception for snapshot files since it allows them to be removed.

Snapshots are created using mount(8). To place a snapshot of `/var` in the file `/var/snapshot/snap`, use the following command:

```
# mount -u -o snapshot /var/snapshot/snap /var
```

Alternatively, use mksnap_ffs(8) to create the snapshot:

```
# mksnap_ffs /var /var/snapshot/snap
```

One can find snapshot files on a file system, such as `/var`, using find(1):

```
# find /var -flags snapshot
```

Once a snapshot has been created, it has several uses:

- Some administrators will use a snapshot file for backup purposes, because the snapshot can be transferred to CDs or tape.

- The file system integrity checker, fsck(8), may be run on the snapshot. Assuming that the file system was clean when it was mounted, this should always provide a clean and unchanging result.

- Running dump(8) on the snapshot will produce a dump file that is consistent with the file system and the timestamp of the snapshot. dump(8) can also take a snapshot, create a dump image, and then remove the snapshot in one command by using `-L`.

- The snapshot can be mounted as a frozen image of the file system. To mount(8) the snapshot `/var/snapshot/snap` run:

```
# mdconfig -a -t vnode -o readonly -f /var/snapshot/snap -u 4
# mount -r /dev/md4 /mnt
```

The frozen `/var` is now available through `/mnt`. Everything will initially be in the same state it was during the snapshot creation time. The only exception is that any earlier snapshots will appear as zero length files. To unmount the snapshot, use:

```
# umount /mnt
# mdconfig -d -u 4
```

For more information about `softupdates` and file system snapshots, including technical papers, visit Marshall Kirk McKusick's website at `http://www.mckusick.com/` .

17.12. 磁碟空間配額(Quota)

磁碟配額(Quota)屬於作業系統上的選用功能， 可以用來限制使用者或群組的可用空間大小，或者檔案的總數多寡。 這功能通常用在多人共用的系統環境上， 因為要限制各使用者或各群組所能運用的系統資源。 如此一來，就可避免磁碟空間被某使用者或某群組全部耗盡。

17.12.1. 啓用磁碟配額

在用磁碟配額之前，請先確認 kernel 已經有作相關設定，也就是 kernel 設定檔要有下面這行：

```
options QUOTA
```

預設的 `GENERIC` kernel 並不會加上這項， 所以若要啓用就必需加上，並重新編譯、安裝 `kernel`。 kernel 設定部分可參閱 章 8, 設定 FreeBSD Kernel 的說明。

接著就是在 `/etc/rc.conf` 設定啓動磁碟配額。 請加上下列這行：

```
enable_quotas="YES"
```

為了能更完善的控管磁碟配額的啓動，還有一個設定可以用。 通常開機時， quotacheck(8) 程式會檢查各檔案系統上的配額。 quotacheck(8) 可以確保配額資料庫的資料與實際檔案系統的資料有符合。 但這功能也會在開機時，會對啓動時間造成相當明顯的影響。 若想跳過這步驟，則可以在 `/etc/rc.conf` 加上：

```
check_quotas="NO"
```

最後，要記得改 `/etc/fstab` 來啓用以檔案系統為對象的磁碟配額功能。 也可以啓用針對使用者或群組， 或者兩者皆有之的磁碟配額。

若要啓用針對使用者的配額，可以在 `/etc/fstab` 內要設定的檔案系統加上 `userquota` 選項。 比如：

```
/dev/da1s2g   /home    ufs rw,userquota 1 2
```

同理若要啓用針對群組的配額，則把剛剛的 userquota 換成 groupquota 即可。 而若要兩者同時啓用， 那麼則是：

```
/dev/da1s2g    /home    ufs rw,userquota,groupquota 1 2
```

針對使用者以及群組的磁碟配額設定檔，預設分別會放在該檔案系統根目錄的 quota.user 以及 quota.group 。 細節部分請參閱 fstab(5)。 雖然 fstab(5) 提到可以為配額設定檔指定其他地方，但並不建議如此作， 因為各種磁碟配額管理工具並不見得對這些預設值能隨之彈性變化。

接下來就可以用新 kernel 來重開機。 /etc/rc 會自動執行相關指令以對 /etc/fstab 有設定配額管理的部分，作初始設定。 所以並不需要逐一手動產生相關空的配額設定檔。

正常操作過程中，並不需要手動執行 quotacheck(8)、quotaon(8) 、quotaoff(8) 這些指令。 不過，若要更熟悉相關操作方式的話， 或許可以閱讀相關的 manual 線上說明。

17.12.2. 設定配額限制

一旦開始啓用配額管理之後，請記得確認是否有真的啓用。 可以打下列指令來作簡單檢查：

```
# quota -v
```

應該可以看到有關各檔案系統的配額限量， 以及現在使用量的摘要訊息。

現在可以開始用 edquota(8) 來設定各磁碟配額的限制。

有幾種選項可以用來限制使用者或群組所能運用的磁碟空間， 以及所能建立的檔案數量多寡。 可以依磁碟空間(block 配額)或檔案數量 (inode 配額)，或者搭配兩者一起設定。 而每種限制還可以細分為兩類：hard(硬性)上限、soft(彈性)上限。

硬性上限是不能超過的。 一旦使用者達到硬性上限時， 就無法在該檔案系統上繼續使用更多的使用空間了。 舉例來說，若有位使用者的硬性上限為 500 KB，而目前用了 490 KB， 那麼他就只能再多用 10 KB 而已，若要新增的檔案有 11 KB 就會失敗。

然而，彈性上限則可允許一定時間內的超額使用，這段期間稱為 grace period(寬限期)，預設值是一週。若使用者持續超額使用並超出 grace period 而逾期，則彈性上限就會轉為硬性上限， 而不允許該使用者繼續新增空間。 直到該使用者的空間已經清到低於彈性上限之後，才會重設 grace period。

下面則是使用 edquota(8) 的例子。 在執行 edquota(8) 時，會進入設定磁碟配額上限的編輯器內，至於是哪一種編輯器則視您的 EDITOR 環境變數而定，若沒設定 EDITOR 的話，則會用 vi 編輯器。

```
# edquota -u test
```

```
Quotas for user test:
/usr: kbytes in use: 65, limits (soft = 50, hard = 75)
        inodes in use: 7, limits (soft = 50, hard = 60)
/usr/var: kbytes in use: 0, limits (soft = 50, hard = 75)
        inodes in use: 0, limits (soft = 50, hard = 60)
```

一般來說，每個啓動了磁碟配額的檔案系統都會有兩行設定。 第一行是 block 上限，而另一行則是 inode 上限。 若要更改磁碟配額上限，只需要修改後面的數值即可。 舉例來說， 要增加這位使用者的 block 上限部分：把彈性上限 50 調為 500， 硬性上限則由 75 調為 600 ，只需修改下面這行：

```
/usr: kbytes in use: 65, limits (soft = 50, hard = 75)
```

改為下列：

```
/usr: kbytes in use: 65, limits (soft = 500, hard = 600)
```

然後存檔離開後，新的配額設定就會立即生效。

有時候會想一次改大範圍 UID 的帳號設定，這時可以用 edquota(8) 的 `-p` 參數功能來完成。 首先， 把某個帳號調為想要的相關配額，然後可以用 `edquota -p protouser startuid-enduid` 之類的方式來改。 舉例來說，假設 `test` 這帳號已經設定好相關配額， 然後要改的對象為 UID 從 10,000 到 19,999 的帳號， 那麼就可以下列指令來設定同樣的配額：

```
# edquota -p test 10000-19999
```

細節說明請參閱 edquota(8)。

17.12.3. 檢查磁碟配額設定、磁碟使用量

可以用 quota(1) 或 repquota(8) 來檢查磁碟配額設定， 以及磁碟使用量。 quota(1) 可用來檢查單一使用者或群組的磁碟配額、 磁碟使用量。 不過一般帳號只能查自己的以及自己群組的磁碟配額、 磁碟使用量，只有系統管理者帳號才能察看所有使用者、 群組的配額設定與使用量。 而 repquota(8) 則可以看到所有已啓動磁碟配額的檔案系統設定、磁碟使用量摘要。

下面例子則是在兩個有配額設定的檔案系統上，打 `quota -v` 的顯示結果：

```
Disk quotas for user test (uid 1002):
     Filesystem  usage    quota   limit   grace   files   quota   limit   grace
          /usr      65*     50      75   5days       7      50      60
       /usr/var      0      50      75                0      50      60
```

在上面這例中，該使用者在 `/usr` 的彈性配額是 50 KB，實際上已經超額多用 15 KB，而 grace period 還有 5 天就逾期。 請注意這個星號 * 是表示目前該使用者已經超越其配額的彈性上限了。

一般來說，若使用者並沒有用到某個檔案系統， 那麼就算該檔案有啓用磁碟配額，在 quota(1) 也不會顯示出來。 而 `-v` 參數則可以把這些檔案系統都全部列出來， 比如上例中的 `/usr/var` 。

17.12.4. 透過 NFS 使用磁碟配額

NFS server 端可以强制以 quota `subsystem`(配額子系統)來用磁碟配額。 而 NFS client 端則可以透過 rpc.rquotad(8) daemon 來讓 quota(1) 指令抓到相關配額資料，也就可以讓 client 端的使用者察看其配額的統計資料。

若要啓用 `rpc.rquotad` ，可以在 `/etc/inetd.conf` 加上下列類似設定：

```
rquotad/1      dgram rpc/udp wait root /usr/libexec/rpc.rquotad rpc.rquotad
```

然後重啓 `inetd` 即可：

```
# kill -HUP `cat /var/run/inetd.pid`
```

17.13. Encrypting Disk Partitions

Contributed by Lucky Green.

FreeBSD offers excellent online protections against unauthorized data access. File permissions and Mandatory Access Control (MAC) help prevent unauthorized users from accessing data while the operating system is active and the computer is powered up. However, the permissions enforced by the operating system are irrelevant if an attacker has physical access to a computer and can move the computer's hard drive to another system to copy and analyze the data.

Regardless of how an attacker may have come into possession of a hard drive or powered-down computer, the GEOM-based cryptographic subsystems built into FreeBSD are able to protect the data on the computer's file systems against even highly-motivated attackers with significant resources. Unlike encryption methods that

encrypt individual files, the built-in `gbde` and `geli` utilities can be used to transparently encrypt entire file systems. No cleartext ever touches the hard drive's platter.

This chapter demonstrates how to create an encrypted file system on FreeBSD. It first demonstrates the process using `gbde` and then demonstrates the same example using `geli`.

17.13.1. Disk Encryption with gbde

The objective of the gbde(4) facility is to provide a formidable challenge for an attacker to gain access to the contents of a cold storage device. However, if the computer is compromised while up and running and the storage device is actively attached, or the attacker has access to a valid passphrase, it offers no protection to the contents of the storage device. Thus, it is important to provide physical security while the system is running and to protect the passphrase used by the encryption mechanism.

This facility provides several barriers to protect the data stored in each disk sector. It encrypts the contents of a disk sector using 128-bit AES in CBC mode. Each sector on the disk is encrypted with a different AES key. For more information on the cryptographic design, including how the sector keys are derived from the user-supplied passphrase, refer to gbde(4).

FreeBSD provides a kernel module for gbde which can be loaded with this command:

```
# kldload geom_bde
```

If using a custom kernel configuration file, ensure it contains this line:

```
options GEOM_BDE
```

The following example demonstrates adding a new hard drive to a system that will hold a single encrypted partition that will be mounted as `/private`.

過程 17.3. Encrypting a Partition with gbde

1. Add the New Hard Drive

   Install the new drive to the system as explained in 節 17.3, “新增磁碟”. For the purposes of this example, a new hard drive partition has been added as `/dev/ad4s1c` and `/dev/ad0s1` * represents the existing standard FreeBSD partitions.

   ```
   # ls /dev/ad*
   /dev/ad0        /dev/ad0s1b     /dev/ad0s1e     /dev/ad4s1
   /dev/ad0s1      /dev/ad0s1c     /dev/ad0s1f     /dev/ad4s1c
   /dev/ad0s1a     /dev/ad0s1d     /dev/ad4
   ```

2. Create a Directory to Hold **gbde** Lock Files

   ```
   # mkdir /etc/gbde
   ```

   The gbde lock file contains information that gbde requires to access encrypted partitions. Without access to the lock file, gbde will not be able to decrypt the data contained in the encrypted partition without significant manual intervention which is not supported by the software. Each encrypted partition uses a separate lock file.

3. Initialize the **gbde** Partition

   A gbde partition must be initialized before it can be used. This initialization needs to be performed only once. This command will open the default editor, in order to set various configuration options in a template. For use with the UFS file system, set the sector_size to 2048:

   ```
   # gbde init /dev/ad4s1c -i -L /etc/gbde/ad4s1c.lock  # $FreeBSD: src/sbin/
   gbde/template.txt,v 1.1.36.1 2009/08/03 08:13:06 kensmith Exp $
   ```

```
#
# Sector size is the smallest unit of data which can be read or written.
# Making it too small decreases performance and decreases available space.
# Making it too large may prevent filesystems from working.  512 is the
# minimum and always safe.  For UFS, use the fragment size
#
sector_size = 2048
[...-]
```

Once the edit is saved, the user will be asked twice to type the passphrase used to secure the data. The passphrase must be the same both times. The ability of gbde to protect data depends entirely on the quality of the passphrase. For tips on how to select a secure passphrase that is easy to remember, see http://world.std.com/~reinhold/diceware.htm.

This initialization creates a lock file for the gbde partition. In this example, it is stored as `/etc/gbde/ad4s1c.lock` . Lock files must end in ".lock" in order to be correctly detected by the `/etc/rc.d/gbde` start up script.

注意

Lock files must be backed up together with the contents of any encrypted partitions. Without the lock file, the legitimate owner will be unable to access the data on the encrypted partition.

4. Attach the Encrypted Partition to the Kernel

```
# gbde attach /dev/ad4s1c -l /etc/gbde/ad4s1c.lock
```

This command will prompt to input the passphrase that was selected during the initialization of the encrypted partition. The new encrypted device will appear in `/dev` as `/dev/device_name.bde` :

```
# ls /dev/ad*
/dev/ad0        /dev/ad0s1b     /dev/ad0s1e     /dev/ad4s1
/dev/ad0s1      /dev/ad0s1c     /dev/ad0s1f     /dev/ad4s1c
/dev/ad0s1a     /dev/ad0s1d     /dev/ad4        /dev/ad4s1c.bde
```

5. Create a File System on the Encrypted Device

Once the encrypted device has been attached to the kernel, a file system can be created on the device. This example creates a UFS file system with soft updates enabled. Be sure to specify the partition which has a `*.bde` extension:

```
# newfs -U /dev/ad4s1c.bde
```

6. Mount the Encrypted Partition

Create a mount point and mount the encrypted file system:

```
# mkdir /private
# mount /dev/ad4s1c.bde /private
```

7. Verify That the Encrypted File System is Available

The encrypted file system should now be visible and available for use:

```
% df -H
Filesystem       Size   Used  Avail Capacity  Mounted on
```

```
/dev/ad0s1a      1037M    72M   883M     8%    /
/devfs            1.0K   1.0K     0B   100%    /dev
/dev/ad0s1f       8.1G    55K   7.5G     0%    /home
/dev/ad0s1e      1037M   1.1M   953M     0%    /tmp
/dev/ad0s1d       6.1G   1.9G   3.7G    35%    /usr
/dev/ad4s1c.bde   150G   4.1K   138G     0%    /private
```

After each boot, any encrypted file systems must be manually re-attached to the kernel, checked for errors, and mounted, before the file systems can be used. To configure these steps, add the following lines to `/etc/rc.conf`:

```
gbde_autoattach_all="YES"
gbde_devices="ad4s1c"
gbde_lockdir="/etc/gbde"
```

This requires that the passphrase be entered at the console at boot time. After typing the correct passphrase, the encrypted partition will be mounted automatically. Additional gbde boot options are available and listed in rc.conf(5).

注意

sysinstall is incompatible with gbde-encrypted devices. All `*.bde` devices must be detached from the kernel before starting sysinstall or it will crash during its initial probing for devices. To detach the encrypted device used in the example, use the following command:

```
# gbde detach /dev/ad4s1c
```

17.13.2. Disk Encryption with geli

Contributed by Daniel Gerzo.

An alternative cryptographic GEOM class is available using `geli`. This control utility adds some features and uses a different scheme for doing cryptographic work. It provides the following features:

- Utilizes the crypto(9) framework and automatically uses cryptographic hardware when it is available.
- Supports multiple cryptographic algorithms such as AES, Blowfish, and 3DES.
- Allows the root partition to be encrypted. The passphrase used to access the encrypted root partition will be requested during system boot.
- Allows the use of two independent keys.
- It is fast as it performs simple sector-to-sector encryption.
- Allows backup and restore of master keys. If a user destroys their keys, it is still possible to get access to the data by restoring keys from the backup.
- Allows a disk to attach with a random, one-time key which is useful for swap partitions and temporary file systems.

More features and usage examples can be found in geli(8).

The following example describes how to generate a key file which will be used as part of the master key for the encrypted provider mounted under `/private`. The key file will provide some random data used to encrypt the master key. The master key will also be protected by a passphrase. The provider's sector size will be 4kB. The example describes how to attach to the `geli` provider, create a file system on it, mount it, work with it, and finally, how to detach it.

過程 17.4. Encrypting a Partition with `geli`

1. Load **`geli`** Support

   Support for `geli` is available as a loadable kernel module. To configure the system to automatically load the module at boot time, add the following line to `/boot/loader.conf` :

   ```
   geom_eli_load="YES"
   ```

   To load the kernel module now:

   ```
   # kldload geom_eli
   ```

   For a custom kernel, ensure the kernel configuration file contains these lines:

   ```
   options GEOM_ELI
   device crypto
   ```

2. Generate the Master Key

   The following commands generate a master key (`/root/da2.key`) that is protected with a passphrase. The data source for the key file is `/dev/random` and the sector size of the provider (`/dev/da2.eli`) is 4kB as a bigger sector size provides better performance:

   ```
   # dd if=/dev/random of=/root/da2.key bs=64 count=1
   # geli init -s 4096 -K /root/da2.key /dev/da2
   Enter new passphrase:
   Reenter new passphrase:
   ```

   It is not mandatory to use both a passphrase and a key file as either method of securing the master key can be used in isolation.

   If the key file is given as "-", standard input will be used. For example, this command generates three key files:

   ```
   # cat keyfile1 keyfile2 keyfile3 | geli init -K - /dev/da2
   ```

3. Attach the Provider with the Generated Key

   To attach the provider, specify the key file, the name of the disk, and the passphrase:

   ```
   # geli attach -k /root/da2.key /dev/da2
   Enter passphrase:
   ```

   This creates a new device with an `.eli` extension:

   ```
   # ls /dev/da2*
   /dev/da2  /dev/da2.eli
   ```

4. Create the New File System

   Next, format the device with the UFS file system and mount it on an existing mount point:

   ```
   # dd if=/dev/random of=/dev/da2.eli bs=1m
   # newfs /dev/da2.eli
   # mount /dev/da2.eli  /private
   ```

   The encrypted file system should now be available for use:

   ```
   # df -H
   Filesystem     Size   Used  Avail Capacity  Mounted on
   /dev/ad0s1a    248M    89M   139M    38%    /
   ```

```
/devfs          1.0K    1.0K      0B   100%    /dev
/dev/ad0s1f     7.7G    2.3G    4.9G    32%    /usr
/dev/ad0s1d     989M    1.5M    909M     0%    /tmp
/dev/ad0s1e     3.9G    1.3G    2.3G    35%    /var
/dev/da2.eli    150G    4.1K    138G     0%    /private
```

Once the work on the encrypted partition is done, and the `/private` partition is no longer needed, it is prudent to put the device into cold storage by unmounting and detaching the `geli` encrypted partition from the kernel:

```
# umount /private
# geli detach da2.eli
```

A `rc.d` script is provided to simplify the mounting of `geli`-encrypted devices at boot time. For this example, add these lines to `/etc/rc.conf` :

```
geli_devices="da2"
geli_da2_flags="-p -k /root/da2.key"
```

This configures `/dev/da2` as a `geli` provider with a master key of `/root/da2.key` . The system will automatically detach the provider from the kernel before the system shuts down. During the startup process, the script will prompt for the passphrase before attaching the provider. Other kernel messages might be shown before and after the password prompt. If the boot process seems to stall, look carefully for the password prompt among the other messages. Once the correct passphrase is entered, the provider is attached. The file system is then mounted, typically by an entry in `/etc/fstab` . Refer to 節 3.7, “掛載與卸載檔案系統” for instructions on how to configure a file system to mount at boot time.

17.14. Encrypting Swap

Written by Christian Brüffer.

Like the encryption of disk partitions, encryption of swap space is used to protect sensitive information. Consider an application that deals with passwords. As long as these passwords stay in physical memory, they are not written to disk and will be cleared after a reboot. However, if FreeBSD starts swapping out memory pages to free space, the passwords may be written to the disk unencrypted. Encrypting swap space can be a solution for this scenario.

This section demonstrates how to configure an encrypted swap partition using gbde(8) or geli(8) encryption. It assumes a UFS file system where `/dev/ad0s1b` is the swap partition.

17.14.1. Configuring Encrypted Swap

Swap partitions are not encrypted by default and should be cleared of any sensitive data before continuing. To overwrite the current swap partition with random garbage, execute the following command:

```
# dd if=/dev/random of=/dev/ ad0s1b bs=1m
```

To encrypt the swap partition using gbde(8), add the `.bde` suffix to the swap line in `/etc/fstab` :

```
# Device  Mountpoint FStype Options  Dump Pass#
/dev/ad0s1b.bde  none  swap sw  0 0
```

To instead encrypt the swap partition using geli(8), use the `.eli` suffix:

```
# Device  Mountpoint FStype Options  Dump Pass#
/dev/ad0s1b.eli  none  swap sw  0 0
```

By default, geli(8) uses the AES algorithm with a key length of 128 bit. These defaults can be altered by using `geli_swap_flags` in `/etc/rc.conf` . The following flags configure encryption using the Blowfish algorithm with a key length of 128 bits and a sectorsize of 4 kilobytes, and sets “detach on last close”:

```
geli_swap_flags="-e blowfish -l 128 -s 4096 -d"
```

Refer to the description of `onetime` in geli(8) for a list of possible options.

17.14.2. Encrypted Swap Verification

Once the system has rebooted, proper operation of the encrypted swap can be verified using `swapinfo`.

If gbde(8) is being used:

```
% swapinfo
Device          1K-blocks     Used    Avail Capacity
/dev/ad0s1b.bde    542720        0   542720     0%
```

If geli(8) is being used:

```
% swapinfo
Device          1K-blocks     Used    Avail Capacity
/dev/ad0s1b.eli    542720        0   542720     0%
```

17.15. Highly Available Storage (HAST)

Contributed by Daniel Gerzo.
With inputs from Freddie Cash, Pawel Jakub Dawidek, Michael W. Lucas # Viktor Petersson.

High availability is one of the main requirements in serious business applications and highly-available storage is a key component in such environments. In FreeBSD, the Highly Available STorage (HAST) framework allows transparent storage of the same data across several physically separated machines connected by a TCP/IP network. HAST can be understood as a network-based RAID1 (mirror), and is similar to the DRBD® storage system used in the GNU/Linux® platform. In combination with other high-availability features of FreeBSD like CARP, HAST makes it possible to build a highly-available storage cluster that is resistant to hardware failures.

The following are the main features of HAST:

- Can be used to mask I/O errors on local hard drives.
- File system agnostic as it works with any file system supported by FreeBSD.
- Efficient and quick resynchronization as only the blocks that were modified during the downtime of a node are synchronized.
- Can be used in an already deployed environment to add additional redundancy.
- Together with CARP, Heartbeat, or other tools, it can be used to build a robust and durable storage system.

After reading this section, you will know:

- What HAST is, how it works, and which features it provides.
- How to set up and use HAST on FreeBSD.
- How to integrate CARP and devd(8) to build a robust storage system.

Before reading this section, you should:

- Understand UNIX® and FreeBSD basics (章 3, UNIX 基礎概念).
- Know how to configure network interfaces and other core FreeBSD subsystems (章 11, 設定與效能調校 (Tuning)).
- Have a good understanding of FreeBSD networking (部 IV, “網路通訊”).

The HAST project was sponsored by The FreeBSD Foundation with support from http://www.omc.net/ and http://www.transip.nl/.

17.15.1. HAST Operation

HAST provides synchronous block-level replication between two physical machines: the primary, also known as the master node, and the secondary, or slave node. These two machines together are referred to as a cluster.

Since HAST works in a primary-secondary configuration, it allows only one of the cluster nodes to be active at any given time. The primary node, also called active, is the one which will handle all the I/O requests to HAST-managed devices. The secondary node is automatically synchronized from the primary node.

The physical components of the HAST system are the local disk on primary node, and the disk on the remote, secondary node.

HAST operates synchronously on a block level, making it transparent to file systems and applications. HAST provides regular GEOM providers in `/dev/hast/` for use by other tools or applications. There is no difference between using HAST-provided devices and raw disks or partitions.

Each write, delete, or flush operation is sent to both the local disk and to the remote disk over TCP/IP. Each read operation is served from the local disk, unless the local disk is not up-to-date or an I/O error occurs. In such cases, the read operation is sent to the secondary node.

HAST tries to provide fast failure recovery. For this reason, it is important to reduce synchronization time after a node's outage. To provide fast synchronization, HAST manages an on-disk bitmap of dirty extents and only synchronizes those during a regular synchronization, with an exception of the initial sync.

There are many ways to handle synchronization. HAST implements several replication modes to handle different synchronization methods:

- memsync: This mode reports a write operation as completed when the local write operation is finished and when the remote node acknowledges data arrival, but before actually storing the data. The data on the remote node will be stored directly after sending the acknowledgement. This mode is intended to reduce latency, but still provides good reliability.
- fullsync: This mode reports a write operation as completed when both the local write and the remote write complete. This is the safest and the slowest replication mode. This mode is the default.
- async: This mode reports a write operation as completed when the local write completes. This is the fastest and the most dangerous replication mode. It should only be used when replicating to a distant node where latency is too high for other modes.

17.15.2. HAST Configuration

The HAST framework consists of several components:

- The hastd(8) daemon which provides data synchronization. When this daemon is started, it will automatically load `geom_gate.ko` .
- The userland management utility, hastctl(8).
- The hast.conf(5) configuration file. This file must exist before starting hastd.

Users who prefer to statically build `GEOM_GATE` support into the kernel should add this line to the custom kernel configuration file, then rebuild the kernel using the instructions in 章 8, 設定 FreeBSD Kernel:

```
options GEOM_GATE
```

The following example describes how to configure two nodes in master-slave/primary-secondary operation using HAST to replicate the data between the two. The nodes will be called `hasta`, with an IP address of `172.16.0.1` ,

and `hastb`, with an IP address of `172.16.0.2`. Both nodes will have a dedicated hard drive `/dev/ad6` of the same size for HAST operation. The HAST pool, sometimes referred to as a resource or the GEOM provider in `/dev/hast/`, will be called `test`.

Configuration of HAST is done using `/etc/hast.conf`. This file should be identical on both nodes. The simplest configuration is:

```
resource test {
 on hasta {
  local /dev/ad6
  remote 172.16.0.2
 }
 on hastb {
  local /dev/ad6
  remote 172.16.0.1
 }
}
```

For more advanced configuration, refer to hast.conf(5).

提示

It is also possible to use host names in the `remote` statements if the hosts are resolvable and defined either in `/etc/hosts` or in the local DNS.

Once the configuration exists on both nodes, the HAST pool can be created. Run these commands on both nodes to place the initial metadata onto the local disk and to start hastd(8):

```
# hastctl create test
# service hastd onestart
```

注意

It is not possible to use GEOM providers with an existing file system or to convert an existing storage to a HAST-managed pool. This procedure needs to store some metadata on the provider and there will not be enough required space available on an existing provider.

A HAST node's `primary` or `secondary` role is selected by an administrator, or software like Heartbeat, using hastctl(8). On the primary node, `hasta`, issue this command:

```
# hastctl role primary test
```

Run this command on the secondary node, `hastb`:

```
# hastctl role secondary test
```

Verify the result by running `hastctl` on each node:

```
# hastctl status test
```

Check the `status` line in the output. If it says `degraded`, something is wrong with the configuration file. It should say `complete` on each node, meaning that the synchronization between the nodes has started. The synchronization completes when `hastctl status` reports 0 bytes of `dirty` extents.

The next step is to create a file system on the GEOM provider and mount it. This must be done on the `primary` node. Creating the file system can take a few minutes, depending on the size of the hard drive. This example creates a UFS file system on `/dev/hast/test` :

```
# newfs -U /dev/hast/test
# mkdir /hast/test
# mount /dev/hast/test /hast/test
```

Once the HAST framework is configured properly, the final step is to make sure that HAST is started automatically during system boot. Add this line to `/etc/rc.conf` :

```
hastd_enable="YES"
```

17.15.2.1. Failover Configuration

The goal of this example is to build a robust storage system which is resistant to the failure of any given node. If the primary node fails, the secondary node is there to take over seamlessly, check and mount the file system, and continue to work without missing a single bit of data.

To accomplish this task, the Common Address Redundancy Protocol (CARP) is used to provide for automatic failover at the IP layer. CARP allows multiple hosts on the same network segment to share an IP address. Set up CARP on both nodes of the cluster according to the documentation available in 節 30.13, “Common Access Redundancy Protocol (CARP)”. In this example, each node will have its own management IP address and a shared IP address of *`172.16.0.254`* . The primary HAST node of the cluster must be the master CARP node.

The HAST pool created in the previous section is now ready to be exported to the other hosts on the network. This can be accomplished by exporting it through NFS or Samba, using the shared IP address *`172.16.0.254`* . The only problem which remains unresolved is an automatic failover should the primary node fail.

In the event of CARP interfaces going up or down, the FreeBSD operating system generates a devd(8) event, making it possible to watch for state changes on the CARP interfaces. A state change on the CARP interface is an indication that one of the nodes failed or came back online. These state change events make it possible to run a script which will automatically handle the HAST failover.

To catch state changes on the CARP interfaces, add this configuration to `/etc/devd.conf` on each node:

```
notify 30 {
 match "system" "IFNET";
 match "subsystem" "carp0";
 match "type" "LINK_UP";
 action "/usr/local/sbin/carp-hast-switch master";
};

notify 30 {
 match "system" "IFNET";
 match "subsystem" "carp0";
 match "type" "LINK_DOWN";
 action "/usr/local/sbin/carp-hast-switch slave";
};
```

注意

If the systems are running FreeBSD 10 or higher, replace `carp0` with the name of the CARP-configured interface.

Restart devd(8) on both nodes to put the new configuration into effect:

```
# service devd restart
```

When the specified interface state changes by going up or down , the system generates a notification, allowing the devd(8) subsystem to run the specified automatic failover script, `/usr/local/sbin/carp-hast-switch`. For further clarification about this configuration, refer to devd.conf(5).

Here is an example of an automated failover script:

```
#!/bin/sh

# Original script by Freddie Cash <fjwcash@gmail.com>
# Modified by Michael W. Lucas <mwlucas@BlackHelicopters.org>
# and Viktor Petersson <vpetersson@wireload.net>

# The names of the HAST resources, as listed in /etc/hast.conf
resources="test"

# delay in mounting HAST resource after becoming master
# make your best guess
delay=3

# logging
log="local0.debug"
name="carp-hast"

# end of user configurable stuff

case "$1" in
 master)
  logger -p $log -t $name "Switching to primary provider for ${resources}."
  sleep ${delay}

  # Wait for any "hastd secondary" processes to stop
  for disk in ${resources}; do
   while $( pgrep -lf "hastd: ${disk} \(secondary\)" > /dev/null 2>&1 ); do
    sleep 1
   done

   # Switch role for each disk
   hastctl role primary ${disk}
   if [ $? -ne 0 -]; then
    logger -p $log -t $name "Unable to change role to primary for resource ${disk}."
    exit 1
   fi
  done

  # Wait for the /dev/hast/* devices to appear
  for disk in ${resources}; do
   for I in $( jot 60 ); do
    [ -c "/dev/hast/${disk}" -] && break
    sleep 0.5
   done

   if [ ! -c "/dev/hast/${disk}" -]; then
    logger -p $log -t $name "GEOM provider /dev/hast/${disk} did not appear."
    exit 1
   fi
  done

  logger -p $log -t $name "Role for HAST resources ${resources} switched to primary."


  logger -p $log -t $name "Mounting disks."
  for disk in ${resources}; do
   mkdir -p /hast/${disk}
   fsck -p -y -t ufs /dev/hast/${disk}
   mount /dev/hast/${disk} /hast/${disk}
  done
```

```
 ;;

 slave)
  logger -p $log -t $name "Switching to secondary provider for ${resources}."

  # Switch roles for the HAST resources
  for disk in ${resources}; do
   if ! mount | grep -q "^/dev/hast/${disk} on "
   then
   else
    umount -f /hast/${disk}
   fi
   sleep $delay
   hastctl role secondary ${disk} 2>&1
   if [ $? -ne 0 -]; then
    logger -p $log -t $name "Unable to switch role to secondary for resource ${disk}."
    exit 1
   fi
   logger -p $log -t $name "Role switched to secondary for resource ${disk}."
  done
 ;;
esac
```

In a nutshell, the script takes these actions when a node becomes master:

- Promotes the HAST pool to primary on the other node.
- Checks the file system under the HAST pool.
- Mounts the pool.

When a node becomes secondary:

- Unmounts the HAST pool.
- Degrades the HAST pool to secondary.

注意

This is just an example script which serves as a proof of concept. It does not handle all the possible scenarios and can be extended or altered in any way, for example, to start or stop required services.

提示

For this example, a standard UFS file system was used. To reduce the time needed for recovery, a journal-enabled UFS or ZFS file system can be used instead.

More detailed information with additional examples can be found at http://wiki.FreeBSD.org/HAST.

17.15.3. Troubleshooting

HAST should generally work without issues. However, as with any other software product, there may be times when it does not work as supposed. The sources of the problems may be different, but the rule of thumb is to ensure that the time is synchronized between the nodes of the cluster.

When troubleshooting HAST, the debugging level of hastd(8) should be increased by starting `hastd` with `-d`. This argument may be specified multiple times to further increase the debugging level. Consider also using `-F`, which starts `hastd` in the foreground.

17.15.3.1. Recovering from the Split-brain Condition

Split-brain occurs when the nodes of the cluster are unable to communicate with each other, and both are configured as primary. This is a dangerous condition because it allows both nodes to make incompatible changes to the data. This problem must be corrected manually by the system administrator.

The administrator must decide which node has more important changes or merge them manually. Then, let HAST perform full synchronization of the node which has the broken data. To do this, issue these commands on the node which needs to be resynchronized:

```
# hastctl role init test
# hastctl create test
# hastctl role secondary test
```

章 18. GEOM: Modular Disk Transformation Framework

Written by Tom Rhodes.

18.1. 概述

本章涵蓋如何在 FreeBSD 的 GEOM 架構下使用磁碟， 包含用來設定幾種常用的 RAID 的控制工具。本章不會深入探討 GEOM 如何處理底層的 I/O，這類資訊請參考 geom(4) 及相關的 SEE ALSO 部份。本章也非 RAID 設定指南，在這裡只會討論目前 GEOM 支援的 RAID 模式。

讀完這章，您將了解：

- 透過 GEOM 可支援哪些模式的 RAID。
- 如何使用基本工具來配置、操作、維護不同模式的 RAID。
- 如何透過 GEOM 來完成鏡射(mirror)、分散連結(stripe)、加密(encrypt)、遠端連接磁碟等。
- 當 GEOM 架構下的磁碟發生問題，如何排除。

在開始閱讀這章之前，您需要：

- 了解 FreeBSD 如何看待磁碟(章 17, 儲存設備篇)。
- 知道如何設定、安裝新的 FreeBSD 核心 (章 8, 設定 FreeBSD Kernel)。

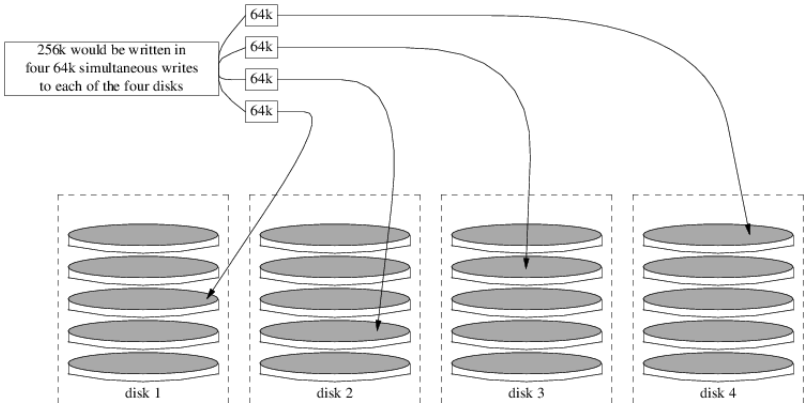
18.2. RAID0 - 分散連結(striping)

Written by Tom Rhodes # Murray Stokely.

分散連結(striping)　可用來連結多個磁碟成為一大塊空間。　很多時候硬體控制器可以完成這件事，不過 GEOM 也提供了軟體版本的 RAID0，也就是分散連結(striping)。

在 RAID0 裡，資料會被切分成很多塊， 再分散寫入全部的磁碟。例如要寫入 256k 的資料到單一磁碟，在四個磁碟的 RAID0 中可同時寫入 64k 到四個磁碟裡， 因此可大幅提升 I/O 效能。如果使用更多的磁碟控制器， I/O 效能可再提升。

由於讀或寫時會同步交錯對許多磁碟進行 I/O 處理，因此 RAID0 的每個磁碟必須大小一樣。



過程 18.1. 用未格式化的 ATA 磁碟來建立分散連結(striping)

1. 載入 geom_stripe kernel module：

```
# kldload geom_stripe.ko
```

2. 確定掛載點(mount point)存在。 如果想用分散連結(striping)的空間做為根目錄(root partition，即 /)， 則先用個暫時的掛載點，如 /mnt：

```
# mkdir /mnt
```

3. 確認要用來分散連結(striping)的裝置名稱，接著建立新的分散連結(striping)。 例如下面的指令會分散連結(striping)兩個未使用、尚未分割區的 ATA 磁碟(/dev/ad2 和 /dev/ad3)：

```
#
  gstripe label -v st0 /dev/ad2 /dev/ad3
```

```
# gstripe label -v st0 /dev/ad2 /dev/ad3
```

4. 用下面的指令來建立分割區表(partition table)：

```
# bsdlabel -wB /dev/stripe/st0
```

5. 除了先前建立的 st0 ，這個步驟還會在 /dev/stripe 下新增兩個裝置： st0a 和 st0c。 利用 newfs 指令可以在 st0a 建立檔案系統：

```
# newfs -U /dev/stripe/st0a
```

螢幕上會有一堆數字傾瀉而過，幾秒鐘後就會完成。此時空間已建立， 可用來掛載使用了。

下面指令可用來手動掛載分散連結(striping)空間：

```
# mount /dev/stripe/st0a /mnt
```

如果要在開機時自動掛載，在 /etc/fstab 加入這塊空間的資訊：

```
# echo "/dev/stripe/st0a /mnt ufs rw 2 2" \
    >> /etc/fstab
```

而 geom kernel module 必須在系統初始化時自動載入， 因此在 /boot/lodaer.conf 加入一行：

```
# echo 'geom_stripe_load="YES"' >> /boot/loader.conf
```

18.3. RAID1 - 鏡射(Mirroring)

許多企業或個人用戶用鏡射(mirroring) 來不中斷系統進行備份。 鏡射簡單來說就是在 B 磁碟上重覆一份 A 磁碟的資料， 或者 C+D 磁碟重覆 A+B 磁碟的資料。不論設定如何， 最重要的是所有磁碟或分割區(partition) 上的資料都會被複製， 之後可在不中斷服務的情況下復原、備份資料，使儲存的資料更安全。

開始之前，請先確定系統上有兩個容量相同的磁碟， 後面的範例假設這兩顆磁碟是 direct access(da(4)) SCSI 磁碟。

首先我們假設 FreeBSD 安裝在第一個磁碟上，且只有兩個分割區(partition)。 其中一個是交換分割區(swap partition，大小為 RAM 的兩倍)，而剩下的全用於根目錄(即 / ， root file system)。當然要在不同掛載點(mount point) 切出更多分割區 (partition) 也可以，不過難度會大幅提升，因為必須手動操作 bsdlabel(8) 和 fdisk(8) 工具。

重開機並等到系統完全初始化完畢，用 root 登入。

建立 /dev/mirror/gm 裝置並以 /dev/da1 連結：

```
# gmirror label -vnb round-robin gm0 /dev/da1
```

這時系統應該會回應：

```
Metadata value stored on /dev/da1.
Done.
```

初始化 GEOM，這動作會自動載入 /boot/kernel/geom_mirror.ko kernel module：

```
# gmirror load
```

注意

這動作應該會在 /dev/mirror 下建立 gm0 裝置結點(device node)。

在這個新建的 gm0 裝置上安置一般的 fdisk label 和開機磁區：

```
# fdisk -vBI /dev/mirror/gm0
```

接著安置 bsdlabel 資訊：

```
# bsdlabel -wB /dev/mirror/gm0s1
```

注意

如果存在多個 slice 和分割區(partition)， 記得修改上兩指令的參數，且另一個磁碟上的 slice 和分割區(partition) 大小必須相同。

用 newfs(8) 工具在 gm0s1a 裝置結點建立預設的檔案系統：

```
# newfs -U /dev/mirror/gm0s1a
```

系統會印出許多資訊和一大堆數字，這是正常的。 確認是否有認何錯誤，接著就可以將這個裝置掛載到 /mnt 掛載點(mount mount)：

```
# mount /dev/mirror/gm0s1a /mnt
```

接著將原本開機磁碟的資料搬移到新的檔案系統(/mnt)。範例是用 dump(8) 和 restore(8) ，不過用 dd(1) 也可以。

```
# dump -L -0 -f- / |(cd /mnt && restore -r -v -f-)
```

執行上述指令時，只要將恰當的檔案系統掛在正確的位置，應該就能成功。

接著編輯 /mnt/etc/fstab 檔將 swap file 那行移除或註解起來。[1]請參考下面範例，並根據新磁碟修改其它的檔案系統資訊：

[1]請注意，將 fstab 的 swap file 那行註解起來，通常表示：您得用別的方法來重建 swap。詳情請參考 節 11.13, “Adding Swap Space”。

```
# Device                Mountpoint      FStype  Options         Dump    Pass#
#/dev/da0s2b             none            swap    sw              0       0
/dev/mirror/gm0s1a       /               ufs     rw              1       1
```

在目前的根目錄及新的根目錄建立 boot.conf 檔案，這個檔案可以『幫助』系統 BIOS 開機：

```
# echo "1:da(1,a)/boot/loader" > /boot.config
```

```
# echo "1:da(1,a)/boot/loader" > /mnt/boot.config
```

注意

在兩個根目錄上都新增檔案是為了安全起見， 如果因為某些原因新的根目錄無法開機，至少還可用原本的根目錄。

接著在 /boot/loader.conf 新增兩行：

```
# echo 'geom_mirror_load="YES"' >> /mnt/boot/loader.conf
```

這會指示 loader(8) 在開機時載入 geom_mirror.ko kernel module。

重開機：

```
# shutdown -r now
```

如果一切順利，系統應該會從 gm0s1a 裝置開機，接下來出現 login 提示畫面。如果出錯了，請參閱下面 Troubleshooting 那一節。 現在可以將 da0 磁碟加入 gm0 裝置：

```
# gmirror configure -a gm0
# gmirror insert gm0 /dev/da0
```

其中 -a 旗標告訴 gmirror(8) 使用「自動同步(automatic synchronization)」，例如自動同步寫入磁碟的動作。 manual 說明了如何重建、取代磁碟等，不過 manual 裡的範例是用 data 而不是 gm0。

18.3.1. Troubleshooting

18.3.1.1. 系統無法開機

如果開機提示類似這樣：

```
ffs_mountroot: can't find rootvp
Root mount failed: 6
mountroot>
```

請用機器面板上的 Power 按鈕或 reset 按鈕來重開機，並在開機選單選 (6)， 這樣子，系統就會進入 loader(8) 交談模式。這時候，請照下面指令來手動載入所需的 kernel module ，也就是 geom_mirror.ko ：

```
OK? load geom_mirror.ko
OK? boot
```

如果這樣成功了的話，表示因為某些原因無法自動載入 kernel module。 請將：

```
options GEOM_MIRROR
```

加入到核心設定檔(kernel configuration file)，重編並安裝核心。 這應該能解決這個問題。

18.4. RAID3 - Byte-level Striping with Dedicated Parity

Written by Mark Gladman # Daniel Gerzo.
Based on documentation by Tom Rhodes # Murray Stokely.

RAID3 is a method used to combine several disk drives into a single volume with a dedicated parity disk. In a RAID3 system, data is split up into a number of bytes that are written across all the drives in the array except for one disk which acts as a dedicated parity disk. This means that disk reads from a RAID3 implementation access all disks in the array. Performance can be enhanced by using multiple disk controllers. The RAID3 array provides a fault tolerance of 1 drive, while providing a capacity of 1 - 1/n times the total capacity of all drives in the array, where n is the number of hard drives in the array. Such a configuration is mostly suitable for storing data of larger sizes such as multimedia files.

At least 3 physical hard drives are required to build a RAID3 array. Each disk must be of the same size, since I/O requests are interleaved to read or write to multiple disks in parallel. Also, due to the nature of RAID3, the number of drives must be equal to 3, 5, 9, 17, and so on, or 2^n + 1.

This section demonstrates how to create a software RAID3 on a FreeBSD system.

注意

While it is theoretically possible to boot from a RAID3 array on FreeBSD, that configuration is uncommon and is not advised.

18.4.1. Creating a Dedicated RAID3 Array

In FreeBSD, support for RAID3 is implemented by the graid3(8) GEOM class. Creating a dedicated RAID3 array on FreeBSD requires the following steps.

1. First, load the `geom_raid3.ko` kernel module by issuing one of the following commands:

   ```
   # graid3 load
   ```

   or:

   ```
   # kldload geom_raid3
   ```

2. Ensure that a suitable mount point exists. This command creates a new directory to use as the mount point:

   ```
   # mkdir /multimedia
   ```

3. Determine the device names for the disks which will be added to the array, and create the new RAID3 device. The final device listed will act as the dedicated parity disk. This example uses three unpartitioned ATA drives: *ada1* and *ada2* for data, and *ada3* for parity.

   ```
   # graid3 label -v gr0 /dev/ada1 /dev/ada2 /dev/ada3
   Metadata value stored on /dev/ada1.
   Metadata value stored on /dev/ada2.
   Metadata value stored on /dev/ada3.
   Done.
   ```

4. Partition the newly created `gr0` device and put a UFS file system on it:

   ```
   # gpart create -s GPT /dev/raid3/gr0
   # gpart add -t freebsd-ufs /dev/raid3/gr0
   # newfs -j /dev/raid3/gr0p1
   ```

Many numbers will glide across the screen, and after a bit of time, the process will be complete. The volume has been created and is ready to be mounted:

```
# mount /dev/raid3/gr0p1 /multimedia/
```

The RAID3 array is now ready to use.

Additional configuration is needed to retain this setup across system reboots.

1. The `geom_raid3.ko` module must be loaded before the array can be mounted. To automatically load the kernel module during system initialization, add the following line to `/boot/loader.conf` :

```
geom_raid3_load="YES"
```

2. The following volume information must be added to `/etc/fstab` in order to automatically mount the array's file system during the system boot process:

```
/dev/raid3/gr0p1 /multimedia ufs rw 2 2
```

18.5. Software RAID Devices

Originally contributed by Warren Block.

Some motherboards and expansion cards add some simple hardware, usually just a ROM, that allows the computer to boot from a RAID array. After booting, access to the RAID array is handled by software running on the computer's main processor. This "hardware-assisted software RAID" gives RAID arrays that are not dependent on any particular operating system, and which are functional even before an operating system is loaded.

Several levels of RAID are supported, depending on the hardware in use. See graid(8) for a complete list.

graid(8) requires the `geom_raid.ko` kernel module, which is included in the `GENERIC` kernel starting with FreeBSD 9.1. If needed, it can be loaded manually with `graid load`.

18.5.1. Creating an Array

Software RAID devices often have a menu that can be entered by pressing special keys when the computer is booting. The menu can be used to create and delete RAID arrays. graid(8) can also create arrays directly from the command line.

`graid label` is used to create a new array. The motherboard used for this example has an Intel software RAID chipset, so the Intel metadata format is specified. The new array is given a label of `gm0`, it is a mirror (RAID1), and uses drives `ada0` and `ada1`.

注意

Some space on the drives will be overwritten when they are made into a new array. Back up existing data first!

```
# graid label Intel gm0 RAID1 ada0 ada1
GEOM_RAID: Intel-a29ea104: Array Intel-a29ea104 created.
GEOM_RAID: Intel-a29ea104: Disk ada0 state changed from NONE to ACTIVE.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:0-ada0 state changed from NONE to ACTIVE.
GEOM_RAID: Intel-a29ea104: Disk ada1 state changed from NONE to ACTIVE.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:1-ada1 state changed from NONE to ACTIVE.
```

```
GEOM_RAID: Intel-a29ea104: Array started.
GEOM_RAID: Intel-a29ea104: Volume gm0 state changed from STARTING to OPTIMAL.
Intel-a29ea104 created
GEOM_RAID: Intel-a29ea104: Provider raid/r0 for volume gm0 created.
```

A status check shows the new mirror is ready for use:

```
# graid status
   Name   Status  Components
raid/r0  OPTIMAL  ada0 (ACTIVE (ACTIVE))
                  ada1 (ACTIVE (ACTIVE))
```

The array device appears in `/dev/raid/` . The first array is called `r0`. Additional arrays, if present, will be `r1`, `r2`, and so on.

The BIOS menu on some of these devices can create arrays with special characters in their names. To avoid problems with those special characters, arrays are given simple numbered names like `r0`. To show the actual labels, like `gm0` in the example above, use sysctl(8):

```
# sysctl kern.geom.raid.name_format=1
```

18.5.2. Multiple Volumes

Some software RAID devices support more than one volume on an array. Volumes work like partitions, allowing space on the physical drives to be split and used in different ways. For example, Intel software RAID devices support two volumes. This example creates a 40 G mirror for safely storing the operating system, followed by a 20 G RAID0 (stripe) volume for fast temporary storage:

```
# graid label -S 40G Intel gm0 RAID1 ada0 ada1
# graid add -S 20G gm0 RAID0
```

Volumes appear as additional `r`*X* entries in `/dev/raid/` . An array with two volumes will show `r0` and `r1`.

See graid(8) for the number of volumes supported by different software RAID devices.

18.5.3. Converting a Single Drive to a Mirror

Under certain specific conditions, it is possible to convert an existing single drive to a graid(8) array without reformatting. To avoid data loss during the conversion, the existing drive must meet these minimum requirements:

- The drive must be partitioned with the MBR partitioning scheme. GPT or other partitioning schemes with metadata at the end of the drive will be overwritten and corrupted by the graid(8) metadata.
- There must be enough unpartitioned and unused space at the end of the drive to hold the graid(8) metadata. This metadata varies in size, but the largest occupies 64 M, so at least that much free space is recommended.

If the drive meets these requirements, start by making a full backup. Then create a single-drive mirror with that drive:

```
# graid label Intel gm0 RAID1 ada0 NONE
```

graid(8) metadata was written to the end of the drive in the unused space. A second drive can now be inserted into the mirror:

```
# graid insert raid/r0 ada1
```

Data from the original drive will immediately begin to be copied to the second drive. The mirror will operate in degraded status until the copy is complete.

18.5.4. Inserting New Drives into the Array

Drives can be inserted into an array as replacements for drives that have failed or are missing. If there are no failed or missing drives, the new drive becomes a spare. For example, inserting a new drive into a working two-drive mirror results in a two-drive mirror with one spare drive, not a three-drive mirror.

In the example mirror array, data immediately begins to be copied to the newly-inserted drive. Any existing information on the new drive will be overwritten.

```
# graid insert raid/r0 ada1
GEOM_RAID: Intel-a29ea104: Disk ada1 state changed from NONE to ACTIVE.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:1-ada1 state changed from NONE to NEW.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:1-ada1 state changed from NEW to REBUILD.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:1-ada1 rebuild start at 0.
```

18.5.5. Removing Drives from the Array

Individual drives can be permanently removed from a from an array and their metadata erased:

```
# graid remove raid/r0 ada1
GEOM_RAID: Intel-a29ea104: Disk ada1 state changed from ACTIVE to OFFLINE.
GEOM_RAID: Intel-a29ea104: Subdisk gm0:1-[unknown] state changed from ACTIVE to NONE.
GEOM_RAID: Intel-a29ea104: Volume gm0 state changed from OPTIMAL to DEGRADED.
```

18.5.6. Stopping the Array

An array can be stopped without removing metadata from the drives. The array will be restarted when the system is booted.

```
# graid stop raid/r0
```

18.5.7. Checking Array Status

Array status can be checked at any time. After a drive was added to the mirror in the example above, data is being copied from the original drive to the new drive:

```
# graid status
   Name    Status  Components
raid/r0  DEGRADED  ada0 (ACTIVE (ACTIVE))
                   ada1 (ACTIVE (REBUILD 28%))
```

Some types of arrays, like `RAID0` or `CONCAT`, may not be shown in the status report if disks have failed. To see these partially-failed arrays, add `-ga`:

```
# graid status -ga
         Name  Status  Components
Intel-e2d07d9a  BROKEN  ada6 (ACTIVE (ACTIVE))
```

18.5.8. Deleting Arrays

Arrays are destroyed by deleting all of the volumes from them. When the last volume present is deleted, the array is stopped and metadata is removed from the drives:

```
# graid delete raid/r0
```

18.5.9. Deleting Unexpected Arrays

Drives may unexpectedly contain graid(8) metadata, either from previous use or manufacturer testing. graid(8) will detect these drives and create an array, interfering with access to the individual drive. To remove the unwanted metadata:

1. Boot the system. At the boot menu, select 2 for the loader prompt. Enter:

```
OK set kern.geom.raid.enable=0
OK boot
```

   The system will boot with graid(8) disabled.

2. Back up all data on the affected drive.

3. As a workaround, graid(8) array detection can be disabled by adding

```
kern.geom.raid.enable=0
```

   to `/boot/loader.conf` .

   To permanently remove the graid(8) metadata from the affected drive, boot a FreeBSD installation CD-ROM or memory stick, and select `Shell`. Use `status` to find the name of the array, typically `raid/r0`:

```
# graid status
   Name   Status  Components
raid/r0  OPTIMAL  ada0 (ACTIVE (ACTIVE))
                  ada1 (ACTIVE (ACTIVE))
```

   Delete the volume by name:

```
# graid delete raid/r0
```

   If there is more than one volume shown, repeat the process for each volume. After the last array has been deleted, the volume will be destroyed.

   Reboot and verify data, restoring from backup if necessary. After the metadata has been removed, the `kern.geom.raid.enable=0` entry in `/boot/loader.conf` can also be removed.

18.6. GEOM Gate Network

GEOM provides a simple mechanism for providing remote access to devices such as disks, CDs, and file systems through the use of the GEOM Gate network daemon, ggated. The system with the device runs the server daemon which handles requests made by clients using ggatec. The devices should not contain any sensitive data as the connection between the client and the server is not encrypted.

Similar to NFS, which is discussed in 節 28.3, “Network File System (NFS)”, ggated is configured using an exports file. This file specifies which systems are permitted to access the exported resources and what level of access they are offered. For example, to give the client `192.168.1.5` read and write access to the fourth slice on the first SCSI disk, create `/etc/gg.exports` with this line:

```
192.168.1.5 RW /dev/da0s4d
```

Before exporting the device, ensure it is not currently mounted. Then, start ggated:

```
# ggated
```

Several options are available for specifying an alternate listening port or changing the default location of the exports file. Refer to ggated(8) for details.

To access the exported device on the client machine, first use `ggatec` to specify the IP address of the server and the device name of the exported device. If successful, this command will display a `ggate` device name to mount. Mount that specified device name on a free mount point. This example connects to the `/dev/da0s4d` partition on `192.168.1.1` , then mounts `/dev/ggate0` on `/mnt`:

```
# ggatec create -o rw 192.168.1.1 /dev/da0s4d
ggate0
# mount /dev/ggate0 /mnt
```

The device on the server may now be accessed through `/mnt` on the client. For more details about `ggatec` and a few usage examples, refer to ggatec(8).

注意

The mount will fail if the device is currently mounted on either the server or any other client on the network. If simultaneous access is needed to network resources, use NFS instead.

When the device is no longer needed, unmount it with `umount` so that the resource is available to other clients.

18.7. Labeling Disk Devices

During system initialization, the FreeBSD kernel creates device nodes as devices are found. This method of probing for devices raises some issues. For instance, what if a new disk device is added via USB? It is likely that a flash device may be handed the device name of `da0` and the original `da0` shifted to `da1`. This will cause issues mounting file systems if they are listed in `/etc/fstab` which may also prevent the system from booting.

One solution is to chain SCSI devices in order so a new device added to the SCSI card will be issued unused device numbers. But what about USB devices which may replace the primary SCSI disk? This happens because USB devices are usually probed before the SCSI card. One solution is to only insert these devices after the system has been booted. Another method is to use only a single ATA drive and never list the SCSI devices in `/etc/fstab` .

A better solution is to use `glabel` to label the disk devices and use the labels in `/etc/fstab` . Because `glabel` stores the label in the last sector of a given provider, the label will remain persistent across reboots. By using this label as a device, the file system may always be mounted regardless of what device node it is accessed through.

注意

`glabel` can create both transient and permanent labels. Only permanent labels are consistent across reboots. Refer to glabel(8) for more information on the differences between labels.

18.7.1. Label Types and Examples

Permanent labels can be a generic or a file system label. Permanent file system labels can be created with tunefs(8) or newfs(8). These types of labels are created in a sub-directory of `/dev`, and will be named according to the file system type. For example, UFS2 file system labels will be created in `/dev/ufs` . Generic permanent labels can be created with `glabel label` . These are not file system specific and will be created in `/dev/label` .

Temporary labels are destroyed at the next reboot. These labels are created in `/dev/label` and are suited to experimentation. A temporary label can be created using `glabel create` .

To create a permanent label for a UFS2 file system without destroying any data, issue the following command:

```
# tunefs -L home /dev/da3
```

警告

If the file system is full, this may cause data corruption.

A label should now exist in `/dev/ufs` which may be added to `/etc/fstab`:

```
/dev/ufs/home  /home            ufs     rw              2       2
```

注意

The file system must not be mounted while attempting to run `tunefs`.

Now the file system may be mounted:

```
# mount /home
```

From this point on, so long as the `geom_label.ko` kernel module is loaded at boot with `/boot/loader.conf` or the `GEOM_LABEL` kernel option is present, the device node may change without any ill effect on the system.

File systems may also be created with a default label by using the `-L` flag with `newfs`. Refer to newfs(8) for more information.

The following command can be used to destroy the label:

```
# glabel destroy home
```

The following example shows how to label the partitions of a boot disk.

範例 18.1. Labeling Partitions on the Boot Disk

By permanently labeling the partitions on the boot disk, the system should be able to continue to boot normally, even if the disk is moved to another controller or transferred to a different system. For this example, it is assumed that a single ATA disk is used, which is currently recognized by the system as `ad0`. It is also assumed that the standard FreeBSD partition scheme is used, with `/`, `/var`, `/usr` and `/tmp`, as well as a swap partition.

Reboot the system, and at the loader(8) prompt, press `4` to boot into single user mode. Then enter the following commands:

```
# glabel label rootfs /dev/ad0s1a
GEOM_LABEL: Label for provider /dev/ad0s1a is label/rootfs
# glabel label var /dev/ad0s1d
GEOM_LABEL: Label for provider /dev/ad0s1d is label/var
# glabel label usr /dev/ad0s1f
GEOM_LABEL: Label for provider /dev/ad0s1f is label/usr
# glabel label tmp /dev/ad0s1e
GEOM_LABEL: Label for provider /dev/ad0s1e is label/tmp
# glabel label swap /dev/ad0s1b
GEOM_LABEL: Label for provider /dev/ad0s1b is label/swap
```

```
# exit
```

The system will continue with multi-user boot. After the boot completes, edit `/etc/fstab` and replace the conventional device names, with their respective labels. The final `/etc/fstab` will look like this:

```
# Device                Mountpoint      FStype  Options         Dump    Pass#
/dev/label/swap         none            swap    sw              0       0
/dev/label/rootfs       /               ufs     rw              1       1
/dev/label/tmp          /tmp            ufs     rw              2       2
/dev/label/usr          /usr            ufs     rw              2       2
/dev/label/var          /var            ufs     rw              2       2
```

The system can now be rebooted. If everything went well, it will come up normally and `mount` will show:

```
# mount
/dev/label/rootfs on / (ufs, local)
devfs on /dev (devfs, local)
/dev/label/tmp on /tmp (ufs, local, soft-updates)
/dev/label/usr on /usr (ufs, local, soft-updates)
/dev/label/var on /var (ufs, local, soft-updates)
```

Starting with FreeBSD 7.2, the glabel(8) class supports a new label type for UFS file systems, based on the unique file system id, `ufsid`. These labels may be found in `/dev/ufsid` and are created automatically during system startup. It is possible to use `ufsid` labels to mount partitions using `/etc/fstab`. Use `glabel status` to receive a list of file systems and their corresponding `ufsid` labels:

```
% glabel status
                  Name  Status  Components
ufsid/486b6fc38d330916     N/A  ad4s1d
ufsid/486b6fc16926168e     N/A  ad4s1f
```

In the above example, `ad4s1d` represents `/var`, while `ad4s1f` represents `/usr`. Using the `ufsid` values shown, these partitions may now be mounted with the following entries in `/etc/fstab`:

```
/dev/ufsid/486b6fc38d330916        /var        ufs        rw        2       2
/dev/ufsid/486b6fc16926168e        /usr        ufs        rw        2       2
```

Any partitions with `ufsid` labels can be mounted in this way, eliminating the need to manually create permanent labels, while still enjoying the benefits of device name independent mounting.

18.8. UFS Journaling Through GEOM

Beginning with FreeBSD 7.0, support for journals on UFS file systems is available. The implementation is provided through the GEOM subsystem and is configured using `gjournal`. Unlike other file system journaling implementations, the `gjournal` method is block based and not implemented as part of the file system. It is a GEOM extension.

Journaling stores a log of file system transactions, such as changes that make up a complete disk write operation, before meta-data and file writes are committed to the disk. This transaction log can later be replayed to redo file system transactions, preventing file system inconsistencies.

This method provides another mechanism to protect against data loss and inconsistencies of the file system. Unlike Soft Updates, which tracks and enforces meta-data updates, and snapshots, which create an image of the file system, a log is stored in disk space specifically for this task. For better performance, the journal may be stored on another disk. In this configuration, the journal provider or storage device should be listed after the device to enable journaling on.

The GENERIC kernel provides support for gjournal. To automatically load the geom_journal.ko kernel module at boot time, add the following line to /boot/loader.conf :

```
geom_journal_load="YES"
```

If a custom kernel is used, ensure the following line is in the kernel configuration file:

```
options GEOM_JOURNAL
```

Once the module is loaded, a journal can be created on a new file system using the following steps. In this example, da4 is a new SCSI disk:

```
# gjournal load
# gjournal label /dev/ da4
```

This will load the module and create a /dev/da4.journal device node on /dev/da4 .

A UFS file system may now be created on the journaled device, then mounted on an existing mount point:

```
# newfs -O 2 -J /dev/ da4.journal
# mount /dev/ da4.journal  /mnt
```

注意

In the case of several slices, a journal will be created for each individual slice. For instance, if ad4s1 and ad4s2 are both slices, then gjournal will create ad4s1.journal and ad4s2.journal .

Journaling may also be enabled on current file systems by using tunefs. However, always make a backup before attempting to alter an existing file system. In most cases, gjournal will fail if it is unable to create the journal, but this does not protect against data loss incurred as a result of misusing tunefs. Refer to gjournal(8) and tunefs(8) for more information about these commands.

It is possible to journal the boot disk of a FreeBSD system. Refer to the article Implementing UFS Journaling on a Desktop PC for detailed instructions.

章 19. The Z File System (ZFS)

Written by Tom Rhodes, Allan Jude, Benedict Reuschling 且 Warren Block.

The Z File System, or ZFS, is an advanced file system designed to overcome many of the major problems found in previous designs.

Originally developed at Sun™, ongoing open source ZFS development has moved to the OpenZFS Project.

ZFS has three major design goals:

- Data integrity: All data includes a checksum of the data. When data is written, the checksum is calculated and written along with it. When that data is later read back, the checksum is calculated again. If the checksums do not match, a data error has been detected. ZFS will attempt to automatically correct errors when data redundancy is available.
- Pooled storage: physical storage devices are added to a pool, and storage space is allocated from that shared pool. Space is available to all file systems, and can be increased by adding new storage devices to the pool.
- Performance: multiple caching mechanisms provide increased performance. ARC is an advanced memory-based read cache. A second level of disk-based read cache can be added with L2ARC, and disk-based synchronous write cache is available with ZIL.

A complete list of features and terminology is shown in 節 19.8, “ZFS Features and Terminology”.

19.1. What Makes ZFS Different

ZFS is significantly different from any previous file system because it is more than just a file system. Combining the traditionally separate roles of volume manager and file system provides ZFS with unique advantages. The file system is now aware of the underlying structure of the disks. Traditional file systems could only be created on a single disk at a time. If there were two disks then two separate file systems would have to be created. In a traditional hardware RAID configuration, this problem was avoided by presenting the operating system with a single logical disk made up of the space provided by a number of physical disks, on top of which the operating system placed a file system. Even in the case of software RAID solutions like those provided by GEOM, the UFS file system living on top of the RAID transform believed that it was dealing with a single device. ZFS's combination of the volume manager and the file system solves this and allows the creation of many file systems all sharing a pool of available storage. One of the biggest advantages to ZFS's awareness of the physical layout of the disks is that existing file systems can be grown automatically when additional disks are added to the pool. This new space is then made available to all of the file systems. ZFS also has a number of different properties that can be applied to each file system, giving many advantages to creating a number of different file systems and datasets rather than a single monolithic file system.

19.2. Quick Start Guide

There is a startup mechanism that allows FreeBSD to mount ZFS pools during system initialization. To enable it, add this line to `/etc/rc.conf` :

```
zfs_enable="YES"
```

Then start the service:

```
# service zfs start
```

The examples in this section assume three SCSI disks with the device names *da0*, *da1*, and *da2*. Users of SATA hardware should instead use *ada* device names.

19.2.1. Single Disk Pool

To create a simple, non-redundant pool using a single disk device:

```
# zpool create example /dev/da0
```

To view the new pool, review the output of `df`:

```
# df
Filesystem  1K-blocks    Used    Avail Capacity  Mounted on
/dev/ad0s1a   2026030  235230  1628718    13%    /
devfs               1       1        0   100%    /dev
/dev/ad0s1d  54098308 1032846 48737598     2%    /usr
example      17547136       0 17547136     0%    /example
```

This output shows that the `example` pool has been created and mounted. It is now accessible as a file system. Files can be created on it and users can browse it:

```
# cd /example
# ls
# touch testfile
# ls -al
total 4
drwxr-xr-x   2 root  wheel    3 Aug 29 23:15 .
drwxr-xr-x  21 root  wheel  512 Aug 29 23:12 ..
-rw-r--r--   1 root  wheel    0 Aug 29 23:15 testfile
```

However, this pool is not taking advantage of any ZFS features. To create a dataset on this pool with compression enabled:

```
# zfs create example/compressed
# zfs set compression=gzip example/compressed
```

The `example/compressed` dataset is now a ZFS compressed file system. Try copying some large files to `/example/compressed`.

Compression can be disabled with:

```
# zfs set compression=off example/compressed
```

To unmount a file system, use `zfs umount` and then verify with `df`:

```
# zfs umount example/compressed
# df
Filesystem  1K-blocks    Used    Avail Capacity  Mounted on
/dev/ad0s1a   2026030  235232  1628716    13%    /
devfs               1       1        0   100%    /dev
/dev/ad0s1d  54098308 1032864 48737580     2%    /usr
example      17547008       0 17547008     0%    /example
```

To re-mount the file system to make it accessible again, use `zfs mount` and verify with `df`:

```
# zfs mount example/compressed
# df
Filesystem         1K-blocks    Used    Avail Capacity  Mounted on
/dev/ad0s1a          2026030  235234  1628714    13%    /
devfs                      1       1        0   100%    /dev
/dev/ad0s1d         54098308 1032864 48737580     2%    /usr
example             17547008       0 17547008     0%    /example
example/compressed  17547008       0 17547008     0%    /example/compressed
```

The pool and file system may also be observed by viewing the output from `mount`:

```
# mount
/dev/ad0s1a on / (ufs, local)
devfs on /dev (devfs, local)
/dev/ad0s1d on /usr (ufs, local, soft-updates)
example on /example (zfs, local)
example/compressed on /example/compressed (zfs, local)
```

After creation, ZFS datasets can be used like any file systems. However, many other features are available which can be set on a per-dataset basis. In the example below, a new file system called `data` is created. Important files will be stored here, so it is configured to keep two copies of each data block:

```
# zfs create example/data
# zfs set copies=2 example/data
```

It is now possible to see the data and space utilization by issuing `df`:

```
# df
Filesystem         1K-blocks    Used    Avail Capacity  Mounted on
/dev/ad0s1a          2026030  235234  1628714    13%    /
devfs                      1       1        0   100%    /dev
/dev/ad0s1d         54098308 1032864 48737580     2%    /usr
example             17547008       0 17547008     0%    /example
example/compressed  17547008       0 17547008     0%    /example/compressed
example/data        17547008       0 17547008     0%    /example/data
```

Notice that each file system on the pool has the same amount of available space. This is the reason for using `df` in these examples, to show that the file systems use only the amount of space they need and all draw from the same pool. ZFS eliminates concepts such as volumes and partitions, and allows multiple file systems to occupy the same pool.

To destroy the file systems and then destroy the pool as it is no longer needed:

```
# zfs destroy example/compressed
# zfs destroy example/data
# zpool destroy example
```

19.2.2. RAID-Z

Disks fail. One method of avoiding data loss from disk failure is to implement RAID. ZFS supports this feature in its pool design. RAID-Z pools require three or more disks but provide more usable space than mirrored pools.

This example creates a RAID-Z pool, specifying the disks to add to the pool:

```
# zpool create storage raidz da0 da1 da2
```

注意

Sun™ recommends that the number of devices used in a RAID-Z configuration be between three and nine. For environments requiring a single pool consisting of 10 disks or more, consider breaking it up into smaller RAID-Z groups. If only two disks are available and redundancy is a requirement, consider using a ZFS mirror. Refer to zpool(8) for more details.

The previous example created the `storage` zpool. This example makes a new file system called `home` in that pool:

```
# zfs create storage/home
```

Compression and keeping extra copies of directories and files can be enabled:

```
# zfs set copies=2 storage/home
# zfs set compression=gzip storage/home
```

To make this the new home directory for users, copy the user data to this directory and create the appropriate symbolic links:

```
# cp -rp /home/* /storage/home
# rm -rf /home /usr/home
# ln -s /storage/home /home
# ln -s /storage/home /usr/home
```

Users data is now stored on the freshly-created `/storage/home` . Test by adding a new user and logging in as that user.

Try creating a file system snapshot which can be rolled back later:

```
# zfs snapshot storage/home@08-30-08
```

Snapshots can only be made of a full file system, not a single directory or file.

The `@` character is a delimiter between the file system name or the volume name. If an important directory has been accidentally deleted, the file system can be backed up, then rolled back to an earlier snapshot when the directory still existed:

```
# zfs rollback storage/home@08-30-08
```

To list all available snapshots, run `ls` in the file system's `.zfs/snapshot` directory. For example, to see the previously taken snapshot:

```
# ls /storage/home/.zfs/snapshot
```

It is possible to write a script to perform regular snapshots on user data. However, over time, snapshots can consume a great deal of disk space. The previous snapshot can be removed using the command:

```
# zfs destroy storage/home@08-30-08
```

After testing, `/storage/home` can be made the real `/home` using this command:

```
# zfs set mountpoint=/home storage/home
```

Run `df` and `mount` to confirm that the system now treats the file system as the real `/home`:

```
# mount
/dev/ad0s1a on / (ufs, local)
devfs on /dev (devfs, local)
/dev/ad0s1d on /usr (ufs, local, soft-updates)
storage on /storage (zfs, local)
storage/home on /home (zfs, local)
# df
Filesystem   1K-blocks    Used    Avail Capacity  Mounted on
/dev/ad0s1a    2026030  235240  1628708    13%    /
devfs                1       1        0   100%    /dev
/dev/ad0s1d   54098308 1032826 48737618     2%    /usr
storage       26320512       0 26320512     0%    /storage
storage/home  26320512       0 26320512     0%    /home
```

This completes the RAID-Z configuration. Daily status updates about the file systems created can be generated as part of the nightly periodic(8) runs. Add this line to `/etc/periodic.conf` :

```
daily_status_zfs_enable="YES"
```

19.2.3. Recovering RAID-Z

Every software RAID has a method of monitoring its `state`. The status of RAID-Z devices may be viewed with this command:

```
# zpool status -x
```

If all pools are Online and everything is normal, the message shows:

```
all pools are healthy
```

If there is an issue, perhaps a disk is in the Offline state, the pool state will look similar to:

```
  pool: storage
 state: DEGRADED
status: One or more devices has been taken offline by the administrator.
 Sufficient replicas exist for the pool to continue functioning in a
 degraded state.
action: Online the device using 'zpool online' or replace the device with
 'zpool replace'.
 scrub: none requested
config:

 NAME        STATE     READ WRITE CKSUM
 storage     DEGRADED     0     0     0
   raidz1    DEGRADED     0     0     0
     da0     ONLINE       0     0     0
     da1     OFFLINE      0     0     0
     da2     ONLINE       0     0     0

errors: No known data errors
```

This indicates that the device was previously taken offline by the administrator with this command:

```
# zpool offline storage da1
```

Now the system can be powered down to replace `da1`. When the system is back online, the failed disk can replaced in the pool:

```
# zpool replace storage da1
```

From here, the status may be checked again, this time without `-x` so that all pools are shown:

```
# zpool status storage
 pool: storage
 state: ONLINE
 scrub: resilver completed with 0 errors on Sat Aug 30 19:44:11 2008
config:

 NAME        STATE     READ WRITE CKSUM
 storage     ONLINE       0     0     0
   raidz1    ONLINE       0     0     0
     da0     ONLINE       0     0     0
     da1     ONLINE       0     0     0
     da2     ONLINE       0     0     0

errors: No known data errors
```

In this example, everything is normal.

19.2.4. Data Verification

ZFS uses checksums to verify the integrity of stored data. These are enabled automatically upon creation of file systems.

警告

Checksums can be disabled, but it is not recommended! Checksums take very little storage space and provide data integrity. Many ZFS features will not work properly with checksums disabled. There is no noticeable performance gain from disabling these checksums.

Checksum verification is known as scrubbing. Verify the data integrity of the `storage` pool with this command:

```
# zpool scrub storage
```

The duration of a scrub depends on the amount of data stored. Larger amounts of data will take proportionally longer to verify. Scrubs are very I/O intensive, and only one scrub is allowed to run at a time. After the scrub completes, the status can be viewed with `status`:

```
# zpool status storage
 pool: storage
 state: ONLINE
 scrub: scrub completed with 0 errors on Sat Jan 26 19:57:37 2013
config:

 NAME        STATE     READ WRITE CKSUM
 storage     ONLINE       0     0     0
   raidz1    ONLINE       0     0     0
     da0     ONLINE       0     0     0
     da1     ONLINE       0     0     0
     da2     ONLINE       0     0     0

errors: No known data errors
```

The completion date of the last scrub operation is displayed to help track when another scrub is required. Routine scrubs help protect data from silent corruption and ensure the integrity of the pool.

Refer to zfs(8) and zpool(8) for other ZFS options.

19.3. `zpool` Administration

ZFS administration is divided between two main utilities. The `zpool` utility controls the operation of the pool and deals with adding, removing, replacing, and managing disks. The `zfs` utility deals with creating, destroying, and managing datasets, both file systems and volumes.

19.3.1. Creating and Destroying Storage Pools

Creating a ZFS storage pool (zpool) involves making a number of decisions that are relatively permanent because the structure of the pool cannot be changed after the pool has been created. The most important decision is what types of vdevs into which to group the physical disks. See the list of vdev types for details about the possible options. After the pool has been created, most vdev types do not allow additional disks to be added to the vdev. The exceptions are mirrors, which allow additional disks to be added to the vdev, and stripes, which can be upgraded to mirrors by attaching an additional disk to the vdev. Although additional vdevs can be added to expand a pool, the layout of the pool cannot be changed after pool creation. Instead, the data must be backed up and the pool destroyed and recreated.

Create a simple mirror pool:

```
# zpool create mypool mirror /dev/ada1 /dev/ada2
```

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada1    ONLINE       0     0     0
            ada2    ONLINE       0     0     0

errors: No known data errors
```

Multiple vdevs can be created at once. Specify multiple groups of disks separated by the vdev type keyword, `mirror` in this example:

```
# zpool create mypool mirror /dev/ada1 /dev/ada2 mirror /dev/ada3 /dev/
ada4
  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada1    ONLINE       0     0     0
            ada2    ONLINE       0     0     0
          mirror-1  ONLINE       0     0     0
            ada3    ONLINE       0     0     0
            ada4    ONLINE       0     0     0

errors: No known data errors
```

Pools can also be constructed using partitions rather than whole disks. Putting ZFS in a separate partition allows the same disk to have other partitions for other purposes. In particular, partitions with bootcode and file systems needed for booting can be added. This allows booting from disks that are also members of a pool. There is no performance penalty on FreeBSD when using a partition rather than a whole disk. Using partitions also allows the administrator to under-provision the disks, using less than the full capacity. If a future replacement disk of the same nominal size as the original actually has a slightly smaller capacity, the smaller partition will still fit, and the replacement disk can still be used.

Create a RAID-Z2 [431] pool using partitions:

```
# zpool create mypool raidz2 /dev/ada0p3 /dev/ada1p3 /dev/ada2p3 /dev/
ada3p3 /dev/ada4p3 /dev/ada5p3
# zpool status
  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          raidz2-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0
            ada3p3  ONLINE       0     0     0
            ada4p3  ONLINE       0     0     0
            ada5p3  ONLINE       0     0     0

errors: No known data errors
```

A pool that is no longer needed can be destroyed so that the disks can be reused. Destroying a pool involves first unmounting all of the datasets in that pool. If the datasets are in use, the unmount operation will fail and the pool will not be destroyed. The destruction of the pool can be forced with `-f`, but this can cause undefined behavior in applications which had open files on those datasets.

19.3.2. Adding and Removing Devices

There are two cases for adding disks to a zpool: attaching a disk to an existing vdev with `zpool attach`, or adding vdevs to the pool with `zpool add`. Only some vdev types allow disks to be added to the vdev after creation.

A pool created with a single disk lacks redundancy. Corruption can be detected but not repaired, because there is no other copy of the data. The copies property may be able to recover from a small failure such as a bad sector, but does not provide the same level of protection as mirroring or RAID-Z. Starting with a pool consisting of a single disk vdev, `zpool attach` can be used to add an additional disk to the vdev, creating a mirror. `zpool attach` can also be used to add additional disks to a mirror group, increasing redundancy and read performance. If the disks being used for the pool are partitioned, replicate the layout of the first disk on to the second, `gpart backup` and `gpart restore` can be used to make this process easier.

Upgrade the single disk (stripe) vdev *`ada0p3`* to a mirror by attaching *`ada1p3`*:

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          ada0p3    ONLINE       0     0     0

errors: No known data errors
# zpool attach mypool ada0p3 ada1p3
Make sure to wait until resilver is done before rebooting.

If you boot from pool 'mypool', you may need to update
boot code on newly attached disk 'ada1p3'.

Assuming you use GPT partitioning and 'da0' is your new boot disk
you may use the following command:

        gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1 da0
# gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1   ada1
bootcode written to ada1
# zpool status
  pool: mypool
 state: ONLINE
status: One or more devices is currently being resilvered.  The pool will
        continue to function, possibly in a degraded state.
action: Wait for the resilver to complete.
  scan: resilver in progress since Fri May 30 08:19:19 2014
        527M scanned out of 781M at 47.9M/s, 0h0m to go
        527M resilvered, 67.53% done
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0  (resilvering)

errors: No known data errors
# zpool status
```

```
  pool: mypool
 state: ONLINE
  scan: resilvered 781M in 0h0m with 0 errors on Fri May 30 08:15:58 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0

errors: No known data errors
```

When adding disks to the existing vdev is not an option, as for RAID-Z, an alternative method is to add another vdev to the pool. Additional vdevs provide higher performance, distributing writes across the vdevs. Each vdev is responsible for providing its own redundancy. It is possible, but discouraged, to mix vdev types, like `mirror` and `RAID-Z`. Adding a non-redundant vdev to a pool containing mirror or RAID-Z vdevs risks the data on the entire pool. Writes are distributed, so the failure of the non-redundant disk will result in the loss of a fraction of every block that has been written to the pool.

Data is striped across each of the vdevs. For example, with two mirror vdevs, this is effectively a RAID 10 that stripes writes across two sets of mirrors. Space is allocated so that each vdev reaches 100% full at the same time. There is a performance penalty if the vdevs have different amounts of free space, as a disproportionate amount of the data is written to the less full vdev.

When attaching additional devices to a boot pool, remember to update the bootcode.

Attach a second mirror group (`ada2p3` and `ada3p3`) to the existing mirror:

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: resilvered 781M in 0h0m with 0 errors on Fri May 30 08:19:35 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0

errors: No known data errors
# zpool add mypool mirror ada2p3 ada3p3
# gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1   ada2
bootcode written to ada2
# gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1   ada3
bootcode written to ada3
# zpool status
  pool: mypool
 state: ONLINE
  scan: scrub repaired 0 in 0h0m with 0 errors on Fri May 30 08:29:51 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0
          mirror-1  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0
            ada3p3  ONLINE       0     0     0

errors: No known data errors
```

Currently, vdevs cannot be removed from a pool, and disks can only be removed from a mirror if there is enough remaining redundancy. If only one disk in a mirror group remains, it ceases to be a mirror and reverts to being a stripe, risking the entire pool if that remaining disk fails.

Remove a disk from a three-way mirror group:

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: scrub repaired 0 in 0h0m with 0 errors on Fri May 30 08:29:51 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0

errors: No known data errors
# zpool detach mypool ada2p3
# zpool status
  pool: mypool
 state: ONLINE
  scan: scrub repaired 0 in 0h0m with 0 errors on Fri May 30 08:29:51 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0

errors: No known data errors
```

19.3.3. Checking the Status of a Pool

Pool status is important. If a drive goes offline or a read, write, or checksum error is detected, the corresponding error count increases. The `status` output shows the configuration and status of each device in the pool and the status of the entire pool. Actions that need to be taken and details about the last `scrub` are also shown.

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: scrub repaired 0 in 2h25m with 0 errors on Sat Sep 14 04:25:50 2013
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          raidz2-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0
            ada3p3  ONLINE       0     0     0
            ada4p3  ONLINE       0     0     0
            ada5p3  ONLINE       0     0     0

errors: No known data errors
```

19.3.4. Clearing Errors

When an error is detected, the read, write, or checksum counts are incremented. The error message can be cleared and the counts reset with `zpool clear mypool`. Clearing the error state can be important for automated

scripts that alert the administrator when the pool encounters an error. Further errors may not be reported if the old errors are not cleared.

19.3.5. Replacing a Functioning Device

There are a number of situations where it may be desirable to replace one disk with a different disk. When replacing a working disk, the process keeps the old disk online during the replacement. The pool never enters a degraded state, reducing the risk of data loss. `zpool replace` copies all of the data from the old disk to the new one. After the operation completes, the old disk is disconnected from the vdev. If the new disk is larger than the old disk, it may be possible to grow the zpool, using the new space. See Growing a Pool.

Replace a functioning device in the pool:

```
# zpool status
  pool: mypool
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0

errors: No known data errors
# zpool replace mypool ada1p3 ada2p3
Make sure to wait until resilver is done before rebooting.

If you boot from pool 'zroot', you may need to update
boot code on newly attached disk 'ada2p3'.

Assuming you use GPT partitioning and 'da0' is your new boot disk
you may use the following command:

        gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1 da0
# gpart bootcode -b /boot/pmbr -p /boot/gptzfsboot -i 1   ada2
# zpool status
  pool: mypool
 state: ONLINE
status: One or more devices is currently being resilvered.  The pool will
        continue to function, possibly in a degraded state.
action: Wait for the resilver to complete.
  scan: resilver in progress since Mon Jun  2 14:21:35 2014
        604M scanned out of 781M at 46.5M/s, 0h0m to go
        604M resilvered, 77.39% done
config:

        NAME             STATE     READ WRITE CKSUM
        mypool           ONLINE       0     0     0
          mirror-0       ONLINE       0     0     0
            ada0p3       ONLINE       0     0     0
            replacing-1  ONLINE       0     0     0
              ada1p3     ONLINE       0     0     0
              ada2p3     ONLINE       0     0     0  (resilvering)

errors: No known data errors
# zpool status
  pool: mypool
 state: ONLINE
  scan: resilvered 781M in 0h0m with 0 errors on Mon Jun  2 14:21:52 2014
config:

        NAME        STATE     READ WRITE CKSUM
```

```
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0

errors: No known data errors
```

19.3.6. Dealing with Failed Devices

When a disk in a pool fails, the vdev to which the disk belongs enters the degraded state. All of the data is still available, but performance may be reduced because missing data must be calculated from the available redundancy. To restore the vdev to a fully functional state, the failed physical device must be replaced. ZFS is then instructed to begin the resilver operation. Data that was on the failed device is recalculated from available redundancy and written to the replacement device. After completion, the vdev returns to online status.

If the vdev does not have any redundancy, or if multiple devices have failed and there is not enough redundancy to compensate, the pool enters the faulted state. If a sufficient number of devices cannot be reconnected to the pool, the pool becomes inoperative and data must be restored from backups.

When replacing a failed disk, the name of the failed disk is replaced with the GUID of the device. A new device name parameter for `zpool replace` is not required if the replacement device has the same device name.

Replace a failed disk using `zpool replace`:

```
# zpool status
  pool: mypool
 state: DEGRADED
status: One or more devices could not be opened.  Sufficient replicas exist for
        the pool to continue functioning in a degraded state.
action: Attach the missing device and online it using 'zpool online'.
   see: http://illumos.org/msg/ZFS-8000-2Q
  scan: none requested
config:

        NAME                     STATE     READ WRITE CKSUM
        mypool                   DEGRADED     0     0     0
          mirror-0               DEGRADED     0     0     0
            ada0p3               ONLINE       0     0     0
            316502962686821739   UNAVAIL      0     0     0  was /dev/ada1p3

errors: No known data errors
# zpool replace mypool 316502962686821739 ada2p3
# zpool status
  pool: mypool
 state: DEGRADED
status: One or more devices is currently being resilvered.  The pool will
        continue to function, possibly in a degraded state.
action: Wait for the resilver to complete.
  scan: resilver in progress since Mon Jun  2 14:52:21 2014
        641M scanned out of 781M at 49.3M/s, 0h0m to go
        640M resilvered, 82.04% done
config:

        NAME                       STATE     READ WRITE CKSUM
        mypool                     DEGRADED     0     0     0
          mirror-0                 DEGRADED     0     0     0
            ada0p3                 ONLINE       0     0     0
            replacing-1            UNAVAIL      0     0     0
              15732067398082357289 UNAVAIL      0     0     0  was /dev/ada1p3/old
              ada2p3               ONLINE       0     0     0  (resilvering)

errors: No known data errors
# zpool status
  pool: mypool
```

```
 state: ONLINE
  scan: resilvered 781M in 0h0m with 0 errors on Mon Jun  2 14:52:38 2014
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0

errors: No known data errors
```

19.3.7. Scrubbing a Pool

It is recommended that pools be scrubbed regularly, ideally at least once every month. The `scrub` operation is very disk-intensive and will reduce performance while running. Avoid high-demand periods when scheduling `scrub` or use vfs.zfs.scrub_delay [429] to adjust the relative priority of the `scrub` to prevent it interfering with other workloads.

```
# zpool scrub mypool
# zpool status
  pool: mypool
 state: ONLINE
  scan: scrub in progress since Wed Feb 19 20:52:54 2014
        116G scanned out of 8.60T at 649M/s, 3h48m to go
        0 repaired, 1.32% done
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          raidz2-0  ONLINE       0     0     0
            ada0p3  ONLINE       0     0     0
            ada1p3  ONLINE       0     0     0
            ada2p3  ONLINE       0     0     0
            ada3p3  ONLINE       0     0     0
            ada4p3  ONLINE       0     0     0
            ada5p3  ONLINE       0     0     0

errors: No known data errors
```

In the event that a scrub operation needs to be cancelled, issue `zpool scrub -s mypool`.

19.3.8. Self-Healing

The checksums stored with data blocks enable the file system to self-heal. This feature will automatically repair data whose checksum does not match the one recorded on another device that is part of the storage pool. For example, a mirror with two disks where one drive is starting to malfunction and cannot properly store the data any more. This is even worse when the data has not been accessed for a long time, as with long term archive storage. Traditional file systems need to run algorithms that check and repair the data like fsck(8). These commands take time, and in severe cases, an administrator has to manually decide which repair operation must be performed. When ZFS detects a data block with a checksum that does not match, it tries to read the data from the mirror disk. If that disk can provide the correct data, it will not only give that data to the application requesting it, but also correct the wrong data on the disk that had the bad checksum. This happens without any interaction from a system administrator during normal pool operation.

The next example demonstrates this self-healing behavior. A mirrored pool of disks `/dev/ada0` and `/dev/ada1` is created.

```
# zpool create healer mirror /dev/ada0 /dev/ada1
# zpool status healer
  pool: healer
 state: ONLINE
```

```
  scan: none requested
config:

    NAME        STATE     READ WRITE CKSUM
    healer      ONLINE       0     0     0
      mirror-0  ONLINE       0     0     0
       ada0     ONLINE       0     0     0
       ada1     ONLINE       0     0     0

errors: No known data errors
# zpool list
NAME     SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
healer   960M  92.5K   960M     0%  1.00x  ONLINE  -
```

Some important data that to be protected from data errors using the self-healing feature is copied to the pool. A checksum of the pool is created for later comparison.

```
# cp /some/important/data /healer
# zfs list
NAME     SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
healer   960M  67.7M   892M     7%  1.00x  ONLINE  -
# sha1 /healer > checksum.txt
# cat checksum.txt
SHA1 (/healer) = 2753eff56d77d9a536ece6694bf0a82740344d1f
```

Data corruption is simulated by writing random data to the beginning of one of the disks in the mirror. To prevent ZFS from healing the data as soon as it is detected, the pool is exported before the corruption and imported again afterwards.

警告

This is a dangerous operation that can destroy vital data. It is shown here for demonstrational purposes only and should not be attempted during normal operation of a storage pool. Nor should this intentional corruption example be run on any disk with a different file system on it. Do not use any other disk device names other than the ones that are part of the pool. Make certain that proper backups of the pool are created before running the command!

```
# zpool export healer
# dd if=/dev/random of=/dev/ada1 bs=1m count=200
200+0 records in
200+0 records out
209715200 bytes transferred in 62.992162 secs (3329227 bytes/sec)
# zpool import healer
```

The pool status shows that one device has experienced an error. Note that applications reading data from the pool did not receive any incorrect data. ZFS provided data from the `ada0` device with the correct checksums. The device with the wrong checksum can be found easily as the `CKSUM` column contains a nonzero value.

```
# zpool status healer
    pool: healer
   state: ONLINE
  status: One or more devices has experienced an unrecoverable error.  An
          attempt was made to correct the error.  Applications are unaffected.
  action: Determine if the device needs to be replaced, and clear the errors
          using 'zpool clear' or replace the device with 'zpool replace'.
     see: http://www.sun.com/msg/ZFS-8000-9P
    scan: none requested
  config:
```

```
      NAME        STATE     READ WRITE CKSUM
      healer      ONLINE       0     0     0
        mirror-0  ONLINE       0     0     0
          ada0    ONLINE       0     0     0
          ada1    ONLINE       0     0     1

errors: No known data errors
```

The error was detected and handled by using the redundancy present in the unaffected `ada0` mirror disk. A checksum comparison with the original one will reveal whether the pool is consistent again.

```
# sha1 /healer >> checksum.txt
# cat checksum.txt
SHA1 (/healer) = 2753eff56d77d9a536ece6694bf0a82740344d1f
SHA1 (/healer) = 2753eff56d77d9a536ece6694bf0a82740344d1f
```

The two checksums that were generated before and after the intentional tampering with the pool data still match. This shows how ZFS is capable of detecting and correcting any errors automatically when the checksums differ. Note that this is only possible when there is enough redundancy present in the pool. A pool consisting of a single device has no self-healing capabilities. That is also the reason why checksums are so important in ZFS and should not be disabled for any reason. No fsck(8) or similar file system consistency check program is required to detect and correct this and the pool was still available during the time there was a problem. A scrub operation is now required to overwrite the corrupted data on `ada1`.

```
# zpool scrub healer
# zpool status healer
  pool: healer
 state: ONLINE
status: One or more devices has experienced an unrecoverable error.  An
            attempt was made to correct the error.  Applications are unaffected.
action: Determine if the device needs to be replaced, and clear the errors
            using 'zpool clear' or replace the device with 'zpool replace'.
   see: http://www.sun.com/msg/ZFS-8000-9P
  scan: scrub in progress since Mon Dec 10 12:23:30 2012
        10.4M scanned out of 67.0M at 267K/s, 0h3m to go
        9.63M repaired, 15.56% done
config:

    NAME        STATE     READ WRITE CKSUM
    healer      ONLINE       0     0     0
      mirror-0  ONLINE       0     0     0
        ada0    ONLINE       0     0     0
        ada1    ONLINE       0     0   627  (repairing)

errors: No known data errors
```

The scrub operation reads data from `ada0` and rewrites any data with an incorrect checksum on `ada1`. This is indicated by the `(repairing)` output from `zpool status`. After the operation is complete, the pool status changes to:

```
# zpool status healer
  pool: healer
 state: ONLINE
status: One or more devices has experienced an unrecoverable error.  An
        attempt was made to correct the error.  Applications are unaffected.
action: Determine if the device needs to be replaced, and clear the errors
             using 'zpool clear' or replace the device with 'zpool replace'.
   see: http://www.sun.com/msg/ZFS-8000-9P
  scan: scrub repaired 66.5M in 0h2m with 0 errors on Mon Dec 10 12:26:25 2012
config:

    NAME        STATE     READ WRITE CKSUM
    healer      ONLINE       0     0     0
      mirror-0  ONLINE       0     0     0
```

```
       ada0     ONLINE       0     0     0
       ada1     ONLINE       0     0 2.72K

errors: No known data errors
```

After the scrub operation completes and all the data has been synchronized from `ada0` to `ada1`, the error messages can be cleared from the pool status by running `zpool clear`.

```
# zpool clear healer
# zpool status healer
  pool: healer
 state: ONLINE
  scan: scrub repaired 66.5M in 0h2m with 0 errors on Mon Dec 10 12:26:25 2012
config:

    NAME        STATE     READ WRITE CKSUM
    healer      ONLINE       0     0     0
      mirror-0  ONLINE       0     0     0
       ada0     ONLINE       0     0     0
       ada1     ONLINE       0     0     0

errors: No known data errors
```

The pool is now back to a fully working state and all the errors have been cleared.

19.3.9. Growing a Pool

The usable size of a redundant pool is limited by the capacity of the smallest device in each vdev. The smallest device can be replaced with a larger device. After completing a replace or resilver operation, the pool can grow to use the capacity of the new device. For example, consider a mirror of a 1 TB drive and a 2 TB drive. The usable space is 1 TB. When the 1 TB drive is replaced with another 2 TB drive, the resilvering process copies the existing data onto the new drive. Because both of the devices now have 2 TB capacity, the mirror's available space can be grown to 2 TB.

Expansion is triggered by using `zpool online -e` on each device. After expansion of all devices, the additional space becomes available to the pool.

19.3.10. Importing and Exporting Pools

Pools are exported before moving them to another system. All datasets are unmounted, and each device is marked as exported but still locked so it cannot be used by other disk subsystems. This allows pools to be imported on other machines, other operating systems that support ZFS, and even different hardware architectures (with some caveats, see zpool(8)). When a dataset has open files, `zpool export -f` can be used to force the export of a pool. Use this with caution. The datasets are forcibly unmounted, potentially resulting in unexpected behavior by the applications which had open files on those datasets.

Export a pool that is not in use:

```
# zpool export mypool
```

Importing a pool automatically mounts the datasets. This may not be the desired behavior, and can be prevented with `zpool import -N`. `zpool import -o` sets temporary properties for this import only. `zpool import altroot=` allows importing a pool with a base mount point instead of the root of the file system. If the pool was last used on a different system and was not properly exported, an import might have to be forced with `zpool import -f`. `zpool import -a` imports all pools that do not appear to be in use by another system.

List all available pools for import:

```
# zpool import
   pool: mypool
     id: 9930174748043525076
  state: ONLINE
```

```
 action: The pool can be imported using its name or numeric identifier.
 config:

        mypool      ONLINE
          ada2p3    ONLINE
```

Import the pool with an alternative root directory:

```
# zpool import -o altroot= /mnt mypool
# zfs list
zfs list
NAME                 USED  AVAIL  REFER  MOUNTPOINT
mypool               110K  47.0G    31K  /mnt/mypool
```

19.3.11. Upgrading a Storage Pool

After upgrading FreeBSD, or if a pool has been imported from a system using an older version of ZFS, the pool can be manually upgraded to the latest version of ZFS to support newer features. Consider whether the pool may ever need to be imported on an older system before upgrading. Upgrading is a one-way process. Older pools can be upgraded, but pools with newer features cannot be downgraded.

Upgrade a v28 pool to support `Feature Flags` :

```
# zpool status
  pool: mypool
 state: ONLINE
status: The pool is formatted using a legacy on-disk format.  The pool can
        still be used, but some features are unavailable.
action: Upgrade the pool using 'zpool upgrade'.  Once this is done, the
        pool will no longer be accessible on software that does not support feat
        flags.
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
     ada0    ONLINE       0     0     0
     ada1    ONLINE       0     0     0

errors: No known data errors
# zpool upgrade
This system supports ZFS pool feature flags.

The following pools are formatted with legacy version numbers and can
be upgraded to use feature flags.  After being upgraded, these pools
will no longer be accessible by software that does not support feature
flags.

VER  POOL
---  ------------
28   mypool

Use 'zpool upgrade -v' for a list of available legacy versions.
Every feature flags pool has all supported features enabled.
# zpool upgrade mypool
This system supports ZFS pool feature flags.

Successfully upgraded 'mypool' from version 28 to feature flags.
Enabled the following features on 'mypool':
  async_destroy
  empty_bpobj
  lz4_compress
  multi_vdev_crash_dump
```

The newer features of ZFS will not be available until `zpool upgrade` has completed. `zpool upgrade -v` can be used to see what new features will be provided by upgrading, as well as which features are already supported.

Upgrade a pool to support additional feature flags:

```
# zpool status
  pool: mypool
 state: ONLINE
status: Some supported features are not enabled on the pool. The pool can
        still be used, but some features are unavailable.
action: Enable all features using 'zpool upgrade'. Once this is done,
        the pool may no longer be accessible by software that does not support
        the features. See zpool-features(7) for details.
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        mypool      ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
     ada0    ONLINE       0     0     0
     ada1    ONLINE       0     0     0

errors: No known data errors
# zpool upgrade
This system supports ZFS pool feature flags.

All pools are formatted using feature flags.


Some supported features are not enabled on the following pools. Once a
feature is enabled the pool may become incompatible with software
that does not support the feature. See zpool-features(7) for details.

POOL  FEATURE
---------------
zstore
      multi_vdev_crash_dump
      spacemap_histogram
      enabled_txg
      hole_birth
      extensible_dataset
      bookmarks
      filesystem_limits
# zpool upgrade mypool
This system supports ZFS pool feature flags.

Enabled the following features on 'mypool':
  spacemap_histogram
  enabled_txg
  hole_birth
  extensible_dataset
  bookmarks
  filesystem_limits
```

警告

The boot code on systems that boot from a pool must be updated to support the new pool version. Use `gpart bootcode` on the partition that contains the boot code. See gpart(8) for more information.

19.3.12. Displaying Recorded Pool History

Commands that modify the pool are recorded. Recorded actions include the creation of datasets, changing properties, or replacement of a disk. This history is useful for reviewing how a pool was created and which user performed a specific action and when. History is not kept in a log file, but is part of the pool itself. The command to review this history is aptly named `zpool history` :

```
# zpool history
History for 'tank':
2013-02-26.23:02:35 zpool create tank mirror /dev/ada0 /dev/ada1
2013-02-27.18:50:58 zfs set atime=off tank
2013-02-27.18:51:09 zfs set checksum=fletcher4 tank
2013-02-27.18:51:18 zfs create tank/backup
```

The output shows `zpool` and `zfs` commands that were executed on the pool along with a timestamp. Only commands that alter the pool in some way are recorded. Commands like `zfs list` are not included. When no pool name is specified, the history of all pools is displayed.

`zpool history` can show even more information when the options `-i` or `-l` are provided. `-i` displays user-initiated events as well as internally logged ZFS events.

```
# zpool history -i
History for 'tank':
2013-02-26.23:02:35 [internal pool create txg:5] pool spa 28; zfs spa 28; zpl 5;uts  9.1-
RELEASE 901000 amd64
2013-02-27.18:50:53 [internal property set txg:50] atime=0 dataset = 21
2013-02-27.18:50:58 zfs set atime=off tank
2013-02-27.18:51:04 [internal property set txg:53] checksum=7 dataset = 21
2013-02-27.18:51:09 zfs set checksum=fletcher4 tank
2013-02-27.18:51:13 [internal create txg:55] dataset = 39
2013-02-27.18:51:18 zfs create tank/backup
```

More details can be shown by adding `-l`. History records are shown in a long format, including information like the name of the user who issued the command and the hostname on which the change was made.

```
# zpool history -l
History for 'tank':
2013-02-26.23:02:35 zpool create tank mirror /dev/ada0 /dev/ada1 [user 0 (root) ↺
on :global]
2013-02-27.18:50:58 zfs set atime=off tank [user 0 (root) on myzfsbox:global]
2013-02-27.18:51:09 zfs set checksum=fletcher4 tank [user 0 (root) on myzfsbox:global]
2013-02-27.18:51:18 zfs create tank/backup [user 0 (root) on myzfsbox:global]
```

The output shows that the `root` user created the mirrored pool with disks `/dev/ada0` and `/dev/ada1` . The hostname `myzfsbox` is also shown in the commands after the pool's creation. The hostname display becomes important when the pool is exported from one system and imported on another. The commands that are issued on the other system can clearly be distinguished by the hostname that is recorded for each command.

Both options to `zpool history` can be combined to give the most detailed information possible for any given pool. Pool history provides valuable information when tracking down the actions that were performed or when more detailed output is needed for debugging.

19.3.13. Performance Monitoring

A built-in monitoring system can display pool I/O statistics in real time. It shows the amount of free and used space on the pool, how many read and write operations are being performed per second, and how much I/O bandwidth is currently being utilized. By default, all pools in the system are monitored and displayed. A pool name can be provided to limit monitoring to just that pool. A basic example:

```
# zpool iostat
               capacity     operations    bandwidth
pool        alloc   free   read  write   read  write
```

```
----------  -----  -----  -----  -----  -----  -----
data         288G  1.53T      2     11  11.3K  57.1K
```

To continuously monitor I/O activity, a number can be specified as the last parameter, indicating a interval in seconds to wait between updates. The next statistic line is printed after each interval. Press Ctrl+C to stop this continuous monitoring. Alternatively, give a second number on the command line after the interval to specify the total number of statistics to display.

Even more detailed I/O statistics can be displayed with `-v`. Each device in the pool is shown with a statistics line. This is useful in seeing how many read and write operations are being performed on each device, and can help determine if any individual device is slowing down the pool. This example shows a mirrored pool with two devices:

```
# zpool iostat -v
                         capacity     operations    bandwidth
pool                   alloc   free   read  write   read  write
----------------------  -----  -----  -----  -----  -----  -----
data                    288G  1.53T      2     12  9.23K  61.5K
  mirror                288G  1.53T      2     12  9.23K  61.5K
    ada1                   -      -      0      4  5.61K  61.7K
    ada2                   -      -      1      4  5.04K  61.7K
----------------------  -----  -----  -----  -----  -----  -----
```

19.3.14. Splitting a Storage Pool

A pool consisting of one or more mirror vdevs can be split into two pools. Unless otherwise specified, the last member of each mirror is detached and used to create a new pool containing the same data. The operation should first be attempted with `-n`. The details of the proposed operation are displayed without it actually being performed. This helps confirm that the operation will do what the user intends.

19.4. `zfs` Administration

The `zfs` utility is responsible for creating, destroying, and managing all ZFS datasets that exist within a pool. The pool is managed using `zpool`.

19.4.1. Creating and Destroying Datasets

Unlike traditional disks and volume managers, space in ZFS is not preallocated. With traditional file systems, after all of the space is partitioned and assigned, there is no way to add an additional file system without adding a new disk. With ZFS, new file systems can be created at any time. Each dataset has properties including features like compression, deduplication, caching, and quotas, as well as other useful properties like readonly, case sensitivity, network file sharing, and a mount point. Datasets can be nested inside each other, and child datasets will inherit properties from their parents. Each dataset can be administered, delegated, replicated, snapshotted, jailed, and destroyed as a unit. There are many advantages to creating a separate dataset for each different type or set of files. The only drawbacks to having an extremely large number of datasets is that some commands like `zfs list` will be slower, and the mounting of hundreds or even thousands of datasets can slow the FreeBSD boot process.

Create a new dataset and enable LZ4 compression on it:

```
# zfs list
NAME                 USED  AVAIL  REFER  MOUNTPOINT
mypool               781M  93.2G   144K  none
mypool/ROOT          777M  93.2G   144K  none
mypool/ROOT/default  777M  93.2G   777M  /
mypool/tmp           176K  93.2G   176K  /tmp
mypool/usr           616K  93.2G   144K  /usr
mypool/usr/home      184K  93.2G   184K  /usr/home
mypool/usr/ports     144K  93.2G   144K  /usr/ports
mypool/usr/src       144K  93.2G   144K  /usr/src
mypool/var          1.20M  93.2G   608K  /var
mypool/var/crash     148K  93.2G   148K  /var/crash
```

```
mypool/var/log        178K  93.2G   178K  /var/log
mypool/var/mail       144K  93.2G   144K  /var/mail
mypool/var/tmp        152K  93.2G   152K  /var/tmp
# zfs create -o compress=lz4  mypool/usr/mydataset
# zfs list
NAME                   USED  AVAIL  REFER  MOUNTPOINT
mypool                 781M  93.2G   144K  none
mypool/ROOT            777M  93.2G   144K  none
mypool/ROOT/default    777M  93.2G   777M  /
mypool/tmp             176K  93.2G   176K  /tmp
mypool/usr             704K  93.2G   144K  /usr
mypool/usr/home        184K  93.2G   184K  /usr/home
mypool/usr/mydataset  87.5K  93.2G  87.5K  /usr/mydataset
mypool/usr/ports       144K  93.2G   144K  /usr/ports
mypool/usr/src         144K  93.2G   144K  /usr/src
mypool/var            1.20M  93.2G   610K  /var
mypool/var/crash       148K  93.2G   148K  /var/crash
mypool/var/log         178K  93.2G   178K  /var/log
mypool/var/mail        144K  93.2G   144K  /var/mail
mypool/var/tmp         152K  93.2G   152K  /var/tmp
```

Destroying a dataset is much quicker than deleting all of the files that reside on the dataset, as it does not involve scanning all of the files and updating all of the corresponding metadata.

Destroy the previously-created dataset:

```
# zfs list
NAME                   USED  AVAIL  REFER  MOUNTPOINT
mypool                 880M  93.1G   144K  none
mypool/ROOT            777M  93.1G   144K  none
mypool/ROOT/default    777M  93.1G   777M  /
mypool/tmp             176K  93.1G   176K  /tmp
mypool/usr             101M  93.1G   144K  /usr
mypool/usr/home        184K  93.1G   184K  /usr/home
mypool/usr/mydataset   100M  93.1G   100M  /usr/mydataset
mypool/usr/ports       144K  93.1G   144K  /usr/ports
mypool/usr/src         144K  93.1G   144K  /usr/src
mypool/var            1.20M  93.1G   610K  /var
mypool/var/crash       148K  93.1G   148K  /var/crash
mypool/var/log         178K  93.1G   178K  /var/log
mypool/var/mail        144K  93.1G   144K  /var/mail
mypool/var/tmp         152K  93.1G   152K  /var/tmp
# zfs destroy mypool/usr/mydataset
# zfs list
NAME                  USED  AVAIL  REFER  MOUNTPOINT
mypool                781M  93.2G   144K  none
mypool/ROOT           777M  93.2G   144K  none
mypool/ROOT/default   777M  93.2G   777M  /
mypool/tmp            176K  93.2G   176K  /tmp
mypool/usr            616K  93.2G   144K  /usr
mypool/usr/home       184K  93.2G   184K  /usr/home
mypool/usr/ports      144K  93.2G   144K  /usr/ports
mypool/usr/src        144K  93.2G   144K  /usr/src
mypool/var           1.21M  93.2G   612K  /var
mypool/var/crash      148K  93.2G   148K  /var/crash
mypool/var/log        178K  93.2G   178K  /var/log
mypool/var/mail       144K  93.2G   144K  /var/mail
mypool/var/tmp        152K  93.2G   152K  /var/tmp
```

In modern versions of ZFS, `zfs destroy` is asynchronous, and the free space might take several minutes to appear in the pool. Use `zpool get freeing` *`poolname`* to see the `freeing` property, indicating how many datasets are having their blocks freed in the background. If there are child datasets, like snapshots or other datasets, then the parent cannot be destroyed. To destroy a dataset and all of its children, use `-r` to recursively destroy the dataset and all of its children. Use `-n -v`to list datasets and snapshots that would be destroyed by

this operation, but do not actually destroy anything. Space that would be reclaimed by destruction of snapshots is also shown.

19.4.2. Creating and Destroying Volumes

A volume is a special type of dataset. Rather than being mounted as a file system, it is exposed as a block device under `/dev/zvol/`*`poolname`*`/`*`dataset`*. This allows the volume to be used for other file systems, to back the disks of a virtual machine, or to be exported using protocols like iSCSI or HAST.

A volume can be formatted with any file system, or used without a file system to store raw data. To the user, a volume appears to be a regular disk. Putting ordinary file systems on these zvols provides features that ordinary disks or file systems do not normally have. For example, using the compression property on a 250 MB volume allows creation of a compressed FAT file system.

```
# zfs create -V 250m -o compression=on tank/fat32
# zfs list tank
NAME USED AVAIL REFER MOUNTPOINT
tank 258M  670M   31K /tank
# newfs_msdos -F32 /dev/zvol/tank/fat32
# mount -t msdosfs /dev/zvol/tank/fat32 /mnt
# df -h /mnt | grep fat32
Filesystem           Size Used Avail Capacity Mounted on
/dev/zvol/tank/fat32 249M  24k  249M     0%   /mnt
# mount | grep fat32
/dev/zvol/tank/fat32 on /mnt (msdosfs, local)
```

Destroying a volume is much the same as destroying a regular file system dataset. The operation is nearly instantaneous, but it may take several minutes for the free space to be reclaimed in the background.

19.4.3. Renaming a Dataset

The name of a dataset can be changed with `zfs rename`. The parent of a dataset can also be changed with this command. Renaming a dataset to be under a different parent dataset will change the value of those properties that are inherited from the parent dataset. When a dataset is renamed, it is unmounted and then remounted in the new location (which is inherited from the new parent dataset). This behavior can be prevented with `-u`.

Rename a dataset and move it to be under a different parent dataset:

```
# zfs list
NAME                  USED  AVAIL  REFER  MOUNTPOINT
mypool                780M  93.2G   144K  none
mypool/ROOT           777M  93.2G   144K  none
mypool/ROOT/default   777M  93.2G   777M  /
mypool/tmp            176K  93.2G   176K  /tmp
mypool/usr            704K  93.2G   144K  /usr
mypool/usr/home       184K  93.2G   184K  /usr/home
mypool/usr/mydataset 87.5K  93.2G  87.5K  /usr/mydataset
mypool/usr/ports      144K  93.2G   144K  /usr/ports
mypool/usr/src        144K  93.2G   144K  /usr/src
mypool/var           1.21M  93.2G   614K  /var
mypool/var/crash      148K  93.2G   148K  /var/crash
mypool/var/log        178K  93.2G   178K  /var/log
mypool/var/mail       144K  93.2G   144K  /var/mail
mypool/var/tmp        152K  93.2G   152K  /var/tmp
# zfs rename mypool/usr/mydataset  mypool/var/newname
# zfs list
NAME                 USED  AVAIL  REFER  MOUNTPOINT
mypool               780M  93.2G   144K  none
mypool/ROOT          777M  93.2G   144K  none
mypool/ROOT/default  777M  93.2G   777M  /
mypool/tmp           176K  93.2G   176K  /tmp
```

```
mypool/usr            616K  93.2G   144K  /usr
mypool/usr/home       184K  93.2G   184K  /usr/home
mypool/usr/ports      144K  93.2G   144K  /usr/ports
mypool/usr/src        144K  93.2G   144K  /usr/src
mypool/var           1.29M  93.2G   614K  /var
mypool/var/crash      148K  93.2G   148K  /var/crash
mypool/var/log        178K  93.2G   178K  /var/log
mypool/var/mail       144K  93.2G   144K  /var/mail
mypool/var/newname   87.5K  93.2G  87.5K  /var/newname
mypool/var/tmp        152K  93.2G   152K  /var/tmp
```

Snapshots can also be renamed like this. Due to the nature of snapshots, they cannot be renamed into a different parent dataset. To rename a recursive snapshot, specify `-r`, and all snapshots with the same name in child datasets with also be renamed.

```
# zfs list -t snapshot
NAME                                USED  AVAIL  REFER  MOUNTPOINT
mypool/var/newname@first_snapshot      0      -  87.5K  -
# zfs rename mypool/var/newname@first_snapshot  new_snapshot_name
# zfs list -t snapshot
NAME                                   USED  AVAIL  REFER  MOUNTPOINT
mypool/var/newname@new_snapshot_name      0      -  87.5K  -
```

19.4.4. Setting Dataset Properties

Each ZFS dataset has a number of properties that control its behavior. Most properties are automatically inherited from the parent dataset, but can be overridden locally. Set a property on a dataset with `zfs set property=value dataset`. Most properties have a limited set of valid values, `zfs get` will display each possible property and valid values. Most properties can be reverted to their inherited values using `zfs inherit`.

User-defined properties can also be set. They become part of the dataset configuration and can be used to provide additional information about the dataset or its contents. To distinguish these custom properties from the ones supplied as part of ZFS, a colon (`:`) is used to create a custom namespace for the property.

```
# zfs set custom:costcenter=1234 tank
# zfs get custom:costcenter tank
NAME PROPERTY           VALUE SOURCE
tank custom:costcenter  1234  local
```

To remove a custom property, use `zfs inherit` with `-r`. If the custom property is not defined in any of the parent datasets, it will be removed completely (although the changes are still recorded in the pool's history).

```
# zfs inherit -r custom:costcenter tank
# zfs get custom:costcenter tank
NAME    PROPERTY           VALUE              SOURCE
tank    custom:costcenter  -                  -
# zfs get all tank | grep custom:costcenter
#
```

19.4.5. Managing Snapshots

Snapshots are one of the most powerful features of ZFS. A snapshot provides a read-only, point-in-time copy of the dataset. With Copy-On-Write (COW), snapshots can be created quickly by preserving the older version of the data on disk. If no snapshots exist, space is reclaimed for future use when data is rewritten or deleted. Snapshots preserve disk space by recording only the differences between the current dataset and a previous version. Snapshots are allowed only on whole datasets, not on individual files or directories. When a snapshot is created from a dataset, everything contained in it is duplicated. This includes the file system properties, files, directories, permissions, and so on. Snapshots use no additional space when they are first created, only consuming space as the blocks they reference are changed. Recursive snapshots taken with `-r` create a snapshot with the same name on the dataset and all of its children, providing a consistent moment-in-time snapshot of all of the file

systems. This can be important when an application has files on multiple datasets that are related or dependent upon each other. Without snapshots, a backup would have copies of the files from different points in time.

Snapshots in ZFS provide a variety of features that even other file systems with snapshot functionality lack. A typical example of snapshot use is to have a quick way of backing up the current state of the file system when a risky action like a software installation or a system upgrade is performed. If the action fails, the snapshot can be rolled back and the system has the same state as when the snapshot was created. If the upgrade was successful, the snapshot can be deleted to free up space. Without snapshots, a failed upgrade often requires a restore from backup, which is tedious, time consuming, and may require downtime during which the system cannot be used. Snapshots can be rolled back quickly, even while the system is running in normal operation, with little or no downtime. The time savings are enormous with multi-terabyte storage systems and the time required to copy the data from backup. Snapshots are not a replacement for a complete backup of a pool, but can be used as a quick and easy way to store a copy of the dataset at a specific point in time.

19.4.5.1. Creating Snapshots

Snapshots are created with `zfs snapshot` *`dataset`*`@`*`snapshotname`*. Adding `-r` creates a snapshot recursively, with the same name on all child datasets.

Create a recursive snapshot of the entire pool:

```
# zfs list -t all
NAME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool                               780M  93.2G   144K  none
mypool/ROOT                          777M  93.2G   144K  none
mypool/ROOT/default                  777M  93.2G   777M  /
mypool/tmp                           176K  93.2G   176K  /tmp
mypool/usr                           616K  93.2G   144K  /usr
mypool/usr/home                      184K  93.2G   184K  /usr/home
mypool/usr/ports                     144K  93.2G   144K  /usr/ports
mypool/usr/src                       144K  93.2G   144K  /usr/src
mypool/var                          1.29M  93.2G   616K  /var
mypool/var/crash                     148K  93.2G   148K  /var/crash
mypool/var/log                       178K  93.2G   178K  /var/log
mypool/var/mail                      144K  93.2G   144K  /var/mail
mypool/var/newname                  87.5K  93.2G  87.5K  /var/newname
mypool/var/newname@new_snapshot_name     0      -  87.5K  -
mypool/var/tmp                       152K  93.2G   152K  /var/tmp
# zfs snapshot -r mypool@my_recursive_snapshot
# zfs list -t snapshot
NAME                                         USED  AVAIL  REFER  MOUNTPOINT
mypool@my_recursive_snapshot                    0      -   144K  -
mypool/ROOT@my_recursive_snapshot               0      -   144K  -
mypool/ROOT/default@my_recursive_snapshot        0      -   777M  -
mypool/tmp@my_recursive_snapshot                0      -   176K  -
mypool/usr@my_recursive_snapshot                0      -   144K  -
mypool/usr/home@my_recursive_snapshot           0      -   184K  -
mypool/usr/ports@my_recursive_snapshot          0      -   144K  -
mypool/usr/src@my_recursive_snapshot            0      -   144K  -
mypool/var@my_recursive_snapshot                0      -   616K  -
mypool/var/crash@my_recursive_snapshot          0      -   148K  -
mypool/var/log@my_recursive_snapshot            0      -   178K  -
mypool/var/mail@my_recursive_snapshot           0      -   144K  -
mypool/var/newname@new_snapshot_name            0      -  87.5K  -
mypool/var/newname@my_recursive_snapshot        0      -  87.5K  -
mypool/var/tmp@my_recursive_snapshot            0      -   152K  -
```

Snapshots are not shown by a normal `zfs list` operation. To list snapshots, `-t snapshot` is appended to `zfs list`. `-t all` displays both file systems and snapshots.

Snapshots are not mounted directly, so path is shown in the `MOUNTPOINT` column. There is no mention of available disk space in the `AVAIL` column, as snapshots cannot be written to after they are created. Compare the snapshot to the original dataset from which it was created:

```
# zfs list -rt all mypool/usr/home
NAME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool/usr/home                      184K  93.2G   184K  /usr/home
mypool/usr/home@my_recursive_snapshot     0      -   184K  -
```

Displaying both the dataset and the snapshot together reveals how snapshots work in COW fashion. They save only the changes (delta) that were made and not the complete file system contents all over again. This means that snapshots take little space when few changes are made. Space usage can be made even more apparent by copying a file to the dataset, then making a second snapshot:

```
# cp /etc/passwd /var/tmp
# zfs snapshot mypool/var/tmp @after_cp
# zfs list -rt all mypool/var/tmp
NAME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool/var/tmp                       206K  93.2G   118K  /var/tmp
mypool/var/tmp@my_recursive_snapshot    88K      -   152K  -
mypool/var/tmp@after_cp                  0      -   118K  -
```

The second snapshot contains only the changes to the dataset after the copy operation. This yields enormous space savings. Notice that the size of the snapshot *mypool/var/tmp@my_recursive_snapshot* also changed in the USED column to indicate the changes between itself and the snapshot taken afterwards.

19.4.5.2. Comparing Snapshots

ZFS provides a built-in command to compare the differences in content between two snapshots. This is helpful when many snapshots were taken over time and the user wants to see how the file system has changed over time. For example, `zfs diff` lets a user find the latest snapshot that still contains a file that was accidentally deleted. Doing this for the two snapshots that were created in the previous section yields this output:

```
# zfs list -rt all mypool/var/tmp
NAME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool/var/tmp                       206K  93.2G   118K  /var/tmp
mypool/var/tmp@my_recursive_snapshot    88K      -   152K  -
mypool/var/tmp@after_cp                  0      -   118K  -
# zfs diff mypool/var/tmp@my_recursive_snapshot
M       /var/tmp/
+       /var/tmp/passwd
```

The command lists the changes between the specified snapshot (in this case *mypool/var/tmp@my_recursive_snapshot*) and the live file system. The first column shows the type of change:

+	The path or file was added.
-	The path or file was deleted.
M	The path or file was modified.
R	The path or file was renamed.

Comparing the output with the table, it becomes clear that *passwd* was added after the snapshot *mypool/var/tmp@my_recursive_snapshot* was created. This also resulted in a modification to the parent directory mounted at */var/tmp*.

Comparing two snapshots is helpful when using the ZFS replication feature to transfer a dataset to a different host for backup purposes.

Compare two snapshots by providing the full dataset name and snapshot name of both datasets:

```
# cp /var/tmp/passwd /var/tmp/passwd.copy
# zfs snapshot mypool/var/tmp@diff_snapshot
# zfs diff mypool/var/tmp@my_recursive_snapshot   mypool/var/
tmp@diff_snapshot
M       /var/tmp/
```

```
+       /var/tmp/passwd
+       /var/tmp/passwd.copy
# zfs diff mypool/var/tmp@my_recursive_snapshot   mypool/var/tmp@after_cp
M       /var/tmp/
+       /var/tmp/passwd
```

A backup administrator can compare two snapshots received from the sending host and determine the actual changes in the dataset. See the Replication section for more information.

19.4.5.3. Snapshot Rollback

When at least one snapshot is available, it can be rolled back to at any time. Most of the time this is the case when the current state of the dataset is no longer required and an older version is preferred. Scenarios such as local development tests have gone wrong, botched system updates hampering the system's overall functionality, or the requirement to restore accidentally deleted files or directories are all too common occurrences. Luckily, rolling back a snapshot is just as easy as typing `zfs rollback` *`snapshotname`*. Depending on how many changes are involved, the operation will finish in a certain amount of time. During that time, the dataset always remains in a consistent state, much like a database that conforms to ACID principles is performing a rollback. This is happening while the dataset is live and accessible without requiring a downtime. Once the snapshot has been rolled back, the dataset has the same state as it had when the snapshot was originally taken. All other data in that dataset that was not part of the snapshot is discarded. Taking a snapshot of the current state of the dataset before rolling back to a previous one is a good idea when some data is required later. This way, the user can roll back and forth between snapshots without losing data that is still valuable.

In the first example, a snapshot is rolled back because of a careless `rm` operation that removes too much data than was intended.

```
# zfs list -rt all mypool/var/tmp
NAME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool/var/tmp                       262K  93.2G   120K  /var/tmp
mypool/var/tmp@my_recursive_snapshot    88K      -   152K  -
mypool/var/tmp@after_cp               53.5K      -   118K  -
mypool/var/tmp@diff_snapshot             0      -   120K  -
% ls /var/tmp
passwd          passwd.copy
% rm /var/tmp/passwd*
% ls /var/tmp
vi.recover
%
```

At this point, the user realized that too many files were deleted and wants them back. ZFS provides an easy way to get them back using rollbacks, but only when snapshots of important data are performed on a regular basis. To get the files back and start over from the last snapshot, issue the command:

```
# zfs rollback mypool/var/tmp@diff_snapshot
% ls /var/tmp
passwd          passwd.copy     vi.recover
```

The rollback operation restored the dataset to the state of the last snapshot. It is also possible to roll back to a snapshot that was taken much earlier and has other snapshots that were created after it. When trying to do this, ZFS will issue this warning:

```
# zfs list -rt snapshot mypool/var/tmp
AME                                 USED  AVAIL  REFER  MOUNTPOINT
mypool/var/tmp@my_recursive_snapshot    88K      -   152K  -
mypool/var/tmp@after_cp               53.5K      -   118K  -
mypool/var/tmp@diff_snapshot             0      -   120K  -
# zfs rollback mypool/var/tmp@my_recursive_snapshot
cannot rollback to 'mypool/var/tmp@my_recursive_snapshot': more recent snapshots exist
use '-r' to force deletion of the following snapshots:
mypool/var/tmp@after_cp
```

```
mypool/var/tmp@diff_snapshot
```

This warning means that snapshots exist between the current state of the dataset and the snapshot to which the user wants to roll back. To complete the rollback, these snapshots must be deleted. ZFS cannot track all the changes between different states of the dataset, because snapshots are read-only. ZFS will not delete the affected snapshots unless the user specifies `-r` to indicate that this is the desired action. If that is the intention, and the consequences of losing all intermediate snapshots is understood, the command can be issued:

```
# zfs rollback -r mypool/var/tmp@my_recursive_snapshot
# zfs list -rt snapshot mypool/var/tmp
NAME                                     USED  AVAIL  REFER  MOUNTPOINT
mypool/var/tmp@my_recursive_snapshot     8K      -   152K  -
% ls /var/tmp
vi.recover
```

The output from `zfs list -t snapshot` confirms that the intermediate snapshots were removed as a result of `zfs rollback -r`.

19.4.5.4. Restoring Individual Files from Snapshots

Snapshots are mounted in a hidden directory under the parent dataset: `.zfs/snapshots/` *`snapshotname`*. By default, these directories will not be displayed even when a standard `ls -a` is issued. Although the directory is not displayed, it is there nevertheless and can be accessed like any normal directory. The property named `snapdir` controls whether these hidden directories show up in a directory listing. Setting the property to `visible` allows them to appear in the output of `ls` and other commands that deal with directory contents.

```
# zfs get snapdir mypool/var/tmp
NAME           PROPERTY  VALUE    SOURCE
mypool/var/tmp  snapdir   hidden   default
% ls -a /var/tmp
.               ..              passwd          vi.recover
# zfs set snapdir=visible mypool/var/tmp
% ls -a /var/tmp
.               ..              .zfs            passwd          vi.recover
```

Individual files can easily be restored to a previous state by copying them from the snapshot back to the parent dataset. The directory structure below `.zfs/snapshot` has a directory named exactly like the snapshots taken earlier to make it easier to identify them. In the next example, it is assumed that a file is to be restored from the hidden `.zfs` directory by copying it from the snapshot that contained the latest version of the file:

```
# rm /var/tmp/passwd
% ls -a /var/tmp
.               ..              .zfs            vi.recover
# ls /var/tmp/.zfs/snapshot
after_cp               my_recursive_snapshot
# ls /var/tmp/.zfs/snapshot/ after_cp
passwd          vi.recover
# cp /var/tmp/.zfs/snapshot/ after_cp/passwd  /var/tmp
```

When `ls .zfs/snapshot` was issued, the `snapdir` property might have been set to hidden, but it would still be possible to list the contents of that directory. It is up to the administrator to decide whether these directories will be displayed. It is possible to display these for certain datasets and prevent it for others. Copying files or directories from this hidden `.zfs/snapshot` is simple enough. Trying it the other way around results in this error:

```
# cp /etc/rc.conf  /var/tmp/.zfs/snapshot/ after_cp/
cp: /var/tmp/.zfs/snapshot/after_cp/rc.conf: Read-only file system
```

The error reminds the user that snapshots are read-only and can not be changed after creation. No files can be copied into or removed from snapshot directories because that would change the state of the dataset they represent.

Snapshots consume space based on how much the parent file system has changed since the time of the snapshot. The `written` property of a snapshot tracks how much space is being used by the snapshot.

Snapshots are destroyed and the space reclaimed with `zfs destroy` *`dataset`*`@`*`snapshot`*. Adding `-r` recursively removes all snapshots with the same name under the parent dataset. Adding `-n -v` to the command displays a list of the snapshots that would be deleted and an estimate of how much space would be reclaimed without performing the actual destroy operation.

19.4.6. Managing Clones

A clone is a copy of a snapshot that is treated more like a regular dataset. Unlike a snapshot, a clone is not read only, is mounted, and can have its own properties. Once a clone has been created using `zfs clone`, the snapshot it was created from cannot be destroyed. The child/parent relationship between the clone and the snapshot can be reversed using `zfs promote`. After a clone has been promoted, the snapshot becomes a child of the clone, rather than of the original parent dataset. This will change how the space is accounted, but not actually change the amount of space consumed. The clone can be mounted at any point within the ZFS file system hierarchy, not just below the original location of the snapshot.

To demonstrate the clone feature, this example dataset is used:

```
# zfs list -rt all camino/home/joe
NAME                    USED  AVAIL  REFER  MOUNTPOINT
camino/home/joe         108K   1.3G    87K  /usr/home/joe
camino/home/joe@plans    21K      -  85.5K  -
camino/home/joe@backup    0K      -    87K  -
```

A typical use for clones is to experiment with a specific dataset while keeping the snapshot around to fall back to in case something goes wrong. Since snapshots can not be changed, a read/write clone of a snapshot is created. After the desired result is achieved in the clone, the clone can be promoted to a dataset and the old file system removed. This is not strictly necessary, as the clone and dataset can coexist without problems.

```
# zfs clone camino/home/joe@backup camino/home/joenew
# ls /usr/home/joe*
/usr/home/joe:
backup.txz     plans.txt

/usr/home/joenew:
backup.txz     plans.txt
# df -h /usr/home
Filesystem          Size    Used   Avail Capacity  Mounted on
usr/home/joe        1.3G     31k    1.3G     0%    /usr/home/joe
usr/home/joenew     1.3G     31k    1.3G     0%    /usr/home/joenew
```

After a clone is created it is an exact copy of the state the dataset was in when the snapshot was taken. The clone can now be changed independently from its originating dataset. The only connection between the two is the snapshot. ZFS records this connection in the property `origin`. Once the dependency between the snapshot and the clone has been removed by promoting the clone using `zfs promote`, the `origin` of the clone is removed as it is now an independent dataset. This example demonstrates it:

```
# zfs get origin camino/home/joenew
NAME                PROPERTY  VALUE                     SOURCE
camino/home/joenew  origin    camino/home/joe@backup    -
# zfs promote camino/home/joenew
# zfs get origin camino/home/joenew
NAME                PROPERTY  VALUE   SOURCE
camino/home/joenew  origin    -       -
```

After making some changes like copying `loader.conf` to the promoted clone, for example, the old directory becomes obsolete in this case. Instead, the promoted clone can replace it. This can be achieved by two consecutive commands: `zfs destroy` on the old dataset and `zfs rename` on the clone to name it like the old dataset (it could also get an entirely different name).

```
# cp /boot/defaults/loader.conf  /usr/home/joenew
# zfs destroy -f  camino/home/joe
# zfs rename  camino/home/joenew  camino/home/joe
# ls /usr/home/joe
backup.txz     loader.conf     plans.txt
# df -h /usr/home
Filesystem          Size    Used   Avail Capacity  Mounted on
usr/home/joe        1.3G    128k    1.3G     0%    /usr/home/joe
```

The cloned snapshot is now handled like an ordinary dataset. It contains all the data from the original snapshot plus the files that were added to it like `loader.conf`. Clones can be used in different scenarios to provide useful features to ZFS users. For example, jails could be provided as snapshots containing different sets of installed applications. Users can clone these snapshots and add their own applications as they see fit. Once they are satisfied with the changes, the clones can be promoted to full datasets and provided to end users to work with like they would with a real dataset. This saves time and administrative overhead when providing these jails.

19.4.7. Replication

Keeping data on a single pool in one location exposes it to risks like theft and natural or human disasters. Making regular backups of the entire pool is vital. ZFS provides a built-in serialization feature that can send a stream representation of the data to standard output. Using this technique, it is possible to not only store the data on another pool connected to the local system, but also to send it over a network to another system. Snapshots are the basis for this replication (see the section on ZFS snapshots). The commands used for replicating data are `zfs send` and `zfs receive`.

These examples demonstrate ZFS replication with these two pools:

```
# zpool list
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
backup  960M    77K   896M     0%  1.00x  ONLINE  -
mypool  984M  43.7M   940M     4%  1.00x  ONLINE  -
```

The pool named *`mypool`* is the primary pool where data is written to and read from on a regular basis. A second pool, *`backup`* is used as a standby in case the primary pool becomes unavailable. Note that this fail-over is not done automatically by ZFS, but must be manually done by a system administrator when needed. A snapshot is used to provide a consistent version of the file system to be replicated. Once a snapshot of *`mypool`* has been created, it can be copied to the *`backup`* pool. Only snapshots can be replicated. Changes made since the most recent snapshot will not be included.

```
# zfs snapshot  mypool@backup1
# zfs list -t snapshot
NAME                    USED  AVAIL  REFER  MOUNTPOINT
mypool@backup1             0      -  43.6M  -
```

Now that a snapshot exists, `zfs send` can be used to create a stream representing the contents of the snapshot. This stream can be stored as a file or received by another pool. The stream is written to standard output, but must be redirected to a file or pipe or an error is produced:

```
# zfs send  mypool@backup1
Error: Stream can not be written to a terminal.
You must redirect standard output.
```

To back up a dataset with `zfs send`, redirect to a file located on the mounted backup pool. Ensure that the pool has enough free space to accommodate the size of the snapshot being sent, which means all of the data contained in the snapshot, not just the changes from the previous snapshot.

```
# zfs send  mypool@backup1  > /backup/backup1
# zpool list
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
backup  960M  63.7M   896M     6%  1.00x  ONLINE  -
```

```
mypool  984M  43.7M   940M     4%  1.00x  ONLINE  -
```

The `zfs send` transferred all the data in the snapshot called *`backup1`* to the pool named *`backup`*. Creating and sending these snapshots can be done automatically with a cron(8) job.

Instead of storing the backups as archive files, ZFS can receive them as a live file system, allowing the backed up data to be accessed directly. To get to the actual data contained in those streams, `zfs receive` is used to transform the streams back into files and directories. The example below combines `zfs send` and `zfs receive` using a pipe to copy the data from one pool to another. The data can be used directly on the receiving pool after the transfer is complete. A dataset can only be replicated to an empty dataset.

```
# zfs snapshot mypool@replica1
# zfs send -v mypool@replica1 | zfs receive backup/mypool
send from @ to mypool@replica1 estimated size is 50.1M
total estimated size is 50.1M
TIME        SENT   SNAPSHOT

# zpool list
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
backup  960M  63.7M   896M     6%  1.00x  ONLINE  -
mypool  984M  43.7M   940M     4%  1.00x  ONLINE  -
```

19.4.7.1. Incremental Backups

`zfs send` can also determine the difference between two snapshots and send only the differences between the two. This saves disk space and transfer time. For example:

```
# zfs snapshot mypool@replica2
# zfs list -t snapshot
NAME                    USED  AVAIL  REFER  MOUNTPOINT
mypool@replica1         5.72M      -  43.6M  -
mypool@replica2             0      -  44.1M  -
# zpool list
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
backup  960M  61.7M   898M     6%  1.00x  ONLINE  -
mypool  960M  50.2M   910M     5%  1.00x  ONLINE  -
```

A second snapshot called *`replica2`* was created. This second snapshot contains only the changes that were made to the file system between now and the previous snapshot, *`replica1`*. Using `zfs send -i` and indicating the pair of snapshots generates an incremental replica stream containing only the data that has changed. This can only succeed if the initial snapshot already exists on the receiving side.

```
# zfs send -v -i mypool@replica1 mypool@replica2 | zfs receive /backup/
mypool
send from @replica1 to mypool@replica2 estimated size is 5.02M
total estimated size is 5.02M
TIME        SENT   SNAPSHOT

# zpool list
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
backup  960M  80.8M   879M     8%  1.00x  ONLINE  -
mypool  960M  50.2M   910M     5%  1.00x  ONLINE  -

# zfs list
NAME                         USED  AVAIL  REFER  MOUNTPOINT
backup                      55.4M   240G   152K  /backup
backup/mypool               55.3M   240G  55.2M  /backup/mypool
mypool                      55.6M  11.6G  55.0M  /mypool

# zfs list -t snapshot
NAME                                       USED  AVAIL  REFER  MOUNTPOINT
backup/mypool@replica1                     104K      -  50.2M  -
```

```
backup/mypool@replica2                    0      -  55.2M  -
mypool@replica1                        29.9K      -  50.0M  -
mypool@replica2                           0      -  55.0M  -
```

The incremental stream was successfully transferred. Only the data that had changed was replicated, rather than the entirety of *replica1*. Only the differences were sent, which took much less time to transfer and saved disk space by not copying the complete pool each time. This is useful when having to rely on slow networks or when costs per transferred byte must be considered.

A new file system, *backup/mypool*, is available with all of the files and data from the pool *mypool*. If `-P` is specified, the properties of the dataset will be copied, including compression settings, quotas, and mount points. When `-R` is specified, all child datasets of the indicated dataset will be copied, along with all of their properties. Sending and receiving can be automated so that regular backups are created on the second pool.

19.4.7.2. Sending Encrypted Backups over SSH

Sending streams over the network is a good way to keep a remote backup, but it does come with a drawback. Data sent over the network link is not encrypted, allowing anyone to intercept and transform the streams back into data without the knowledge of the sending user. This is undesirable, especially when sending the streams over the internet to a remote host. SSH can be used to securely encrypt data send over a network connection. Since ZFS only requires the stream to be redirected from standard output, it is relatively easy to pipe it through SSH. To keep the contents of the file system encrypted in transit and on the remote system, consider using PEFS.

A few settings and security precautions must be completed first. Only the necessary steps required for the `zfs send` operation are shown here. For more information on SSH, see 節 13.8, “OpenSSH”.

This configuration is required:

- Passwordless SSH access between sending and receiving host using SSH keys
- Normally, the privileges of the `root` user are needed to send and receive streams. This requires logging in to the receiving system as `root`. However, logging in as `root` is disabled by default for security reasons. The ZFS Delegation system can be used to allow a non-`root` user on each system to perform the respective send and receive operations.
- On the sending system:

  ```
  # zfs allow -u someuser send,snapshot  mypool
  ```

- To mount the pool, the unprivileged user must own the directory, and regular users must be allowed to mount file systems. On the receiving system:

  ```
  # sysctl vfs.usermount=1
  vfs.usermount: 0 -> 1
  # echo vfs.usermount=1 >> /etc/sysctl.conf
  # zfs create recvpool/backup
  # zfs allow -u someuser create,mount,receive  recvpool/backup
  # chown someuser /recvpool/backup
  ```

The unprivileged user now has the ability to receive and mount datasets, and the *home* dataset can be replicated to the remote system:

```
% zfs snapshot -r mypool/home@monday
% zfs send -R mypool/home@monday | ssh someuser@backuphost  zfs recv -
dvu recvpool/backup
```

A recursive snapshot called *monday* is made of the file system dataset *home* that resides on the pool *mypool*. Then it is sent with `zfs send -R` to include the dataset, all child datasets, snaphots, clones, and settings in the stream. The output is piped to the waiting `zfs receive` on the remote host *backuphost* through SSH. Using a fully qualified domain name or IP address is recommended. The receiving machine writes the data to the *backup*

dataset on the *recvpool* pool. Adding `-d` to `zfs recv` overwrites the name of the pool on the receiving side with the name of the snapshot. `-u` causes the file systems to not be mounted on the receiving side. When `-v` is included, more detail about the transfer is shown, including elapsed time and the amount of data transferred.

19.4.8. Dataset, User, and Group Quotas

Dataset quotas are used to restrict the amount of space that can be consumed by a particular dataset. Reference Quotas work in very much the same way, but only count the space used by the dataset itself, excluding snapshots and child datasets. Similarly, user and group quotas can be used to prevent users or groups from using all of the space in the pool or dataset.

To enforce a dataset quota of 10 GB for `storage/home/bob` :

```
# zfs set quota=10G storage/home/bob
```

To enforce a reference quota of 10 GB for `storage/home/bob` :

```
# zfs set refquota=10G storage/home/bob
```

To remove a quota of 10 GB for `storage/home/bob` :

```
# zfs set quota=none storage/home/bob
```

The general format is `userquota@` *`user=size`*, and the user's name must be in one of these formats:

- POSIX compatible name such as *`joe`*.
- POSIX numeric ID such as *`789`*.
- SID name such as *`joe.bloggs@example.com`* .
- SID numeric ID such as *`S-1-123-456-789`* .

For example, to enforce a user quota of 50 GB for the user named *`joe`*:

```
# zfs set userquota@joe=50G
```

To remove any quota:

```
# zfs set userquota@joe=none
```

注意

User quota properties are not displayed by `zfs get all`. Non-`root` users can only see their own quotas unless they have been granted the `userquota` privilege. Users with this privilege are able to view and set everyone's quota.

The general format for setting a group quota is: `groupquota@` *`group=size`*.

To set the quota for the group *`firstgroup`* to 50 GB, use:

```
# zfs set groupquota@firstgroup=50G
```

To remove the quota for the group *`firstgroup`* , or to make sure that one is not set, instead use:

```
# zfs set groupquota@firstgroup=none
```

As with the user quota property, non-`root` users can only see the quotas associated with the groups to which they belong. However, `root` or a user with the `groupquota` privilege can view and set all quotas for all groups.

To display the amount of space used by each user on a file system or snapshot along with any quotas, use `zfs userspace`. For group information, use `zfs groupspace`. For more information about supported options or how to display only specific options, refer to zfs(1).

Users with sufficient privileges, and `root`, can list the quota for `storage/home/bob` using:

```
# zfs get quota storage/home/bob
```

19.4.9. Reservations

Reservations guarantee a minimum amount of space will always be available on a dataset. The reserved space will not be available to any other dataset. This feature can be especially useful to ensure that free space is available for an important dataset or log files.

The general format of the `reservation` property is `reservation=`*`size`*, so to set a reservation of 10 GB on `storage/home/bob`, use:

```
# zfs set reservation=10G storage/home/bob
```

To clear any reservation:

```
# zfs set reservation=none storage/home/bob
```

The same principle can be applied to the `refreservation` property for setting a Reference Reservation, with the general format `refreservation=`*`size`*.

This command shows any reservations or refreservations that exist on `storage/home/bob`:

```
# zfs get reservation storage/home/bob
# zfs get refreservation storage/home/bob
```

19.4.10. Compression

ZFS provides transparent compression. Compressing data at the block level as it is written not only saves space, but can also increase disk throughput. If data is compressed by 25%, but the compressed data is written to the disk at the same rate as the uncompressed version, resulting in an effective write speed of 125%. Compression can also be a great alternative to Deduplication because it does not require additional memory.

ZFS offers several different compression algorithms, each with different trade-offs. With the introduction of LZ4 compression in ZFS v5000, it is possible to enable compression for the entire pool without the large performance trade-off of other algorithms. The biggest advantage to LZ4 is the early abort feature. If LZ4 does not achieve at least 12.5% compression in the first part of the data, the block is written uncompressed to avoid wasting CPU cycles trying to compress data that is either already compressed or uncompressible. For details about the different compression algorithms available in ZFS, see the Compression entry in the terminology section.

The administrator can monitor the effectiveness of compression using a number of dataset properties.

```
# zfs get used,compressratio,compression,logicalused   mypool/
compressed_dataset
NAME        PROPERTY          VALUE     SOURCE
mypool/compressed_dataset  used              449G      -
mypool/compressed_dataset  compressratio     1.11x     -
mypool/compressed_dataset  compression       lz4       local
mypool/compressed_dataset  logicalused       496G      -
```

The dataset is currently using 449 GB of space (the used property). Without compression, it would have taken 496 GB of space (the `logicallyused` property). This results in the 1.11:1 compression ratio.

Compression can have an unexpected side effect when combined with User Quotas. User quotas restrict how much space a user can consume on a dataset, but the measurements are based on how much space is used after compression. So if a user has a quota of 10 GB, and writes 10 GB of compressible data, they will still be able to store

additional data. If they later update a file, say a database, with more or less compressible data, the amount of space available to them will change. This can result in the odd situation where a user did not increase the actual amount of data (the `logicalused` property), but the change in compression caused them to reach their quota limit.

Compression can have a similar unexpected interaction with backups. Quotas are often used to limit how much data can be stored to ensure there is sufficient backup space available. However since quotas do not consider compression, more data may be written than would fit with uncompressed backups.

19.4.11. Deduplication

When enabled, deduplication uses the checksum of each block to detect duplicate blocks. When a new block is a duplicate of an existing block, ZFS writes an additional reference to the existing data instead of the whole duplicate block. Tremendous space savings are possible if the data contains many duplicated files or repeated information. Be warned: deduplication requires an extremely large amount of memory, and most of the space savings can be had without the extra cost by enabling compression instead.

To activate deduplication, set the `dedup` property on the target pool:

```
# zfs set dedup=on pool
```

Only new data being written to the pool will be deduplicated. Data that has already been written to the pool will not be deduplicated merely by activating this option. A pool with a freshly activated deduplication property will look like this example:

```
# zpool list
NAME  SIZE ALLOC  FREE CAP DEDUP HEALTH ALTROOT
pool 2.84G 2.19M 2.83G  0% 1.00x ONLINE -
```

The `DEDUP` column shows the actual rate of deduplication for the pool. A value of `1.00x` shows that data has not been deduplicated yet. In the next example, the ports tree is copied three times into different directories on the deduplicated pool created above.

```
# zpool list
for d in dir1 dir2 dir3; do
for> mkdir $d && cp -R /usr/ports $d &
for> done
```

Redundant data is detected and deduplicated:

```
# zpool list
NAME SIZE  ALLOC FREE CAP DEDUP HEALTH ALTROOT
pool 2.84G 20.9M 2.82G 0% 3.00x ONLINE -
```

The `DEDUP` column shows a factor of `3.00x`. Multiple copies of the ports tree data was detected and deduplicated, using only a third of the space. The potential for space savings can be enormous, but comes at the cost of having enough memory to keep track of the deduplicated blocks.

Deduplication is not always beneficial, especially when the data on a pool is not redundant. ZFS can show potential space savings by simulating deduplication on an existing pool:

```
# zdb -S pool
Simulated DDT histogram:

bucket              allocated                       referenced
______   ______________________________   ______________________________
refcnt   blocks   LSIZE   PSIZE   DSIZE   blocks   LSIZE   PSIZE   DSIZE
------   ------   -----   -----   -----   ------   -----   -----   -----
     1    2.58M    289G    264G    264G    2.58M    289G    264G    264G
     2     206K   12.6G   10.4G   10.4G     430K   26.4G   21.6G   21.6G
     4    37.6K    692M    276M    276M     170K   3.04G   1.26G   1.26G
     8    2.18K   45.2M   19.4M   19.4M    20.0K    425M    176M    176M
    16      174   2.83M   1.20M   1.20M    3.33K   48.4M   20.4M   20.4M
    32       40   2.17M    222K    222K    1.70K   97.2M   9.91M   9.91M
```

```
    64        9     56K   10.5K   10.5K      865   4.96M    948K    948K
   128        2   9.50K      2K      2K      419   2.11M    438K    438K
   256        5   61.5K     12K     12K    1.90K   23.0M   4.47M   4.47M
    1K        2      1K      1K      1K    2.98K   1.49M   1.49M   1.49M
 Total    2.82M    303G    275G    275G    3.20M    319G    287G    287G

dedup = 1.05, compress = 1.11, copies = 1.00, dedup * compress / copies = 1.16
```

After `zdb -S` finishes analyzing the pool, it shows the space reduction ratio that would be achieved by activating deduplication. In this case, `1.16` is a very poor space saving ratio that is mostly provided by compression. Activating deduplication on this pool would not save any significant amount of space, and is not worth the amount of memory required to enable deduplication. Using the formula ratio = dedup * compress / copies, system administrators can plan the storage allocation, deciding whether the workload will contain enough duplicate blocks to justify the memory requirements. If the data is reasonably compressible, the space savings may be very good. Enabling compression first is recommended, and compression can also provide greatly increased performance. Only enable deduplication in cases where the additional savings will be considerable and there is sufficient memory for the DDT.

19.4.12. ZFS and Jails

`zfs jail` and the corresponding `jailed` property are used to delegate a ZFS dataset to a Jail. `zfs jail` *`jailid`* attaches a dataset to the specified jail, and `zfs unjail` detaches it. For the dataset to be controlled from within a jail, the `jailed` property must be set. Once a dataset is jailed, it can no longer be mounted on the host because it may have mount points that would compromise the security of the host.

19.5. Delegated Administration

A comprehensive permission delegation system allows unprivileged users to perform ZFS administration functions. For example, if each user's home directory is a dataset, users can be given permission to create and destroy snapshots of their home directories. A backup user can be given permission to use replication features. A usage statistics script can be allowed to run with access only to the space utilization data for all users. It is even possible to delegate the ability to delegate permissions. Permission delegation is possible for each subcommand and most properties.

19.5.1. Delegating Dataset Creation

`zfs allow` *`someuser`* `create` *`mydataset`* gives the specified user permission to create child datasets under the selected parent dataset. There is a caveat: creating a new dataset involves mounting it. That requires setting the FreeBSD `vfs.usermount` sysctl(8) to `1` to allow non-root users to mount a file system. There is another restriction aimed at preventing abuse: non-`root` users must own the mountpoint where the file system is to be mounted.

19.5.2. Delegating Permission Delegation

`zfs allow` *`someuser`* `allow` *`mydataset`* gives the specified user the ability to assign any permission they have on the target dataset, or its children, to other users. If a user has the `snapshot` permission and the `allow` permission, that user can then grant the `snapshot` permission to other users.

19.6. Advanced Topics

19.6.1. Tuning

There are a number of tunables that can be adjusted to make ZFS perform best for different workloads.

- **`vfs.zfs.arc_max`** - Maximum size of the ARC. The default is all RAM less 1 GB, or one half of RAM, whichever is more. However, a lower value should be used if the system will be running any other daemons

or processes that may require memory. This value can only be adjusted at boot time, and is set in `/boot/loader.conf`.

- **`vfs.zfs.arc_meta_limit`** - Limit the portion of the ARC that can be used to store metadata. The default is one fourth of `vfs.zfs.arc_max`. Increasing this value will improve performance if the workload involves operations on a large number of files and directories, or frequent metadata operations, at the cost of less file data fitting in the ARC. This value can only be adjusted at boot time, and is set in `/boot/loader.conf`.

- **`vfs.zfs.arc_min`** - Minimum size of the ARC. The default is one half of `vfs.zfs.arc_meta_limit`. Adjust this value to prevent other applications from pressuring out the entire ARC. This value can only be adjusted at boot time, and is set in `/boot/loader.conf`.

- **`vfs.zfs.vdev.cache.size`** - A preallocated amount of memory reserved as a cache for each device in the pool. The total amount of memory used will be this value multiplied by the number of devices. This value can only be adjusted at boot time, and is set in `/boot/loader.conf`.

- **`vfs.zfs.min_auto_ashift`** - Minimum `ashift` (sector size) that will be used automatically at pool creation time. The value is a power of two. The default value of `9` represents `2^9 = 512`, a sector size of 512 bytes. To avoid write amplification and get the best performance, set this value to the largest sector size used by a device in the pool.

  Many drives have 4 KB sectors. Using the default `ashift` of `9` with these drives results in write amplification on these devices. Data that could be contained in a single 4 KB write must instead be written in eight 512-byte writes. ZFS tries to read the native sector size from all devices when creating a pool, but many drives with 4 KB sectors report that their sectors are 512 bytes for compatibility. Setting `vfs.zfs.min_auto_ashift` to `12` (`2^12 = 4096`) before creating a pool forces ZFS to use 4 KB blocks for best performance on these drives.

  Forcing 4 KB blocks is also useful on pools where disk upgrades are planned. Future disks are likely to use 4 KB sectors, and `ashift` values cannot be changed after a pool is created.

  In some specific cases, the smaller 512-byte block size might be preferable. When used with 512-byte disks for databases, or as storage for virtual machines, less data is transferred during small random reads. This can provide better performance, especially when using a smaller ZFS record size.

- **`vfs.zfs.prefetch_disable`** - Disable prefetch. A value of `0` is enabled and `1` is disabled. The default is `0`, unless the system has less than 4 GB of RAM. Prefetch works by reading larger blocks than were requested into the ARC in hopes that the data will be needed soon. If the workload has a large number of random reads, disabling prefetch may actually improve performance by reducing unnecessary reads. This value can be adjusted at any time with sysctl(8).

- **`vfs.zfs.vdev.trim_on_init`** - Control whether new devices added to the pool have the `TRIM` command run on them. This ensures the best performance and longevity for SSDs, but takes extra time. If the device has already been secure erased, disabling this setting will make the addition of the new device faster. This value can be adjusted at any time with sysctl(8).

- **`vfs.zfs.write_to_degraded`** - Control whether new data is written to a vdev that is in the DEGRADED state. Defaults to `0`, preventing writes to any top level vdev that is in a degraded state. The administrator may wish to allow writing to degraded vdevs to prevent the amount of free space across the vdevs from becoming unbalanced, which will reduce read and write performance. This value can be adjusted at any time with sysctl(8).

- **`vfs.zfs.vdev.max_pending`** - Limit the number of pending I/O requests per device. A higher value will keep the device command queue full and may give higher throughput. A lower value will reduce latency. This value can be adjusted at any time with sysctl(8).

- **`vfs.zfs.top_maxinflight`** - Maxmimum number of outstanding I/Os per top-level vdev. Limits the depth of the command queue to prevent high latency. The limit is per top-level vdev, meaning the limit applies to each mirror [431], RAID-Z [431], or other vdev independently. This value can be adjusted at any time with sysctl(8).

- **vfs.zfs.l2arc_write_max** - Limit the amount of data written to the L2ARC per second. This tunable is designed to extend the longevity of SSDs by limiting the amount of data written to the device. This value can be adjusted at any time with sysctl(8).
- **vfs.zfs.l2arc_write_boost** - The value of this tunable is added to vfs.zfs.l2arc_write_max [429] and increases the write speed to the SSD until the first block is evicted from the L2ARC. This "Turbo Warmup Phase" is designed to reduce the performance loss from an empty L2ARC after a reboot. This value can be adjusted at any time with sysctl(8).
- **vfs.zfs.scrub_delay** - Number of ticks to delay between each I/O during a scrub. To ensure that a scrub does not interfere with the normal operation of the pool, if any other I/O is happening the scrub will delay between each command. This value controls the limit on the total IOPS (I/Os Per Second) generated by the scrub. The granularity of the setting is determined by the value of kern.hz which defaults to 1000 ticks per second. This setting may be changed, resulting in a different effective IOPS limit. The default value is 4, resulting in a limit of: 1000 ticks/sec / 4 = 250 IOPS. Using a value of *20* would give a limit of: 1000 ticks/sec / 20 = 50 IOPS. The speed of scrub is only limited when there has been recent activity on the pool, as determined by vfs.zfs.scan_idle [429]. This value can be adjusted at any time with sysctl(8).
- **vfs.zfs.resilver_delay** - Number of milliseconds of delay inserted between each I/O during a resilver. To ensure that a resilver does not interfere with the normal operation of the pool, if any other I/O is happening the resilver will delay between each command. This value controls the limit of total IOPS (I/Os Per Second) generated by the resilver. The granularity of the setting is determined by the value of kern.hz which defaults to 1000 ticks per second. This setting may be changed, resulting in a different effective IOPS limit. The default value is 2, resulting in a limit of: 1000 ticks/sec / 2 = 500 IOPS. Returning the pool to an Online state may be more important if another device failing could Fault the pool, causing data loss. A value of 0 will give the resilver operation the same priority as other operations, speeding the healing process. The speed of resilver is only limited when there has been other recent activity on the pool, as determined by vfs.zfs.scan_idle [429]. This value can be adjusted at any time with sysctl(8).
- **vfs.zfs.scan_idle** - Number of milliseconds since the last operation before the pool is considered idle. When the pool is idle the rate limiting for scrub and resilver are disabled. This value can be adjusted at any time with sysctl(8).
- **vfs.zfs.txg.timeout** - Maximum number of seconds between transaction groups. The current transaction group will be written to the pool and a fresh transaction group started if this amount of time has elapsed since the previous transaction group. A transaction group my be triggered earlier if enough data is written. The default value is 5 seconds. A larger value may improve read performance by delaying asynchronous writes, but this may cause uneven performance when the transaction group is written. This value can be adjusted at any time with sysctl(8).

19.6.2. ZFS on i386

Some of the features provided by ZFS are memory intensive, and may require tuning for maximum efficiency on systems with limited RAM.

19.6.2.1. Memory

As a bare minimum, the total system memory should be at least one gigabyte. The amount of recommended RAM depends upon the size of the pool and which ZFS features are used. A general rule of thumb is 1 GB of RAM for every 1 TB of storage. If the deduplication feature is used, a general rule of thumb is 5 GB of RAM per TB of storage to be deduplicated. While some users successfully use ZFS with less RAM, systems under heavy load may panic due to memory exhaustion. Further tuning may be required for systems with less than the recommended RAM requirements.

19.6.2.2. Kernel Configuration

Due to the address space limitations of the i386™ platform, ZFS users on the i386™ architecture must add this option to a custom kernel configuration file, rebuild the kernel, and reboot:

```
options         KVA_PAGES=512
```

This expands the kernel address space, allowing the `vm.kvm_size` tunable to be pushed beyond the currently imposed limit of 1 GB, or the limit of 2 GB for PAE. To find the most suitable value for this option, divide the desired address space in megabytes by four. In this example, it is `512` for 2 GB.

19.6.2.3. Loader Tunables

The `kmem` address space can be increased on all FreeBSD architectures. On a test system with 1 GB of physical memory, success was achieved with these options added to `/boot/loader.conf` , and the system restarted:

```
vm.kmem_size="330M"
vm.kmem_size_max="330M"
vfs.zfs.arc_max="40M"
vfs.zfs.vdev.cache.size="5M"
```

For a more detailed list of recommendations for ZFS-related tuning, see http://wiki.freebsd.org/ZFSTuningGuide.

19.7. Additional Resources

- FreeBSD Wiki - ZFS
- FreeBSD Wiki - ZFS Tuning
- Illumos Wiki - ZFS
- Oracle Solaris ZFS Administration Guide
- ZFS Evil Tuning Guide
- ZFS Best Practices Guide
- Calomel Blog - ZFS Raidz Performance, Capacity and Integrity

19.8. ZFS Features and Terminology

ZFS is a fundamentally different file system because it is more than just a file system. ZFS combines the roles of file system and volume manager, enabling additional storage devices to be added to a live system and having the new space available on all of the existing file systems in that pool immediately. By combining the traditionally separate roles, ZFS is able to overcome previous limitations that prevented RAID groups being able to grow. Each top level device in a zpool is called a vdev, which can be a simple disk or a RAID transformation such as a mirror or RAID-Z array. ZFS file systems (called datasets) each have access to the combined free space of the entire pool. As blocks are allocated from the pool, the space available to each file system decreases. This approach avoids the common pitfall with extensive partitioning where free space becomes fragmented across the partitions.

zpool	A storage pool is the most basic building block of ZFS. A pool is made up of one or more vdevs, the underlying devices that store the data. A pool is then used to create one or more file systems (datasets) or block devices (volumes). These datasets and volumes share the pool of remaining free space. Each pool is uniquely identified by a name and a GUID. The features available are determined by the ZFS version number on the pool.

注意

FreeBSD 9.0 and 9.1 include support for ZFS version 28. Later versions use ZFS version 5000 with feature flags. The new feature flags system allows greater cross-compatibility with other implementations of ZFS.

vdev Types

A pool is made up of one or more vdevs, which themselves can be a single disk or a group of disks, in the case of a RAID transform. When multiple vdevs are used, ZFS spreads data across the vdevs to increase performance and maximize usable space.

- Disk - The most basic type of vdev is a standard block device. This can be an entire disk (such as `/dev/ada0` or `/dev/da0`) or a partition (`/dev/ada0p3`). On FreeBSD, there is no performance penalty for using a partition rather than the entire disk. This differs from recommendations made by the Solaris documentation.

- File - In addition to disks, ZFS pools can be backed by regular files, this is especially useful for testing and experimentation. Use the full path to the file as the device path in the zpool create command. All vdevs must be at least 128 MB in size.

- Mirror - When creating a mirror, specify the `mirror` keyword followed by the list of member devices for the mirror. A mirror consists of two or more devices, all data will be written to all member devices. A mirror vdev will only hold as much data as its smallest member. A mirror vdev can withstand the failure of all but one of its members without losing any data.

  注意

  A regular single disk vdev can be upgraded to a mirror vdev at any time with `zpool attach`.

- RAID-Z - ZFS implements RAID-Z, a variation on standard RAID-5 that offers better distribution of parity and eliminates the “RAID-5 write hole” in which the data and parity information become

	inconsistent after an unexpected restart. ZFS supports three levels of RAID-Z which provide varying levels of redundancy in exchange for decreasing levels of usable storage. The types are named RAID-Z1 through RAID-Z3 based on the number of parity devices in the array and the number of disks which can fail while the pool remains operational. In a RAID-Z1 configuration with four disks, each 1 TB, usable storage is 3 TB and the pool will still be able to operate in degraded mode with one faulted disk. If an additional disk goes offline before the faulted disk is replaced and resilvered, all data in the pool can be lost. In a RAID-Z3 configuration with eight disks of 1 TB, the volume will provide 5 TB of usable space and still be able to operate with three faulted disks. Sun™ recommends no more than nine disks in a single vdev. If the configuration has more disks, it is recommended to divide them into separate vdevs and the pool data will be striped across them. A configuration of two RAID-Z2 vdevs consisting of 8 disks each would create something similar to a RAID-60 array. A RAID-Z group's storage capacity is approximately the size of the smallest disk multiplied by the number of non-parity disks. Four 1 TB disks in RAID-Z1 has an effective size of approximately 3 TB, and an array of eight 1 TB disks in RAID-Z3 will yield 5 TB of usable space. • Spare - ZFS has a special pseudo-vdev type for keeping track of available hot spares. Note that installed hot spares are not deployed automatically; they must manually be configured to replace the failed device using `zfs replace`. • Log - ZFS Log Devices, also known as ZFS Intent Log (ZIL) move the intent log from the regular pool devices to a dedicated device, typically an SSD. Having a dedicated log device can significantly improve the performance of applications with a high volume of synchronous writes, especially databases. Log devices can be mirrored, but RAID-Z is not supported. If multiple log devices are used, writes will be load balanced across them. • Cache - Adding a cache vdev to a zpool will add the storage of the cache to the L2ARC. Cache devices cannot be mirrored. Since a cache device only stores additional copies of existing data, there is no risk of data loss.
Transaction Group (TXG)	Transaction Groups are the way changed blocks are grouped together and eventually written to the pool. Transaction groups are the atomic unit that ZFS uses to

	assert consistency. Each transaction group is assigned a unique 64-bit consecutive identifier. There can be up to three active transaction groups at a time, one in each of these three states: • Open - When a new transaction group is created, it is in the open state, and accepts new writes. There is always a transaction group in the open state, however the transaction group may refuse new writes if it has reached a limit. Once the open transaction group has reached a limit, or the `vfs.zfs.txg.timeout` [429] has been reached, the transaction group advances to the next state. • Quiescing - A short state that allows any pending operations to finish while not blocking the creation of a new open transaction group. Once all of the transactions in the group have completed, the transaction group advances to the final state. • Syncing - All of the data in the transaction group is written to stable storage. This process will in turn modify other data, such as metadata and space maps, that will also need to be written to stable storage. The process of syncing involves multiple passes. The first, all of the changed data blocks, is the biggest, followed by the metadata, which may take multiple passes to complete. Since allocating space for the data blocks generates new metadata, the syncing state cannot finish until a pass completes that does not allocate any additional space. The syncing state is also where synctasks are completed. Synctasks are administrative operations, such as creating or destroying snapshots and datasets, that modify the uberblock are completed. Once the sync state is complete, the transaction group in the quiescing state is advanced to the syncing state. All administrative functions, such as `snapshot` are written as part of the transaction group. When a synctask is created, it is added to the currently open transaction group, and that group is advanced as quickly as possible to the syncing state to reduce the latency of administrative commands.
Adaptive Replacement Cache (ARC)	ZFS uses an Adaptive Replacement Cache (ARC), rather than a more traditional Least Recently Used (LRU) cache. An LRU cache is a simple list of items in the cache, sorted by when each object was most recently used. New items are added to the top of the list. When the cache is full, items from the bottom of the list are evicted to make room for more active objects. An ARC consists of four lists; the Most Recently Used (MRU) and Most Frequently Used (MFU) objects, plus a ghost list for each. These ghost lists track recently evicted objects to prevent them from being added back to the cache.

	This increases the cache hit ratio by avoiding objects that have a history of only being used occasionally. Another advantage of using both an MRU and MFU is that scanning an entire file system would normally evict all data from an MRU or LRU cache in favor of this freshly accessed content. With ZFS, there is also an MFU that only tracks the most frequently used objects, and the cache of the most commonly accessed blocks remains.
L2ARC	L2ARC is the second level of the ZFS caching system. The primary ARC is stored in RAM. Since the amount of available RAM is often limited, ZFS can also use cache vdevs [432]. Solid State Disks (SSDs) are often used as these cache devices due to their higher speed and lower latency compared to traditional spinning disks. L2ARC is entirely optional, but having one will significantly increase read speeds for files that are cached on the SSD instead of having to be read from the regular disks. L2ARC can also speed up deduplication because a DDT that does not fit in RAM but does fit in the L2ARC will be much faster than a DDT that must be read from disk. The rate at which data is added to the cache devices is limited to prevent prematurely wearing out SSDs with too many writes. Until the cache is full (the first block has been evicted to make room), writing to the L2ARC is limited to the sum of the write limit and the boost limit, and afterwards limited to the write limit. A pair of sysctl(8) values control these rate limits. `vfs.zfs.l2arc_write_max` [429] controls how many bytes are written to the cache per second, while `vfs.zfs.l2arc_write_boost` [429] adds to this limit during the "Turbo Warmup Phase" (Write Boost).
ZIL	ZIL accelerates synchronous transactions by using storage devices like SSDs that are faster than those used in the main storage pool. When an application requests a synchronous write (a guarantee that the data has been safely stored to disk rather than merely cached to be written later), the data is written to the faster ZIL storage, then later flushed out to the regular disks. This greatly reduces latency and improves performance. Only synchronous workloads like databases will benefit from a ZIL. Regular asynchronous writes such as copying files will not use the ZIL at all.
Copy-On-Write	Unlike a traditional file system, when data is overwritten on ZFS, the new data is written to a different block rather than overwriting the old data in place. Only when this write is complete is the metadata then updated to point to the new location. In the event of a shorn write (a system crash or power loss in the middle of writing a file), the entire original contents of the file are still available and the incomplete write is discarded. This also means that ZFS does not require a fsck(8) after an unexpected shutdown.

Dataset	Dataset is the generic term for a ZFS file system, volume, snapshot or clone. Each dataset has a unique name in the format *poolname/path@snapshot* . The root of the pool is technically a dataset as well. Child datasets are named hierarchically like directories. For example, *mypool/home* , the home dataset, is a child of *mypool* and inherits properties from it. This can be expanded further by creating *mypool/home/user* . This grandchild dataset will inherit properties from the parent and grandparent. Properties on a child can be set to override the defaults inherited from the parents and grandparents. Administration of datasets and their children can be delegated.
File system	A ZFS dataset is most often used as a file system. Like most other file systems, a ZFS file system is mounted somewhere in the systems directory hierarchy and contains files and directories of its own with permissions, flags, and other metadata.
Volume	In additional to regular file system datasets, ZFS can also create volumes, which are block devices. Volumes have many of the same features, including copy-on-write, snapshots, clones, and checksumming. Volumes can be useful for running other file system formats on top of ZFS, such as UFS virtualization, or exporting iSCSI extents.
Snapshot	The copy-on-write (COW) design of ZFS allows for nearly instantaneous, consistent snapshots with arbitrary names. After taking a snapshot of a dataset, or a recursive snapshot of a parent dataset that will include all child datasets, new data is written to new blocks, but the old blocks are not reclaimed as free space. The snapshot contains the original version of the file system, and the live file system contains any changes made since the snapshot was taken. No additional space is used. As new data is written to the live file system, new blocks are allocated to store this data. The apparent size of the snapshot will grow as the blocks are no longer used in the live file system, but only in the snapshot. These snapshots can be mounted read only to allow for the recovery of previous versions of files. It is also possible to rollback a live file system to a specific snapshot, undoing any changes that took place after the snapshot was taken. Each block in the pool has a reference counter which keeps track of how many snapshots, clones, datasets, or volumes make use of that block. As files and snapshots are deleted, the reference count is decremented. When a block is no longer referenced, it is reclaimed as free space. Snapshots can also be marked with a hold. When a snapshot is held, any attempt to destroy it will return an EBUSY error. Each snapshot can have multiple holds, each with a unique name. The release command removes the hold so the snapshot can deleted. Snapshots can be taken on volumes, but

	they can only be cloned or rolled back, not mounted independently.
Clone	Snapshots can also be cloned. A clone is a writable version of a snapshot, allowing the file system to be forked as a new dataset. As with a snapshot, a clone initially consumes no additional space. As new data is written to a clone and new blocks are allocated, the apparent size of the clone grows. When blocks are overwritten in the cloned file system or volume, the reference count on the previous block is decremented. The snapshot upon which a clone is based cannot be deleted because the clone depends on it. The snapshot is the parent, and the clone is the child. Clones can be promoted, reversing this dependency and making the clone the parent and the previous parent the child. This operation requires no additional space. Because the amount of space used by the parent and child is reversed, existing quotas and reservations might be affected.
Checksum	Every block that is allocated is also checksummed. The checksum algorithm used is a per-dataset property, see `set`. The checksum of each block is transparently validated as it is read, allowing ZFS to detect silent corruption. If the data that is read does not match the expected checksum, ZFS will attempt to recover the data from any available redundancy, like mirrors or RAID-Z). Validation of all checksums can be triggered with `scrub`. Checksum algorithms include: • `fletcher2` • `fletcher4` • `sha256` The `fletcher` algorithms are faster, but `sha256` is a strong cryptographic hash and has a much lower chance of collisions at the cost of some performance. Checksums can be disabled, but it is not recommended.
Compression	Each dataset has a compression property, which defaults to off. This property can be set to one of a number of compression algorithms. This will cause all new data that is written to the dataset to be compressed. Beyond a reduction in space used, read and write throughput often increases because fewer blocks are read or written. • LZ4 - Added in ZFS pool version 5000 (feature flags), LZ4 is now the recommended compression algorithm. LZ4 compresses approximately 50% faster than LZJB when operating on compressible data, and is over three times faster when operating on uncompressible data. LZ4 also decompresses approximately 80% faster than LZJB. On modern CPUs, LZ4 can often compress at over 500 MB/s, and decompress at over 1.5 GB/s (per single CPU core).

	 注意 LZ4 compression is only available after FreeBSD 9.2. • LZJB - The default compression algorithm. Created by Jeff Bonwick (one of the original creators of ZFS). LZJB offers good compression with less CPU overhead compared to GZIP. In the future, the default compression algorithm will likely change to LZ4. • GZIP - A popular stream compression algorithm available in ZFS. One of the main advantages of using GZIP is its configurable level of compression. When setting the `compress` property, the administrator can choose the level of compression, ranging from `gzip1`, the lowest level of compression, to `gzip9`, the highest level of compression. This gives the administrator control over how much CPU time to trade for saved disk space. • ZLE - Zero Length Encoding is a special compression algorithm that only compresses continuous runs of zeros. This compression algorithm is only useful when the dataset contains large blocks of zeros.
Copies	When set to a value greater than 1, the `copies` property instructs ZFS to maintain multiple copies of each block in the File System or Volume. Setting this property on important datasets provides additional redundancy from which to recover a block that does not match its checksum. In pools without redundancy, the copies feature is the only form of redundancy. The copies feature can recover from a single bad sector or other forms of minor corruption, but it does not protect the pool from the loss of an entire disk.
Deduplication	Checksums make it possible to detect duplicate blocks of data as they are written. With deduplication, the reference count of an existing, identical block is increased, saving storage space. To detect duplicate blocks, a deduplication table (DDT) is kept in memory. The table contains a list of unique checksums, the location of those blocks, and a reference count. When new data is written, the checksum is calculated and compared to the list. If a match is found, the existing block is used. The SHA256 checksum algorithm is used with deduplication to provide a secure cryptographic hash. Deduplication is tunable. If `dedup` is `on`, then a matching checksum is assumed to mean that the data is identical. If `dedup` is set to `verify`, then the data in the two blocks will be checked byte-for-byte to ensure

	it is actually identical. If the data is not identical, the hash collision will be noted and the two blocks will be stored separately. Because DDT must store the hash of each unique block, it consumes a very large amount of memory. A general rule of thumb is 5-6 GB of ram per 1 TB of deduplicated data). In situations where it is not practical to have enough RAM to keep the entire DDT in memory, performance will suffer greatly as the DDT must be read from disk before each new block is written. Deduplication can use L2ARC to store the DDT, providing a middle ground between fast system memory and slower disks. Consider using compression instead, which often provides nearly as much space savings without the additional memory requirement.
Scrub	Instead of a consistency check like fsck(8), ZFS has `scrub`. `scrub` reads all data blocks stored on the pool and verifies their checksums against the known good checksums stored in the metadata. A periodic check of all the data stored on the pool ensures the recovery of any corrupted blocks before they are needed. A scrub is not required after an unclean shutdown, but is recommended at least once every three months. The checksum of each block is verified as blocks are read during normal use, but a scrub makes certain that even infrequently used blocks are checked for silent corruption. Data security is improved, especially in archival storage situations. The relative priority of `scrub` can be adjusted with `vfs.zfs.scrub_delay` [429] to prevent the scrub from degrading the performance of other workloads on the pool.
Dataset Quota	ZFS provides very fast and accurate dataset, user, and group space accounting in addition to quotas and space reservations. This gives the administrator fine grained control over how space is allocated and allows space to be reserved for critical file systems. ZFS supports different types of quotas: the dataset quota, the reference quota (refquota), the user quota, and the group quota. Quotas limit the amount of space that a dataset and all of its descendants, including snapshots of the dataset, child datasets, and the snapshots of those datasets, can consume. 注意 Quotas cannot be set on volumes, as the `volsize` property acts as an implicit quota.

Reference Quota	A reference quota limits the amount of space a dataset can consume by enforcing a hard limit. However, this hard limit includes only space that the dataset references and does not include space used by descendants, such as file systems or snapshots.
User Quota	User quotas are useful to limit the amount of space that can be used by the specified user.
Group Quota	The group quota limits the amount of space that a specified group can consume.
Dataset Reservation	The `reservation` property makes it possible to guarantee a minimum amount of space for a specific dataset and its descendants. If a 10 GB reservation is set on `storage/home/bob` , and another dataset tries to use all of the free space, at least 10 GB of space is reserved for this dataset. If a snapshot is taken of `storage/home/bob` , the space used by that snapshot is counted against the reservation. The `refreservation` property works in a similar way, but it excludes descendants like snapshots. Reservations of any sort are useful in many situations, such as planning and testing the suitability of disk space allocation in a new system, or ensuring that enough space is available on file systems for audio logs or system recovery procedures and files.
Reference Reservation	The `refreservation` property makes it possible to guarantee a minimum amount of space for the use of a specific dataset excluding its descendants. This means that if a 10 GB reservation is set on `storage/home/bob` , and another dataset tries to use all of the free space, at least 10 GB of space is reserved for this dataset. In contrast to a regular reservation, space used by snapshots and descendant datasets is not counted against the reservation. For example, if a snapshot is taken of `storage/home/bob` , enough disk space must exist outside of the `refreservation` amount for the operation to succeed. Descendants of the main data set are not counted in the `refreservation` amount and so do not encroach on the space set.
Resilver	When a disk fails and is replaced, the new disk must be filled with the data that was lost. The process of using the parity information distributed across the remaining drives to calculate and write the missing data to the new drive is called resilvering.
Online	A pool or vdev in the `Online` state has all of its member devices connected and fully operational. Individual devices in the `Online` state are functioning normally.
Offline	Individual devices can be put in an `Offline` state by the administrator if there is sufficient redundancy to avoid putting the pool or vdev into a Faulted state. An administrator may choose to offline a disk

	in preparation for replacing it, or to make it easier to identify.
Degraded	A pool or vdev in the `Degraded` state has one or more disks that have been disconnected or have failed. The pool is still usable, but if additional devices fail, the pool could become unrecoverable. Reconnecting the missing devices or replacing the failed disks will return the pool to an Online state after the reconnected or new device has completed the Resilver process.
Faulted	A pool or vdev in the `Faulted` state is no longer operational. The data on it can no longer be accessed. A pool or vdev enters the `Faulted` state when the number of missing or failed devices exceeds the level of redundancy in the vdev. If missing devices can be reconnected, the pool will return to a Online state. If there is insufficient redundancy to compensate for the number of failed disks, then the contents of the pool are lost and must be restored from backups.

章 20. Other File Systems

Written by Tom Rhodes.

20.1. Synopsis

File systems are an integral part of any operating system. They allow users to upload and store files, provide access to data, and make hard drives useful. Different operating systems differ in their native file system. Traditionally, the native FreeBSD file system has been the Unix File System UFS which has been modernized as UFS2. Since FreeBSD 7.0, the Z File System (ZFS) is also available as a native file system. See 章 19, The Z File System (ZFS) for more information.

In addition to its native file systems, FreeBSD supports a multitude of other file systems so that data from other operating systems can be accessed locally, such as data stored on locally attached USB storage devices, flash drives, and hard disks. This includes support for the Linux® Extended File System (EXT) and the Reiser file system.

There are different levels of FreeBSD support for the various file systems. Some require a kernel module to be loaded and others may require a toolset to be installed. Some non-native file system support is full read-write while others are read-only.

After reading this chapter, you will know:

- The difference between native and supported file systems.
- Which file systems are supported by FreeBSD.
- How to enable, configure, access, and make use of non-native file systems.

Before reading this chapter, you should:

- Understand UNIX® and FreeBSD basics.
- Be familiar with the basics of kernel configuration and compilation.
- Feel comfortable installing software in FreeBSD.
- Have some familiarity with disks, storage, and device names in FreeBSD.

20.2. Linux® File Systems

FreeBSD provides built-in support for several Linux® file systems. This section demonstrates how to load support for and how to mount the supported Linux® file systems.

20.2.1. ext2

Kernel support for ext2 file systems has been available since FreeBSD 2.2. In FreeBSD 8.x and earlier, the code is licensed under the GPL. Since FreeBSD 9.0, the code has been rewritten and is now BSD licensed.

The ext2fs(5) driver allows the FreeBSD kernel to both read and write to ext2 file systems.

注意

This driver can also be used to access ext3 and ext4 file systems. However, ext3 journaling, extended attributes, and inodes greater than 128-bytes are not supported. Support for ext4 is read-only.

To access an ext file system, first load the kernel loadable module:

```
# kldload ext2fs
```

Then, mount the ext volume by specifying its FreeBSD partition name and an existing mount point. This example mounts `/dev/ad1s1` on `/mnt`:

```
# mount -t ext2fs /dev/ad1s1 /mnt
```

20.2.2. XFS

A FreeBSD kernel can be configured to provide read-only support for XFS file systems.

To compile in XFS support, add the following option to a custom kernel configuration file and recompile the kernel using the instructions in 章 8, 設定 FreeBSD Kernel:

```
options XFS
```

Then, to mount an XFS volume located on `/dev/ad1s1` :

```
# mount -t xfs /dev/ad1s1 /mnt
```

The sysutils/xfsprogs package or port provides additional utilities, with man pages, for using, analyzing, and repairing XFS file systems.

20.2.3. ReiserFS

FreeBSD provides read-only support for The Reiser file system, ReiserFS.

To load the reiserfs(5) driver:

```
# kldload reiserfs
```

Then, to mount a ReiserFS volume located on `/dev/ad1s1` :

```
# mount -t reiserfs /dev/ad1s1 /mnt
```

章 21. Virtualization(虛擬機器)

Contributed by Murray Stokely.

21.1. Synopsis

虛擬機器軟體可以讓同一台機器得以同時執行多種作業系統。 在 PC 上， 通常這類系統都是在宿主(host)機器上裝虛擬機器軟體，來跑一堆 guest OS 。

讀完這章，您將了解：

- host OS 以及 guest OS 的區別。
- 如何在搭載 Intel® CPU 的 Apple® Macintosh® 電腦上安裝 FreeBSD 。
- 如何在 Linux 上以 Xen™ 來安裝 FreeBSD。
- 如何在 Microsoft® Windows® 上以 Virtual PC 安裝 FreeBSD。
- 如何在虛擬機器對 FreeBSD 系統作性能調校，以取得最佳效能。

在開始閱讀這章之前，您需要：

- 瞭解 UNIX® 及 FreeBSD 相關基本概念 (章 3, UNIX 基礎概念)。
- 知道如何安裝 FreeBSD(章 2, 安裝 FreeBSD 9.X 和更新的版本)。
- 知道如何設定網路(章 30, 網路進階練功房)。
- 知道如何以 ports/packages 來安裝應用程式 (章 4, 軟體套件管理篇：Packages 及 Ports 機制)。

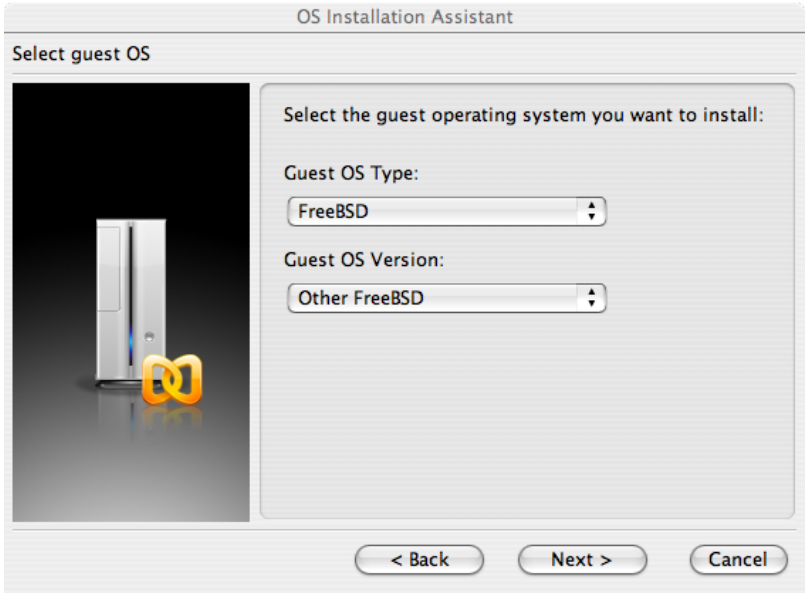
21.2. 安裝 FreeBSD 爲 Guest OS

21.2.1. MacOS 上的 Parallels

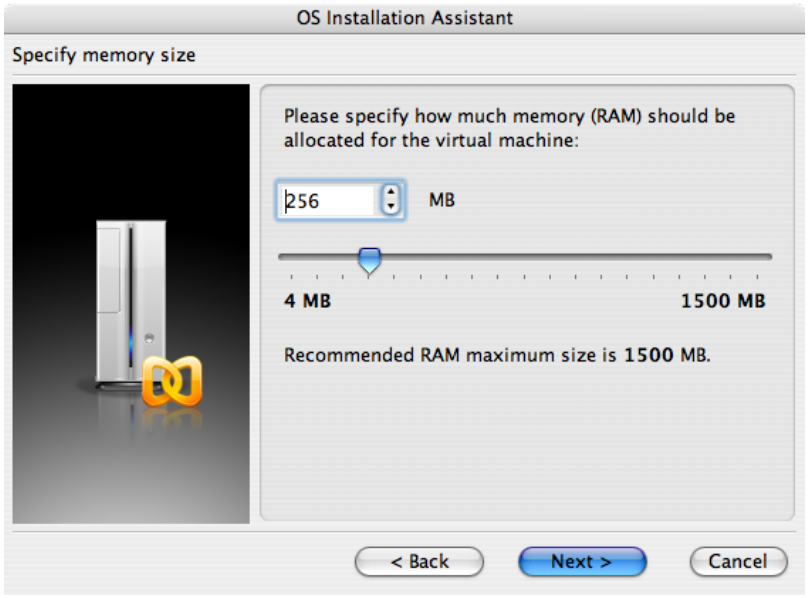
Mac® 版的 Parallels Desktop 乃是可用於搭配 Intel® CPU 以及 Mac OS® 10.4.6 以上的 Apple® Mac® 電腦的商業軟體。 FreeBSD 是其有完整支援的 guest OS 之一。 在 Mac OS® X 裝好 Parallels 後， 必須針對所欲安裝的 guest OS 來作相關的虛擬機器設定。

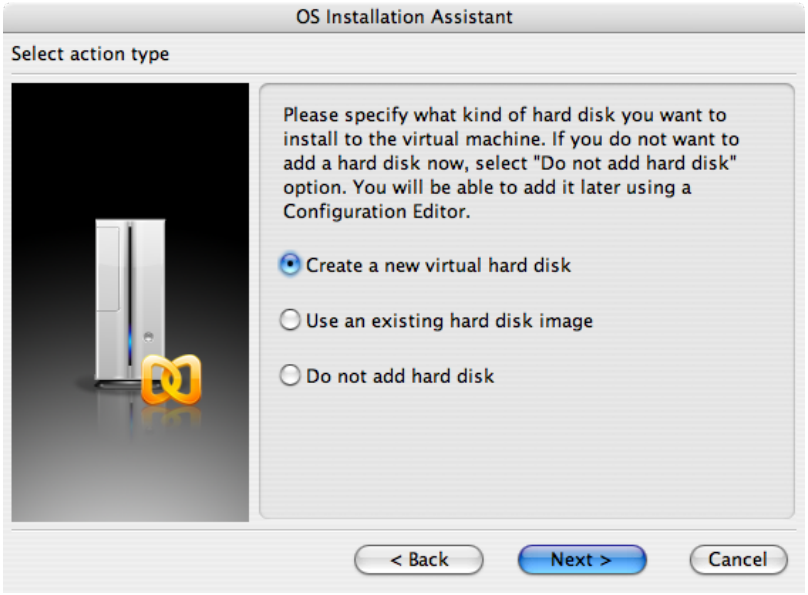
21.2.1.1. 在 Parallels/Mac OS® X 上安裝 FreeBSD

在 Mac OS® X/Parallels 上安裝 FreeBSD 的第一步是新增虛擬機器。 如下所示，在提示視窗內請將 Guest OS Type 勾選為 FreeBSD：

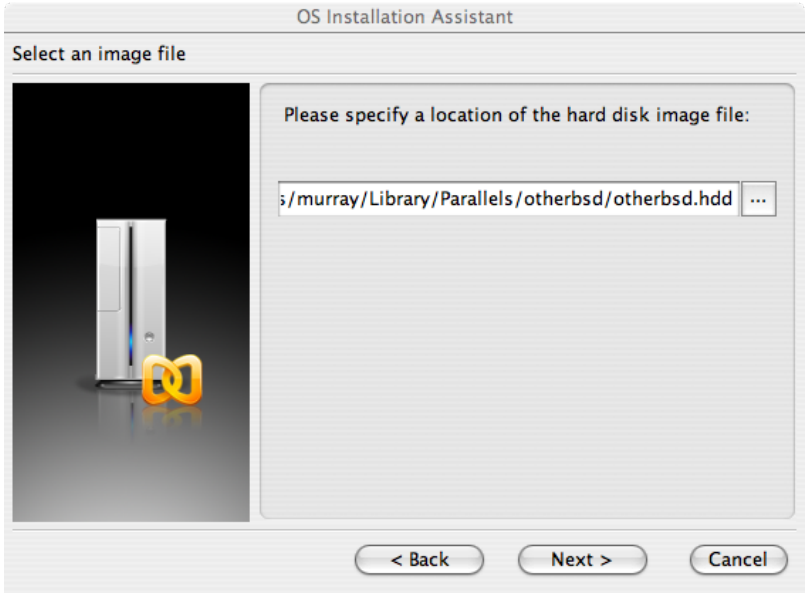


並依據自身需求來規劃硬碟容量跟記憶體的分配。 對大多數在 Parallels 使用的情況而言，大約 4GB 硬碟以及 512MB RAM 就夠用了：

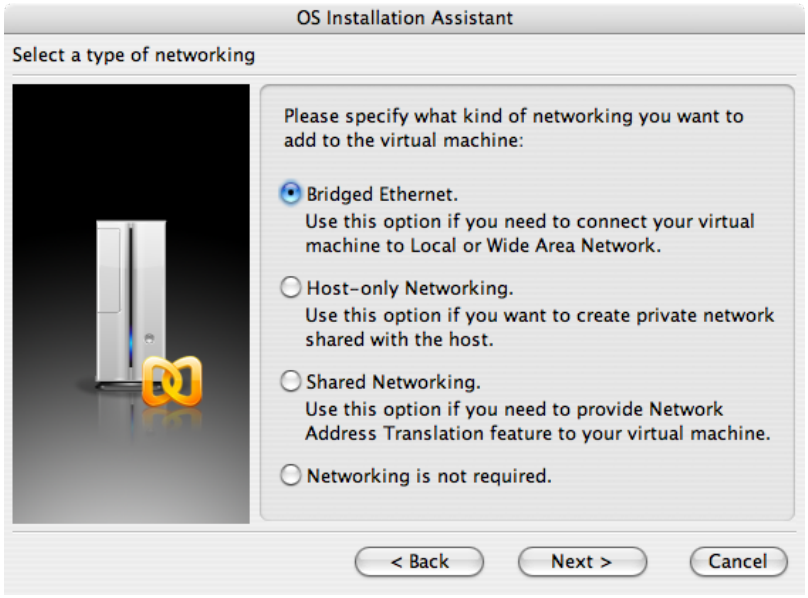


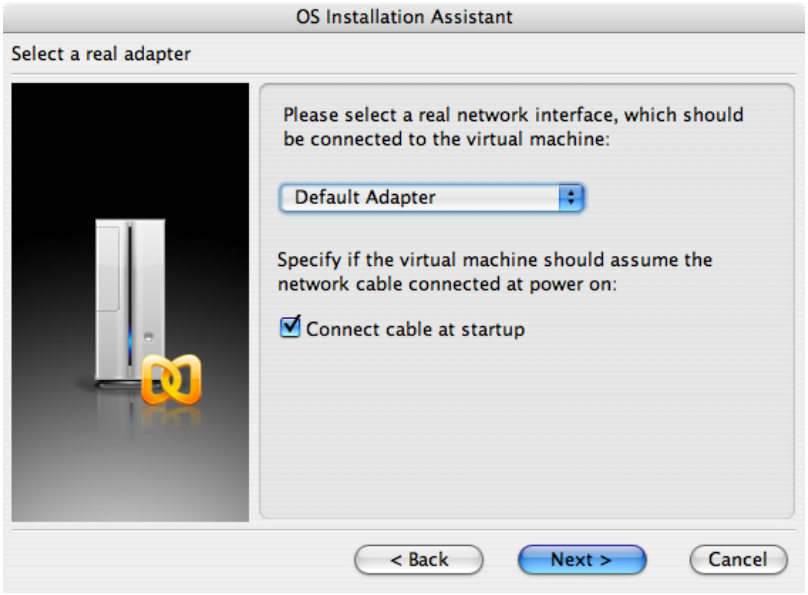

OS Installation Assistant
Select action type
Please specify what kind of hard disk you want to install to the virtual machine. If you do not want to add a hard disk now, select "Do not add hard disk" option. You will be able to add it later using a Configuration Editor.
Create a new virtual hard disk
Use an existing hard disk image
Do not add hard disk
< Back
Next >
Cancel

OS Installation Assistant
Specify hard disk options
Please specify a preferred virtual disk size:
8000
MB
Select disk format:
Expanding (recommended).
Disk image file is small initially and grows as you add more data to the virtual machine. This disk format takes less time to create and saves disk space on the host.
Plain.
Disk image file consumes all the allocated space right from the start. It takes more time to create but allows guest OS to operate faster.
< Back
Next >
Cancel

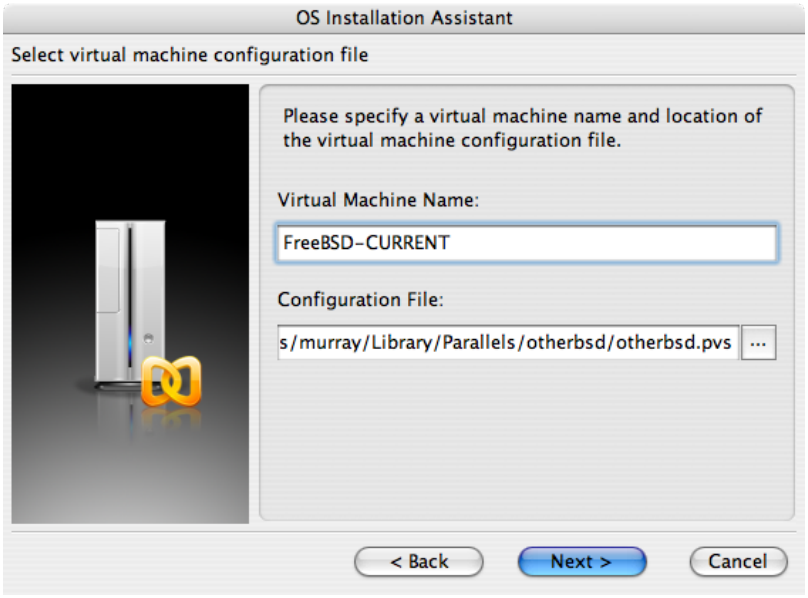


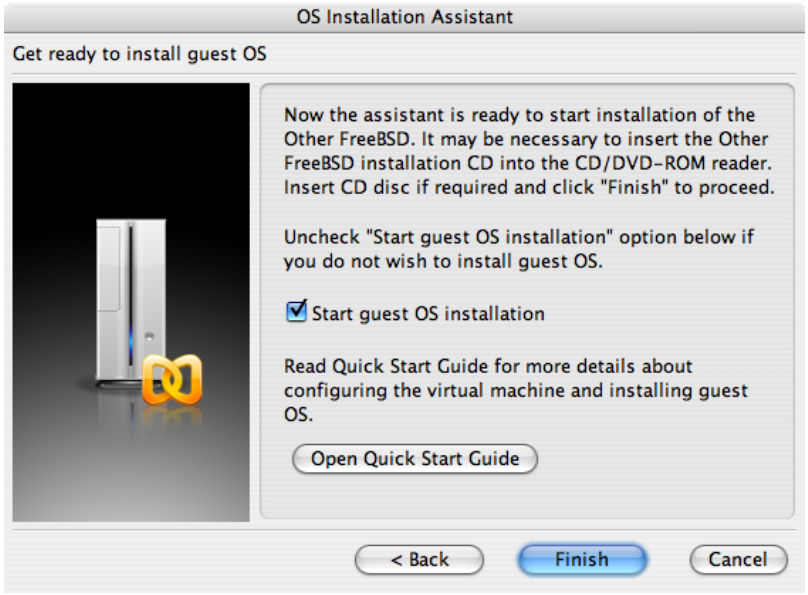
接下來，選擇網路種類以及網路卡：



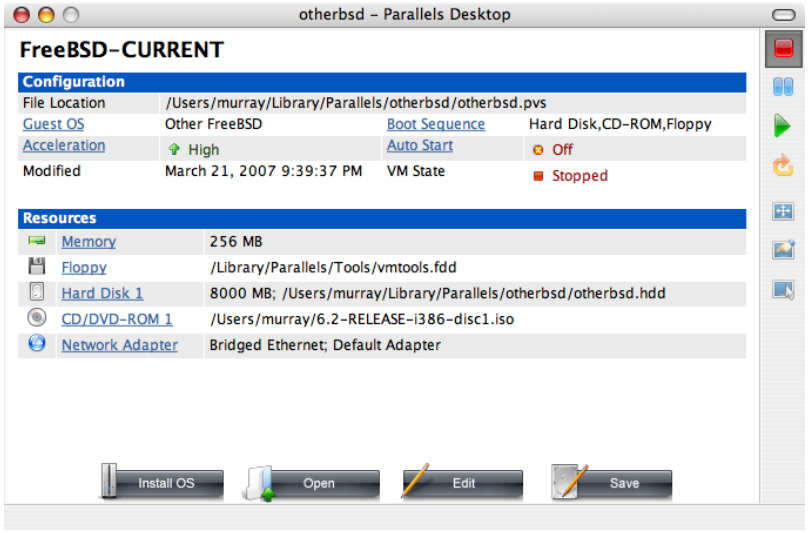


最後，儲存設定檔就完成設定了：

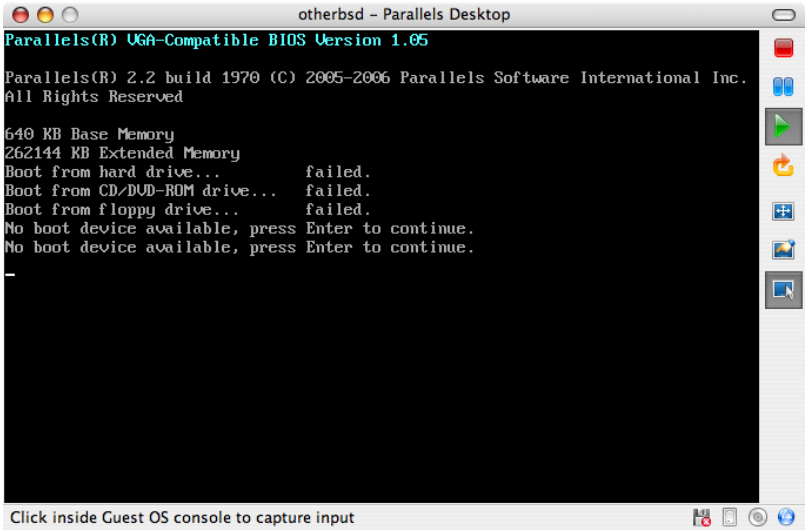




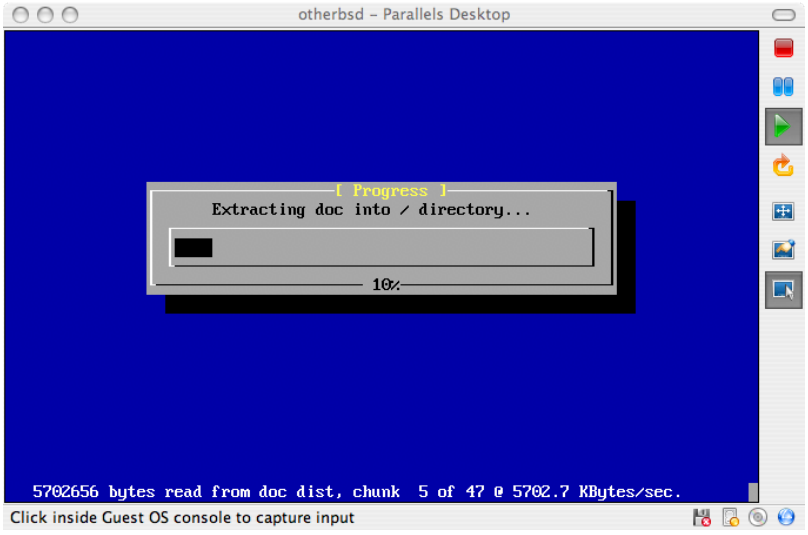
在 FreeBSD 虛擬機器新增後，就可以繼續以其安裝 FreeBSD。 安裝方面，比較好的作法是使用官方的 FreeBSD 光碟或者從官方 FTP 站下載 ISO image 檔。 若您的 Mac® 本機已經有該 ISO 檔， 或者 Mac® 的光碟機內有放安裝片，那麼就可以在 FreeBSD 的 Parallels 視窗右下角按下光碟片圖示。 接著會出現一個視窗，可以把虛擬機器內的光碟機設定到該 ISO 檔， 或者是實體光碟機。



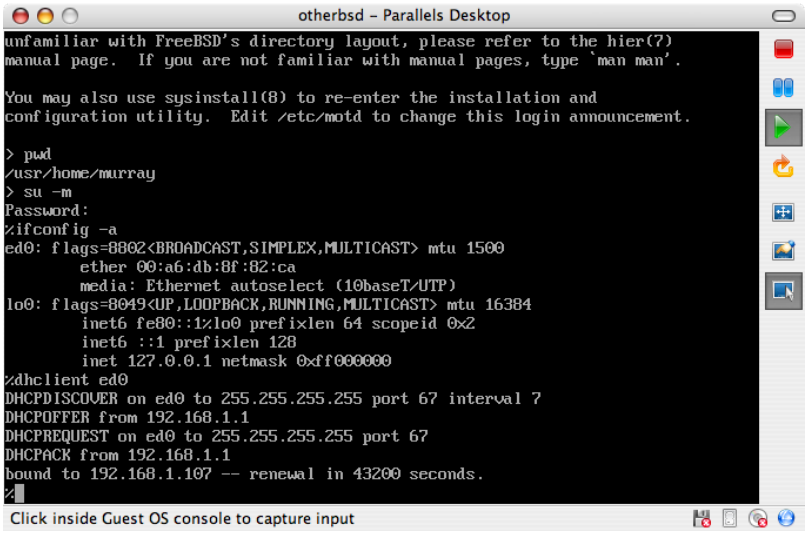
設好光碟片來源之後，就可以按下重開機圖示以重開 FreeBSD 虛擬機器。 Parallels 會以特殊 BIOS 開機，並與普通的 BIOS 一樣會先檢查是否有光碟機。



此時，它就會找到 FreeBSD 安裝片，並開始安裝過程。 這時候也可順便裝 Xorg， 但先不要進行相關設定。



完成安裝過程之後，就可以重開剛裝的 FreeBSD 虛擬機器。



21.2.1.2. 在 Mac OS® X/Parallels 上設定 FreeBSD

把 FreeBSD 成功裝到 Mac OS® X 的 Parallels 之後，還需要作一些設定步驟， 以便將虛擬機器內的 FreeBSD 最佳化。

1. 設定 boot loader 參數

   最重要的步驟乃是藉由調降 `kern.hz` 來降低 Parallels 環境內 FreeBSD 的 CPU 佔用率。 可以在 `/boot/loader.conf` 內加上下列設定即可：

   ```
   kern.hz=100
   ```

   若不作這設定，那麼光是 idle 狀態的 FreeBSD (Parallels guest OS) 就會在僅單一處理器的 iMac® 上佔了大約 15% 的 CPU 佔用率。 作上述修改之後，佔用率就會降至大約 5%。

2. 設定新的 kernel 設定檔

   可以放心把所有 SCSI、FireWire、USB 相關設備都移除。 Parallels 有提供 ed(4) 的虛擬網卡，因此，除了 ed(4) 以及 miibus(4) 以外的其他網路卡也都可以從 kernel 中移除。

3. 設定網路

   可以替虛擬機器簡單用 DHCP 來設定與 Mac® 相同的 LAN 網路環境，只要在 `/etc/rc.conf` 內加上 `ifconfig_ed0="DHCP"` 即可完成。 其他進階的網路設定方式，請參考 章 30, 網路進階練功房。

21.2.2. 在 Linux 透過 Xen™ 跑 FreeBSD

Contributed by Fukang Chen (Loader).

Xen™ hypervisor 乃是開放源碼的 paravirtualization 產品，並由商業公司(XenSource)提供支援。 Guest OS 通常被稱為 domU `domains`，而 host OS 則是被稱為 `dom0`。 在 Linux 上建立 FreeBSD 虛擬機器的第一步，則是安裝 Linux dom0 的 Xen™。 在本例中， host OS 乃是 Slackware `Linux`。

21.2.2.1. 在 Linux dom0 上設定 Xen™ 3

1. 從 XenSource 網站下載 Xen™ 3.0

   從 `http://www.xensource.com/` 下載 xen-3.0.4_1-src.tgz。

2. 解壓縮

   ```
   # cd xen-3.0.4_1-src
   # KERNELS="linux-2.6-xen0 linux-2.6-xenU" make world
   # make install
   ```

注意

為 dom0 重新編譯 `kernel`：

```
# cd xen-3.0.4_1-src/linux-2.6.16.33-xen0
# make menuconfig
# make
# make install
```

舊版的 Xen™ 可能需要用 `make ARCH=xen menuconfig`

3. 增加選項到 Grub 的 menu.lst 選單

   修改 `/boot/grub/menu.lst` 加上下列設定：

```
title Xen-3.0.4
root (hd0,0)
kernel /boot/xen-3.0.4-1.gz dom0_mem=262144
module /boot/vmlinuz-2.6.16.33-xen0 root=/dev/hda1 ro
```

4. 重開機並進入 Xen™

   首先，修改 `/etc/xen/xend-config.sxp` 加上下列設定：

```
(network-script 'network-bridge netdev=eth0')
```

   接下來，就可以啓動 Xen™：

```
# /etc/init.d/xend start
# /etc/init.d/xendomains start
```

   現在 dom0 已經開始運作：

```
# xm list
Name                                        ID   Mem VCPUs      State   Time(s)
Domain-0                                     0   256     1     r-----  54452.9
```

21.2.2.2. FreeBSD 7-CURRENT domU

從 http://www.fsmware.com/ 下載搭配 Xen™ 3.0 的 FreeBSD domU kernel 相關檔案

- kernel-current
- mdroot-7.0.bz2
- xmexample1.bsd

把 `xmexample1.bsd` 設定檔放到 `/etc/xen/` ，並修改 kernel 及 disk image 相關位置。 以下是示範的例子：

```
kernel = "/opt/kernel-current"
memory = 256
name = "freebsd"
vif = [ '' -]
disk = [ 'file:/opt/mdroot-7.0,hda1,w' -]
#on_crash    = 'preserve'
extra = "boot_verbose"
extra += ",boot_single"
extra += ",kern.hz=100"
extra += ",vfs.root.mountfrom=ufs:/dev/xbd769a"
```

其中 `mdroot-7.0.bz2` 檔要記得解壓縮之。

接下來，要修改 `kernel-current` 設定檔的 __xen_guest 小節，並加上 Xen™ 3.0.3 所需的 VIRT_BASE：

```
# objcopy kernel-current -R __xen_guest
# perl -e 'print
 "LOADER=generic,GUEST_OS=freebsd,GUEST_VER=7.0,XEN_VER=xen-3.0,BSD_SYMTAB,VIRT_BASE=0xC0
> tmp
# objcopy kernel-current --add-section __xen_guest=tmp
```

```
# objdump -j __xen_guest -s kernel-current
```

```
kernel-current:     file format elf32-i386

Contents of section __xen_guest:
 0000 4c4f4144 45523d67 656e6572 69632c47  LOADER=generic,G
 0010 55455354 5f4f533d 66726565 6273642c  UEST_OS=freebsd,
 0020 47554553 545f5645 523d372e 302c5845  GUEST_VER=7.0,XE
 0030 4e5f5645 523d7865 6e2d332e 302c4253  N_VER=xen-3.0,BS
 0040 445f5359 4d544142 2c564952 545f4241  D_SYMTAB,VIRT_BA
 0050 53453d30 78433030 30303030 3000      SE=0xC0000000.
```

現在可以新增並啓動 domU 囉：

```
# xm create /etc/xen/xmexample1.bsd -c
Using config file "/etc/xen/xmexample1.bsd".
Started domain freebsd
WARNING: loader(8) metadata is missing!
Copyright (c) 1992-2006 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 1989, 1991, 1992, 1993, 1994
The Regents of the University of California. All rights reserved.
FreeBSD 7.0-CURRENT #113: Wed Jan  4 06:25:43 UTC 2006
    kmacy@freebsd7.gateway.2wire.net:/usr/home/kmacy/p4/freebsd7_xen3/src/sys/i386-xen/
compile/XENCONF
WARNING: DIAGNOSTIC option enabled, expect reduced performance.
Xen reported: 1796.927 MHz processor.
Timecounter "ixen" frequency 1796927000 Hz quality 0
CPU: Intel(R) Pentium(R) 4 CPU 1.80GHz (1796.93-MHz 686-class CPU)
  Origin = "GenuineIntel"  Id = 0xf29  Stepping = 9
  ↺
Features=0xbfebfbff<FPU,VME,DE,PSE,TSC,MSR,PAE,MCE,CX8,APIC,SEP,MTRR,PGE,MCA,CMOV,PAT,PSE36,CLFLUSH,
  DTS,ACPI,MMX,FXSR,SSE,SSE2,SS,HTT,TM,PBE>
  Features2=0x4400<CNTX-ID,<b14>>
real memory  = 265244672 (252 MB)
avail memory = 255963136 (244 MB)
xc0: <Xen Console> on motherboard
cpu0 on motherboard
Timecounters tick every 10.000 msec
[XEN] Initialising virtual ethernet driver.
xn0: Ethernet address: 00:16:3e:6b:de:3a
[XEN]
Trying to mount root from ufs:/dev/xbd769a
WARNING: / was not properly dismounted
Loading configuration files.
No suitable dump device was found.
Entropy harvesting: interrupts ethernet point_to_point kickstart.
Starting file system checks:
/dev/xbd769a: 18859 files, 140370 used, 113473 free (10769 frags, 12838 blocks, 4.2% ↺
fragmentation)
Setting hostname: demo.freebsd.org.
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
   inet6 ::1 prefixlen 128
   inet6 fe80::1%lo0 prefixlen 64 scopeid 0x2
   inet 127.0.0.1 netmask 0xff000000
Additional routing options:.
Mounting NFS file systems:.
Starting syslogd.
/etc/rc: WARNING: Dump device does not exist.  Savecore not run.
ELF ldconfig path: /lib /usr/lib /usr/lib/compat /usr/X11R6/lib /usr/local/lib
a.out ldconfig path: /usr/lib/aout /usr/lib/compat/aout /usr/X11R6/lib/aout
Starting usbd.
usb: Kernel module not available: No such file or directory
Starting local daemons:.
Updating motd.
Starting sshd.
Initial i386 initialization:.
Additional ABI support: linux.
Starting cron.
```

```
Local package initialization:.
Additional TCP options:.
Starting background file system checks in 60 seconds.

Sun Apr  1 02:11:43 UTC 2007

FreeBSD/i386 (demo.freebsd.org) (xc0)

login:
```

現在 domU 應該可以跑 FreeBSD 7.0-CURRENT kernel：

```
# uname -a
FreeBSD demo.freebsd.org 7.0-CURRENT FreeBSD 7.0-CURRENT #113: Wed Jan  4 06:25:43 UTC ↺
2006
kmacy@freebsd7.gateway.2wire.net:/usr/home/kmacy/p4/freebsd7_xen3/src/sys/i386-xen/
compile/XENCONF  i386
```

接下來是設定 domU 的網路，FreeBSD domU 會用代號為 xn0 的特殊網路卡：

```
# ifconfig xn0 10.10.10.200 netmask 255.0.0.0
# ifconfig
xn0: flags=843<UP,BROADCAST,RUNNING,SIMPLEX> mtu 1500
    inet 10.10.10.200 netmask 0xff000000 broadcast 10.255.255.255
    ether 00:16:3e:6b:de:3a
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
      inet6 ::1 prefixlen 128
      inet6 fe80::1%lo0 prefixlen 64 scopeid 0x2
      inet 127.0.0.1 netmask 0xff000000
```

在 dom0 Slackware 上應該會出現一些 Xen™ 專用的網路卡：

```
# ifconfig
eth0      Link encap:Ethernet  HWaddr 00:07:E9:A0:02:C2
          inet addr:10.10.10.130  Bcast:0.0.0.0  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:815 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1400 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:204857 (200.0 KiB)  TX bytes:129915 (126.8 KiB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:16436  Metric:1
          RX packets:99 errors:0 dropped:0 overruns:0 frame:0
          TX packets:99 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:9744 (9.5 KiB)  TX bytes:9744 (9.5 KiB)

peth0     Link encap:Ethernet  HWaddr FE:FF:FF:FF:FF:FF
          UP BROADCAST RUNNING NOARP  MTU:1500  Metric:1
          RX packets:1853349 errors:0 dropped:0 overruns:0 frame:0
          TX packets:952923 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:2432115831 (2.2 GiB)  TX bytes:86528526 (82.5 MiB)
          Base address:0xc000 Memory:ef020000-ef040000

vif0.1    Link encap:Ethernet  HWaddr FE:FF:FF:FF:FF:FF
          UP BROADCAST RUNNING NOARP  MTU:1500  Metric:1
          RX packets:1400 errors:0 dropped:0 overruns:0 frame:0
          TX packets:815 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:129915 (126.8 KiB)  TX bytes:204857 (200.0 KiB)

vif1.0    Link encap:Ethernet  HWaddr FE:FF:FF:FF:FF:FF
```

```
          UP BROADCAST RUNNING NOARP  MTU:1500  Metric:1
          RX packets:3 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2 errors:0 dropped:157 overruns:0 carrier:0
          collisions:0 txqueuelen:1
          RX bytes:140 (140.0 b)  TX bytes:158 (158.0 b)

xenbr1    Link encap:Ethernet  HWaddr FE:FF:FF:FF:FF:FF
          UP BROADCAST RUNNING NOARP  MTU:1500  Metric:1
          RX packets:4 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:112 (112.0 b)  TX bytes:0 (0.0 b)
```

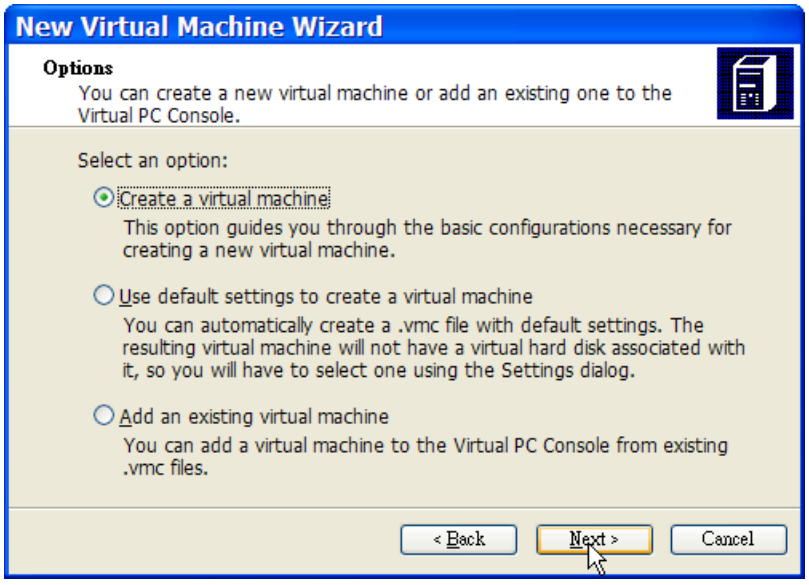
```
# brctl show
bridge name     bridge id           STP enabled         interfaces
xenbr1          8000.feffffffffff   no                  vif0.1
                                                        peth0
                                                        vif1.0
```

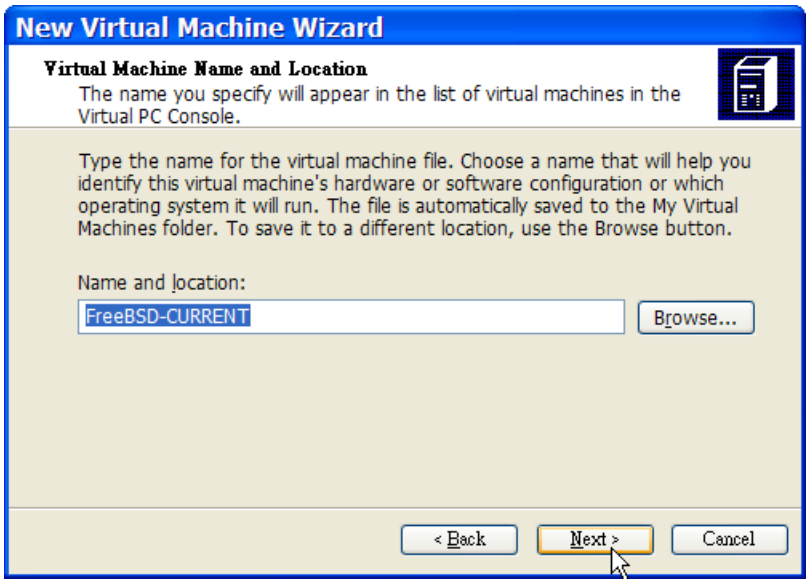
21.2.3. Windows® 上的 Virtual PC

Virtual PC 是 Microsoft® 的 Windows® 軟體產品，可以免費下載使用。 相關系統需求，請參閱 system requirements 說明。 在 Microsoft® Windows® 裝完 Virtual PC 之後， 必須針對所欲安裝的虛擬機器來作相關設定。

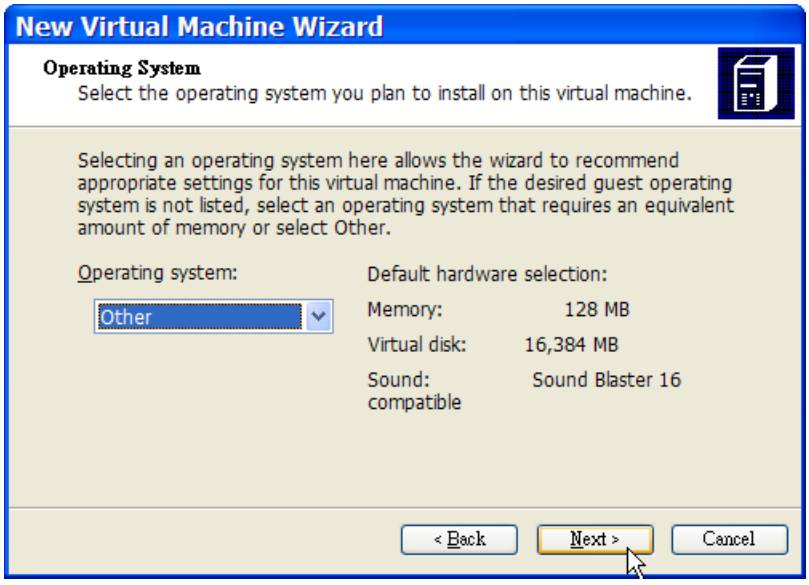
21.2.3.1. 在 Virtual PC/Microsoft® Windows® 上安裝 FreeBSD

在 Microsoft® Windows®/Virtual PC 上安裝 FreeBSD 的第一步是新增虛擬機器。 如下所示， 在提示視窗內請選擇 Create a virtual `machine`：

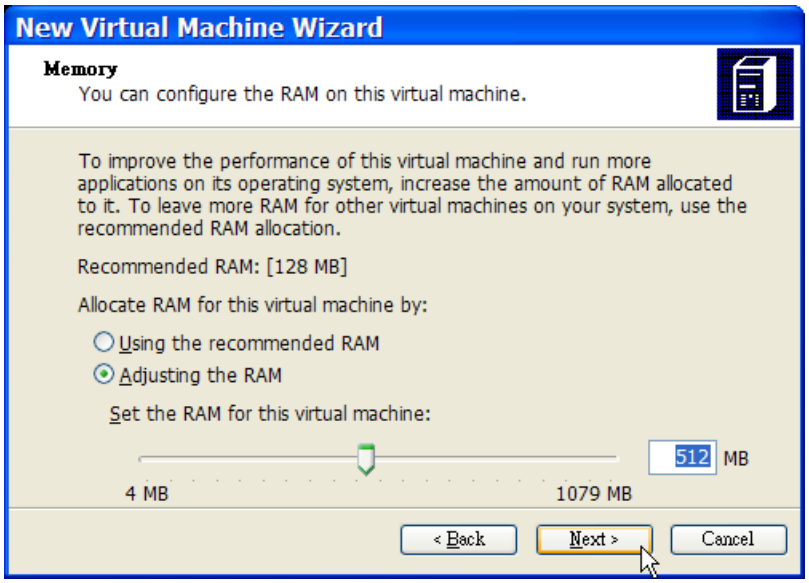


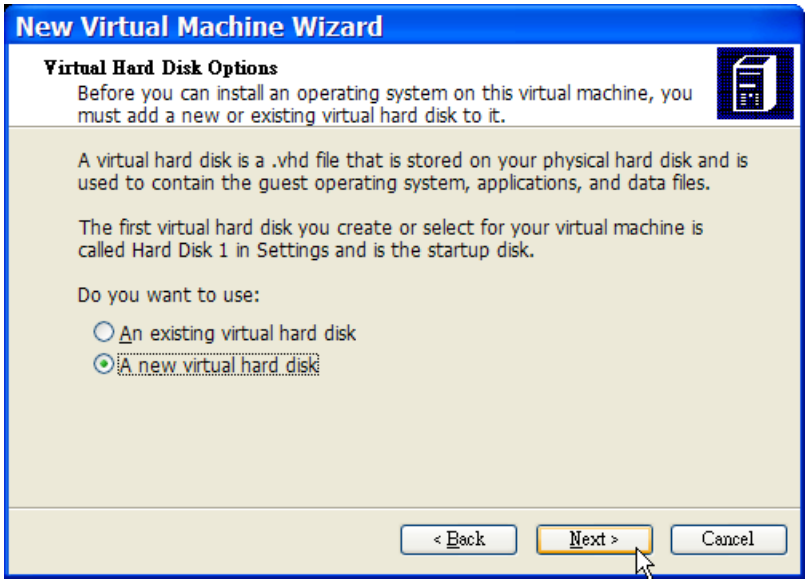


然後在 Operating system 處選 Other：

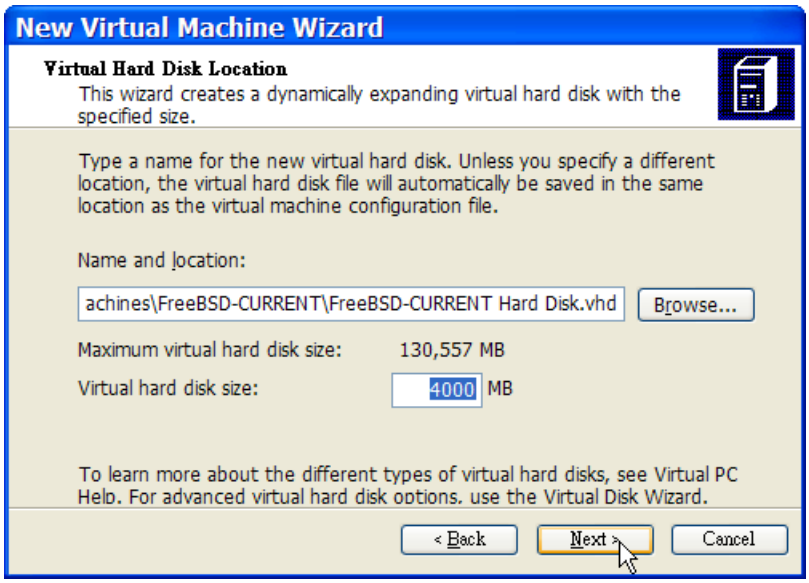


並依據自身需求來規劃硬碟容量跟記憶體的分配。 對大多數在 Virtual PC 使用 FreeBSD 的情況而言，大約 4GB 硬碟空間以及 512MB RAM 就夠用了：

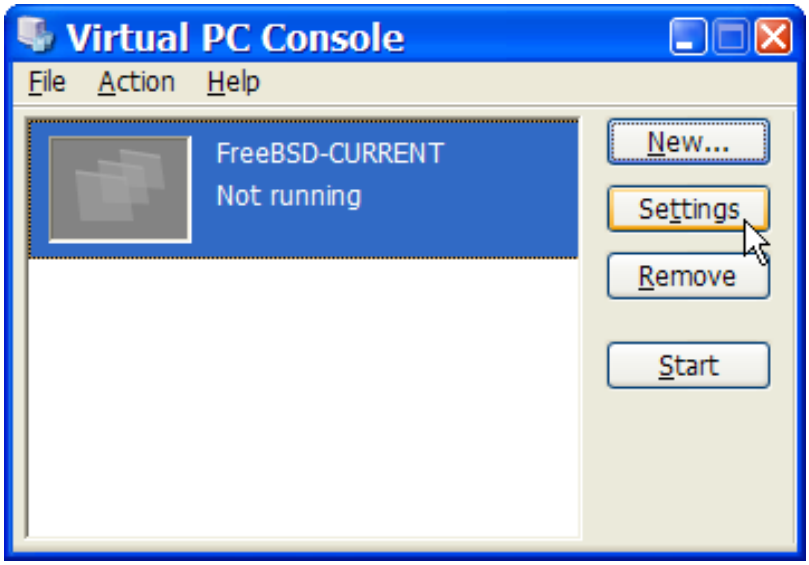

New Virtual Machine Wizard
Memory
You can configure the RAM on this virtual machine.
To improve the performance of this virtual machine and run more applications on its operating system, increase the amount of RAM allocated to it. To leave more RAM for other virtual machines on your system, use the recommended RAM allocation.
Recommended RAM: [128 MB]
Allocate RAM for this virtual machine by:
Using the recommended RAM
Adjusting the RAM
Set the RAM for this virtual machine:
512 MB
4 MB
1079 MB
< Back
Next >
Cancel

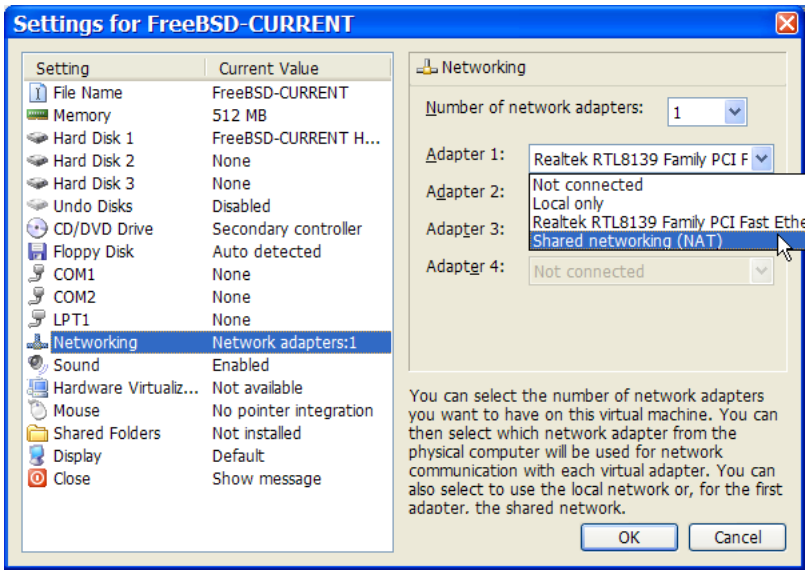

New Virtual Machine Wizard
Virtual Hard Disk Options
Before you can install an operating system on this virtual machine, you must add a new or existing virtual hard disk to it.
A virtual hard disk is a .vhd file that is stored on your physical hard disk and is used to contain the guest operating system, applications, and data files.
The first virtual hard disk you create or select for your virtual machine is called Hard Disk 1 in Settings and is the startup disk.
Do you want to use:
An existing virtual hard disk
A new virtual hard disk
< Back
Next >
Cancel

儲存設定檔：

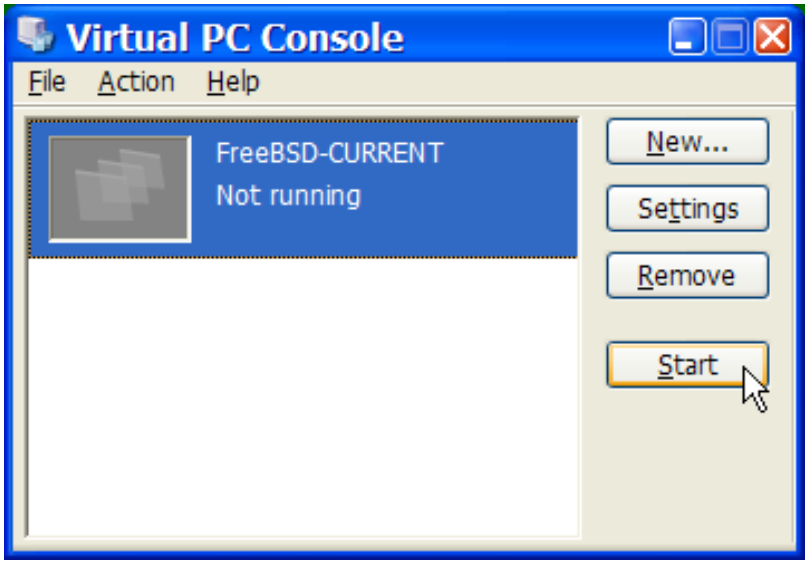


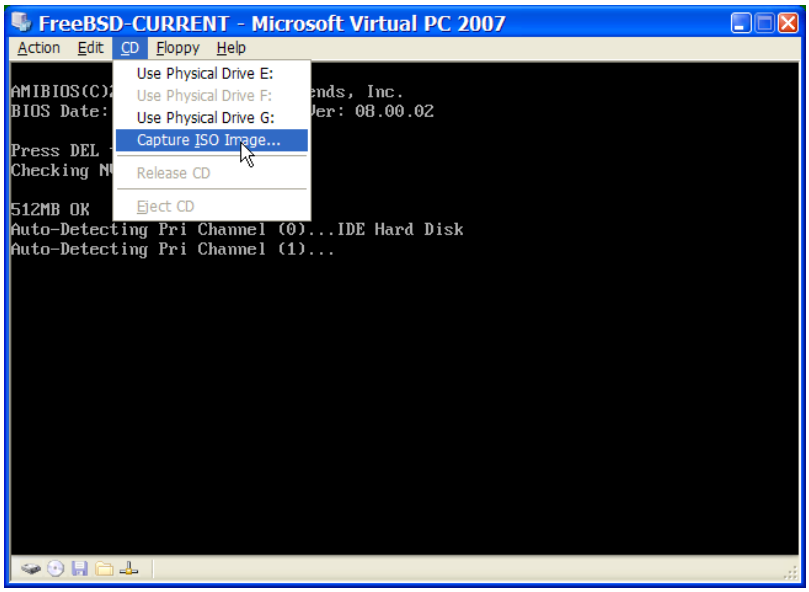
接下來選剛剛所新增的 FreeBSD 虛擬機器，並按下 Settings，以設定網路種類以及網路卡：



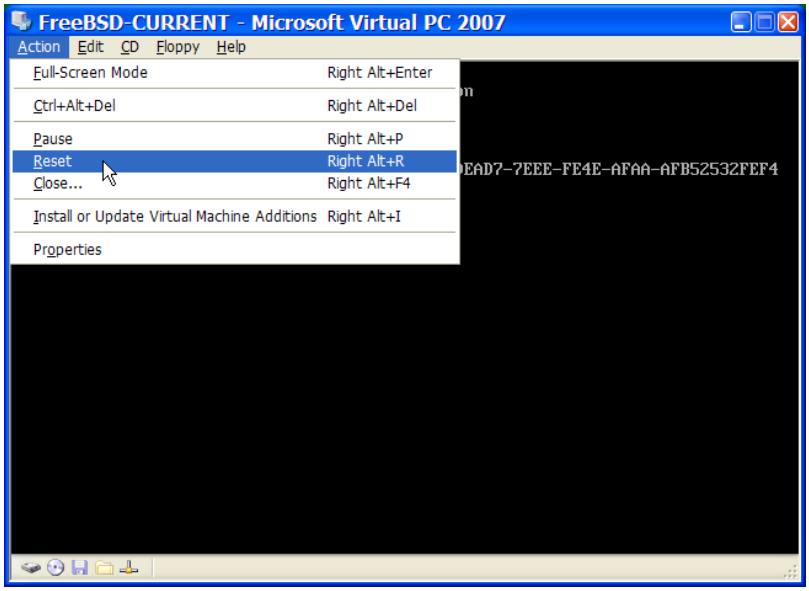


在 FreeBSD 虛擬機器新增後，就可以繼續以其安裝 FreeBSD。 安裝方面，比較好的作法是使用官方的 FreeBSD 光碟或者從官方 FTP 站下載 ISO image 檔。 若您的 Windows® 檔案系統內已經有該 ISO 檔， 或者光碟機內有放安裝片，那麼就可以在 FreeBSD 虛擬機器上連按兩下，以開始啓動。 接著在 Virtual PC 視窗內按 CD 再按 Capture ISO Image... 。 接著會出現一個視窗，可以把虛擬機器內的光碟機設定到該 ISO 檔， 或者是實體光碟機。

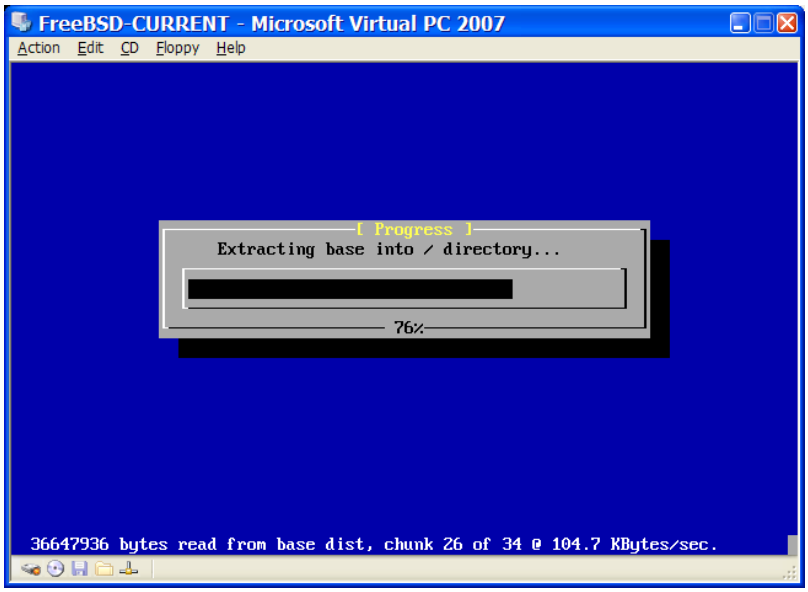




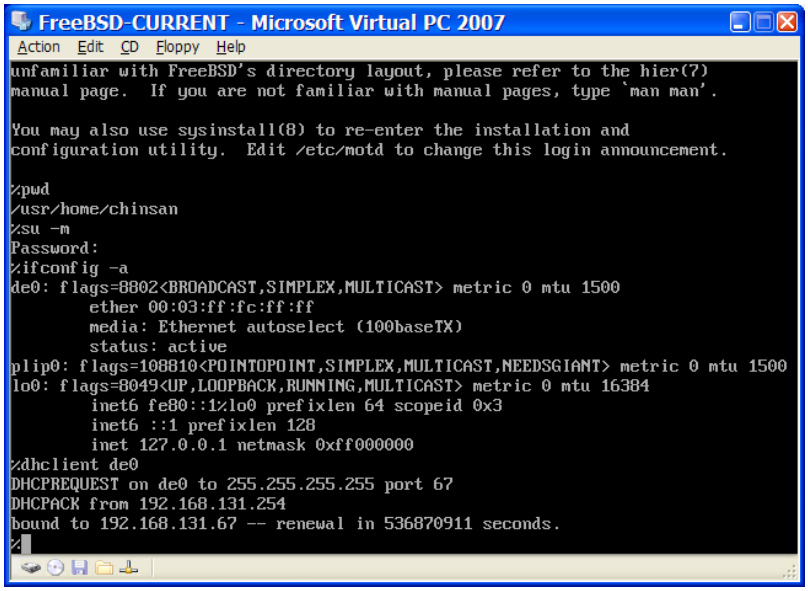
設好光碟片來源之後，就可以重開機，也就是先按 Action 再按 Reset 即可。 Virtual PC 會以特殊 BIOS 開機，並與普通 BIOS 一樣會先檢查是否有光碟機。



此時，它就會找到 FreeBSD 安裝片，並開始安裝過程。 這時候也可順便裝 Xorg， 但先不要進行相關設定。



完成安裝之後，記得把光碟片退出或者 ISO image 退片。 最後， 把裝好的 FreeBSD 虛擬機器重開機即可。



21.2.3.2. 調整 Microsoft® Windows®/Virtual PC 上的 FreeBSD

在 Microsoft® Windows® 上以 Virtual PC 裝好 FreeBSD 後，還需要作一些設定步驟， 以便將虛擬機器內的 FreeBSD 最佳化。

1. 設定 boot loader 參數

   最重要的步驟乃是藉由調降 `kern.hz` 來降低 Virtual PC 環境內 FreeBSD 的 CPU 佔用率。 可以在 `/boot/loader.conf` 內加上下列設定即可：

   ```
   kern.hz=100
   ```

   若不作這設定，那麼光是 idle 狀態的 FreeBSD Virtual PC guest OS 就會在僅單一處理器的電腦上佔了大約 40% 的 CPU 佔用率。 作上述修改之後，佔用率就會降至大約 3%。

2. 設定新的 kernel 設定檔

   可以放心把所有 SCSI、FireWire、USB 相關設備都移除。 Virtual PC 有提供 de(4) 的虛擬網卡，因此除了 de(4) 以及 miibus(4) 以外的其他網路卡也都可以從 kernel 中移除。

3. 設定網路

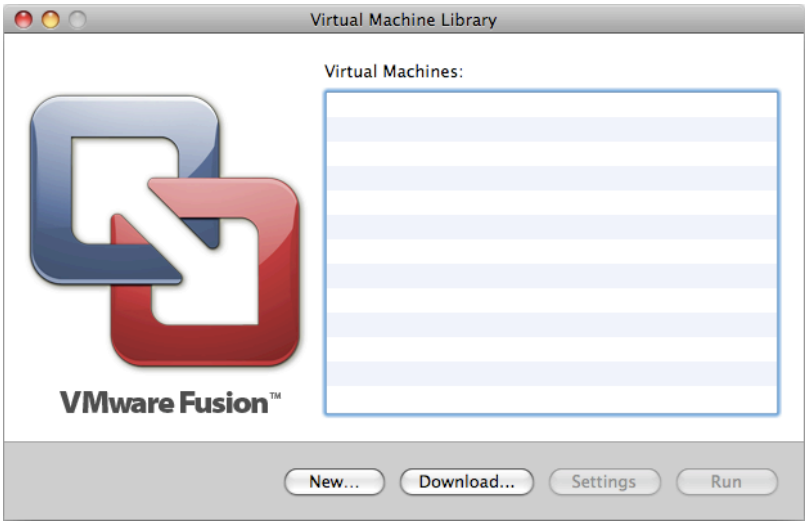
   可以替虛擬機器簡單用 DHCP 來設定與 host(Microsoft® Windows®) 相同的 LAN 網路環境，只要在 `/etc/rc.conf` 加上 `ifconfig_de0="DHCP"` 即可完成。 其他進階的網路設定方式，請參閱 章 30, 網路進階練功房。

21.2.4. 在 MacOS 上的 VMware

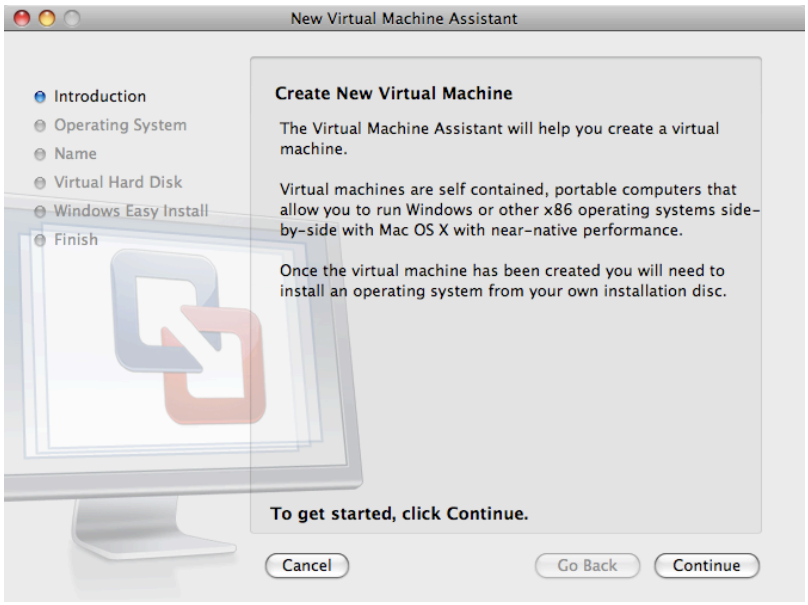
Mac® 上的 VMWare Fusion 乃是可用於搭配 Intel® CPU 以及 Mac OS® 10.4.9 之 Apple® Mac® 以上的 Apple® Mac® 電腦之商業軟體。 FreeBSD 是其有完整支援的 guest OS 之一。 在 Mac OS® X 上裝完 VMWare Fusion 之後， 必須針對所欲安裝的 guest OS 來作相關的虛擬機器設定。

21.2.4.1. 在 VMWare/Mac OS® X 上安裝 FreeBSD

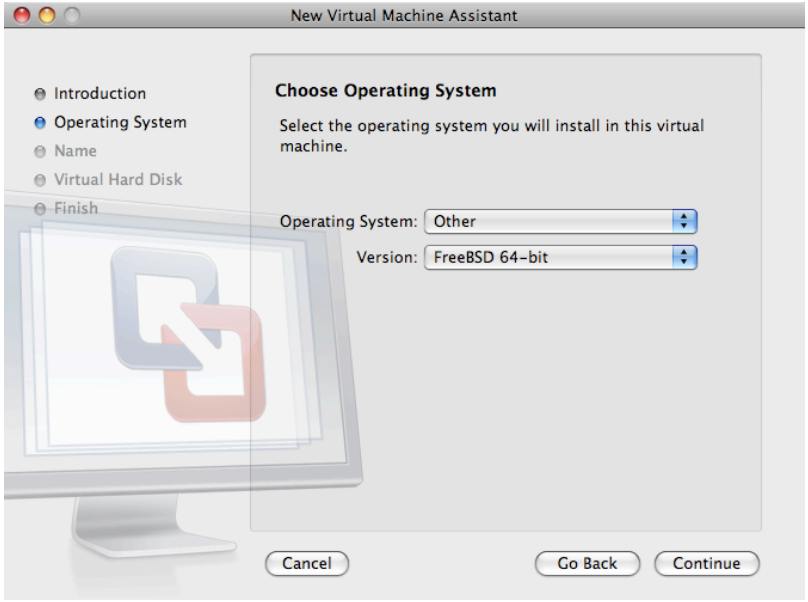
首先執行 VMWare Fusion，而其 Virtual Machine Library 也會隨之一併載入，這時請按 "New" 來建立 VM(虛擬機器)：



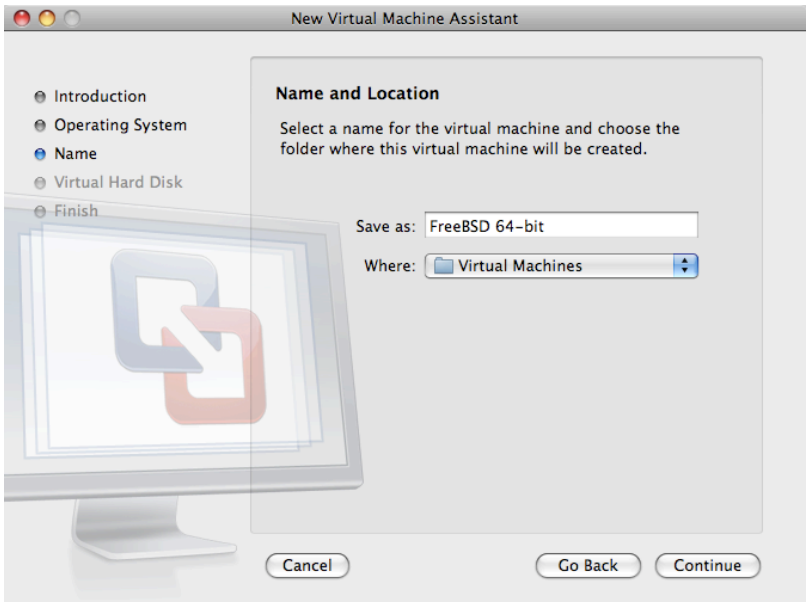
接著會有 New Virtual Machine Assistant 來協助您建立 VM，請按 Continue 繼續：



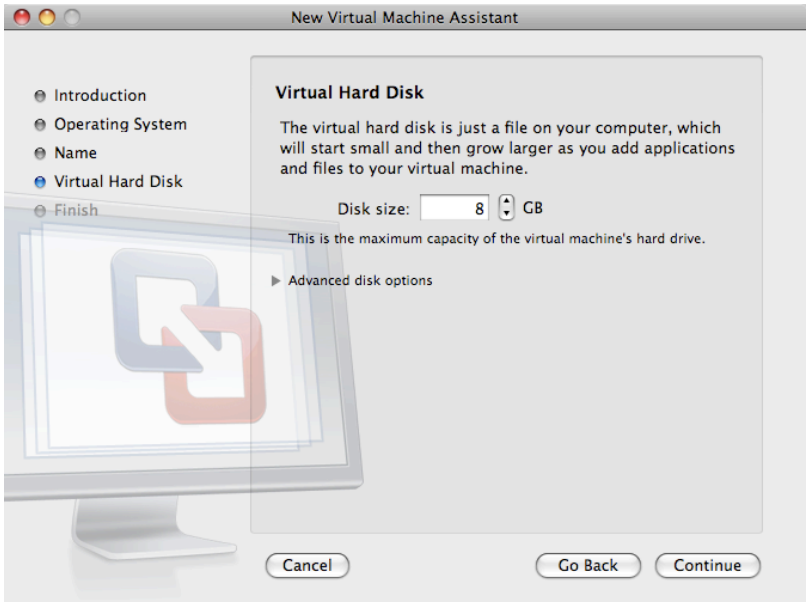
在 Operating System 選 `Other`，以及 Version 處請選擇是否要 FreeBSD 或 FreeBSD 64-`bit`，這部份請依自身需求是否有要 64-bit 支援而定：



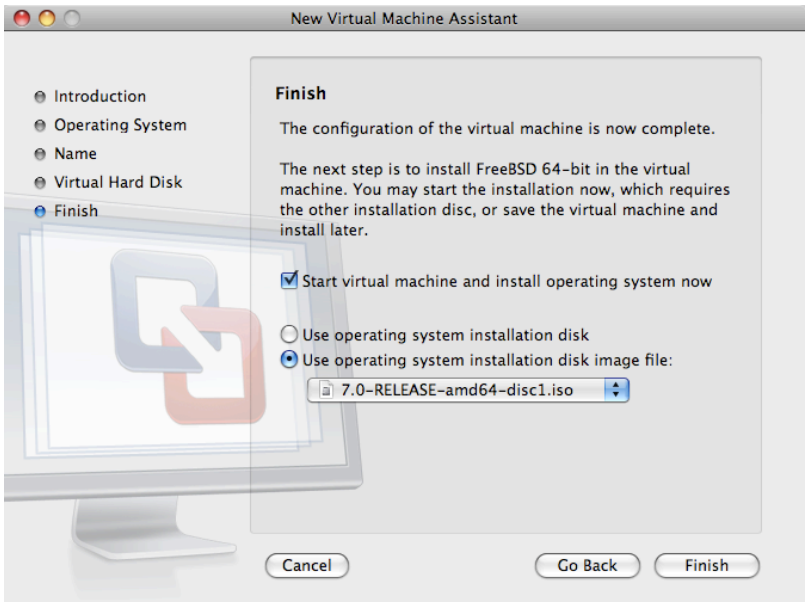
接著設定 VM image 檔要存到何處，以及決定名稱：



決定該 VM 的虛擬硬碟要用多大：

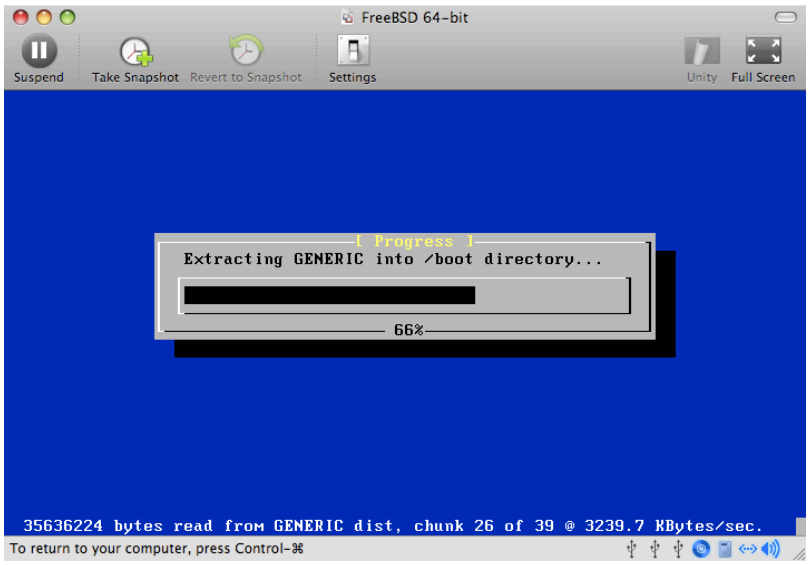


選擇要裝 VM 的方式為何，要用 ISO image 檔或者光碟機：



按 Finish 以完畢，接著就會啓動該 VM：

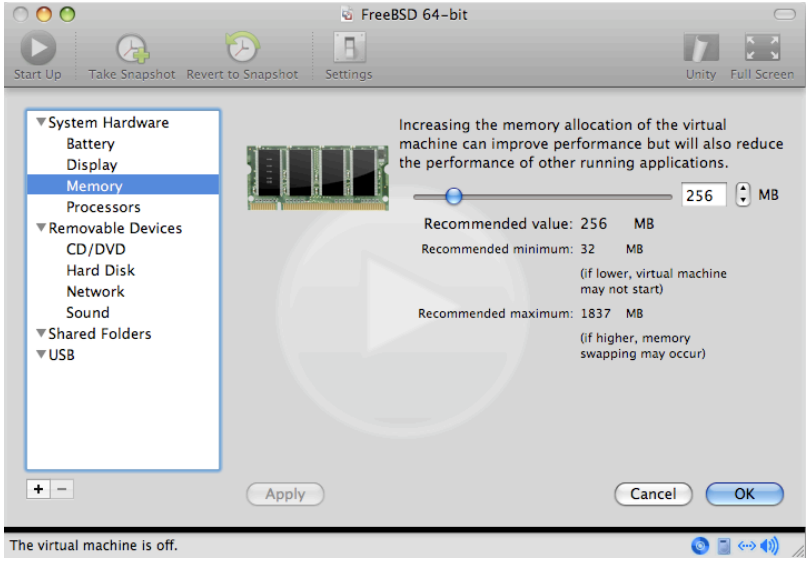
接著就照以往安裝 FreeBSD 的方式來裝，若不熟的話請參閱 章 2, 安裝 FreeBSD 9.X 和更新的版本：



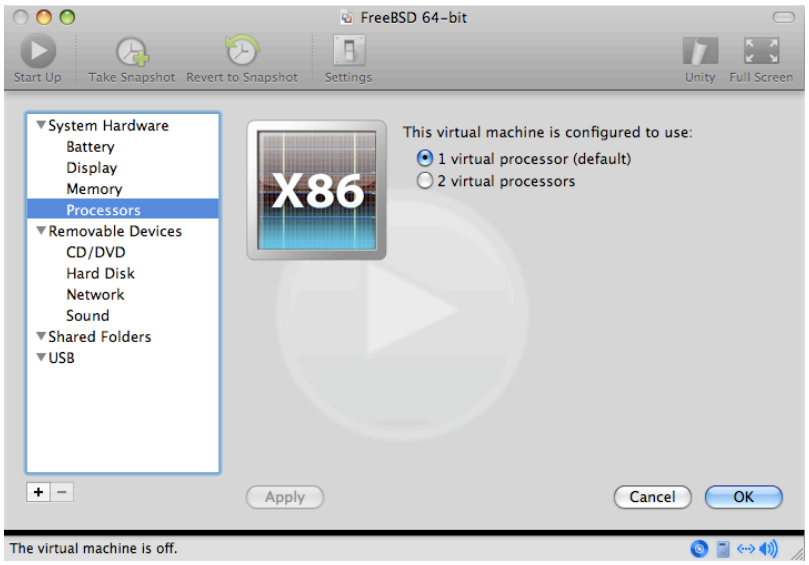
裝完之後，就可以修改一些 VM 設定，像是記憶體大小：

注意

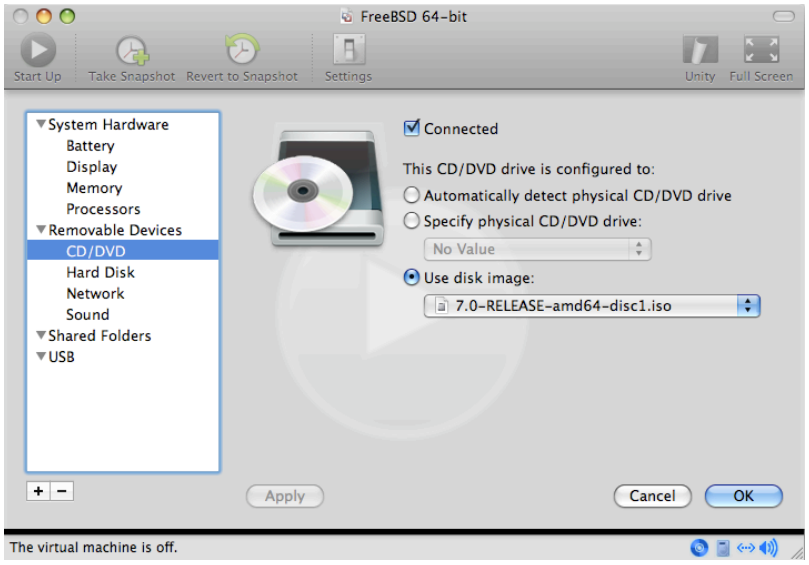
VM 在運作之時，不能修改 VM 的硬體設定。



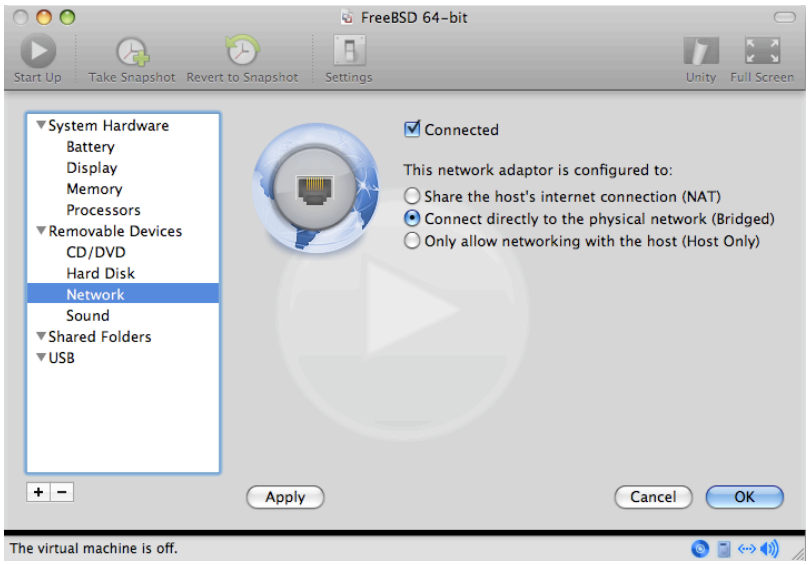
調整 VM 的 CPU 數量：



光碟機狀態，通常不再需要用的時候，就可以切斷其與 VM 的連接：



最後要改的則是 VM 的網路設定。 若除了 Host OS 之外的機器也能連到 `VM`，那麼請選 Connect directly to the physical network (`Bridged`)，否則就選 Share the host's internet connection (NAT) 即可讓 VM 連到 `Internet`，但外面則無法連入該 `VM`。



改完上述設定之後，就可以啓動新裝妥的 FreeBSD 虛擬機器。

21.2.4.2. 調整 Mac OS® X/VMWare 上的 FreeBSD

把 FreeBSD 成功裝到 Mac OS® X 的 VMWare 之後，還需要作一些設定步驟， 以便將虛擬機器內的 FreeBSD 最佳化。

1. 設定 boot loader 參數

   最重要的步驟乃是藉由調降 `kern.hz` 來降低 VMWare 環境內 FreeBSD 的 CPU 佔用率。 可以在 `/boot/loader.conf` 內加上下列設定即可：

   ```
   kern.hz=100
   ```

   若不作這設定，那麼光是 idle 狀態的 FreeBSD (VMWare guest OS) 就會在僅單一處理器的 iMac® 上佔了大約 15% 的 CPU 佔用率。 作上述修改之後， 佔用率就會降至大約 5%。

2. 設定新的 kernel 設定檔

   可以放心把所有 FireWire、USB 相關設備都移除。 VMWare 有提供 em(4) 的虛擬網卡， 因此，除了 em(4) 以及 miibus(4) 以外的其他網路卡， 也都可以從 kernel 中移除。

3. 設定網路

   可以替虛擬機器簡單用 DHCP 來設定與 host Mac® 相同的 LAN 網路環境，只要在 `/etc/rc.conf` 加上 `ifconfig_em0="DHCP"` 即可。 其他進階的網路設定方式，請參考 章 30, 網路進階練功房。

21.3. 以 FreeBSD 爲 Host OS

目前，尚未有任何虛擬機器軟體有官方支援 FreeBSD 作為 host OS， 但蠻多人都有在用舊版 VMware 所提供的這項功能。 不過，目前已經有人為讓 Xen™ 能夠以 FreeBSD 為 host OS 為目標，而進行相關工作。

章 22. 語系設定 - I18N/L10N 用法與設定

Contributed by Andrey Chernov.
Rewritten by Michael C. Wu.

22.1. 概述

由於 FreeBSD 是分佈全世界的使用者及志工所支持的計畫，本章主要探討的是 FreeBSD 的國際化、本土化議題，以便讓母語不是英語系的人也能順利完成各項工作。 在作業系統、應用程式兩種層面，主要都是透過 i18n 標準來實作的，所以， 這裡我們將會介紹大致運作方式。

讀完這章，您將了解：

- 各種不同的語言與地區設定如何在作業系統上進行編碼。
- 如何設定登入用的 shell 語系環境。
- 如何將你的 console 設為英語以外的語系設定。
- 如何使用不同語系的設定，來讓 X Window 運作更親切。
- 哪邊可以找到更多與 i18n 規格相容的應用程式規格資料。

在開始閱讀這章之前，您需要：

- 知道如何以 ports/packages 來安裝應用程式(章 4, 軟體套件管理篇：Packages 及 Ports 機制)。

22.2. L10N 基礎概念

22.2.1. 什麼是 I18N/L10N?

程式開發人員習慣把 internationalization 縮寫為 I18N，中間的數字 18 乃是最前與最後面字母之間的字母個數總和， 而 L10N 也是以一樣的方式，是 “localization” 的縮寫。 只要有符合 I18N/L10N 規格、協定的應用程式，就可以讓使用者依各自語系而作設定。

I18N 應用程式是以 I18N 開發工具來進行開發的， 它可以讓程式開發人員透過寫簡單的文字檔，就可以把執行畫面上的選單、訊息翻譯為各語系的版本。 我們強烈建議程式開發人員遵循這個遊戲規則。

22.2.2. 爲何該使用 I18N/L10N？

只要有符合 I18N/L10N 標準，就可以輕鬆地看、輸入、處理非英文的資料。

22.2.3. I18N 支援哪些語系？

I18N 和 L10N 並非 FreeBSD 所特有的，目前這世界上的幾乎任一主要語系都有支援， 像是：中文、德文、日文、韓文、法文、俄文、越南文等等。

22.3. 使用語系設定(Localization)

I18N 和 L10N 並非 FreeBSD 所特有的，而是共通的遊戲規則。 我們鼓勵你在 FreeBSD 世界中同樣遵守這項遊戲規則。

Locale 設定由三個部分所組成：語言代碼(Language Code)、國碼(Country Code)、編碼(Encoding)。 所以，Locale 的設定名稱就是由這三個一起組成：

```
####_##.##
```

22.3.1. 語言、國碼

使用者必須要先知道這些特定的國碼、語言代碼(國碼會告訴應用程式該使用哪一種語言)， 才能讓 FreeBSD 或其他支援 I18N 的 UNIX® 類系統作 locale 相關設定。 此外，網頁瀏覽器(borwser)、SMTP/POP 主機、Web 主機等也都以這架構為主。 下面是如何使用『語言代碼、國碼』的例子：

語言代碼/國碼	簡介
en_US	英文(美國)
ru_RU	俄文(俄國)
zh_TW	正體中文(台灣)

22.3.2. 編碼

有些語言並非採用 ASCII 編碼，可能是： 8-bit、wide 或 multibyte 字元，詳情請參閱 multibyte(3)。 較古早的程式可能無法正確判別、或誤判為特殊控制字元。而較新的程式都可以辨認 8-bit 字元。 由於各程式的作法不一，使用者可能需要在編譯程式時，加上 wide 或 multibyte 字元的支援設定，或是正確調整才行。 要輸入、處理 wide 或 multibyte 字元的話，可多多利用 FreeBSD Ports Collection 內有各國語言版本的程式。 詳情請參閱 FreeBSD 各 port 中的 I18N 相關文件。

Specifically, the user needs to look at the application documentation to decide on how to configure it correctly or to pass correct values into the configure/Makefile/compiler.

Some things to keep in mind are:

- Language specific single C chars character sets (see multibyte(3)), e.g. ISO8859-1, ISO8859-15, KOI8-R, CP437.
- Wide or multibyte encodings, e.g. EUC, Big5.

You can check the active list of character sets at the IANA Registry.

注意

FreeBSD use X11-compatible locale encodings instead.

22.3.3. I18N Applications

In the FreeBSD Ports and Package system, I18N applications have been named with `I18N` in their names for easy identification. However, they do not always support the language needed.

22.3.4. Setting Locale

Usually it is sufficient to export the value of the locale name as `LANG` in the login shell. This could be done in the user's `~/.login_conf` file or in the startup file of the user's shell (`~/.profile`, `~/.bashrc`, `~/.cshrc`). There is no need to set the locale subsets such as `LC_CTYPE`, `LC_CTIME`. Please refer to language-specific FreeBSD documentation for more information.

You should set the following two environment variables in your configuration files:

- `LANG` for POSIX® setlocale(3) family functions
- `MM_CHARSET` for applications' MIME character set

This includes the user shell configuration, the specific application configuration, and the X11 configuration.

22.3.4.1. Setting Locale Methods

There are two methods for setting locale, and both are described below. The first (recommended one) is by assigning the environment variables in login class, and the second is by adding the environment variable assignments to the system's shell startup file.

22.3.4.1.1. Login Classes Method

This method allows environment variables needed for locale name and MIME character sets to be assigned once for every possible shell instead of adding specific shell assignments to each shell's startup file. User Level Setup can be done by an user himself and Administrator Level Setup require superuser privileges.

22.3.4.1.1.1. User Level Setup

Here is a minimal example of a `.login_conf` file in user's home directory which has both variables set for Latin-1 encoding:

```
me:\
 :charset=ISO-8859-1:\
 :lang=de_DE.ISO8859-1:
```

Here is an example of a `.login_conf` that sets the variables for Traditional Chinese in BIG-5 encoding. Notice the many more variables set because some software does not respect locale variables correctly for Chinese, Japanese, and Korean.

```
#Users who do not wish to use monetary units or time formats
#of Taiwan can manually change each variable
me:\
 :lang=zh_TW.Big5:\
 :lc_all=zh_TW.Big:\
 :lc_collate=zh_TW.Big5:\
 :lc_ctype=zh_TW.Big5:\
 :lc_messages=zh_TW.Big5:\
 :lc_monetary=zh_TW.Big5:\
 :lc_numeric=zh_TW.Big5:\
 :lc_time=zh_TW.Big5:\
 :charset=big5:\
 :xmodifiers="@im=xcin": #Setting the XIM Input Server
```

See Administrator Level Setup and login.conf(5) for more details.

22.3.4.1.1.2. Administrator Level Setup

Verify that the user's login class in `/etc/login.conf` sets the correct language. Make sure these settings appear in `/etc/login.conf` :

```
language_name :accounts_title :\
 :charset=MIME_charset :\
 :lang=locale_name :\
 :tc=default:
```

So sticking with our previous example using Latin-1, it would look like this:

```
german:German Users Accounts:\
 :charset=ISO-8859-1:\
```

```
 :lang=de_DE.ISO8859-1:\
 :tc=default:
```

Before changing users Login Classes execute the following command

```
# cap_mkdb /etc/login.conf
```

to make new configuration in `/etc/login.conf` visible to the system.

Changing Login Classes with vipw(8)

Use `vipw` to add new users, and make the entry look like this:

```
user:password:1111:11:language:0:0:User Name:/home/user:/bin/sh
```

Changing Login Classes with adduser(8)

Use `adduser` to add new users, and do the following:

- Set `defaultclass = language` in `/etc/adduser.conf`. Keep in mind you must enter a `default` class for all users of other languages in this case.
- An alternative variant is answering the specified language each time that

  ```
  Enter login class: default []:
  ```

  appears from adduser(8).
- Another alternative is to use the following for each user of a different language that you wish to add:

  ```
  # adduser -class language
  ```

Changing Login Classes with pw(8)

If you use pw(8) for adding new users, call it in this form:

```
# pw useradd user_name -L language
```

22.3.4.1.2. Shell Startup File Method

注意

This method is not recommended because it requires a different setup for each possible shell program chosen. Use the Login Class Method instead.

To add the locale name and MIME character set, just set the two environment variables shown below in the `/etc/profile` and/or `/etc/csh.login` shell startup files. We will use the German language as an example below:

In `/etc/profile` :

```
LANG=de_DE.ISO8859-1; export LANG
MM_CHARSET=ISO-8859-1; export MM_CHARSET
```

Or in `/etc/csh.login` :

```
setenv LANG de_DE.ISO8859-1
```

```
setenv MM_CHARSET ISO-8859-1
```

Alternatively, you can add the above instructions to `/usr/share/skel/dot.profile` (similar to what was used in `/etc/profile` above), or `/usr/share/skel/dot.login` (similar to what was used in `/etc/csh.login` above).

For X11:

In `$HOME/.xinitrc` :

```
LANG=de_DE.ISO8859-1; export LANG
```

Or:

```
setenv LANG de_DE.ISO8859-1
```

Depending on your shell (see above).

22.3.5. Console Setup

For all single C chars character sets, set the correct console fonts in `/etc/rc.conf` for the language in question with:

```
font8x16=font_name
font8x14=font_name
font8x8=font_name
```

The *font_name* here is taken from the `/usr/share/syscons/fonts` directory, without the `.fnt` suffix.

Also be sure to set the correct keymap and screenmap for your single C chars character set through `sysinstall` (`/stand/sysinstall` in FreeBSD versions older than 5.2). Once inside sysinstall, choose Configure, then Console. Alternatively, you can add the following to `/etc/rc.conf` :

```
scrnmap=screenmap_name
keymap=keymap_name
keychange="fkey_number sequence "
```

The *screenmap_name* here is taken from the `/usr/share/syscons/scrnmaps` directory, without the `.scm` suffix. A screenmap with a corresponding mapped font is usually needed as a workaround for expanding bit 8 to bit 9 on a VGA adapter's font character matrix in pseudographics area, i.e., to move letters out of that area if screen font uses a bit 8 column.

If you have the moused daemon enabled by setting the following in your `/etc/rc.conf` :

```
moused_enable="YES"
```

then examine the mouse cursor information in the next paragraph.

By default the mouse cursor of the syscons(4) driver occupies the 0xd0-0xd3 range in the character set. If your language uses this range, you need to move the cursor's range outside of it. To enable the workaround for FreeBSD, add the following line to `/etc/rc.conf` :

```
mousechar_start=3
```

The *keymap_name* here is taken from the `/usr/share/syscons/keymaps` directory, without the `.kbd` suffix. If you are uncertain which keymap to use, you use can kbdmap(1) to test keymaps without rebooting.

The `keychange` is usually needed to program function keys to match the selected terminal type because function key sequences cannot be defined in the key map.

Also be sure to set the correct console terminal type in `/etc/ttys` for all `ttyv*` entries. Current pre-defined correspondences are:

Character Set	Terminal Type
ISO8859-1 or ISO8859-15	`cons25l1`
ISO8859-2	`cons25l2`
ISO8859-7	`cons25l7`
KOI8-R	`cons25r`
KOI8-U	`cons25u`
CP437 (VGA default)	`cons25`
US-ASCII	`cons25w`

For wide or multibyte characters languages, use the correct FreeBSD port in your `/usr/ports/language` directory. Some ports appear as console while the system sees it as serial vtty's, hence you must reserve enough vtty's for both X11 and the pseudo-serial console. Here is a partial list of applications for using other languages in console:

Language	Location
Traditional Chinese (BIG-5)	chinese/big5con
Japanese	japanese/kon2-16dot or japanese/mule-freewnn
Korean	korean/han

22.3.6. X11 Setup

Although X11 is not part of the FreeBSD Project, we have included some information here for FreeBSD users. For more details, refer to the Xorg web site or whichever X11 Server you use.

In `~/.Xresources` , you can additionally tune application specific I18N settings (e.g., fonts, menus, etc.).

22.3.6.1. Displaying Fonts

Install Xorg server (x11-servers/xorg-server) or XFree86™ server (x11-servers/XFree86-4-Server), then install the language TrueType® fonts. Setting the correct locale should allow you to view your selected language in menus and such.

22.3.6.2. Inputting Non-English Characters

The X11 Input Method (XIM) Protocol is a new standard for all X11 clients. All X11 applications should be written as XIM clients that take input from XIM Input servers. There are several XIM servers available for different languages.

22.3.7. Printer Setup

Some single C chars character sets are usually hardware coded into printers. Wide or multibyte character sets require special setup and we recommend using apsfilter. You may also convert the document to PostScript® or PDF formats using language specific converters.

22.3.8. Kernel and File Systems

The FreeBSD fast filesystem (FFS) is 8-bit clean, so it can be used with any single C chars character set (see multibyte(3)), but there is no character set name stored in the filesystem; i.e., it is raw 8-bit and does not know anything about encoding order. Officially, FFS does not support any form of wide or multibyte character sets yet. However, some wide or multibyte character sets have independent patches for FFS enabling such support. They are

only temporary unportable solutions or hacks and we have decided to not include them in the source tree. Refer to respective languages' web sites for more information and the patch files.

The FreeBSD MS-DOS® filesystem has the configurable ability to convert between MS-DOS®, Unicode character sets and chosen FreeBSD filesystem character sets. See mount_msdos(8) for details.

22.4. Compiling I18N Programs

Many FreeBSD Ports have been ported with I18N support. Some of them are marked with -I18N in the port name. These and many other programs have built in support for I18N and need no special consideration.

However, some applications such as MySQL need to be have the `Makefile` configured with the specific charset. This is usually done in the `Makefile` or done by passing a value to configure in the source.

22.5. Localizing FreeBSD to Specific Languages

22.5.1. Russian Language (KOI8-R Encoding)

Originally contributed by Andrey Chernov.

For more information about KOI8-R encoding, see the KOI8-R References (Russian Net Character Set).

22.5.1.1. Locale Setup

Put the following lines into your `~/.login_conf` file:

```
me:My Account:\
 :charset=KOI8-R:\
 :lang=ru_RU.KOI8-R:
```

See earlier in this chapter for examples of setting up the locale.

22.5.1.2. Console Setup

- Add the following line to your `/etc/rc.conf` file:

  ```
  mousechar_start=3
  ```

- Also, use following settings in `/etc/rc.conf` :

  ```
  keymap="ru.koi8-r"
  scrnmap="koi8-r2cp866"
  font8x16="cp866b-8x16"
  font8x14="cp866-8x14"
  font8x8="cp866-8x8"
  ```

- For each `ttyv*` entry in `/etc/ttys` , use `cons25r` as the terminal type.

See earlier in this chapter for examples of setting up the console.

22.5.1.3. Printer Setup

Since most printers with Russian characters come with hardware code page CP866, a special output filter is needed to convert from KOI8-R to CP866. Such a filter is installed by default as `/usr/libexec/lpr/ru/koi2alt` . A Russian printer `/etc/printcap` entry should look like:

```
lp|Russian local line printer:\
 :sh:of=/usr/libexec/lpr/ru/koi2alt:\
 :lp=/dev/lpt0:sd=/var/spool/output/lpd:lf=/var/log/lpd-errs:
```

See printcap(5) for a detailed description.

22.5.1.4. MS-DOS® FS and Russian Filenames

The following example fstab(5) entry enables support for Russian filenames in mounted MS-DOS® filesystems:

```
/dev/ad0s2      /dos/c  msdos   rw,-Wkoi2dos,-Lru_RU.KOI8-R 0 0
```

The option `-L` selects the locale name used, and `-W` sets the character conversion table. To use the `-W` option, be sure to mount `/usr` before the MS-DOS® partition because the conversion tables are located in `/usr/libdata/msdosfs` . For more information, see the mount_msdos(8) manual page.

22.5.1.5. X11 Setup

1. Do non-X locale setup first as described.
2. If you use Xorg, install x11-fonts/xorg-fonts-cyrillic package.

   Check the `"Files"` section in your `/etc/X11/xorg.conf` file. The following lines must be added before any other `FontPath` entries:

   ```
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/misc"
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/75dpi"
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/100dpi"
   ```

   If you use a high resolution video mode, swap the 75 dpi and 100 dpi lines.
3. To activate a Russian keyboard, add the following to the `"Keyboard"` section of your `xorg.conf` file.

   ```
   Option "XkbLayout"   "us,ru"
   Option "XkbOptions"  "grp:toggle"
   ```

   Also make sure that `XkbDisable` is turned off (commented out) there.

   For `grp:caps_toggle` the RUS/LAT switch will be CapsLock. The old CapsLock function is still available via Shift+CapsLock (in LAT mode only). For `grp:toggle` the RUS/LAT switch will be Right Alt. `grp:caps_toggle` does not work in Xorg for unknown reason.

   If you have “Windows®” keys on your keyboard, and notice that some non-alphabetical keys are mapped incorrectly in RUS mode, add the following line in your `xorg.conf` file.

   ```
   Option "XkbVariant" ",winkeys"
   ```

注意

The Russian XKB keyboard may not work with non-localized applications.

注意

Minimally localized applications should call a `XtSetLanguageProc (NULL, NULL, NULL);` function early in the program.

See KOI8-R for X Window for more instructions on localizing X11 applications.

22.5.2. Traditional Chinese Localization for Taiwan

The FreeBSD-Taiwan Project has an Chinese HOWTO for FreeBSD at http://netlab.cse.yzu.edu.tw/~statue/freebsd/zh-tut/ using many Chinese ports. Current editor for the FreeBSD Chinese HOWTO is Shen Chuan-Hsing <statue@freebsd.sinica.edu.tw>.

Chuan-Hsing Shen <statue@freebsd.sinica.edu.tw> has created the Chinese FreeBSD Collection (CFC) using FreeBSD-Taiwan's zh-L10N-tut. The packages and the script files are available at ftp://freebsd.csie.nctu.edu.tw/pub/taiwan/CFC/ .

22.5.3. German Language Localization (for All ISO 8859-1 Languages)

Slaven Rezic <eserte@cs.tu-berlin.de> wrote a tutorial how to use umlauts on a FreeBSD machine. The tutorial is written in German and available at http://www.de.FreeBSD.org/de/umlaute/ .

22.5.4. Japanese and Korean Language Localization

For Japanese, refer to http://www.jp.FreeBSD.org/ , and for Korean, refer to http://www.kr.FreeBSD.org/ .

22.5.5. Non-English FreeBSD Documentation

Some FreeBSD contributors have translated parts of FreeBSD to other languages. They are available through links on the main site or in /usr/share/doc .

章 23. 更新、升級 FreeBSD

Restructured, reorganized, and parts updated by Jim Mock.
Original work by Jordan Hubbard, Poul-Henning Kamp, John Polstra 且 Nik Clayton.

23.1. 概述

FreeBSD 是個持續發展的作業系統。有些人喜歡官方釋出的版本， 有些人則喜歡和官方最新的開發版本保持同步。然而即使是官方釋出的版本仍然時常有安全性更新或和其他緊急修復。無論使用哪種版本，FreeBSD都提供所有必須的工具來讓系統保持最新，而且可以輕易升級不同版本。本章將描述如何追蹤開發版本，和保持FreeBSD系統維持最新的基本工具。

讀完這章，您將了解：

- 如何使用 freebsd-update, Subversion, 或 CTM 讓 FreeBSD 系統保持在最新的版本。
- 如何比較安裝系統和原始複製的狀態。
- 如何使用 Subversion或是documentation ports來使已安裝的文件保持最新。
- 兩個開發分支的差異：FreeBSD-STABLE 和 FreeBSD-CURRENT。
- 如何重新編譯和重新安裝整個基礎系統。

在開始閱讀這章之前，您需要：

- 設定好你的網路 (章 30, 網路進階練功房)。
- 知道如何安裝第三方軟體 (章 4, 軟體套件管理篇：Packages 及 Ports 機制).

注意

本章中，使用 svn 來獲得和更新 FreeBSD 原始碼。 為了能使用他，首先要安裝 devel/subversion port 或 package。

23.2. FreeBSD Update

Written by Tom Rhodes.
Based on notes provided by Colin Percival.

即時應用安全性更新與升級作業系統到新的發行版本對一個持續運作的系統是重要的。FreeBSD 包括一個叫 `freebsd-update` 的工具程式可以執行這兩項任務。

這個工具程式支援 FreeBSD 二進制安全性與和錯誤更新， 不需要手動編譯和安裝修復或新核心。 安全性團隊目前支援的所有架構和發行版都可以取得二進制更新。 目前支援的發行版列表和他們的支援期限都列於 `http://www.FreeBSD.org/security/` 。

這個工具程式也支援作業系統升級到次要的發行版本和升級到令一個發行版分支升級到新的發行版本前，要檢查他的發行宣告，因為他包含發行版本相關的重要資訊。發行公告可以由`http://www.FreeBSD.org/releases/` 取得。

注意

如果有使用crontab來執行 freebsd-update(8)，那必須在升級作業系統前先停用。

這節描述 freebsd-update 使用的設定檔， 示範如何運用安全性修補和如何升級到主要或次要的作業系統發行版， 以及討論某些升級作業系統的考量。

23.2.1. 設定檔

freebsd-update 預設的設定檔不需變更即可運作。 有些使用者可能想要調校預設的設定檔 /etc/freebsd-update.conf 來對程序有更好的控制。這個設定檔的註解說明了可以使用的選項， 但以下可能需要更多一些的解釋：

```
# Components of the base system which should be kept updated.
Components world kernel
```

這個參數控制 FreeBSD 的哪個部份將保持最新。 預設是將更新整個 base system 和核心。 個別元件可以被指定， 例如：src/base 或 src/sys 。然而最好的選項是維持預設設定， 因為改變設定去包括特定項目， 則每個需要的項目都必須要列出。 時間一久可能會因為原始碼和二進制檔案沒有更新而造成慘重的後果。

```
# Paths which start with anything matching an entry in an IgnorePaths
# statement will be ignored.
IgnorePaths /boot/kernel/linker.hints
```

保持特定的目錄，例如 /bin 或 /sbin, 在更新過程不被更動，可以將他們的路徑加到此敘述中。 這個選項可以防止 freebsd-update 覆蓋本機的修改。

```
# Paths which start with anything matching an entry in an UpdateIfUnmodified
# statement will only be updated if the contents of the file have not been
# modified by the user (unless changes are merged; see below).
UpdateIfUnmodified /etc/ /var/ /root/ /.cshrc /.profile
```

這個選項只會更新特定目錄中未修改的設定檔。 任何使用者修改的檔案都不會自動更新。 有另一個選項——KeepModifiedMetadata 會指示 freebsd-update 在合併時將改變儲存下來

```
# When upgrading to a new FreeBSD release, files which match MergeChanges
# will have any local changes merged into the version from the new release.
MergeChanges /etc/ /var/named/etc/ /boot/device.hints
```

列出 freebsd-update 應嘗試合併的設定檔目錄。 檔案合併過程是一系列類似mergemaster(8)的diff(1)修補， 但是選項比較少。 合併可以接受，開啓編輯器，或是令freebsd-update 中止。 如果有疑慮，備份 /etc，然後同意合併。 更多關於mergemaster 的資訊， 參見 節 23.6.4, “Merging Configuration Files”。

```
# Directory in which to store downloaded updates and temporary
# files used by FreeBSD Update.
# WorkDir /var/db/freebsd-update
```

這個目錄是所有修補檔和暫存檔放置處。 當使用者進行版本升級時，這個位置應該要有至少1GB的可用磁碟空間。

```
# When upgrading between releases, should the list of Components be
# read strictly (StrictComponents yes) or merely as a list of components
# which *might* be installed of which FreeBSD Update should figure out
# which actually are installed and upgrade those (StrictComponents no)?
# StrictComponents no
```

當這個選項設定為yes， freebsd-update 將會假設 Components 列表已完成，將不會嘗試做列表外的改變。 實際上 freebsd-update 將嘗試更新每一個屬於 Components 列表的檔案。

23.2.2. 運用安全性修補

運用 FreeBSD 安全性修補的過程已經被簡化， 允許系統管理員使用`freebsd-update` 保持系統更新。 更多關於FreeBSD 安全性報告的資訊可以參考 節 13.11, “FreeBSD Security Advisories”。

FreeBSD 安全性修補可以使用以下指令下載與安裝。 第一個指令將決定是否有尚未完成的修補，如果有，將列出執行修補將會變更的檔案清單。第二個指令將會執行修補。

```
# freebsd-update fetch
# freebsd-update install
```

如果更新執行任何核心修補，系統將會重新開機以使用修補過的核心。 如果在任何執行中的二進位檔進行修補，被影響的應用程式將會重新啓動來使用修補過的二進位檔。

將以下項目加入 `/etc/crontab` 系統可以每天自動檢查是否有更新:

```
@daily                                  root    freebsd-update cron
```

如果有新的修補，它們將會自動下載，但是還不會執行。 管理者`root` 將會收到email來檢視修補然後手動執行 `freebsd-update install` 來安裝

如果有發生任何錯誤，`freebsd-update` 可以使用以下指令回溯最後的變更：

```
# freebsd-update rollback
Uninstalling updates... done.
```

再次，如果核心或任何核心模組有變更，系統將重新開機，受影響的二進位檔會重新執行。

只有 `GENERIC` 核心可以自動被 `freebsd-update` 更新。 如果有安裝自訂的核心，在`freebsd-update` 完成安裝更新後，將會被重新編譯和重新安裝。 然而，如果 `/boot/GENERIC` 存在，`freebsd-update` 將會偵測和更新 `GENERIC` 核心， 即使他並非目前系統正在執行的核心。

注意

永遠在 `/boot/GENERIC` 保留一份 `GENERIC` 核心的備份。這對於診斷不同的問題與版本的升級有幫助。 參考節 23.2.3.1, “ FreeBSD 9.X 以上自訂核心” 或 節 23.2.3.2, “FreeBSD 8.X 自訂核心” 關於如何備份 `GENERIC` 核心的說明

除非 `/etc/freebsd-update.conf` 的預設設定被改變， `freebsd-update` 將安裝更新過的核心原始碼和其餘的更新 然後就可以照平常的方式重新編譯和重新安裝新的自訂核心。

以 `freebsd-update` 發行的更新並非總是包含核心。 如果核心的原始碼沒有被 `freebsd-update install` 變更，並不需要重新編譯自訂核心。 然而 `freebsd-update` 總是會更新 `/usr/src/sys/conf/newvers.sh` 。目前修補的程度， 如同執行 `uname -r` 顯示的 `-p` 數字是由這個檔案取得。 即使沒有做任何改變，重新編譯核心會讓 `uname` 正確地報告目前系統修補的程度。 這對於維護多個系統特別有幫助，可以讓你快速評估每個系統安裝的更新。

23.2.3. 執行主要和次要的版本升級

從FreeBSD的次要版本升級到另一個版本，例如從 FreeBSD 9.0 到 FreeBSD 9.1, 叫作 次要版本更新。 主要版本更新發生在當 FreeBSD 從一個主要版本升級到主要版本升級到另一個主要版本時 ，例如從 FreeBSD 9.X 到 FreeBSD `10.X`。 兩種更新都可以透過提供 `freebsd-update` 發行版本來執行。

注意

如果系統正在執行自訂的核心，開始升級前， 確定 GENERIC 核心的副本在 /boot/GENERIC 。 參考節 23.2.3.1, “ FreeBSD 9.X 以上自訂核心” 或 節 23.2.3.2, “FreeBSD 8.X 自訂核心” 關於如何製作 GENERIC 核心副本的說明。

以下的指令執行在 FreeBSD 9.0 系統時， 將會把系統升級至 FreeBSD 9.1：

```
# freebsd-update -r 9.1-RELEASE upgrade
```

當收到這個指令後， freebsd-update 將會評估設定檔和目前的系統來收集升級需要的資訊。 螢幕上的清單會顯示偵測到或沒偵測到哪些元件。例如：

```
Looking up update.FreeBSD.org mirrors... 1 mirrors found.
Fetching metadata signature for 9.0-RELEASE from update1.FreeBSD.org... done.
Fetching metadata index... done.
Inspecting system... done.

The following components of FreeBSD seem to be installed:
kernel/smp src/base src/bin src/contrib src/crypto src/etc src/games
src/gnu src/include src/krb5 src/lib src/libexec src/release src/rescue
src/sbin src/secure src/share src/sys src/tools src/ubin src/usbin
world/base world/info world/lib32 world/manpages

The following components of FreeBSD do not seem to be installed:
kernel/generic world/catpages world/dict world/doc world/games
world/proflibs

Does this look reasonable (y/n)? y
```

此時，freebsd-update 將嘗試下載所有升級需要的檔案。 在某些案例，使用者會被提示一些關於安裝什麼或是如何進行的問題。

當使用自訂核心，上述的步驟將會產生如下列的警告：

```
WARNING: This system is running a "MYKERNEL" kernel, which is not a
kernel configuration distributed as part of FreeBSD 9.0-RELEASE.
This kernel will not be updated: you MUST update the kernel manually
before running "/usr/sbin/freebsd-update install"
```

這個警告可以安全地忽略，升級過程將會立即使用更新過的 GENERIC 核心

一旦所有的修補都被下載到本地的系統， 它們將會被運用。這個過程可能會花點時間，取決於機器的速度和工作量 設定檔將會被合併。 合併的過程中當檔案被合併或是手動合併螢幕上出現編輯器時需要使用者介入。 每一個成功合併的結果將會顯示給使用者。 失敗或是被忽略的合併將會使程序中斷。使用者稍候可能想要備份 /etc 和手動合併重要的檔案，例如： master.passwd 或 group 。

注意

當所有修補和合併在另一個目錄進行時，系統還不會被警告。 一旦所有修補都成功運用，所有設定檔都被合併，而且過程順利，使用者可以以下指令來將這些改變付諸於磁碟上：

```
# freebsd-update install
```

核心和核心模組將會先被修補。如果系統正在執行自訂核心，使用 nextboot(8) 指令設定下次開機的核心為更新過的 /boot/GENERIC ：

```
# nextboot -k GENERIC
```

警告

如果機器以遠端遙控來更新， 使用GENERIC 核心重新開機前， 確定他包含所有系統開機需要的驅動程式而且連接網路， 特別是當執行的自訂核心包含核心模組提供內建功能時， 確定暫時地使用 /boot/loader.conf 工具載入這些模組到 GENERIC 核心。 建議停用非必須的服務和磁碟與網路掛載直到升級程序完成。

機器現在應該更新過的核心重新開機：

```
# shutdown -r now
```

一旦系統重新上線，使用以下指令重新開始 freebsd-update 。 因為程序的狀態已被儲存，freebsd-update 將不會重頭開始，他會進行到下一個階段 ，移除所有舊的共用程式庫和目標檔。

```
# freebsd-update install
```

注意

根據程式庫版本編號， 可能有兩個而不是三個安裝階段。

升級程序現在完成了。如果這是主要的版本升級，參考 節 23.2.3.3, “主要版本更新後更新 Packages” 的描述重新安裝所有的ports和套件。

23.2.3.1. FreeBSD 9.X 以上自訂核心

使用 freebsd-update 前，確定有一份核心的副本, ensure that a copy of the GENERIC kernel exists in /boot/GENERIC . If a custom kernel has only been built once, the kernel in /boot/kernel.old is the GENERIC kernel. Simply rename this directory to /boot/kernel .

If a custom kernel has been built more than once or if it is unknown how many times the custom kernel has been built, obtain a copy of the GENERIC kernel that matches the current version of the operating system. If physical access to the system is available, a copy of the GENERIC kernel can be installed from the installation media:

```
# mount /cdrom
# cd /cdrom/usr/freebsd-dist
# tar -C/ -xvf kernel.txz boot/kernel/kernel
```

Alternately, the GENERIC kernel may be rebuilt and installed from source:

```
# cd /usr/src
# make kernel __MAKE_CONF=/dev/null SRCCONF=/dev/null
```

For this kernel to be identified as the GENERIC kernel by freebsd-update , the GENERIC configuration file must not have been modified in any way. It is also suggested that the kernel is built without any other special options.

Rebooting into the GENERIC kernel is not required as freebsd-update only needs /boot/GENERIC to exist.

23.2.3.2. FreeBSD 8.X 自訂核心

On an FreeBSD 8.X system, the instructions for obtaining or building a GENERIC kernel differ slightly.

Assuming physical access to the machine is possible, a copy of the GENERIC kernel can be installed from the installation media using the following commands:

```
# mount /cdrom
# cd /cdrom/X.Y-RELEASE /kernels
# ./install.sh GENERIC
```

Replace *X.Y-RELEASE* with the version of the release being used. The GENERIC kernel will be installed in /boot/GENERIC by default.

To instead build the GENERIC kernel from source:

```
# cd /usr/src
# env DESTDIR=/boot/GENERIC make kernel __MAKE_CONF=/dev/null SRCCONF=/
dev/null
# mv /boot/GENERIC/boot/kernel/* /boot/GENERIC
# rm -rf /boot/GENERIC/boot
```

For this kernel to be picked up as GENERIC by freebsd-update , the GENERIC configuration file must not have been modified in any way. It is also suggested that it is built without any other special options.

Rebooting into the GENERIC kernel is not required.

23.2.3.3. 主要版本更新後更新 Packages

一般來說，次要版本更新後安裝的應用程式可以沒有問題地繼續執行。 主要版本間使用不同的應用程式二進位介面 Application Binary Interfaces (ABIs)，會破壞大部份第三方應用程式。 主要版本更新後，所有安裝的套件和 ports 需要使用應用程式來升級，例如 ports-mgmt/portmaster 重新編譯所有應用程式，可以使用以下指令完成：

```
# portmaster -af
```

這個指令將會顯示每個程式的設定選項設定畫面，等待使用者的互動。 如果要使用預設的選項，可以在上述指令使用 -G選項。

一旦軟體升級完成，執行 freebsd-update 來完成所有升級過程的零碎事情 ：

```
# freebsd-update install
```

如果是暫時使用 GENERIC 核心， 現在請使用 章 8, 設定 FreeBSD Kernel的說明編譯和安裝新的自訂核心。

重新開機進入新版的 FreeBSD。現在已經完成升級過程了。

23.2.4. 系統狀態比較

已安裝的 FreeBSD 版本可以使用 freebsd-update IDS 來跟另一個已知好的複製版本來做測試。 這個指令評估系統應用程式，程式庫和設定檔案目前的版本， 可以被當成內建的入侵偵測系統來使用 (IDS)。

警告

這個指令不是取代真正的 IDS ，例如 security/snort。當 freebsd-update 儲存資料在磁碟裡，是有被竄改的可能性 可以使用 kern.securelevel 或是將沒有在使用

> 的 `freebsd-update` 的資料儲存在唯讀檔案系統來減少這樣的可能性， 比較好的解決方法是將系統和安全的磁碟，例如 DVD 或是安全的外接 USB 磁碟裝置做比較。 另類的方法是使用在 節 13.2.6, “Binary Verification” 描述的內建應用程式提供的 IDS 功能

為了開始比較，先指定特定的輸出檔案來儲存結果：

```
# freebsd-update IDS >> outfile.ids
```

現在系統將會被檢查， 而包含已知發行版和現在安裝版的SHA256雜湊值 的冗長檔案清單將會被送至指定的輸出檔。

清單的項目相當長，但是輸出格式很容易被分析。 例如，要獲得一個和發行版不同的檔案清單，可以下以下指令：

```
# cat outfile.ids | awk '{ print $1 }' | more
/etc/master.passwd
/etc/motd
/etc/passwd
/etc/pf.conf
```

這個輸出範例已經被截短，原來有更多的檔案存在。 有些檔案自然會有修改。例如，如果有使用者被加入系統， `/etc/passwd` 會被修改 如果 `freebsd-update` 有更新過，核心模組可能會不同 為了要排除特定的檔案或目錄，把它們加到`/etc/freebsd-update.conf` 裡的 `IDSIgnorePaths` 選項。

23.3. 更新文件組

文件是FreeBSD作業系統不可或缺的一部份。 最新版本的 FreeBSD 文件可以在 FreeBSD 網站取得(http://www.freebsd.org/doc/), 很方便有一份最新的FreeBSD 網站，使用手冊， 常見問答和文章的本地端副本。

這一節描述如何使用原始碼或是 FreeBSD Ports 管理機制將 本地端FreeBSD文件保持最新。

編輯和發佈文件更正的資訊 請參考 FreeBSD 文件計劃新貢獻者入門書 (http://www.freebsd.org/doc/en_US.ISO8859-1/books/fdp-primer/).

23.3.1. 從原始碼更新文件

重新從原始碼編譯FreeBSD 文件需要一些不是屬於 FreeBSD 基礎系統的工具 這些需要的工具包括 svn 可以從 textproc/docproj 套件安裝或是 FreeBSD 文件計劃的開發的port

一旦安裝好，請使用 svn 來取得乾淨的文件原始碼副本。 將 *`https://svn0.us-west.FreeBSD.org`* 置換成 節 A.4.4, “Subversion Mirror Sites” 裡地理位置和你最近的鏡像站：

```
# svn checkout https://svn0.us-west.FreeBSD.org /doc/head /usr/doc
```

第一次下載文件原始碼需要花點時間，請讓他執行完畢

將來文件原始碼更新的取得可以執行：

```
# svn update /usr/doc
```

當最新的文件原始碼快照已經抓取到 `/usr/doc` ，一切都已就緒可以對已安裝的文件進行更新。

要完整更新所有語言，可以執行:

```
# cd /usr/doc
```

```
# make install clean
```

如果只要更新一個特定的語言，可以在 /usr/doc 中特定語言的子目錄執行 make:

```
# cd /usr/doc/en_US.ISO8859-1
# make install clean
```

另一個更新文件的方法是在 /usr/doc 或特定語言的子目錄執行:

```
# make update
```

輸出格式可以經由設定 FORMATS 來指：

```
# cd /usr/doc
# make FORMATS='html html-split' install clean
```

有幾個選項可以使得只要更新部份文件或是建立特定翻譯的過程更加簡易。 這些選項可以在 /etc/make.conf 中設定成整個系統的選項， 或是經由命令列傳送給 make。

這些選項包括:

DOC_LANG
: 要建立或是安裝的語言和編碼清單，例如英文文件用 en_US.ISO8859-1 。

FORMATS
: 單一格式或是要建立的輸出格式清單。目前支援 html, html-split , txt, ps, 和 pdf。

DOCDIR
: 安裝文件的位置。預設裝在 /usr/share/doc 。

更多關於FreeBSD全系統的make 變數， 請參考make.conf(5)。

23.3.2. 從 Ports 更新文件

Based on the work of Marc Fonvieille.

前一節說明了從原始碼更新 FreeBSD 文件的方法。本節敘述使用 Ports Collection 的另一種方法：

- Install pre-built packages of the documentation, without having to locally build anything or install the documentation toolchain.
- Build the documentation sources through the ports framework, making the checkout and build steps a bit easier.

This method of updating the FreeBSD documentation is supported by a set of documentation ports and packages which are updated by the Documentation Engineering Team <doceng@FreeBSD.org > on a monthly basis. These are listed in the FreeBSD Ports Collection, under the docs category (http://www.freshports.org/docs/).

Organization of the documentation ports is as follows:

- The misc/freebsd-doc-en package or port installs all of the English documentation.
- The misc/freebsd-doc-all meta-package or port installs all documentation in all available languages.
- There is a package and port for each translation, such as misc/freebsd-doc-hu for the Hungarian documentation.

When binary packages are used, the FreeBSD documentation will be installed in all available formats for the given language. For example, the following command will install the latest package of the Hungarian documentation:

```
# pkg install hu-freebsd-doc
```

注意

Packages use a format that differs from the corresponding port's name: *lang*-freebsd-doc, where *lang* is the short format of the language code, such as hu for Hungarian, or zh_cn for Simplified Chinese.

To specify the format of the documentation, build the port instead of installing the package. For example, to build and install the English documentation:

```
# cd /usr/ports/misc/freebsd-doc-en
# make install clean
```

The port provides a configuration menu where the format to build and install can be specified. By default, split HTML, similar to the format used on http://www.FreeBSD.org , and PDF are selected.

Alternately, several make options can be specified when building a documentation port, including:

WITH_HTML
: Builds the HTML format with a single HTML file per document. The formatted documentation is saved to a file called article.html , or book.html .

WITH_PDF
: The formatted documentation is saved to a file called article.pdf or book.pdf .

DOCBASE
: Specifies where to install the documentation. It defaults to /usr/local/share/doc/freebsd .

This example uses variables to install the Hungarian documentation as a PDF in the specified directory:

```
# cd /usr/ports/misc/freebsd-doc-hu
# make -DWITH_PDF DOCBASE=share/doc/freebsd/hu install clean
```

Documentation packages or ports can be updated using the instructions in 章 4, 軟體套件管理篇：Packages 及 Ports 機制. For example, the following command updates the installed Hungarian documentation using ports-mgmt/portmaster by using packages only:

```
# portmaster -PP hu-freebsd-doc
```

23.4. 追蹤發展分支

FreeBSD 有兩個發展分支： FreeBSD-CURRENT and FreeBSD-STABLE.

本節將將解釋每個分支和他的預設的使用者，以及如何保持每個分支系統在最新。

23.4.1. 使用 FreeBSD-CURRENT

FreeBSD-CURRENT 是 FreeBSD 開發的“最前線”，FreeBSD–CURRENT的使用者應有較强的技術能力。 技術能力較弱的使用者想追蹤發展分支應該追蹤 FreeBSD-STABLE。

FreeBSD-CURRENT 是 FreeBSD 最新的原始碼，包括正在進行的工作， 實驗性的改變，以及可能會或可能不會在下一個官方發行版出現的過渡時期機制。 而許多 FreeBSD 開發者每天編譯 FreeBSD-CURRENT 原始碼，可能有一段短暫的時間原始碼無法編譯成功。 這些問題會儘快被解決，但是無論 FreeBSD-CURRENT 帶來災難或是新功能，在同步原始碼時都要考量的問題。

FreeBSD-CURRENT 適合下列三類人：

1. 積極致力於某一部份原始碼樹的 FreeBSD 社群成員。

2. 擔任積極測試者的 FreeBSD 社群成員。 他們願意花時間解決問題，提出 FreeBSD 改變的建議和的大方向，並發布修補。

3. 關注某些事物，或是想參考目前的原始碼，或是偶爾提供註解或貢獻原始碼的使用者。

FreeBSD-CURRENT 不應該被認為是在下一版發行前 取得最新功能的快速途徑，因為尚未發行的功能並未被完整測試，很可能有bug。 他也不是一個取得bug修補的快速方式， 因為任何已知bug的修補有可能產生新的bug。 FreeBSD-CURRENT 沒有任何 “官方支援” 。

追蹤 FreeBSD-CURRENT：

1. 加入 freebsd-current 和 svn-src-head 郵件論壇。這是必須的 以查看人們關於系統目前狀態的評論並接收 FreeBSD-CURRENT 目前狀態的重要公告。

   svn-src-head 論壇紀錄每一次修改的紀錄， 和可能產生的副作用的相關資訊

   前往 http://lists.FreeBSD.org/mailman/listinfo，點選論壇來訂閱，照網頁指示的步驟作， 為了追蹤整個原始碼樹，不是只有 FreeBSD-CURRENT 的改變，請訂閱 svn-src-all論壇。

2. 同步 FreeBSD-CURRENT 原始碼。 通常使用 svn 來檢查節 A.4.4, “Subversion Mirror Sites” 列出的 Subversion 鏡像站 `head` 分支的–CURRENT 原始碼。

   網路很慢或是受到限制的使用者可以如節 A.3, “Using CTM” 所描述的，使用 CTM 來替代，但是他並不如 svn 一樣值得信賴， svn 是建議的同步原始碼的方法。

3. 由於程式碼庫的大小的， 有些使用者選擇只同步部份他們有興趣或提供修補貢獻的部份原始碼。然而， 計劃從原始碼編譯整個作業系統的使用者必須下載 全部 的FreeBSD-CURRENT，而不是只有選擇的部份。

   編譯 FreeBSD-CURRENT 前 ，請非常仔細地閱讀 `/usr/src/Makefile` 並遵從 節 23.6, “重新編譯 World”的指示。 閱讀 FreeBSD-CURRENT 郵遞論壇 和 `/usr/src/UPDATING` 來掌握下一發行版的最新狀態。

4. 熱血！很鼓勵 FreeBSD-CURRENT 使用者 發表他們對加强哪些功能或是修復哪些錯誤的建議。 如果您在建議時能附上相關程式碼的話， 那真是太棒了！

23.4.2. 使用 FreeBSD-STABLE

主要發行版就是由 FreeBSD-STABLE 這個開發分支而來。 修改進入這個分支的速度比較慢， 並且假設這些修改已經先在 FreeBSD-CURRENT 測試過。 這仍然是一個開發分支，而且在任何時候，FreeBSD–STABLE 的原始碼都可能適合或不適合一般的使用。他就只是另一個開發分支，不是給終端使用者用的。 沒有要進行測試的使用者應該執行最新的 FreeBSD 發行版。

若有興趣去追蹤、貢獻 FreeBSD 開發過程，尤其是會跟 FreeBSD接下來的發行版有關的人,應該考慮採用 FreeBSD-STABLE。

儘管 FreeBSD-STABLE 應該在任何時候均能正確編譯、運作，但是沒有人能擔保一定如此。因為使用 FreeBSD-STABLE 的人比 FreeBSD-CURRENT多，無可避免地， 有時候會在 FreeBSD-STABLE 發現錯誤和極端的狀況，而這在 FreeBSD-CURRENT 並非顯而易見。 由於上述這些理由，我們並不建議盲目追隨 FreeBSD-STABLE。 特別重要的是 不要在沒有於開發或測試環境完整測試程式碼之前， 升級任何上線的伺服器到 FreeBSD-STABLE。

追蹤 FreeBSD-STABLE:

1. 訂閱freebsd-stable論壇來隨時瞭解 FreeBSD-STABLE 編譯時的相依關係 或是其他特別需要注意的議題。開發者在考慮一些有爭議的修正或更新時，就會先在這裡發信說明， 給使用者有機會可以反應， 看他們對所提的更改是否有什麼建議或問題。

訂閱要追蹤分支的 svn相關論壇。 例如，追蹤9-STABLE分支的使用者應該訂閱svn-src-stable-9論壇。 這個論壇紀錄每一次修改的紀錄，和可能產生的副作用的相關資訊。

前往http://lists.FreeBSD.org/mailman/listinfo，點選論壇來訂閱，照網頁指示的步驟作， 為了追蹤整個原始碼樹，請訂閱svn-src-all論壇。

2. 要安裝一個新的 FreeBSD-STABLE 系統， 從 FreeBSD 鏡像站安裝最新的 FreeBSD-STABLE 發行版 或使用從 FreeBSD-STABLE每個月的 snapshot built來安裝。更多關於快照的資訊， 請參考www.freebsd.org/snapshots。

   要編譯或升級已經安裝的 FreeBSD 系統至 FreeBSD-STABLE， 請使用svn 來檢查要安裝分支的原始碼。 分支的名稱，例如 `stable/9`，列在www.freebsd.org/releng。 如果沒有可靠的網際網路連線可以使用 CTM (節 A.3, “Using CTM”)。

3. 在編譯或升級到 FreeBSD-STABLE 之前 ， 請仔細閱讀 `/usr/src/Makefile` 並遵照節 23.6, “重新編譯 World”的指示。閱讀 FreeBSD-STABLE 郵遞論壇 和 `/usr/src/UPDATING` 下一發行版的最新狀態。

23.5. 同步原始碼

有幾種不同的方法保持 FreeBSD 原始碼在最新狀態。 這節比較這兩個主要的方法： Subversion 和 CTM。

警告

雖然有可能只更新部份原始碼樹，但是唯一支援的更新步驟是更新整個樹併重新編譯所有在使用者空間的程式， 例如在`/bin` 和 `/sbin`，以及核心原始碼。 只更新部份原始碼樹，只更新核心，或只更新使用者空間的程式時常會導致編譯錯誤，核心錯誤或是資料惡化等問題。

Subversion使用更新原始碼的 pull 模型。使用者，或是 `cron` 手稿語言，呼叫更新本地端原始碼的 `svn` 程式。 Subversion is the preferred method for updating local source trees as updates are up-to-the-minute and the user controls when updates are downloaded. It is easy to restrict updates to specific files or directories and the requested updates are generated on the fly by the server. 如何使用How to synchronize source using Subversion同步原始碼，描述於節 A.4, “Using Subversion”。

CTM does not interactively compare the local sources with those on the master archive or otherwise pull them across. Instead, a script which identifies changes in files since its previous run is executed several times a day on the master CTM machine. Any detected changes are compressed, stamped with a sequence-number, and encoded for transmission over email in printable ASCII only. Once downloaded, these deltas can be run through `ctm.rmail` which will automatically decode, verify, and apply the changes to the user's copy of the sources. This process is more efficient than Subversion and places less strain on server resources since it is a push, rather than a pull, model. Instructions for using CTM to synchronize source can be found at 節 A.3, “Using CTM”.

If a user inadvertently wipes out portions of the local archive, Subversion will detect and rebuild the damaged portions. CTM will not, and if a user deletes some portion of the source tree and does not have a backup, they will have to start from scratch from the most recent base delta and rebuild it all with CTM.

23.6. 重新編譯 World

一旦本地端的原始碼樹和 FreeBSD 的特定版本同步後， 例如 FreeBSD-STABLE or FreeBSD-CURRENT，原始碼樹就可以用來重新編譯系統。 這個過程叫重新編譯 `world`。

重新編譯 world 之前 ，請確定執行以下任務：

過程 23.1. 編譯 world 之前 執行這些任務

1. 備份所有重要資料到另一個系統或是可攜式媒體， 檢查備份的完整性，手邊準備一個可以開機的安裝媒體。 再次强調在重新編譯系統 之前，製作系統的備份是非常重要的。 While rebuilding world is an easy task, there will inevitably be times when mistakes in the source tree render the system unbootable. You will probably never have to use the backup, but it is better to be safe than sorry!

2. Review the recent freebsd-stable or freebsd-current entries, depending upon the branch being tracked. Be aware of any known problems and which systems are affected. If a known issue affects the version of synchronized code, wait for an “all clear” announcement to be posted stating that the problem has been solved. Resynchronize the sources to ensure that the local version of source has the needed fix.

3. Read `/usr/src/UPDATING` for any extra steps necessary for that version of the source. This file contains important information about potential problems and may specify the order to run certain commands. Many upgrades require specific additional steps such as renaming or deleting specific files prior to installing the new world. These will be listed at the end of this file where the currently recommended upgrade sequence is explicitly spelled out. If `UPDATING` contradicts any steps in this chapter, the instructions in `UPDATING` take precedence and should be followed.

不要使用 `make world`

某些比較老的文件建議使用 `make world` 。然而，這個指令掠略過某些重要的步驟，只適合專家使用。 大部分的情況，使用 `make world` 都是錯誤的，應該用這裡描述的步驟代替。

23.6.1. 程序概要

The build world process assumes an upgrade from an older FreeBSD version using the source of a newer version that was obtained using the instructions in 節 23.5, “同步原始碼”.

In FreeBSD, the term “world” includes the kernel, core system binaries, libraries, programming files, and built-in compiler. The order in which these components are built and installed is important.

For example, the old compiler might have a bug and not be able to compile the new kernel. Since the new kernel should be built with the new compiler, the new compiler must be built, but not necessarily installed, before the new kernel is built.

The new world might rely on new kernel features, so the new kernel must be installed before the new world is installed. The old world might not run correctly on the new kernel, so the new world must be installed immediately upon installing the new kernel.

Some configuration changes must be made before the new world is installed, but others might break the old world. Hence, two different configuration upgrade steps are used. For the most part, the update process only replaces or adds files and existing old files are not deleted. Since this can cause problems, `/usr/src/UPDATING` will indicate if any files need to be manually deleted and at which step to do so.

These concerns have led to the recommended upgrade sequence described in the following procedure.

注意

It is a good idea to save the output from running `make` to a file. If something goes wrong, a copy of the error message can be posted to one of the FreeBSD mailing lists.

The easiest way to do this is to use `script` with a parameter that specifies the name of the file to save all output to. Do not save the output to `/tmp` as this directory may be cleared at next reboot. A better place to save the file is `/var/tmp`. Run this command immediately before rebuilding the world, and then type **`exit`** when the process has finished:

```
# script /var/tmp/mw.out
Script started, output file is /var/tmp/mw.out
```

過程 23.2. Overview of Build World Process

The commands used in the build world process should be run in the order specified here. This section summarizes the function of each command.

1. If the build world process has previously been run on this system, a copy of the previous build may still exist in `/usr/obj`. To speed up the new build world process, and possibly save some dependency headaches, remove this directory if it already exists:

   ```
   # chflags -R noschg /usr/obj/*
   # rm -rf /usr/obj
   ```

2. Compile the new compiler and a few related tools, then use the new compiler to compile the rest of the new world. The result is saved to `/usr/obj`.

   ```
   # cd /usr/src
   # make buildworld
   ```

3. Use the new compiler residing in `/usr/obj` to build the new kernel, in order to protect against compiler-kernel mismatches. This is necessary, as certain memory structures may have changed, and programs like `ps` and `top` will fail to work if the kernel and source code versions are not the same.

   ```
   # make buildkernel
   ```

4. Install the new kernel and kernel modules, making it possible to boot with the newly updated kernel. If `kern.securelevel` has been raised above `1` and `noschg` or similar flags have been set on the kernel binary, drop the system into single-user mode first. Otherwise, this command can be run from multi-user mode without problems. See init(8) for details about `kern.securelevel` and chflags(1) for details about the various file flags.

   ```
   # make installkernel
   ```

5. Drop the system into single-user mode in order to minimize problems from updating any binaries that are already running. It also minimizes any problems from running the old world on a new kernel.

   ```
   # shutdown now
   ```

   Once in single-user mode, run these commands if the system is formatted with UFS:

   ```
   # mount -u /
   # mount -a -t ufs
   # swapon -a
   ```

   If the system is instead formatted with ZFS, run these two commands. This example assumes a zpool name of `zroot`:

   ```
   # zfs set readonly=off zroot
   # zfs mount -a
   ```

6. Optional: If a keyboard mapping other than the default US English is desired, it can be changed with kbdmap(1):

```
# kbdmap
```

7. Then, for either file system, if the CMOS clock is set to local time (this is true if the output of date(1) does not show the correct time and zone), run:

```
# adjkerntz -i
```

8. Remaking the world will not update certain directories, such as `/etc`, `/var` and `/usr`, with new or changed configuration files. The next step is to perform some initial configuration file updates to `/etc` in preparation for the new world. The following command compares only those files that are essential for the success of `installworld` . For instance, this step may add new groups, system accounts, or startup scripts which have been added to FreeBSD since the last update. This is necessary so that the `installworld` step will be able to use any new system accounts, groups, and scripts. Refer to 節 23.6.4, "Merging Configuration Files" for more detailed instructions about this command:

```
# mergemaster -p
```

9. Install the new world and system binaries from `/usr/obj` .

```
# cd /usr/src
# make installworld
```

10. Update any remaining configuration files.

```
# mergemaster -iF
```

11. Delete any obsolete files. This is important as they may cause problems if left on the disk.

```
# make delete-old
```

12. A full reboot is now needed to load the new kernel and new world with the new configuration files.

```
# reboot
```

13. Make sure that all installed ports have first been rebuilt before old libraries are removed using the instructions in 節 4.5.3, "升級已安裝的 Ports". When finished, remove any obsolete libraries to avoid conflicts with newer ones. For a more detailed description of this step, refer to 節 23.6.5, "Deleting Obsolete Files and Libraries".

```
# make delete-old-libs
```

If the system can have a window of down-time, consider compiling the system in single-user mode instead of compiling the system in multi-user mode, and then dropping into single-user mode for the installation. Reinstalling the system touches a lot of important system files, all the standard system binaries, libraries, and include files. Changing these on a running system, particularly one with active users, is asking for trouble.

23.6.2. Configuration Files

This build world process uses several configuration files.

The `Makefile` located in `/usr/src` describes how the programs that comprise FreeBSD should be built and the order in which they should be built.

The options available to `make` are described in make.conf(5) and some common examples are included in `/usr/share/examples/etc/make.conf` . Any options which are added to `/etc/make.conf` will control the

how make runs and builds programs. These options take effect every time make is used, including compiling applications from the Ports Collection, compiling custom C programs, or building the FreeBSD operating system. Changes to some settings can have far-reaching and potentially surprising effects. Read the comments in both locations and keep in mind that the defaults have been chosen for a combination of performance and safety.

How the operating system is built from source code is controlled by /etc/src.conf . Unlike /etc/make.conf , the contents of /etc/src.conf only take effect when the FreeBSD operating system itself is being built. Descriptions of the many options available for this file are shown in src.conf(5). Be cautious about disabling seemingly unneeded kernel modules and build options. Sometimes there are unexpected or subtle interactions.

23.6.3. Variables and Targets

The general format for using make is as follows:

```
# make -x -DVARIABLE target
```

In this example, -x is an option passed to make. Refer to make(1) for examples of the available options.

To pass a variable, specify the variable name with -DVARIABLE . The behavior of the Makefile is controlled by variables. These can either be set in /etc/make.conf or they can be specified when using make. For example, this variable specifies that profiled libraries should not be built:

```
# make -DNO_PROFILE target
```

It corresponds with this setting in /etc/make.conf :

```
NO_PROFILE=    true     #    Avoid compiling profiled libraries
```

The target tells make what to do and the Makefile defines the available targets. Some targets are used by the build process to break out the steps necessary to rebuild the system into a number of sub-steps.

Having separate options is useful for two reasons. First, it allows for a build that does not affect any components of a running system. Because of this, buildworld can be safely run on a machine running in multi-user mode. It is still recommended that installworld be run in part in single-user mode, though.

Secondly, it allows NFS mounts to be used to upgrade multiple machines on a network, as described in 節 23.7, “追蹤多追蹤多部機器”.

It is possible to specify -j which will cause make to spawn several simultaneous processes. Since much of the compiling process is I/O-bound rather than CPU-bound, this is useful on both single CPU and multi-CPU machines.

On a single-CPU machine, run the following command to have up to 4 processes running at any one time. Empirical evidence posted to the mailing lists shows this generally gives the best performance benefit.

```
# make -j4 buildworld
```

On a multi-CPU machine, try values between 6 and 10 to see how they speed things up.

注意

If any variables were specified to make buildworld , specify the same variables to make installworld . However, -j must never be used with installworld .

For example, if this command was used:

```
# make -DNO_PROFILE buildworld
```

Install the results with:

```
# make -DNO_PROFILE installworld
```

Otherwise, the second command will try to install profiled libraries that were not built during the `make buildworld` phase.

23.6.4. Merging Configuration Files

Contributed by Tom Rhodes.

FreeBSD provides the mergemaster(8) Bourne script to aid in determining the differences between the configuration files in `/etc`, and the configuration files in `/usr/src/etc` . This is the recommended solution for keeping the system configuration files up to date with those located in the source tree.

Before using `mergemaster` , it is recommended to first copy the existing `/etc` somewhere safe. Include `-R` which does a recursive copy and `-p` which preserves times and the ownerships on files:

```
# cp -Rp /etc /etc.old
```

When run, `mergemaster` builds a temporary root environment, from `/` down, and populates it with various system configuration files. Those files are then compared to the ones currently installed in the system. Files that differ will be shown in diff(1) format, with the `+` sign representing added or modified lines, and `-` representing lines that will be either removed completely or replaced with a new file. Refer to diff(1) for more information about how file differences are shown.

Next, `mergemaster` will display each file that differs, and present options to: delete the new file, referred to as the temporary file, install the temporary file in its unmodified state, merge the temporary file with the currently installed file, or view the results again.

Choosing to delete the temporary file will tell `mergemaster` to keep the current file unchanged and to delete the new version. This option is not recommended. To get help at any time, type ? at the `mergemaster` prompt. If the user chooses to skip a file, it will be presented again after all other files have been dealt with.

Choosing to install the unmodified temporary file will replace the current file with the new one. For most unmodified files, this is the best option.

Choosing to merge the file will present a text editor, and the contents of both files. The files can be merged by reviewing both files side by side on the screen, and choosing parts from both to create a finished product. When the files are compared side by side, l selects the left contents and r selects contents from the right. The final output will be a file consisting of both parts, which can then be installed. This option is customarily used for files where settings have been modified by the user.

Choosing to view the results again will redisplay the file differences.

After `mergemaster` is done with the system files, it will prompt for other options. It may prompt to rebuild the password file and will finish up with an option to remove left-over temporary files.

23.6.5. Deleting Obsolete Files and Libraries

Based on notes provided by Anton Shterenlikht.

As a part of the FreeBSD development lifecycle, files and their contents occasionally become obsolete. This may be because functionality is implemented elsewhere, the version number of the library has changed, or it was removed from the system entirely. These obsoleted files, libraries, and directories should be removed when updating the system. This ensures that the system is not cluttered with old files which take up unnecessary space on the storage

and backup media. Additionally, if the old library has a security or stability issue, the system should be updated to the newer library to keep it safe and to prevent crashes caused by the old library. Files, directories, and libraries which are considered obsolete are listed in `/usr/src/ObsoleteFiles.inc` . The following instructions should be used to remove obsolete files during the system upgrade process.

After the `make installworld` and the subsequent `mergemaster` have finished successfully, check for obsolete files and libraries:

```
# cd /usr/src
# make check-old
```

If any obsolete files are found, they can be deleted using the following command:

```
# make delete-old
```

A prompt is displayed before deleting each obsolete file. To skip the prompt and let the system remove these files automatically, use `BATCH_DELETE_OLD_FILES` :

```
# make -DBATCH_DELETE_OLD_FILES delete-old
```

The same goal can be achieved by piping these commands through `yes`:

```
# yes|make delete-old
```

Warning

Deleting obsolete files will break applications that still depend on those obsolete files. This is especially true for old libraries. In most cases, the programs, ports, or libraries that used the old library need to be recompiled before `make delete-old-libs` is executed.

Utilities for checking shared library dependencies include sysutils/libchk and sysutils/bsdadminscripts.

Obsolete shared libraries can conflict with newer libraries, causing messages like these:

```
/usr/bin/ld: warning: libz.so.4, needed by /usr/local/lib/libtiff.so, may conflict with ↺
libz.so.5
/usr/bin/ld: warning: librpcsvc.so.4, needed by /usr/local/lib/libXext.so, may conflict ↺
with librpcsvc.so.5
```

To solve these problems, determine which port installed the library:

```
# pkg which /usr/local/lib/libtiff.so
  /usr/local/lib/libtiff.so was installed by package tiff-3.9.4
# pkg which /usr/local/lib/libXext.so
  /usr/local/lib/libXext.so was installed by package libXext-1.1.1,1
```

Then deinstall, rebuild, and reinstall the port. To automate this process, ports-mgmt/portmaster can be used. After all ports are rebuilt and no longer use the old libraries, delete the old libraries using the following command:

```
# make delete-old-libs
```

If something goes wrong, it is easy to rebuild a particular piece of the system. For example, if `/etc/magic` was accidentally deleted as part of the upgrade or merge of `/etc`, `file` will stop working. To fix this, run:

```
# cd /usr/src/usr.bin/file
# make all install
```

23.6.6. Common Questions

Do I need to re-make the world for every change?
: It depends upon the nature of the change. For example, if svn only shows the following files as being updated:

```
src/games/cribbage/instr.c
src/games/sail/pl_main.c
src/release/sysinstall/config.c
src/release/sysinstall/media.c
src/share/mk/bsd.port.mk
```

: it probably is not worth rebuilding the entire world. Instead, go into the appropriate sub-directories and run `make all install`. But if something major changes, such as `src/lib/libc/stdlib`, consider rebuilding world.

: Some users rebuild world every fortnight and let changes accumulate over that fortnight. Others only re-make those things that have changed and are careful to spot all the dependencies. It all depends on how often a user wants to upgrade and whether they are tracking FreeBSD-STABLE or FreeBSD-CURRENT.

What would cause a compile to fail with lots of signal 11 (or other signal number) errors?
: This normally indicates a hardware problem. Building world is an effective way to stress test hardware, especially memory. A sure indicator of a hardware issue is when make is restarted and it dies at a different point in the process.

: To resolve this error, swap out the components in the machine, starting with RAM, to determine which component is failing.

Can `/usr/obj` be removed when finished?
: This directory contains all the object files that were produced during the compilation phase. Normally, one of the first steps in the `make buildworld` process is to remove this directory and start afresh. Keeping `/usr/obj` around when finished makes little sense, and its removal frees up a approximately 2GB of disk space.

Can interrupted builds be resumed?
: This depends on how far into the process the problem occurs. In general, `make buildworld` builds new copies of essential tools and the system libraries. These tools and libraries are then installed, used to rebuild themselves, and are installed again. The rest of the system is then rebuilt with the new system tools.

: During the last stage, it is fairly safe to run these commands as they will not undo the work of the previous `make buildworld`:

```
# cd /usr/src
# make -DNO_CLEAN all
```

: If this message appears:

```
------------------------------------------------------------
Building everything..
------------------------------------------------------------
```

: in the `make buildworld` output, it is probably fairly safe to do so.

: If that message is not displayed, it is always better to be safe than sorry and to restart the build from scratch.

Is it possible to speed up making the world?
: Several actions can speed up the build world process. For example, the entire process can be run from single-user mode. However, this will prevent users from having access to the system until the process is complete.

: Careful file system design or the use of ZFS datasets can make a difference. Consider putting `/usr/src` and `/usr/obj` on separate file systems. If possible, place the file systems on separate disks on separate disk

controllers. When mounting `/usr/src`, use `noatime` which prevents the file system from recording the file access time. If `/usr/src` is not on its own file system, consider remounting `/usr` with `noatime`.

The file system holding `/usr/obj` can be mounted or remounted with `async` so that disk writes happen asynchronously. The write completes immediately, and the data is written to the disk a few seconds later. This allows writes to be clustered together, and can provide a dramatic performance boost.

警告

Keep in mind that this option makes the file system more fragile. With this option, there is an increased chance that, should power fail, the file system will be in an unrecoverable state when the machine restarts.

If `/usr/obj` is the only directory on this file system, this is not a problem. If you have other, valuable data on the same file system, ensure that there are verified backups before enabling this option.

Turn off profiling by setting "NO_PROFILE=true" in `/etc/make.conf`.

Pass `-jn` to make(1) to run multiple processes in parallel. This usually helps on both single- and multi-processor machines.

What if something goes wrong?

First, make absolutely sure that the environment has no extraneous cruft from earlier builds:

```
# chflags -R noschg /usr/obj/usr
# rm -rf /usr/obj/usr
# cd /usr/src
# make cleandir
# make cleandir
```

Yes, `make cleandir` really should be run twice.

Then, restart the whole process, starting with `make buildworld`.

If problems persist, send the error and the output of `uname -a` to FreeBSD general questions 郵遞論壇. Be prepared to answer other questions about the setup!

23.7. 追蹤多追蹤多部機器

Contributed by Mike Meyer.

當有多部機器需要追蹤同一個原始碼樹， 會浪費磁碟空間，網路頻寬，和 中央處理器周期來讓每個系統下載原始碼和編譯所有東西。 解決方法是有解決方法是有一台機器做大部份的工作，剩下的機器經由 NFS 來掛載這個工作。這一節概述了一個如此做的方法。 更多關於使用 NFS的資訊，請參考節 28.3, "Network File System (NFS)"。

First, identify a set of machines which will run the same set of binaries, known as a build set. Each machine can have a custom kernel, but will run the same userland binaries. From that set, choose a machine to be the build machine that the world and kernel are built on. Ideally, this is a fast machine that has sufficient spare CPU to run `make buildworld` and `make buildkernel`.

Select a machine to be the test machine, which will test software updates before they are put into production. This must be a machine that can afford to be down for an extended period of time. It can be the build machine, but need not be.

All the machines in this build set need to mount `/usr/obj` and `/usr/src` from the build machine via NFS. For multiple build sets, `/usr/src` should be on one build machine, and NFS mounted on the rest.

Ensure that `/etc/make.conf` and `/etc/src.conf` on all the machines in the build set agree with the build machine. That means that the build machine must build all the parts of the base system that any machine in the build set is going to install. Also, each build machine should have its kernel name set with `KERNCONF` in `/etc/make.conf`, and the build machine should list them all in its `KERNCONF`, listing its own kernel first. The build machine must have the kernel configuration files for each machine in its `/usr/src/sys/`*`arch`*`/conf`.

On the build machine, build the kernel and world as described in 節 23.6, “重新編譯 World”, but do not install anything on the build machine. Instead, install the built kernel on the test machine. On the test machine, mount `/usr/src` and `/usr/obj` via NFS. Then, run `shutdown now` to go to single-user mode in order to install the new kernel and world and run `mergemaster` as usual. When done, reboot to return to normal multi-user operations.

After verifying that everything on the test machine is working properly, use the same procedure to install the new software on each of the other machines in the build set.

The same methodology can be used for the ports tree. The first step is to share `/usr/ports` via NFS to all the machines in the build set. To configure `/etc/make.conf` to share distfiles, set `DISTDIR` to a common shared directory that is writable by whichever user `root` is mapped to by the NFS mount. Each machine should set `WRKDIRPREFIX` to a local build directory, if ports are to be built locally. Alternately, if the build system is to build and distribute packages to the machines in the build set, set `PACKAGES` on the build system to a directory similar to `DISTDIR`.

章 24. DTrace

Written by Tom Rhodes.

24.1. Synopsis

DTrace, also known as Dynamic Tracing, was developed by Sun™ as a tool for locating performance bottlenecks in production and pre-production systems. In addition to diagnosing performance problems, DTrace can be used to help investigate and debug unexpected behavior in both the FreeBSD kernel and in userland programs.

DTrace is a remarkable profiling tool, with an impressive array of features for diagnosing system issues. It may also be used to run pre-written scripts to take advantage of its capabilities. Users can author their own utilities using the DTrace D Language, allowing them to customize their profiling based on specific needs.

The FreeBSD implementation provides full support for kernel DTrace and experimental support for userland DTrace. Userland DTrace allows users to perform function boundary tracing for userland programs using the `pid` provider, and to insert static probes into userland programs for later tracing. Some ports, such as databases/postgres-server and lang/php5 have a DTrace option to enable static probes. FreeBSD 10.0-RELEASE has reasonably good userland DTrace support, but it is not considered production ready. In particular, it is possible to crash traced programs.

After reading this chapter, you will know:

- What DTrace is and what features it provides.
- Differences between the Solaris™ DTrace implementation and the one provided by FreeBSD.
- How to enable and use DTrace on FreeBSD.

Before reading this chapter, you should:

- Understand UNIX® and FreeBSD basics (章 3, UNIX 基礎概念).
- Have some familiarity with security and how it pertains to FreeBSD (章 13, 系統安全).

24.2. Implementation Differences

While the DTrace in FreeBSD is similar to that found in Solaris™, differences do exist. The primary difference is that in FreeBSD, DTrace is implemented as a set of kernel modules and DTrace can not be used until the modules are loaded. To load all of the necessary modules:

```
# kldload dtraceall
```

Beginning with FreeBSD 10.0-RELEASE, the modules are automatically loaded when `dtrace` is run.

FreeBSD uses the `DDB_CTF` kernel option to enable support for loading CTF data from kernel modules and the kernel itself. CTF is the Solaris™ Compact C Type Format which encapsulates a reduced form of debugging information similar to DWARF and the venerable stabs. CTF data is added to binaries by the `ctfconvert` and `ctfmerge` build tools. The `ctfconvert` utility parses DWARF ELF debug sections created by the compiler and `ctfmerge` merges CTF ELF sections from objects into either executables or shared libraries.

Some different providers exist for FreeBSD than for Solaris™. Most notable is the `dtmalloc` provider, which allows tracing `malloc()` by type in the FreeBSD kernel. Some of the providers found in Solaris™, such as `cpc` and `mib`, are not present in FreeBSD. These may appear in future versions of FreeBSD. Moreover, some of the

providers available in both operating systems are not compatible, in the sense that their probes have different argument types. Thus, D scripts written on Solaris™ may or may not work unmodified on FreeBSD, and vice versa.

Due to security differences, only `root` may use DTrace on FreeBSD. Solaris™ has a few low level security checks which do not yet exist in FreeBSD. As such, the `/dev/dtrace/dtrace` is strictly limited to `root`.

DTrace falls under the Common Development and Distribution License (CDDL) license. To view this license on FreeBSD, see `/usr/src/cddl/contrib/opensolaris/OPENSOLARIS.LICENSE` or view it online at `http://opensource.org/licenses/CDDL-1.0` . While a FreeBSD kernel with DTrace support is BSD licensed, the CDDL is used when the modules are distributed in binary form or the binaries are loaded.

24.3. Enabling DTrace Support

In FreeBSD 9.2 and 10.0, DTrace support is built into the `GENERIC` kernel. Users of earlier versions of FreeBSD or who prefer to statically compile in DTrace support should add the following lines to a custom kernel configuration file and recompile the kernel using the instructions in 章 8, 設定 FreeBSD Kernel:

```
options         KDTRACE_HOOKS
options         DDB_CTF
options  DEBUG=-g
```

Users of the AMD64 architecture should also add this line:

```
options         KDTRACE_FRAME
```

This option provides support for FBT. While DTrace will work without this option, there will be limited support for function boundary tracing.

Once the FreeBSD system has rebooted into the new kernel, or the DTrace kernel modules have been loaded using `kldload dtraceall` , the system will need support for the Korn shell as the DTrace Toolkit has several utilities written in `ksh`. Make sure that the shells/ksh93 package or port is installed. It is also possible to run these tools under shells/pdksh or shells/mksh.

Finally, install the current DTrace Toolkit, a collection of ready-made scripts for collecting system information. There are scripts to check open files, memory, CPU usage, and a lot more. FreeBSD 10 installs a few of these scripts into `/usr/share/dtrace` . On other FreeBSD versions, or to install the full DTrace Toolkit, use the sysutils/DTraceToolkit package or port.

注意

The scripts found in `/usr/share/dtrace` have been specifically ported to FreeBSD. Not all of the scripts found in the DTrace Toolkit will work as-is on FreeBSD and some scripts may require some effort in order for them to work on FreeBSD.

The DTrace Toolkit includes many scripts in the special language of DTrace. This language is called the D language and it is very similar to C++. An in depth discussion of the language is beyond the scope of this document. It is extensively discussed at `http://wikis.oracle.com/display/DTrace/Documentation` .

24.4. Using DTrace

DTrace scripts consist of a list of one or more probes, or instrumentation points, where each probe is associated with an action. Whenever the condition for a probe is met, the associated action is executed. For example, an action may occur when a file is opened, a process is started, or a line of code is executed. The action might be to log some

information or to modify context variables. The reading and writing of context variables allows probes to share information and to cooperatively analyze the correlation of different events.

To view all probes, the administrator can execute the following command:

```
# dtrace -l | more
```

Each probe has an `ID`, a `PROVIDER` (dtrace or fbt), a `MODULE`, and a `FUNCTION NAME`. Refer to dtrace(1) for more information about this command.

The examples in this section provide an overview of how to use two of the fully supported scripts from the DTrace Toolkit: the `hotkernel` and `procsystime` scripts.

The `hotkernel` script is designed to identify which function is using the most kernel time. It will produce output similar to the following:

```
# cd /usr/share/dtrace/toolkit
# ./hotkernel
Sampling... Hit Ctrl-C to end.
```

As instructed, use the Ctrl+C key combination to stop the process. Upon termination, the script will display a list of kernel functions and timing information, sorting the output in increasing order of time:

```
kernel`_thread_lock_flags                           2   0.0%
0xc1097063                                          2   0.0%
kernel`sched_userret                                2   0.0%
kernel`kern_select                                  2   0.0%
kernel`generic_copyin                               3   0.0%
kernel`_mtx_assert                                  3   0.0%
kernel`vm_fault                                     3   0.0%
kernel`sopoll_generic                               3   0.0%
kernel`fixup_filename                               4   0.0%
kernel`_isitmyx                                     4   0.0%
kernel`find_instance                                4   0.0%
kernel`_mtx_unlock_flags                            5   0.0%
kernel`syscall                                      5   0.0%
kernel`DELAY                                        5   0.0%
0xc108a253                                          6   0.0%
kernel`witness_lock                                 7   0.0%
kernel`read_aux_data_no_wait                        7   0.0%
kernel`Xint0x80_syscall                             7   0.0%
kernel`witness_checkorder                           7   0.0%
kernel`sse2_pagezero                                8   0.0%
kernel`strncmp                                      9   0.0%
kernel`spinlock_exit                               10   0.0%
kernel`_mtx_lock_flags                             11   0.0%
kernel`witness_unlock                              15   0.0%
kernel`sched_idletd                               137   0.3%
0xc10981a5                                      42139  99.3%
```

This script will also work with kernel modules. To use this feature, run the script with `-m`:

```
# ./hotkernel -m
Sampling... Hit Ctrl-C to end.
^C
MODULE                                          COUNT   PCNT
0xc107882e                                          1   0.0%
0xc10e6aa4                                          1   0.0%
0xc1076983                                          1   0.0%
0xc109708a                                          1   0.0%
0xc1075a5d                                          1   0.0%
0xc1077325                                          1   0.0%
0xc108a245                                          1   0.0%
0xc107730d                                          1   0.0%
```

```
0xc1097063                                                2   0.0%
0xc108a253                                               73   0.0%
kernel                                                  874   0.4%
0xc10981a5                                           213781  99.6%
```

The `procsystime` script captures and prints the system call time usage for a given process ID (PID) or process name. In the following example, a new instance of `/bin/csh` was spawned. Then, `procsystime` was executed and remained waiting while a few commands were typed on the other incarnation of `csh`. These are the results of this test:

```
# ./procsystime -n csh
Tracing... Hit Ctrl-C to end...
^C

Elapsed Times for processes csh,

         SYSCALL          TIME (ns)
          getpid              6131
       sigreturn              8121
           close             19127
           fcntl             19959
             dup             26955
         setpgid             28070
            stat             31899
       setitimer             40938
           wait4             62717
       sigaction             67372
     sigprocmask            119091
    gettimeofday            183710
           write            263242
          execve            492547
           ioctl            770073
           vfork           3258923
      sigsuspend           6985124
            read        3988049784
```

As shown, the `read()` system call used the most time in nanoseconds while the `getpid()` system call used the least amount of time.

部 IV. 網路通訊

FreeBSD 是一種廣泛的被使用在高效能的網路伺服器中的作業系統，這些章節包含了：

- 序列埠通訊
- PPP 和 PPPoE
- 電子郵件
- 執行網路伺服程式
- 防火牆
- 其他的進階網路主題

這些章節是讓您在需要查資料的時候翻閱用的。 您不需要依照特定的順序來讀，也不需要將這些章節全部讀過之後才將 FreeBSD 用在網路環境下。

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章 25. Serial Communications

25.1. Synopsis

UNIX® has always had support for serial communications. In fact, the very first UNIX® machines relied on serial lines for user input and output. Things have changed a lot from the days when the average "terminal" consisted of a 10-character-per-second serial printer and a keyboard. This chapter will cover some of the ways in which FreeBSD uses serial communications.

After reading this chapter, you will know:

- How to connect terminals to your FreeBSD system.
- How to use a modem to dial out to remote hosts.
- How to allow remote users to login to your system with a modem.
- How to boot your system from a serial console.

Before reading this chapter, you should:

- Know how to configure and install a new kernel (章 8, 設定 FreeBSD Kernel).
- Understand UNIX® permissions and processes (章 3, UNIX 基礎概念).
- Have access to the technical manual for the serial hardware (modem or multi-port card) that you would like to use with FreeBSD.

25.2. Introduction

25.2.1. Terminology

bps
: Bits per Second —— the rate at which data is transmitted

DTE
: Data Terminal Equipment —— for example, your computer

DCE
: Data Communications Equipment —— your modem

RS-232
: EIA standard for hardware serial communications

When talking about communications data rates, this section does not use the term "baud". Baud refers to the number of electrical state transitions that may be made in a period of time, while "bps" (bits per second) is the correct term to use (at least it does not seem to bother the curmudgeons quite as much).

25.2.2. Cables and Ports

To connect a modem or terminal to your FreeBSD system, you will need a serial port on your computer and the proper cable to connect to your serial device. If you are already familiar with your hardware and the cable it requires, you can safely skip this section.

25.2.2.1. Cables

There are several different kinds of serial cables. The two most common types for our purposes are null-modem cables and standard (“straight”) RS-232 cables. The documentation for your hardware should describe the type of cable required.

25.2.2.1.1. Null-modem Cables

A null-modem cable passes some signals, such as “Signal Ground”, straight through, but switches other signals. For example, the “Transmitted Data” pin on one end goes to the “Received Data” pin on the other end.

You can also construct your own null-modem cable for use with terminals (e.g., for quality purposes). This table shows the RS-232C signals and the pin numbers on a DB-25 connector. Note that the standard also calls for a straight-through pin 1 to pin 1 Protective Ground line, but it is often omitted. Some terminals work OK using only pins 2, 3 and 7, while others require different configurations than the examples shown below.

表格 25.1. DB-25 to DB-25 Null-Modem Cable

Signal	Pin #		Pin #	Signal
SG	7	connects to	7	SG
TD	2	connects to	3	RD
RD	3	connects to	2	TD
RTS	4	connects to	5	CTS
CTS	5	connects to	4	RTS
DTR	20	connects to	6	DSR
DTR	20	connects to	8	DCD
DSR	6	connects to	20	DTR
DCD	8	connects to	20	DTR

Here are two other schemes more common nowadays.

表格 25.2. DB-9 to DB-9 Null-Modem Cable

Signal	Pin #		Pin #	Signal
RD	2	connects to	3	TD
TD	3	connects to	2	RD
DTR	4	connects to	6	DSR
DTR	4	connects to	1	DCD
SG	5	connects to	5	SG
DSR	6	connects to	4	DTR
DCD	1	connects to	4	DTR
RTS	7	connects to	8	CTS
CTS	8	connects to	7	RTS

表格 25.3. DB-9 to DB-25 Null-Modem Cable

Signal	Pin #		Pin #	Signal
RD	2	connects to	2	TD
TD	3	connects to	3	RD
DTR	4	connects to	6	DSR

Signal	Pin #		Pin #	Signal
DTR	4	connects to	8	DCD
SG	5	connects to	7	SG
DSR	6	connects to	20	DTR
DCD	1	connects to	20	DTR
RTS	7	connects to	5	CTS
CTS	8	connects to	4	RTS

注意

When one pin at one end connects to a pair of pins at the other end, it is usually implemented with one short wire between the pair of pins in their connector and a long wire to the other single pin.

The above designs seems to be the most popular. In another variation (explained in the book RS-232 Made Easy) SG connects to SG, TD connects to RD, RTS and CTS connect to DCD, DTR connects to DSR, and vice-versa.

25.2.2.1.2. Standard RS-232C Cables

A standard serial cable passes all of the RS-232C signals straight through. That is, the "Transmitted Data" pin on one end of the cable goes to the "Transmitted Data" pin on the other end. This is the type of cable to use to connect a modem to your FreeBSD system, and is also appropriate for some terminals.

25.2.2.2. Ports

Serial ports are the devices through which data is transferred between the FreeBSD host computer and the terminal. This section describes the kinds of ports that exist and how they are addressed in FreeBSD.

25.2.2.2.1. Kinds of Ports

Several kinds of serial ports exist. Before you purchase or construct a cable, you need to make sure it will fit the ports on your terminal and on the FreeBSD system.

Most terminals will have DB-25 ports. Personal computers, including PCs running FreeBSD, will have DB-25 or DB-9 ports. If you have a multiport serial card for your PC, you may have RJ-12 or RJ-45 ports.

See the documentation that accompanied the hardware for specifications on the kind of port in use. A visual inspection of the port often works too.

25.2.2.2.2. Port Names

In FreeBSD, you access each serial port through an entry in the `/dev` directory. There are two different kinds of entries:

- Call-in ports are named `/dev/ttydN` where *N* is the port number, starting from zero. Generally, you use the call-in port for terminals. Call-in ports require that the serial line assert the data carrier detect (DCD) signal to work correctly.
- Call-out ports are named `/dev/cuadN` . You usually do not use the call-out port for terminals, just for modems. You may use the call-out port if the serial cable or the terminal does not support the carrier detect signal.

注意

Call-out ports are named `/dev/cuaaN` in FreeBSD 5.X and older.

If you have connected a terminal to the first serial port (`COM1` in MS-DOS®), then you will use `/dev/ttyd0` to refer to the terminal. If the terminal is on the second serial port (also known as `COM2`), use `/dev/ttyd1`, and so forth.

25.2.3. Kernel Configuration

FreeBSD supports four serial ports by default. In the MS-DOS® world, these are known as `COM1`, `COM2`, `COM3`, and `COM4`. FreeBSD currently supports "dumb" multiport serial interface cards, such as the BocaBoard 1008 and 2016, as well as more intelligent multi-port cards such as those made by Digiboard and Stallion Technologies. However, the default kernel only looks for the standard COM ports.

To see if your kernel recognizes any of your serial ports, watch for messages while the kernel is booting, or use the `/sbin/dmesg` command to replay the kernel's boot messages. In particular, look for messages that start with the characters `sio`.

提示

To view just the messages that have the word `sio`, use the command:

```
# /sbin/dmesg | grep 'sio'
```

For example, on a system with four serial ports, these are the serial-port specific kernel boot messages:

```
sio0 at 0x3f8-0x3ff irq 4 on isa
sio0: type 16550A
sio1 at 0x2f8-0x2ff irq 3 on isa
sio1: type 16550A
sio2 at 0x3e8-0x3ef irq 5 on isa
sio2: type 16550A
sio3 at 0x2e8-0x2ef irq 9 on isa
sio3: type 16550A
```

If your kernel does not recognize all of your serial ports, you will probably need to configure your kernel in the `/boot/device.hints` file. You can also comment-out or completely remove lines for devices you do not have.

On FreeBSD 4.X you have to edit your kernel configuration file. For detailed information on configuring your kernel, please see 章 8, 設定 FreeBSD Kernel. The relevant device lines would look like this:

```
device  sio0 at isa? port IO_COM1 irq 4
device  sio1 at isa? port IO_COM2 irq 3
device  sio2 at isa? port IO_COM3 irq 5
device  sio3 at isa? port IO_COM4 irq 9
```

Please refer to the sio(4) manual page for more information on serial ports and multiport boards configuration. Be careful if you are using a configuration file that was previously used for a different version of FreeBSD because the device flags and the syntax have changed between versions.

注意

`port IO_COM1` is a substitution for `port 0x3f8`, `IO_COM2` is `0x2f8`, `IO_COM3` is `0x3e8`, and `IO_COM4` is `0x2e8`, which are fairly common port addresses for their respective serial ports; interrupts 4, 3, 5, and 9 are fairly common interrupt request lines. Also note that regular serial ports cannot share interrupts on ISA-bus PCs (multiport boards have on-board electronics that allow all the 16550A's on the board to share one or two interrupt request lines).

25.2.4. Device Special Files

Most devices in the kernel are accessed through "device special files", which are located in the `/dev` directory. The `sio` devices are accessed through the `/dev/ttydN` (dial-in) and `/dev/cuadN` (call-out) devices. FreeBSD also provides initialization devices (`/dev/ttydN.init` and `/dev/cuadN.init` on FreeBSD 6.X, `/dev/ttyidN` and `/dev/cuaidN` on FreeBSD 5.X and older) and locking devices (`/dev/ttydN.lock` and `/dev/cuadN.lock` on FreeBSD 6.X, `/dev/ttyldN` and `/dev/cualdN` on FreeBSD 5.X and older). The initialization devices are used to initialize communications port parameters each time a port is opened, such as `crtscts` for modems which use `RTS/CTS` signaling for flow control. The locking devices are used to lock flags on ports to prevent users or programs changing certain parameters; see the manual pages termios(4), sio(4), and stty(1) for information on the terminal settings, locking and initializing devices, and setting terminal options, respectively.

25.2.4.1. Making Device Special Files

注意

FreeBSD 5.0 includes the devfs(5) filesystem which automatically creates device nodes as needed. If you are running a version of FreeBSD with `devfs` enabled then you can safely skip this section.

A shell script called `MAKEDEV` in the `/dev` directory manages the device special files. To use `MAKEDEV` to make dial-up device special files for `COM1` (port 0), `cd` to `/dev` and issue the command `MAKEDEV ttyd0`. Likewise, to make dial-up device special files for `COM2` (port 1), use `MAKEDEV ttyd1`.

`MAKEDEV` not only creates the `/dev/ttydN` device special files, but also the `/dev/cuaaN`, `/dev/cuaiaN`, `/dev/cualaN`, `/dev/ttyldN`, and `/dev/ttyidN` nodes.

After making new device special files, be sure to check the permissions on the files (especially the `/dev/cua*` files) to make sure that only users who should have access to those device special files can read and write on them —— you probably do not want to allow your average user to use your modems to dial-out. The default permissions on the `/dev/cua*` files should be sufficient:

```
crw-rw----    1 uucp     dialer    28, 129 Feb 15 14:38 /dev/cuaa1
crw-rw----    1 uucp     dialer    28, 161 Feb 15 14:38 /dev/cuaia1
crw-rw----    1 uucp     dialer    28, 193 Feb 15 14:38 /dev/cuala1
```

These permissions allow the user `uucp` and users in the group `dialer` to use the call-out devices.

25.2.5. Serial Port Configuration

The `ttydN` (or `cuadN`) device is the regular device you will want to open for your applications. When a process opens the device, it will have a default set of terminal I/O settings. You can see these settings with the command

```
# stty -a -f /dev/ttyd1
```

When you change the settings to this device, the settings are in effect until the device is closed. When it is reopened, it goes back to the default set. To make changes to the default set, you can open and adjust the settings of the "initial state" device. For example, to turn on `CLOCAL` mode, 8 bit communication, and `XON/XOFF` flow control by default for `ttyd5`, type:

```
# stty -f /dev/ttyd5.init clocal cs8 ixon ixoff
```

System-wide initialization of the serial devices is controlled in `/etc/rc.d/serial`. This file affects the default settings of serial devices.

注意

On FreeBSD 4.X, system-wide initialization of the serial devices is controlled in `/etc/rc.serial`.

To prevent certain settings from being changed by an application, make adjustments to the "lock state" device. For example, to lock the speed of `ttyd5` to 57600 bps, type:

```
# stty -f /dev/ttyd5.lock 57600
```

Now, an application that opens `ttyd5` and tries to change the speed of the port will be stuck with 57600 bps.

Naturally, you should make the initial state and lock state devices writable only by the `root` account.

25.3. Terminals

Contributed by Sean Kelly.

Terminals provide a convenient and low-cost way to access your FreeBSD system when you are not at the computer's console or on a connected network. This section describes how to use terminals with FreeBSD.

25.3.1. Uses and Types of Terminals

The original UNIX® systems did not have consoles. Instead, people logged in and ran programs through terminals that were connected to the computer's serial ports. It is quite similar to using a modem and terminal software to dial into a remote system to do text-only work.

Today's PCs have consoles capable of high quality graphics, but the ability to establish a login session on a serial port still exists in nearly every UNIX® style operating system today; FreeBSD is no exception. By using a terminal attached to an unused serial port, you can log in and run any text program that you would normally run on the console or in an `xterm` window in the X Window System.

For the business user, you can attach many terminals to a FreeBSD system and place them on your employees' desktops. For a home user, a spare computer such as an older IBM PC or a Macintosh® can be a terminal wired into a more powerful computer running FreeBSD. You can turn what might otherwise be a single-user computer into a powerful multiple user system.

For FreeBSD, there are three kinds of terminals:

- Dumb terminals
- PCs acting as terminals
- X terminals

The remaining subsections describe each kind.

25.3.1.1. Dumb Terminals

Dumb terminals are specialized pieces of hardware that let you connect to computers over serial lines. They are called “dumb” because they have only enough computational power to display, send, and receive text. You cannot run any programs on them. It is the computer to which you connect them that has all the power to run text editors, compilers, email, games, and so forth.

There are hundreds of kinds of dumb terminals made by many manufacturers, including Digital Equipment Corporation's VT-100 and Wyse's WY-75. Just about any kind will work with FreeBSD. Some high-end terminals can even display graphics, but only certain software packages can take advantage of these advanced features.

Dumb terminals are popular in work environments where workers do not need access to graphical applications such as those provided by the X Window System.

25.3.1.2. PCs Acting as Terminals

If a dumb terminal has just enough ability to display, send, and receive text, then certainly any spare personal computer can be a dumb terminal. All you need is the proper cable and some terminal emulation software to run on the computer.

Such a configuration is popular in homes. For example, if your spouse is busy working on your FreeBSD system's console, you can do some text-only work at the same time from a less powerful personal computer hooked up as a terminal to the FreeBSD system.

25.3.1.3. X Terminals

X terminals are the most sophisticated kind of terminal available. Instead of connecting to a serial port, they usually connect to a network like Ethernet. Instead of being relegated to text-only applications, they can display any X application.

We introduce X terminals just for the sake of completeness. However, this chapter does not cover setup, configuration, or use of X terminals.

25.3.2. Configuration

This section describes what you need to configure on your FreeBSD system to enable a login session on a terminal. It assumes you have already configured your kernel to support the serial port to which the terminal is connected ——and that you have connected it.

Recall from 章 12, FreeBSD 開機流程篇 that the `init` process is responsible for all process control and initialization at system startup. One of the tasks performed by `init` is to read the `/etc/ttys` file and start a `getty` process on the available terminals. The `getty` process is responsible for reading a login name and starting the `login` program.

Thus, to configure terminals for your FreeBSD system the following steps should be taken as `root`:

1. Add a line to `/etc/ttys` for the entry in the `/dev` directory for the serial port if it is not already there.
2. Specify that `/usr/libexec/getty` be run on the port, and specify the appropriate *`getty`* type from the `/etc/gettytab` file.

3. Specify the default terminal type.

4. Set the port to “on.”

5. Specify whether the port should be “secure.”

6. Force `init` to reread the `/etc/ttys` file.

As an optional step, you may wish to create a custom *`getty`* type for use in step 2 by making an entry in `/etc/gettytab`. This chapter does not explain how to do so; you are encouraged to see the gettytab(5) and the getty(8) manual pages for more information.

25.3.2.1. Adding an Entry to `/etc/ttys`

The `/etc/ttys` file lists all of the ports on your FreeBSD system where you want to allow logins. For example, the first virtual console `ttyv0` has an entry in this file. You can log in on the console using this entry. This file also contains entries for the other virtual consoles, serial ports, and pseudo-ttys. For a hardwired terminal, just list the serial port's `/dev` entry without the `/dev` part (for example, `/dev/ttyv0` would be listed as `ttyv0`).

A default FreeBSD install includes an `/etc/ttys` file with support for the first four serial ports: `ttyd0` through `ttyd3`. If you are attaching a terminal to one of those ports, you do not need to add another entry.

範例 25.1. Adding Terminal Entries to `/etc/ttys`

Suppose we would like to connect two terminals to the system: a Wyse-50 and an old 286 IBM PC running Procomm terminal software emulating a VT-100 terminal. We connect the Wyse to the second serial port and the 286 to the sixth serial port (a port on a multiport serial card). The corresponding entries in the `/etc/ttys` file would look like this:

```
ttyd1❶  "/usr/libexec/getty std.38400"❷  wy50❸  on❹  insecure❺
ttyd5   "/usr/libexec/getty std.19200"  vt100  on  insecure
```

❶ The first field normally specifies the name of the terminal special file as it is found in `/dev`.

❷ The second field is the command to execute for this line, which is usually getty(8). `getty` initializes and opens the line, sets the speed, prompts for a user name and then executes the login(1) program.

The `getty` program accepts one (optional) parameter on its command line, the *`getty`* type. A *`getty`* type configures characteristics on the terminal line, like bps rate and parity. The `getty` program reads these characteristics from the file `/etc/gettytab`.

The file `/etc/gettytab` contains lots of entries for terminal lines both old and new. In almost all cases, the entries that start with the text `std` will work for hardwired terminals. These entries ignore parity. There is a `std` entry for each bps rate from 110 to 115200. Of course, you can add your own entries to this file. The gettytab(5) manual page provides more information.

When setting the *`getty`* type in the `/etc/ttys` file, make sure that the communications settings on the terminal match.

For our example, the Wyse-50 uses no parity and connects at 38400 bps. The 286 PC uses no parity and connects at 19200 bps.

❸ The third field is the type of terminal usually connected to that tty line. For dial-up ports, `unknown` or `dialup` is typically used in this field since users may dial up with practically any type of terminal or software. For hardwired terminals, the terminal type does not change, so you can put a real terminal type from the termcap(5) database file in this field.

For our example, the Wyse-50 uses the real terminal type while the 286 PC running Procomm will be set to emulate at VT-100.

❹ The fourth field specifies if the port should be enabled. Putting `on` here will have the `init` process start the program in the second field, `getty`. If you put `off` in this field, there will be no `getty`, and hence no logins on the port.

❺ The final field is used to specify whether the port is secure. Marking a port as secure means that you trust it enough to allow the `root` account (or any account with a user ID of 0) to login from that port. Insecure ports do not allow `root` logins. On an insecure port, users must login from unprivileged accounts and then use su(1) or a similar mechanism to gain superuser privileges.

It is highly recommended that you use "insecure" even for terminals that are behind locked doors. It is quite easy to login and use `su` if you need superuser privileges.

25.3.2.2. Force `init` to Reread `/etc/ttys`

After making the necessary changes to the `/etc/ttys` file you should send a SIGHUP (hangup) signal to the `init` process to force it to re-read its configuration file. For example:

```
# kill -HUP 1
```

注意

`init` is always the first process run on a system, therefore it will always have PID 1.

If everything is set up correctly, all cables are in place, and the terminals are powered up, then a `getty` process should be running on each terminal and you should see login prompts on your terminals at this point.

25.3.3. Troubleshooting Your Connection

Even with the most meticulous attention to detail, something could still go wrong while setting up a terminal. Here is a list of symptoms and some suggested fixes.

25.3.3.1. No Login Prompt Appears

Make sure the terminal is plugged in and powered up. If it is a personal computer acting as a terminal, make sure it is running terminal emulation software on the correct serial port.

Make sure the cable is connected firmly to both the terminal and the FreeBSD computer. Make sure it is the right kind of cable.

Make sure the terminal and FreeBSD agree on the bps rate and parity settings. If you have a video display terminal, make sure the contrast and brightness controls are turned up. If it is a printing terminal, make sure paper and ink are in good supply.

Make sure that a `getty` process is running and serving the terminal. For example, to get a list of running `getty` processes with `ps`, type:

```
# ps -axww|grep getty
```

You should see an entry for the terminal. For example, the following display shows that a `getty` is running on the second serial port `ttyd1` and is using the `std.38400` entry in `/etc/gettytab` :

```
22189  d1  Is+    0:00.03 /usr/libexec/getty std.38400 ttyd1
```

If no `getty` process is running, make sure you have enabled the port in `/etc/ttys` . Also remember to run `kill -HUP 1` after modifying the `ttys` file.

If the `getty` process is running but the terminal still does not display a login prompt, or if it displays a prompt but will not allow you to type, your terminal or cable may not support hardware handshaking. Try changing the entry in `/etc/ttys` from `std.38400` to `3wire.38400` remember to run `kill -HUP 1` after modifying `/etc/ttys`). The `3wire` entry is similar to `std`, but ignores hardware handshaking. You may need to reduce the baud rate or enable software flow control when using `3wire` to prevent buffer overflows.

25.3.3.2. If Garbage Appears Instead of a Login Prompt

Make sure the terminal and FreeBSD agree on the bps rate and parity settings. Check the `getty` processes to make sure the correct *`getty`* type is in use. If not, edit `/etc/ttys` and run `kill -HUP 1`.

25.3.3.3. Characters Appear Doubled; the Password Appears When Typed

Switch the terminal (or the terminal emulation software) from “half duplex” or “local echo” to “full duplex.”

25.4. Dial-in Service

Contributed by Guy Helmer.
Additions by Sean Kelly.

Configuring your FreeBSD system for dial-in service is very similar to connecting terminals except that you are dealing with modems instead of terminals.

25.4.1. External vs. Internal Modems

External modems seem to be more convenient for dial-up, because external modems often can be semi-permanently configured via parameters stored in non-volatile RAM and they usually provide lighted indicators that display the state of important RS-232 signals. Blinking lights impress visitors, but lights are also very useful to see whether a modem is operating properly.

Internal modems usually lack non-volatile RAM, so their configuration may be limited only to setting DIP switches. If your internal modem has any signal indicator lights, it is probably difficult to view the lights when the system's cover is in place.

25.4.1.1. Modems and Cables

If you are using an external modem, then you will of course need the proper cable. A standard RS-232C serial cable should suffice as long as all of the normal signals are wired:

表格 25.4. Signal Names

Acronyms	Names
RD	Received Data
TD	Transmitted Data
DTR	Data Terminal Ready
DSR	Data Set Ready
DCD	Data Carrier Detect (RS-232's Received Line Signal Detector)
SG	Signal Ground
RTS	Request to Send
CTS	Clear to Send

FreeBSD needs the RTS and CTS signals for flow control at speeds above 2400 bps, the CD signal to detect when a call has been answered or the line has been hung up, and the DTR signal to reset the modem after a session is complete. Some cables are wired without all of the needed signals, so if you have problems, such as a login session not going away when the line hangs up, you may have a problem with your cable.

Like other UNIX® like operating systems, FreeBSD uses the hardware signals to find out when a call has been answered or a line has been hung up and to hangup and reset the modem after a call. FreeBSD avoids sending commands to the modem or watching for status reports from the modem. If you are familiar with connecting modems to PC-based bulletin board systems, this may seem awkward.

25.4.2. Serial Interface Considerations

FreeBSD supports NS8250-, NS16450-, NS16550-, and NS16550A-based EIA RS-232C (CCITT V.24) communications interfaces. The 8250 and 16450 devices have single-character buffers. The 16550 device provides a 16-character buffer, which allows for better system performance. (Bugs in plain 16550's prevent the use of the 16-character buffer, so use 16550A's if possible). Because single-character-buffer devices require more work by the operating system than the 16-character-buffer devices, 16550A-based serial interface cards are much preferred. If the system has many active serial ports or will have a heavy load, 16550A-based cards are better for low-error-rate communications.

25.4.3. Quick Overview

As with terminals, `init` spawns a `getty` process for each configured serial port for dial-in connections. For example, if a modem is attached to `/dev/ttyd0` , the command `ps ax` might show this:

```
 4850 ??  I      0:00.09 /usr/libexec/getty V19200 ttyd0
```

When a user dials the modem's line and the modems connect, the CD (Carrier Detect) line is reported by the modem. The kernel notices that carrier has been detected and completes `getty`'s open of the port. `getty` sends a `login:` prompt at the specified initial line speed. `getty` watches to see if legitimate characters are received, and, in a typical configuration, if it finds junk (probably due to the modem's connection speed being different than `getty`'s speed), `getty` tries adjusting the line speeds until it receives reasonable characters.

After the user enters his/her login name, `getty` executes `/usr/bin/login` , which completes the login by asking for the user's password and then starting the user's shell.

25.4.4. Configuration Files

There are three system configuration files in the `/etc` directory that you will probably need to edit to allow dial-up access to your FreeBSD system. The first, `/etc/gettytab` , contains configuration information for the `/usr/libexec/getty` daemon. Second, `/etc/ttys` holds information that tells `/sbin/init` what `tty` devices should have `getty` processes running on them. Lastly, you can place port initialization commands in the `/etc/rc.d/serial` script.

There are two schools of thought regarding dial-up modems on UNIX®. One group likes to configure their modems and systems so that no matter at what speed a remote user dials in, the local computer-to-modem RS-232 interface runs at a locked speed. The benefit of this configuration is that the remote user always sees a system login prompt immediately. The downside is that the system does not know what a user's true data rate is, so full-screen programs like Emacs will not adjust their screen-painting methods to make their response better for slower connections.

The other school configures their modems' RS-232 interface to vary its speed based on the remote user's connection speed. For example, V.32bis (14.4 Kbps) connections to the modem might make the modem run its RS-232 interface at 19.2 Kbps, while 2400 bps connections make the modem's RS-232 interface run at 2400 bps. Because `getty` does not understand any particular modem's connection speed reporting, `getty` gives a `login:` message at an initial speed and watches the characters that come back in response. If the user sees junk, it is assumed that they know they should press the Enter key until they see a recognizable prompt. If the data rates do not match,

`getty` sees anything the user types as "junk", tries going to the next speed and gives the `login:` prompt again. This procedure can continue ad nauseam, but normally only takes a keystroke or two before the user sees a good prompt. Obviously, this login sequence does not look as clean as the former "locked-speed" method, but a user on a low-speed connection should receive better interactive response from full-screen programs.

This section will try to give balanced configuration information, but is biased towards having the modem's data rate follow the connection rate.

25.4.4.1. `/etc/gettytab`

`/etc/gettytab` is a termcap(5)-style file of configuration information for getty(8). Please see the gettytab(5) manual page for complete information on the format of the file and the list of capabilities.

25.4.4.1.1. Locked-speed Config

If you are locking your modem's data communications rate at a particular speed, you probably will not need to make any changes to `/etc/gettytab` .

25.4.4.1.2. Matching-speed Config

You will need to set up an entry in `/etc/gettytab` to give `getty` information about the speeds you wish to use for your modem. If you have a 2400 bps modem, you can probably use the existing `D2400` entry.

```
#
# Fast dialup terminals, 2400/1200/300 rotary (can start either way)
#
D2400|d2400|Fast-Dial-2400:\
        :nx=D1200:tc=2400-baud:
3|D1200|Fast-Dial-1200:\
        :nx=D300:tc=1200-baud:
5|D300|Fast-Dial-300:\
        :nx=D2400:tc=300-baud:
```

If you have a higher speed modem, you will probably need to add an entry in `/etc/gettytab` ; here is an entry you could use for a 14.4 Kbps modem with a top interface speed of 19.2 Kbps:

```
#
# Additions for a V.32bis Modem
#
um|V300|High Speed Modem at 300,8-bit:\
        :nx=V19200:tc=std.300:
un|V1200|High Speed Modem at 1200,8-bit:\
        :nx=V300:tc=std.1200:
uo|V2400|High Speed Modem at 2400,8-bit:\
        :nx=V1200:tc=std.2400:
up|V9600|High Speed Modem at 9600,8-bit:\
        :nx=V2400:tc=std.9600:
uq|V19200|High Speed Modem at 19200,8-bit:\
        :nx=V9600:tc=std.19200:
```

This will result in 8-bit, no parity connections.

The example above starts the communications rate at 19.2 Kbps (for a V.32bis connection), then cycles through 9600 bps (for V.32), 2400 bps, 1200 bps, 300 bps, and back to 19.2 Kbps. Communications rate cycling is implemented with the `nx=` ("next table") capability. Each of the lines uses a `tc=` ("table continuation") entry to pick up the rest of the "standard" settings for a particular data rate.

If you have a 28.8 Kbps modem and/or you want to take advantage of compression on a 14.4 Kbps modem, you need to use a higher communications rate than 19.2 Kbps. Here is an example of a `gettytab` entry starting a 57.6 Kbps:

```
#
```

```
# Additions for a V.32bis or V.34 Modem
# Starting at 57.6 Kbps
#
vm|VH300|Very High Speed Modem at 300,8-bit:\
        :nx=VH57600:tc=std.300:
vn|VH1200|Very High Speed Modem at 1200,8-bit:\
        :nx=VH300:tc=std.1200:
vo|VH2400|Very High Speed Modem at 2400,8-bit:\
        :nx=VH1200:tc=std.2400:
vp|VH9600|Very High Speed Modem at 9600,8-bit:\
        :nx=VH2400:tc=std.9600:
vq|VH57600|Very High Speed Modem at 57600,8-bit:\
        :nx=VH9600:tc=std.57600:
```

If you have a slow CPU or a heavily loaded system and do not have 16550A-based serial ports, you may receive sio "silo" errors at 57.6 Kbps.

25.4.4.2. `/etc/ttys`

Configuration of the `/etc/ttys` file was covered in 範例 25.1, "Adding Terminal Entries to `/etc/ttys`". Configuration for modems is similar but we must pass a different argument to `getty` and specify a different terminal type. The general format for both locked-speed and matching-speed configurations is:

```
ttyd0   "/usr/libexec/getty XXX"   dialup on
```

The first item in the above line is the device special file for this entry —— `ttyd0` means `/dev/ttyd0` is the file that this `getty` will be watching. The second item, `"/usr/libexec/getty xxx"` (*xxx* will be replaced by the initial `gettytab` capability) is the process `init` will run on the device. The third item, `dialup`, is the default terminal type. The fourth parameter, `on`, indicates to `init` that the line is operational. There can be a fifth parameter, `secure`, but it should only be used for terminals which are physically secure (such as the system console).

The default terminal type (`dialup` in the example above) may depend on local preferences. `dialup` is the traditional default terminal type on dial-up lines so that users may customize their login scripts to notice when the terminal is `dialup` and automatically adjust their terminal type. However, the author finds it easier at his site to specify `vt102` as the default terminal type, since the users just use VT102 emulation on their remote systems.

After you have made changes to `/etc/ttys`, you may send the `init` process a HUP signal to re-read the file. You can use the command

```
# kill -HUP 1
```

to send the signal. If this is your first time setting up the system, you may want to wait until your modem(s) are properly configured and connected before signaling `init`.

25.4.4.2.1. Locked-speed Config

For a locked-speed configuration, your `ttys` entry needs to have a fixed-speed entry provided to `getty`. For a modem whose port speed is locked at 19.2 Kbps, the `ttys` entry might look like this:

```
ttyd0   "/usr/libexec/getty std.19200"   dialup on
```

If your modem is locked at a different data rate, substitute the appropriate value for `std.speed` instead of `std.19200`. Make sure that you use a valid type listed in `/etc/gettytab`.

25.4.4.2.2. Matching-speed Config

In a matching-speed configuration, your `ttys` entry needs to reference the appropriate beginning "auto-baud" (sic) entry in `/etc/gettytab`. For example, if you added the above suggested entry for a matching-speed

modem that starts at 19.2 Kbps (the `gettytab` entry containing the `V19200` starting point), your `ttys` entry might look like this:

```
ttyd0   "/usr/libexec/getty V19200"   dialup on
```

25.4.4.3. `/etc/rc.d/serial`

High-speed modems, like V.32, V.32bis, and V.34 modems, need to use hardware (`RTS/CTS`) flow control. You can add `stty` commands to `/etc/rc.d/serial` to set the hardware flow control flag in the FreeBSD kernel for the modem ports.

For example to set the `termios` flag `crtscts` on serial port #1's (`COM2`) dial-in and dial-out initialization devices, the following lines could be added to `/etc/rc.d/serial` :

```
# Serial port initial configuration
stty -f /dev/ttyd1.init crtscts
stty -f /dev/cuad1.init crtscts
```

25.4.5. Modem Settings

If you have a modem whose parameters may be permanently set in non-volatile RAM, you will need to use a terminal program (such as Telix under MS-DOS® or `tip` under FreeBSD) to set the parameters. Connect to the modem using the same communications speed as the initial speed `getty` will use and configure the modem's non-volatile RAM to match these requirements:

- CD asserted when connected
- DTR asserted for operation; dropping DTR hangs up line and resets modem
- CTS transmitted data flow control
- Disable XON/XOFF flow control
- RTS received data flow control
- Quiet mode (no result codes)
- No command echo

Please read the documentation for your modem to find out what commands and/or DIP switch settings you need to give it.

For example, to set the above parameters on a U.S. Robotics® Sportster® 14,400 external modem, one could give these commands to the modem:

```
ATZ
AT&C1&D2&H1&I0&R2&W
```

You might also want to take this opportunity to adjust other settings in the modem, such as whether it will use V.42bis and/or MNP5 compression.

The U.S. Robotics® Sportster® 14,400 external modem also has some DIP switches that need to be set; for other modems, perhaps you can use these settings as an example:

- Switch 1: UP —— DTR Normal
- Switch 2: N/A (Verbal Result Codes/Numeric Result Codes)
- Switch 3: UP —— Suppress Result Codes

- Switch 4: DOWN —— No echo, offline commands
- Switch 5: UP —— Auto Answer
- Switch 6: UP —— Carrier Detect Normal
- Switch 7: UP —— Load NVRAM Defaults
- Switch 8: N/A (Smart Mode/Dumb Mode)

Result codes should be disabled/suppressed for dial-up modems to avoid problems that can occur if `getty` mistakenly gives a `login:` prompt to a modem that is in command mode and the modem echoes the command or returns a result code. This sequence can result in a extended, silly conversation between `getty` and the modem.

25.4.5.1. Locked-speed Config

For a locked-speed configuration, you will need to configure the modem to maintain a constant modem-to-computer data rate independent of the communications rate. On a U.S. Robotics® Sportster® 14,400 external modem, these commands will lock the modem-to-computer data rate at the speed used to issue the commands:

```
ATZ
AT&B1&W
```

25.4.5.2. Matching-speed Config

For a variable-speed configuration, you will need to configure your modem to adjust its serial port data rate to match the incoming call rate. On a U.S. Robotics® Sportster® 14,400 external modem, these commands will lock the modem's error-corrected data rate to the speed used to issue the commands, but allow the serial port rate to vary for non-error-corrected connections:

```
ATZ
AT&B2&W
```

25.4.5.3. Checking the Modem's Configuration

Most high-speed modems provide commands to view the modem's current operating parameters in a somewhat human-readable fashion. On the U.S. Robotics® Sportster® 14,400 external modems, the command `ATI5` displays the settings that are stored in the non-volatile RAM. To see the true operating parameters of the modem (as influenced by the modem's DIP switch settings), use the commands `ATZ` and then `ATI4`.

If you have a different brand of modem, check your modem's manual to see how to double-check your modem's configuration parameters.

25.4.6. Troubleshooting

Here are a few steps you can follow to check out the dial-up modem on your system.

25.4.6.1. Checking Out the FreeBSD System

Hook up your modem to your FreeBSD system, boot the system, and, if your modem has status indication lights, watch to see whether the modem's DTR indicator lights when the `login:` prompt appears on the system's console —— if it lights up, that should mean that FreeBSD has started a `getty` process on the appropriate communications port and is waiting for the modem to accept a call.

If the DTR indicator does not light, login to the FreeBSD system through the console and issue a `ps ax` to see if FreeBSD is trying to run a `getty` process on the correct port. You should see lines like these among the processes displayed:

```
  114 ??  I      0:00.10 /usr/libexec/getty V19200 ttyd0
```

```
  115 ??  I      0:00.10 /usr/libexec/getty V19200 ttyd1
```

If you see something different, like this:

```
  114 d0  I      0:00.10 /usr/libexec/getty V19200 ttyd0
```

and the modem has not accepted a call yet, this means that `getty` has completed its open on the communications port. This could indicate a problem with the cabling or a mis-configured modem, because `getty` should not be able to open the communications port until CD (carrier detect) has been asserted by the modem.

If you do not see any `getty` processes waiting to open the desired `ttydN` port, double-check your entries in `/etc/ttys` to see if there are any mistakes there. Also, check the log file `/var/log/messages` to see if there are any log messages from `init` or `getty` regarding any problems. If there are any messages, triple-check the configuration files `/etc/ttys` and `/etc/gettytab` , as well as the appropriate device special files `/dev/ttydN`, for any mistakes, missing entries, or missing device special files.

25.4.6.2. Try Dialing In

Try dialing into the system; be sure to use 8 bits, no parity, and 1 stop bit on the remote system. If you do not get a prompt right away, or get garbage, try pressing Enter about once per second. If you still do not see a `login:` prompt after a while, try sending a `BREAK`. If you are using a high-speed modem to do the dialing, try dialing again after locking the dialing modem's interface speed (via `AT&B1` on a U.S. Robotics® Sportster® modem, for example).

If you still cannot get a `login:` prompt, check `/etc/gettytab` again and double-check that

- The initial capability name specified in `/etc/ttys` for the line matches a name of a capability in `/etc/gettytab`
- Each `nx=` entry matches another `gettytab` capability name
- Each `tc=` entry matches another `gettytab` capability name

If you dial but the modem on the FreeBSD system will not answer, make sure that the modem is configured to answer the phone when DTR is asserted. If the modem seems to be configured correctly, verify that the DTR line is asserted by checking the modem's indicator lights (if it has any).

If you have gone over everything several times and it still does not work, take a break and come back to it later. If it still does not work, perhaps you can send an electronic mail message to the FreeBSD general questions 郵遞論壇 describing your modem and your problem, and the good folks on the list will try to help.

25.5. Dial-out Service

The following are tips for getting your host to be able to connect over the modem to another computer. This is appropriate for establishing a terminal session with a remote host.

This is useful to log onto a BBS.

This kind of connection can be extremely helpful to get a file on the Internet if you have problems with PPP. If you need to FTP something and PPP is broken, use the terminal session to FTP it. Then use zmodem to transfer it to your machine.

25.5.1. My Stock Hayes Modem Is Not Supported, What Can I Do?

Actually, the manual page for `tip` is out of date. There is a generic Hayes dialer already built in. Just use `at=hayes` in your `/etc/remote` file.

The Hayes driver is not smart enough to recognize some of the advanced features of newer modems——messages like `BUSY`, `NO DIALTONE`, or `CONNECT 115200` will just confuse it. You should turn those messages off when you use `tip` (using `ATX0&W`).

Also, the dial timeout for `tip` is 60 seconds. Your modem should use something less, or else tip will think there is a communication problem. Try `ATS7=45&W`.

注意

As shipped, `tip` does not yet support Hayes modems fully. The solution is to edit the file `tipconf.h` in the directory `/usr/src/usr.bin/tip/tip`. Obviously you need the source distribution to do this.

Edit the line `#define HAYES 0` to `#define HAYES 1`. Then `make` and `make install`. Everything works nicely after that.

25.5.2. How Am I Expected to Enter These AT Commands?

Make what is called a "direct" entry in your `/etc/remote` file. For example, if your modem is hooked up to the first serial port, `/dev/cuad0`, then put in the following line:

```
cuad0:dv=/dev/cuad0:br#19200:pa=none
```

Use the highest bps rate your modem supports in the br capability. Then, type `tip cuad0` and you will be connected to your modem.

Or use `cu` as `root` with the following command:

```
# cu -lline -sspeed
```

`line` is the serial port (e.g.`/dev/cuad0`) and *`speed`* is the speed (e.g.`57600`). When you are done entering the AT commands hit ~. to exit.

25.5.3. The @ Sign for the pn Capability Does Not Work!

The `@` sign in the phone number capability tells tip to look in `/etc/phones` for a phone number. But the `@` sign is also a special character in capability files like `/etc/remote`. Escape it with a backslash:

```
pn=\@
```

25.5.4. How Can I Dial a Phone Number on the Command Line?

Put what is called a "generic" entry in your `/etc/remote` file. For example:

```
tip115200|Dial any phone number at 115200 bps:\
        :dv=/dev/cuad0:br#115200:at=hayes:pa=none:du:
tip57600|Dial any phone number at 57600 bps:\
        :dv=/dev/cuad0:br#57600:at=hayes:pa=none:du:
```

Then you can do things like:

```
# tip -115200 5551234
```

If you prefer `cu` over `tip`, use a generic `cu` entry:

```
cu115200|Use cu to dial any number at 115200bps:\
```

```
        :dv=/dev/cuad1:br#57600:at=hayes:pa=none:du:
```

and type:

```
# cu 5551234 -s 115200
```

25.5.5. Do I Have to Type in the bps Rate Every Time I Do That?

Put in an entry for `tip1200` or `cu1200`, but go ahead and use whatever bps rate is appropriate with the br capability. `tip` thinks a good default is 1200 bps which is why it looks for a `tip1200` entry. You do not have to use 1200 bps, though.

25.5.6. I Access a Number of Hosts Through a Terminal Server

Rather than waiting until you are connected and typing `CONNECT <host>` each time, use tip's `cm` capability. For example, these entries in `/etc/remote`:

```
pain|pain.deep13.com|Forrester's machine:\
        :cm=CONNECT pain\n:tc=deep13:
muffin|muffin.deep13.com|Frank's machine:\
        :cm=CONNECT muffin\n:tc=deep13:
deep13:Gizmonics Institute terminal server:\
        :dv=/dev/cuad2:br#38400:at=hayes:du:pa=none:pn=5551234:
```

will let you type `tip pain` or `tip muffin` to connect to the hosts pain or muffin, and `tip deep13` to get to the terminal server.

25.5.7. Can Tip Try More Than One Line for Each Site?

This is often a problem where a university has several modem lines and several thousand students trying to use them.

Make an entry for your university in `/etc/remote` and use `@` for the `pn` capability:

```
big-university:\
        :pn=\@:tc=dialout
dialout:\
        :dv=/dev/cuad3:br#9600:at=courier:du:pa=none:
```

Then, list the phone numbers for the university in `/etc/phones`:

```
big-university 5551111
big-university 5551112
big-university 5551113
big-university 5551114
```

`tip` will try each one in the listed order, then give up. If you want to keep retrying, run `tip` in a while loop.

25.5.8. Why Do I Have to Hit Ctrl+P Twice to Send Ctrl+P Once?

Ctrl+P is the default "force" character, used to tell `tip` that the next character is literal data. You can set the force character to any other character with the `~s` escape, which means "set a variable."

Type `~sforce=single-char` followed by a newline. *`single-char`* is any single character. If you leave out *`single-char`*, then the force character is the nul character, which you can get by typing Ctrl+2 or Ctrl+Space. A pretty good value for *`single-char`* is Shift+Ctrl+6, which is only used on some terminal servers.

You can have the force character be whatever you want by specifying the following in your `$HOME/.tiprc` file:

```
force=<single-char>
```

25.5.9. Suddenly Everything I Type Is in Upper Case??

You must have pressed Ctrl+A, `tip`'s "raise character," specially designed for people with broken caps-lock keys. Use `~s` as above and set the variable `raisechar` to something reasonable. In fact, you can set it to the same as the force character, if you never expect to use either of these features.

Here is a sample .tiprc file perfect for Emacs users who need to type Ctrl+2 and Ctrl+A a lot:

```
force=^^
raisechar=^^
```

The ^^ is Shift+Ctrl+6.

25.5.10. How Can I Do File Transfers with `tip`?

If you are talking to another UNIX® system, you can send and receive files with `~p` (put) and `~t` (take). These commands run `cat` and `echo` on the remote system to accept and send files. The syntax is:

`~p` local-file [remote-file]

`~t` remote-file [local-file]

There is no error checking, so you probably should use another protocol, like zmodem.

25.5.11. How Can I Run zmodem with `tip`?

To receive files, start the sending program on the remote end. Then, type `~C rz` to begin receiving them locally.

To send files, start the receiving program on the remote end. Then, type `~C sz files` to send them to the remote system.

25.6. Setting Up the Serial Console

Contributed by Kazutaka YOKOTA.
Based on a document by Bill Paul.

25.6.1. Introduction

FreeBSD has the ability to boot on a system with only a dumb terminal on a serial port as a console. Such a configuration should be useful for two classes of people: system administrators who wish to install FreeBSD on machines that have no keyboard or monitor attached, and developers who want to debug the kernel or device drivers.

As described in 章 12, FreeBSD 開機流程篇, FreeBSD employs a three stage bootstrap. The first two stages are in the boot block code which is stored at the beginning of the FreeBSD slice on the boot disk. The boot block will then load and run the boot loader (`/boot/loader`) as the third stage code.

In order to set up the serial console you must configure the boot block code, the boot loader code and the kernel.

25.6.2. Serial Console Configuration, Terse Version

This section assumes that you are using the default setup and just want a fast overview of setting up the serial console.

1. Connect the serial cable to COM1 and the controlling terminal.

2. To see all boot messages on the serial console, issue the following command while logged in as the superuser:

```
# echo 'console="comconsole"' >> /boot/loader.conf
```

3. Edit `/etc/ttys` and change `off` to `on` and `dialup` to `vt100` for the `ttyd0` entry. Otherwise a password will not be required to connect via the serial console, resulting in a potential security hole.

4. Reboot the system to see if the changes took effect.

If a different configuration is required, a more in depth configuration explanation exists in 節 25.6.3, “Serial Console Configuration”.

25.6.3. Serial Console Configuration

1. Prepare a serial cable.

   You will need either a null-modem cable or a standard serial cable and a null-modem adapter. See 節 25.2.2, “Cables and Ports” for a discussion on serial cables.

2. Unplug your keyboard.

   Most PC systems probe for the keyboard during the Power-On Self-Test (POST) and will generate an error if the keyboard is not detected. Some machines complain loudly about the lack of a keyboard and will not continue to boot until it is plugged in.

   If your computer complains about the error, but boots anyway, then you do not have to do anything special. (Some machines with Phoenix BIOS installed merely say Keyboard failed and continue to boot normally.)

   If your computer refuses to boot without a keyboard attached then you will have to configure the BIOS so that it ignores this error (if it can). Consult your motherboard's manual for details on how to do this.

提示

Set the keyboard to “Not installed” in the BIOS setup. You will still be able to use your keyboard. All this does is tell the BIOS not to probe for a keyboard at power-on. Your BIOS should not complain if the keyboard is absent. You can leave the keyboard plugged in even with this flag set to “Not installed” and the keyboard will still work.

注意

If your system has a PS/2® mouse, chances are very good that you may have to unplug your mouse as well as your keyboard. This is because PS/2® mice share some hardware with the keyboard and leaving the mouse plugged in can fool the keyboard probe into thinking the keyboard is still there. It is said that a Gateway 2000 Pentium 90 MHz system with an AMI BIOS that behaves this way. In general, this is not a problem since the mouse is not much good without the keyboard anyway.

3. Plug a dumb terminal into `COM1` (`sio0`).

   If you do not have a dumb terminal, you can use an old PC/XT with a modem program, or the serial port on another UNIX® box. If you do not have a `COM1` (`sio0`), get one. At this time, there is no way to select a port other than `COM1` for the boot blocks without recompiling the boot blocks. If you are already using `COM1` for another device, you will have to temporarily remove that device and install a new boot block and kernel once you get FreeBSD up and running. (It is assumed that `COM1` will be available on a file/compute/terminal server

anyway; if you really need `COM1` for something else (and you cannot switch that something else to `COM2` (`sio1`)), then you probably should not even be bothering with all this in the first place.)

4. Make sure the configuration file of your kernel has appropriate flags set for `COM1` (`sio0`).

   Relevant flags are:

   `0x10`
   : Enables console support for this unit. The other console flags are ignored unless this is set. Currently, at most one unit can have console support; the first one (in config file order) with this flag set is preferred. This option alone will not make the serial port the console. Set the following flag or use the `-h` option described below, together with this flag.

   `0x20`
   : Forces this unit to be the console (unless there is another higher priority console), regardless of the `-h` option discussed below. The flag `0x20` must be used together with the `0x10` flag.

   `0x40`
   : Reserves this unit (in conjunction with `0x10`) and makes the unit unavailable for normal access. You should not set this flag to the serial port unit which you want to use as the serial console. The only use of this flag is to designate the unit for kernel remote debugging. See The Developer's Handbook for more information on remote debugging.

   注意

   In FreeBSD 4.0 or later the semantics of the flag `0x40` are slightly different and there is another flag to specify a serial port for remote debugging.

   Example:

   ```
   device sio0 at isa? port IO_COM1 flags 0x10 irq 4
   ```

   See the sio(4) manual page for more details.

   If the flags were not set, you need to run UserConfig (on a different console) or recompile the kernel.

5. Create `boot.config` in the root directory of the `a` partition on the boot drive.

   This file will instruct the boot block code how you would like to boot the system. In order to activate the serial console, you need one or more of the following options——if you want multiple options, include them all on the same line:

   `-h`
   : Toggles internal and serial consoles. You can use this to switch console devices. For instance, if you boot from the internal (video) console, you can use `-h` to direct the boot loader and the kernel to use the serial port as its console device. Alternatively, if you boot from the serial port, you can use the `-h` to tell the boot loader and the kernel to use the video display as the console instead.

   `-D`
   : Toggles single and dual console configurations. In the single configuration the console will be either the internal console (video display) or the serial port, depending on the state of the `-h` option above. In the dual console configuration, both the video display and the serial port will become the console at the same time, regardless of the state of the `-h` option. However, note that the dual console configuration takes effect only during the boot block is running. Once the boot loader gets control, the console specified by the `-h` option becomes the only console.

`-P`

Makes the boot block probe the keyboard. If no keyboard is found, the `-D` and `-h` options are automatically set.

注意

Due to space constraints in the current version of the boot blocks, the `-P` option is capable of detecting extended keyboards only. Keyboards with less than 101 keys (and without F11 and F12 keys) may not be detected. Keyboards on some laptop computers may not be properly found because of this limitation. If this is the case with your system, you have to abandon using the `-P` option. Unfortunately there is no workaround for this problem.

Use either the `-P` option to select the console automatically, or the `-h` option to activate the serial console.

You may include other options described in boot(8) as well.

The options, except for `-P`, will be passed to the boot loader (`/boot/loader`). The boot loader will determine which of the internal video or the serial port should become the console by examining the state of the `-h` option alone. This means that if you specify the `-D` option but not the `-h` option in `/boot.config` , you can use the serial port as the console only during the boot block; the boot loader will use the internal video display as the console.

6. Boot the machine.

When you start your FreeBSD box, the boot blocks will echo the contents of `/boot.config` to the console. For example:

```
/boot.config: -P
Keyboard: no
```

The second line appears only if you put `-P` in `/boot.config` and indicates presence/absence of the keyboard. These messages go to either serial or internal console, or both, depending on the option in `/boot.config` .

Options	Message goes to
none	internal console
`-h`	serial console
`-D`	serial and internal consoles
`-Dh`	serial and internal consoles
`-P`, keyboard present	internal console
`-P`, keyboard absent	serial console

After the above messages, there will be a small pause before the boot blocks continue loading the boot loader and before any further messages printed to the console. Under normal circumstances, you do not need to interrupt the boot blocks, but you may want to do so in order to make sure things are set up correctly.

Hit any key, other than Enter, at the console to interrupt the boot process. The boot blocks will then prompt you for further action. You should now see something like:

```
>> FreeBSD/i386 BOOT
Default: 0:ad(0,a)/boot/loader
```

```
boot:
```

Verify the above message appears on either the serial or internal console or both, according to the options you put in `/boot.config` . If the message appears in the correct console, hit Enter to continue the boot process.

If you want the serial console but you do not see the prompt on the serial terminal, something is wrong with your settings. In the meantime, you enter `-h` and hit Enter/Return (if possible) to tell the boot block (and then the boot loader and the kernel) to choose the serial port for the console. Once the system is up, go back and check what went wrong.

After the boot loader is loaded and you are in the third stage of the boot process you can still switch between the internal console and the serial console by setting appropriate environment variables in the boot loader. See 節 25.6.6, “Changing Console from the Boot Loader”.

25.6.4. Summary

Here is the summary of various settings discussed in this section and the console eventually selected.

25.6.4.1. Case 1: You Set the Flags to 0x10 for `sio0`

```
device sio0 at isa? port IO_COM1 flags 0x10 irq 4
```

Options in /boot.config	Console during boot blocks	Console during boot loader	Console in kernel
nothing	internal	internal	internal
`-h`	serial	serial	serial
`-D`	serial and internal	internal	internal
`-Dh`	serial and internal	serial	serial
`-P`, keyboard present	internal	internal	internal
`-P`, keyboard absent	serial and internal	serial	serial

25.6.4.2. Case 2: You Set the Flags to 0x30 for sio0

```
device sio0 at isa? port IO_COM1 flags 0x30 irq 4
```

Options in /boot.config	Console during boot blocks	Console during boot loader	Console in kernel
nothing	internal	internal	serial
`-h`	serial	serial	serial
`-D`	serial and internal	internal	serial
`-Dh`	serial and internal	serial	serial
`-P`, keyboard present	internal	internal	serial
`-P`, keyboard absent	serial and internal	serial	serial

25.6.5. Tips for the Serial Console

25.6.5.1. Setting a Faster Serial Port Speed

By default, the serial port settings are: 9600 baud, 8 bits, no parity, and 1 stop bit. If you wish to change the speed, you need to recompile at least the boot blocks. Add the following line to `/etc/make.conf` and compile new boot blocks:

```
BOOT_COMCONSOLE_SPEED=19200
```

See 節 25.6.5.2, “Using Serial Port Other Than `sio0` for the Console” for detailed instructions about building and installing new boot blocks.

If the serial console is configured in some other way than by booting with `-h`, or if the serial console used by the kernel is different from the one used by the boot blocks, then you must also add the following option to the kernel configuration file and compile a new kernel:

```
options CONSPEED=19200
```

25.6.5.2. Using Serial Port Other Than `sio0` for the Console

Using a port other than `sio0` as the console requires some recompiling. If you want to use another serial port for whatever reasons, recompile the boot blocks, the boot loader and the kernel as follows.

1. Get the kernel source.
2. Edit `/etc/make.conf` and set `BOOT_COMCONSOLE_PORT` to the address of the port you want to use (0x3F8, 0x2F8, 0x3E8 or 0x2E8). Only `sio0` through `sio3` (`COM1` through `COM4`) can be used; multiport serial cards will not work. No interrupt setting is needed.
3. Create a custom kernel configuration file and add appropriate flags for the serial port you want to use. For example, if you want to make `sio1` (`COM2`) the console:

   ```
   device sio1 at isa? port IO_COM2 flags 0x10 irq 3
   ```

   or

   ```
   device sio1 at isa? port IO_COM2 flags 0x30 irq 3
   ```

   The console flags for the other serial ports should not be set.
4. Recompile and install the boot blocks and the boot loader:

   ```
   # cd /sys/boot
   # make clean
   # make
   # make install
   ```
5. Rebuild and install the kernel.
6. Write the boot blocks to the boot disk with disklabel(8) and boot from the new kernel.

25.6.5.3. Entering the DDB Debugger from the Serial Line

If you wish to drop into the kernel debugger from the serial console (useful for remote diagnostics, but also dangerous if you generate a spurious BREAK on the serial port!) then you should compile your kernel with the following options:

```
options BREAK_TO_DEBUGGER
options DDB
```

25.6.5.4. Getting a Login Prompt on the Serial Console

While this is not required, you may wish to get a login prompt over the serial line, now that you can see boot messages and can enter the kernel debugging session through the serial console. Here is how to do it.

Open the file `/etc/ttys` with an editor and locate the lines:

```
ttyd0 "/usr/libexec/getty std.9600" unknown off secure
ttyd1 "/usr/libexec/getty std.9600" unknown off secure
ttyd2 "/usr/libexec/getty std.9600" unknown off secure
ttyd3 "/usr/libexec/getty std.9600" unknown off secure
```

`ttyd0` through `ttyd3` corresponds to `COM1` through `COM4`. Change `off` to `on` for the desired port. If you have changed the speed of the serial port, you need to change `std.9600` to match the current setting, e.g. `std.19200`.

You may also want to change the terminal type from `unknown` to the actual type of your serial terminal.

After editing the file, you must `kill -HUP 1` to make this change take effect.

25.6.6. Changing Console from the Boot Loader

Previous sections described how to set up the serial console by tweaking the boot block. This section shows that you can specify the console by entering some commands and environment variables in the boot loader. As the boot loader is invoked at the third stage of the boot process, after the boot block, the settings in the boot loader will override the settings in the boot block.

25.6.6.1. Setting Up the Serial Console

You can easily specify the boot loader and the kernel to use the serial console by writing just one line in `/boot/loader.rc`:

```
set console="comconsole"
```

This will take effect regardless of the settings in the boot block discussed in the previous section.

You had better put the above line as the first line of `/boot/loader.rc` so as to see boot messages on the serial console as early as possible.

Likewise, you can specify the internal console as:

```
set console="vidconsole"
```

If you do not set the boot loader environment variable `console`, the boot loader, and subsequently the kernel, will use whichever console indicated by the `-h` option in the boot block.

In versions 3.2 or later, you may specify the console in `/boot/loader.conf.local` or `/boot/loader.conf`, rather than in `/boot/loader.rc`. In this method your `/boot/loader.rc` should look like:

```
include /boot/loader.4th
start
```

Then, create `/boot/loader.conf.local` and put the following line there.

```
console=comconsole
```

or

```
console=vidconsole
```

See loader.conf(5) for more information.

注意

At the moment, the boot loader has no option equivalent to the `-P` option in the boot block, and there is no provision to automatically select the internal console and the serial console based on the presence of the keyboard.

25.6.6.2. Using a Serial Port Other Than `sio0` for the Console

You need to recompile the boot loader to use a serial port other than `sio0` for the serial console. Follow the procedure described in 節 25.6.5.2, “Using Serial Port Other Than `sio0` for the Console”.

25.6.7. Caveats

The idea here is to allow people to set up dedicated servers that require no graphics hardware or attached keyboards. Unfortunately, while most systems will let you boot without a keyboard, there are quite a few that will not let you boot without a graphics adapter. Machines with AMI BIOSes can be configured to boot with no graphics adapter installed simply by changing the “graphics adapter” setting in the CMOS configuration to “Not installed.”

However, many machines do not support this option and will refuse to boot if you have no display hardware in the system. With these machines, you will have to leave some kind of graphics card plugged in, (even if it is just a junky mono board) although you will not have to attach a monitor. You might also try installing an AMI BIOS.

章 26. PPP and SLIP

Restructured, reorganized, and updated by Jim Mock.

26.1. Synopsis

FreeBSD has a number of ways to link one computer to another. To establish a network or Internet connection through a dial-up modem, or to allow others to do so through you, requires the use of PPP or SLIP. This chapter describes setting up these modem-based communication services in detail.

After reading this chapter, you will know:

- How to set up user PPP.
- How to set up kernel PPP.
- How to set up PPPoE (PPP over Ethernet).
- How to set up PPPoA (PPP over ATM).
- How to configure and set up a SLIP client and server.

Before reading this chapter, you should:

- Be familiar with basic network terminology.
- Understand the basics and purpose of a dialup connection and PPP and/or SLIP.

You may be wondering what the main difference is between user PPP and kernel PPP. The answer is simple: user PPP processes the inbound and outbound data in userland rather than in the kernel. This is expensive in terms of copying the data between the kernel and userland, but allows a far more feature-rich PPP implementation. User PPP uses the `tun` device to communicate with the outside world whereas kernel PPP uses the `ppp` device.

注意

Throughout in this chapter, user PPP will simply be referred to as ppp unless a distinction needs to be made between it and any other PPP software such as pppd. Unless otherwise stated, all of the commands explained in this chapter should be executed as `root`.

26.2. Using User PPP

Updated and enhanced by Tom Rhodes.
Originally contributed by Brian Somers.
With input from Nik Clayton, Dirk Frömberg # Peter Childs.

26.2.1. User PPP

26.2.1.1. Assumptions

This document assumes you have the following:

- An account with an Internet Service Provider (ISP) which you connect to using PPP.

- You have a modem or other device connected to your system and configured correctly which allows you to connect to your ISP.
- The dial-up number(s) of your ISP.
- Your login name and password. (Either a regular UNIX® style login and password pair, or a PAP or CHAP login and password pair.)
- The IP address of one or more name servers. Normally, you will be given two IP addresses by your ISP to use for this. If they have not given you at least one, then you can use the `enable dns` command in `ppp.conf` and ppp will set the name servers for you. This feature depends on your ISPs PPP implementation supporting DNS negotiation.

The following information may be supplied by your ISP, but is not completely necessary:

- The IP address of your ISP's gateway. The gateway is the machine to which you will connect and will be set up as your default route. If you do not have this information, we can make one up and your ISP's PPP server will tell us the correct value when we connect.

  This IP number is referred to as `HISADDR` by ppp.
- The netmask you should use. If your ISP has not provided you with one, you can safely use `255.255.255.255` .
- If your ISP provides you with a static IP address and hostname, you can enter it. Otherwise, we simply let the peer assign whatever IP address it sees fit.

If you do not have any of the required information, contact your ISP.

注意

Throughout this section, many of the examples showing the contents of configuration files are numbered by line. These numbers serve to aid in the presentation and discussion only and are not meant to be placed in the actual file. Proper indentation with tab and space characters is also important.

26.2.1.2. Creating PPP Device Nodes

Under normal circumstances, most users will only need one `tun` device (`/dev/tun0`). References to `tun0` below may be changed to `tunN` where *N* is any unit number corresponding to your system.

For FreeBSD installations that do not have devfs(5) enabled (FreeBSD 4.X and earlier), the existence of the `tun0` device should be verified (this is not necessary if devfs(5) is enabled as device nodes will be created on demand).

The easiest way to make sure that the `tun0` device is configured correctly is to remake the device. To remake the device, do the following:

```
# cd /dev
# sh MAKEDEV tun0
```

If you need 16 tunnel devices in your kernel, you will need to create them. This can be done by executing the following commands:

```
# cd /dev
# sh MAKEDEV tun15
```

26.2.1.3. Automatic PPP Configuration

Both `ppp` and `pppd` (the kernel level implementation of PPP) use the configuration files located in the `/etc/ppp` directory. Examples for user ppp can be found in `/usr/share/examples/ppp/` .

Configuring `ppp` requires that you edit a number of files, depending on your requirements. What you put in them depends to some extent on whether your ISP allocates IP addresses statically (i.e., you get given one IP address, and always use that one) or dynamically (i.e., your IP address changes each time you connect to your ISP).

26.2.1.3.1. PPP and Static IP Addresses

You will need to edit the `/etc/ppp/ppp.conf` configuration file. It should look similar to the example below.

注意

Lines that end in a `:` start in the first column (beginning of the line)—— all other lines should be indented as shown using spaces or tabs.

```
1     default:
2       set log Phase Chat LCP IPCP CCP tun command
3       ident user-ppp VERSION (built COMPILATIONDATE)
4       set device /dev/cuaa0
5       set speed 115200
6       set dial "ABORT BUSY ABORT NO\\sCARRIER TIMEOUT 5 \
7                 \"\" AT OK-AT-OK ATE1Q0 OK \\dATDT\\T TIMEOUT 40 CONNECT"
8       set timeout 180
9       enable dns
10
11    provider:
12      set phone "(123) 456 7890"
13      set authname foo
14      set authkey bar
15      set login "TIMEOUT 10 \"\" \"\" gin:--gin: \\U word: \\P col: ppp"
16      set timeout 300
17      set ifaddr x.x.x.x y.y.y.y 255.255.255.255 0.0.0.0
18      add default HISADDR
```

Line 1:
Identifies the default entry. Commands in this entry are executed automatically when ppp is run.

Line 2:
Enables logging parameters. When the configuration is working satisfactorily, this line should be reduced to saying

```
set log phase tun
```

in order to avoid excessive log file sizes.

Line 3:
Tells PPP how to identify itself to the peer. PPP identifies itself to the peer if it has any trouble negotiating and setting up the link, providing information that the peers administrator may find useful when investigating such problems.

Line 4:
Identifies the device to which the modem is connected. `COM1` is `/dev/cuaa0` and `COM2` is `/dev/cuaa1` .

Line 5:
Sets the speed you want to connect at. If 115200 does not work (it should with any reasonably new modem), try 38400 instead.

Line 6 & 7:
The dial string. User PPP uses an expect-send syntax similar to the chat(8) program. Refer to the manual page for information on the features of this language.

Note that this command continues onto the next line for readability. Any command in `ppp.conf` may do this if the last character on the line is a ``\'' character.

Line 8:
Sets the idle timeout for the link. 180 seconds is the default, so this line is purely cosmetic.

Line 9:
Tells PPP to ask the peer to confirm the local resolver settings. If you run a local name server, this line should be commented out or removed.

Line 10:
A blank line for readability. Blank lines are ignored by PPP.

Line 11:
Identifies an entry for a provider called “provider”. This could be changed to the name of your ISP so that later you can use the `load ISP` to start the connection.

Line 12:
Sets the phone number for this provider. Multiple phone numbers may be specified using the colon (`:`) or pipe character (`|`)as a separator. The difference between the two separators is described in ppp(8). To summarize, if you want to rotate through the numbers, use a colon. If you want to always attempt to dial the first number first and only use the other numbers if the first number fails, use the pipe character. Always quote the entire set of phone numbers as shown.

You must enclose the phone number in quotation marks (`"`) if there is any intention on using spaces in the phone number. This can cause a simple, yet subtle error.

Line 13 & 14:
Identifies the user name and password. When connecting using a UNIX® style login prompt, these values are referred to by the `set login` command using the \U and \P variables. When connecting using PAP or CHAP, these values are used at authentication time.

Line 15:
If you are using PAP or CHAP, there will be no login at this point, and this line should be commented out or removed. See PAP and CHAP authentication for further details.

The login string is of the same chat-like syntax as the dial string. In this example, the string works for a service whose login session looks like this:

```
J. Random Provider
login: foo
password: bar
protocol: ppp
```

You will need to alter this script to suit your own needs. When you write this script for the first time, you should ensure that you have enabled “chat” logging so you can determine if the conversation is going as expected.

Line 16:
Sets the default idle timeout (in seconds) for the connection. Here, the connection will be closed automatically after 300 seconds of inactivity. If you never want to timeout, set this value to zero or use the `-ddial` command line switch.

Line 17:
Sets the interface addresses. The string `x.x.x.x` should be replaced by the IP address that your provider has allocated to you. The string `y.y.y.y` should be replaced by the IP address that your ISP indicated for

their gateway (the machine to which you connect). If your ISP has not given you a gateway address, use `10.0.0.2/0`. If you need to use a "guessed" address, make sure that you create an entry in `/etc/ppp/ppp.linkup` as per the instructions for PPP and Dynamic IP addresses. If this line is omitted, `ppp` cannot run in `-auto` mode.

Line 18:
Adds a default route to your ISP's gateway. The special word `HISADDR` is replaced with the gateway address specified on line 17. It is important that this line appears after line 17, otherwise `HISADDR` will not yet be initialized.

If you do not wish to run ppp in `-auto`, this line should be moved to the `ppp.linkup` file.

It is not necessary to add an entry to `ppp.linkup` when you have a static IP address and are running ppp in `-auto` mode as your routing table entries are already correct before you connect. You may however wish to create an entry to invoke programs after connection. This is explained later with the sendmail example.

Example configuration files can be found in the `/usr/share/examples/ppp/` directory.

26.2.1.3.2. PPP and Dynamic IP Addresses

If your service provider does not assign static IP addresses, `ppp` can be configured to negotiate the local and remote addresses. This is done by "guessing" an IP address and allowing `ppp` to set it up correctly using the IP Configuration Protocol (IPCP) after connecting. The `ppp.conf` configuration is the same as PPP and Static IP Addresses, with the following change:

```
17      set ifaddr 10.0.0.1/0 10.0.0.2/0 255.255.255.255
```

Again, do not include the line number, it is just for reference. Indentation of at least one space is required.

Line 17:
The number after the `/` character is the number of bits of the address that ppp will insist on. You may wish to use IP numbers more appropriate to your circumstances, but the above example will always work.

The last argument (`0.0.0.0`) tells PPP to start negotiations using address `0.0.0.0` rather than `10.0.0.1` and is necessary for some ISPs. Do not use `0.0.0.0` as the first argument to `set ifaddr` as it prevents PPP from setting up an initial route in `-auto` mode.

If you are not running in `-auto` mode, you will need to create an entry in `/etc/ppp/ppp.linkup`. `ppp.linkup` is used after a connection has been established. At this point, `ppp` will have assigned the interface addresses and it will now be possible to add the routing table entries:

```
1     provider:
2      add default HISADDR
```

Line 1:
On establishing a connection, `ppp` will look for an entry in `ppp.linkup` according to the following rules: First, try to match the same label as we used in `ppp.conf`. If that fails, look for an entry for the IP address of our gateway. This entry is a four-octet IP style label. If we still have not found an entry, look for the `MYADDR` entry.

Line 2:
This line tells `ppp` to add a default route that points to `HISADDR`. `HISADDR` will be replaced with the IP number of the gateway as negotiated by the IPCP.

See the `pmdemand` entry in the files `/usr/share/examples/ppp/ppp.conf.sample` and `/usr/share/examples/ppp/ppp.linkup.sample` for a detailed example.

26.2.1.3.3. Receiving Incoming Calls

When you configure ppp to receive incoming calls on a machine connected to a LAN, you must decide if you wish to forward packets to the LAN. If you do, you should allocate the peer an IP number from your LAN's subnet, and use the command `enable proxy` in your `/etc/ppp/ppp.conf` file. You should also confirm that the `/etc/rc.conf` file contains the following:

```
gateway_enable="YES"
```

26.2.1.3.4. Which getty?

Configuring FreeBSD for Dial-up Services provides a good description on enabling dial-up services using getty(8).

An alternative to `getty` is mgetty, a smarter version of `getty` designed with dial-up lines in mind.

The advantages of using `mgetty` is that it actively talks to modems, meaning if port is turned off in `/etc/ttys` then your modem will not answer the phone.

Later versions of `mgetty` (from 0.99beta onwards) also support the automatic detection of PPP streams, allowing your clients script-less access to your server.

Refer to Mgetty and AutoPPP for more information on `mgetty`.

26.2.1.3.5. PPP Permissions

The `ppp` command must normally be run as the `root` user. If however, you wish to allow `ppp` to run in server mode as a normal user by executing `ppp` as described below, that user must be given permission to run `ppp` by adding them to the `network` group in `/etc/group`.

You will also need to give them access to one or more sections of the configuration file using the `allow` command:

```
allow users fred mary
```

If this command is used in the `default` section, it gives the specified users access to everything.

26.2.1.3.6. PPP Shells for Dynamic-IP Users

Create a file called `/etc/ppp/ppp-shell` containing the following:

```
#!/bin/sh
IDENT=`echo $0 | sed -e 's/^.*-\(.*\)$/\1/'`
CALLEDAS="$IDENT"
TTY=`tty`

if [ x$IDENT = xdialup -]; then
        IDENT=`basename $TTY`
fi

echo "PPP for $CALLEDAS on $TTY"
echo "Starting PPP for $IDENT"

exec /usr/sbin/ppp -direct $IDENT
```

This script should be executable. Now make a symbolic link called `ppp-dialup` to this script using the following commands:

```
# ln -s ppp-shell /etc/ppp/ppp-dialup
```

You should use this script as the shell for all of your dialup users. This is an example from `/etc/passwd` for a dialup PPP user with username `pchilds` (remember do not directly edit the password file, use vipw(8)).

```
pchilds:*:1011:300:Peter Childs PPP:/home/ppp:/etc/ppp/ppp-dialup
```

Create a `/home/ppp` directory that is world readable containing the following 0 byte files:

```
-r--r--r--   1 root     wheel           0 May 27 02:23 .hushlogin
```

```
-r--r--r--   1 root     wheel           0 May 27 02:22 .rhosts
```

which prevents `/etc/motd` from being displayed.

26.2.1.3.7. PPP Shells for Static-IP Users

Create the `ppp-shell` file as above, and for each account with statically assigned IPs create a symbolic link to `ppp-shell`.

For example, if you have three dialup customers, `fred`, `sam`, and `mary`, that you route class C networks for, you would type the following:

```
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-fred
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-sam
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-mary
```

Each of these users dialup accounts should have their shell set to the symbolic link created above (for example, `mary`'s shell should be `/etc/ppp/ppp-mary`).

26.2.1.3.8. Setting Up `ppp.conf` for Dynamic-IP Users

The `/etc/ppp/ppp.conf` file should contain something along the lines of:

```
default:
  set debug phase lcp chat
  set timeout 0

ttyd0:
  set ifaddr 203.14.100.1 203.14.100.20 255.255.255.255
  enable proxy

ttyd1:
  set ifaddr 203.14.100.1 203.14.100.21 255.255.255.255
  enable proxy
```

注意

The indenting is important.

The `default:` section is loaded for each session. For each dialup line enabled in `/etc/ttys` create an entry similar to the one for `ttyd0:` above. Each line should get a unique IP address from your pool of IP addresses for dynamic users.

26.2.1.3.9. Setting Up `ppp.conf` for Static-IP Users

Along with the contents of the sample `/usr/share/examples/ppp/ppp.conf` above you should add a section for each of the statically assigned dialup users. We will continue with our `fred`, `sam`, and `mary` example.

```
fred:
  set ifaddr 203.14.100.1 203.14.101.1 255.255.255.255

sam:
  set ifaddr 203.14.100.1 203.14.102.1 255.255.255.255

mary:
  set ifaddr 203.14.100.1 203.14.103.1 255.255.255.255
```

The file `/etc/ppp/ppp.linkup` should also contain routing information for each static IP user if required. The line below would add a route for the `203.14.101.0` class C via the client's ppp link.

```
fred:
  add 203.14.101.0 netmask 255.255.255.0 HISADDR

sam:
  add 203.14.102.0 netmask 255.255.255.0 HISADDR

mary:
  add 203.14.103.0 netmask 255.255.255.0 HISADDR
```

26.2.1.3.10. `mgetty` and AutoPPP

Configuring and compiling `mgetty` with the `AUTO_PPP` option enabled allows `mgetty` to detect the LCP phase of PPP connections and automatically spawn off a ppp shell. However, since the default login/password sequence does not occur it is necessary to authenticate users using either PAP or CHAP.

This section assumes the user has successfully configured, compiled, and installed a version of `mgetty` with the `AUTO_PPP` option (v0.99beta or later).

Make sure your `/usr/local/etc/mgetty+sendfax/login.config` file has the following in it:

```
/AutoPPP/ -     -        /etc/ppp/ppp-pap-dialup
```

This will tell `mgetty` to run the `ppp-pap-dialup` script for detected PPP connections.

Create a file called `/etc/ppp/ppp-pap-dialup` containing the following (the file should be executable):

```
#!/bin/sh
exec /usr/sbin/ppp -direct pap$IDENT
```

For each dialup line enabled in `/etc/ttys`, create a corresponding entry in `/etc/ppp/ppp.conf`. This will happily co-exist with the definitions we created above.

```
pap:
  enable pap
  set ifaddr 203.14.100.1 203.14.100.20-203.14.100.40
  enable proxy
```

Each user logging in with this method will need to have a username/password in `/etc/ppp/ppp.secret` file, or alternatively add the following option to authenticate users via PAP from the `/etc/passwd` file.

```
enable passwdauth
```

If you wish to assign some users a static IP number, you can specify the number as the third argument in `/etc/ppp/ppp.secret`. See `/usr/share/examples/ppp/ppp.secret.sample` for examples.

26.2.1.3.11. MS Extensions

It is possible to configure PPP to supply DNS and NetBIOS nameserver addresses on demand.

To enable these extensions with PPP version 1.x, the following lines might be added to the relevant section of `/etc/ppp/ppp.conf`.

```
enable msext
set ns 203.14.100.1 203.14.100.2
set nbns 203.14.100.5
```

And for PPP version 2 and above:

```
accept dns
set dns 203.14.100.1 203.14.100.2
set nbns 203.14.100.5
```

This will tell the clients the primary and secondary name server addresses, and a NetBIOS nameserver host.

In version 2 and above, if the `set dns` line is omitted, PPP will use the values found in `/etc/resolv.conf` .

26.2.1.3.12. PAP and CHAP Authentication

Some ISPs set their system up so that the authentication part of your connection is done using either of the PAP or CHAP authentication mechanisms. If this is the case, your ISP will not give a `login:` prompt when you connect, but will start talking PPP immediately.

PAP is less secure than CHAP, but security is not normally an issue here as passwords, although being sent as plain text with PAP, are being transmitted down a serial line only. There is not much room for crackers to "eavesdrop".

Referring back to the PPP and Static IP addresses or PPP and Dynamic IP addresses sections, the following alterations must be made:

```
13      set authname MyUserName
14      set authkey MyPassword
15      set login
```

Line 13:
This line specifies your PAP/CHAP user name. You will need to insert the correct value for *MyUserName* .

Line 14:
This line specifies your PAP/CHAP password. You will need to insert the correct value for *MyPassword* . You may want to add an additional line, such as:

```
16      accept PAP
```

or

```
16      accept CHAP
```

to make it obvious that this is the intention, but PAP and CHAP are both accepted by default.

Line 15:
Your ISP will not normally require that you log into the server if you are using PAP or CHAP. You must therefore disable your "set login" string.

26.2.1.3.13. Changing Your `ppp` Configuration on the Fly

It is possible to talk to the `ppp` program while it is running in the background, but only if a suitable diagnostic port has been set up. To do this, add the following line to your configuration:

```
set server /var/run/ppp-tun%d DiagnosticPassword 0177
```

This will tell PPP to listen to the specified UNIX® domain socket, asking clients for the specified password before allowing access. The `%d` in the name is replaced with the `tun` device number that is in use.

Once a socket has been set up, the pppctl(8) program may be used in scripts that wish to manipulate the running program.

26.2.1.4. Using PPP Network Address Translation Capability

PPP has ability to use internal NAT without kernel diverting capabilities. This functionality may be enabled by the following line in `/etc/ppp/ppp.conf` :

```
nat enable yes
```

Alternatively, PPP NAT may be enabled by command-line option `-nat`. There is also `/etc/rc.conf` knob named `ppp_nat` , which is enabled by default.

If you use this feature, you may also find useful the following `/etc/ppp/ppp.conf` options to enable incoming connections forwarding:

```
nat port tcp 10.0.0.2:ftp ftp
nat port tcp 10.0.0.2:http http
```

or do not trust the outside at all

```
nat deny_incoming yes
```

26.2.1.5. Final System Configuration

You now have `ppp` configured, but there are a few more things to do before it is ready to work. They all involve editing the `/etc/rc.conf` file.

Working from the top down in this file, make sure the `hostname=` line is set, e.g.:

```
hostname="foo.example.com"
```

If your ISP has supplied you with a static IP address and name, it is probably best that you use this name as your host name.

Look for the `network_interfaces` variable. If you want to configure your system to dial your ISP on demand, make sure the `tun0` device is added to the list, otherwise remove it.

```
network_interfaces="lo0 tun0"
ifconfig_tun0=
```

注意

The `ifconfig_tun0` variable should be empty, and a file called `/etc/start_if.tun0` should be created. This file should contain the line:

```
ppp -auto mysystem
```

This script is executed at network configuration time, starting your ppp daemon in automatic mode. If you have a LAN for which this machine is a gateway, you may also wish to use the `-alias` switch. Refer to the manual page for further details.

Make sure that the router program is set to `NO` with the following line in your `/etc/rc.conf` :

```
router_enable="NO"
```

It is important that the `routed` daemon is not started, as `routed` tends to delete the default routing table entries created by `ppp`.

It is probably worth your while ensuring that the `sendmail_flags` line does not include the `-q` option, otherwise `sendmail` will attempt to do a network lookup every now and then, possibly causing your machine to dial out. You may try:

```
sendmail_flags="-bd"
```

The downside of this is that you must force `sendmail` to re-examine the mail queue whenever the ppp link is up by typing:

```
# /usr/sbin/sendmail -q
```

You may wish to use the `!bg` command in `ppp.linkup` to do this automatically:

```
1     provider:
```

```
2       delete ALL
3       add 0 0 HISADDR
4       !bg sendmail -bd -q30m
```

If you do not like this, it is possible to set up a "dfilter" to block SMTP traffic. Refer to the sample files for further details.

All that is left is to reboot the machine. After rebooting, you can now either type:

```
# ppp
```

and then `dial provider` to start the PPP session, or, if you want `ppp` to establish sessions automatically when there is outbound traffic (and you have not created the `start_if.tun0` script), type:

```
# ppp -auto provider
```

26.2.1.6. Summary

To recap, the following steps are necessary when setting up ppp for the first time:

Client side:

1. Ensure that the `tun` device is built into your kernel.
2. Ensure that the `tunN` device file is available in the `/dev` directory.
3. Create an entry in `/etc/ppp/ppp.conf` . The `pmdemand` example should suffice for most ISPs.
4. If you have a dynamic IP address, create an entry in `/etc/ppp/ppp.linkup` .
5. Update your `/etc/rc.conf` file.
6. Create a `start_if.tun0` script if you require demand dialing.

Server side:

1. Ensure that the `tun` device is built into your kernel.
2. Ensure that the `tunN` device file is available in the `/dev` directory.
3. Create an entry in `/etc/passwd` (using the vipw(8) program).
4. Create a profile in this users home directory that runs `ppp -direct direct-server` or similar.
5. Create an entry in `/etc/ppp/ppp.conf` . The `direct-server` example should suffice.
6. Create an entry in `/etc/ppp/ppp.linkup` .
7. Update your `/etc/rc.conf` file.

26.3. Using Kernel PPP

Parts originally contributed by Gennady B. Sorokopud # Robert Huff.

26.3.1. Setting Up Kernel PPP

Before you start setting up PPP on your machine, make sure that `pppd` is located in `/usr/sbin` and the directory `/etc/ppp` exists.

pppd can work in two modes:

1. As a "client" —— you want to connect your machine to the outside world via a PPP serial connection or modem line.

2. As a "server" —— your machine is located on the network, and is used to connect other computers using PPP.

In both cases you will need to set up an options file (/etc/ppp/options or ~/.ppprc if you have more than one user on your machine that uses PPP).

You will also need some modem/serial software (preferably comms/kermit), so you can dial and establish a connection with the remote host.

26.3.2. Using pppd as a Client

Based on information provided by Trev Roydhouse.

The following /etc/ppp/options might be used to connect to a Cisco terminal server PPP line.

```
crtscts         # enable hardware flow control
modem           # modem control line
noipdefault     # remote PPP server must supply your IP address
                # if the remote host does not send your IP during IPCP
                # negotiation, remove this option
passive         # wait for LCP packets
domain ppp.foo.com      # put your domain name here

:<remote_ip>    # put the IP of remote PPP host here
                # it will be used to route packets via PPP link
                # if you didn't specified the noipdefault option
                # change this line to <local_ip>:<remote_ip>

defaultroute    # put this if you want that PPP server will be your
                # default router
```

To connect:

1. Dial to the remote host using Kermit (or some other modem program), and enter your user name and password (or whatever is needed to enable PPP on the remote host).

2. Exit Kermit (without hanging up the line).

3. Enter the following:

   ```
   # /usr/src/usr.sbin/pppd.new/pppd /dev/tty01 19200
   ```

   Be sure to use the appropriate speed and device name.

Now your computer is connected with PPP. If the connection fails, you can add the debug option to the /etc/ppp/options file, and check console messages to track the problem.

Following /etc/ppp/pppup script will make all 3 stages automatic:

```
#!/bin/sh
ps ax |grep pppd |grep -v grep
pid=`ps ax |grep pppd |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing pppd, PID=' ${pid}
        kill ${pid}
fi
ps ax |grep kermit |grep -v grep
pid=`ps ax |grep kermit |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing kermit, PID=' ${pid}
```

```
        kill -9 ${pid}
fi

ifconfig ppp0 down
ifconfig ppp0 delete

kermit -y /etc/ppp/kermit.dial
pppd /dev/tty01 19200
```

`/etc/ppp/kermit.dial` is a Kermit script that dials and makes all necessary authorization on the remote host (an example of such a script is attached to the end of this document).

Use the following `/etc/ppp/pppdown` script to disconnect the PPP line:

```
#!/bin/sh
pid=`ps ax |grep pppd |grep -v grep|awk '{print $1;}'`
if [ X${pid} != "X" -] -; then
        echo 'killing pppd, PID=' ${pid}
        kill -TERM ${pid}
fi

ps ax |grep kermit |grep -v grep
pid=`ps ax |grep kermit |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing kermit, PID=' ${pid}
        kill -9 ${pid}
fi

/sbin/ifconfig ppp0 down
/sbin/ifconfig ppp0 delete
kermit -y /etc/ppp/kermit.hup
/etc/ppp/ppptest
```

Check to see if `pppd` is still running by executing `/usr/etc/ppp/ppptest` , which should look like this:

```
#!/bin/sh
pid=`ps ax| grep pppd |grep -v grep|awk '{print $1;}'`
if [ X${pid} != "X" -] -; then
        echo 'pppd running: PID=' ${pid-NONE}
else
        echo 'No pppd running.'
fi
set -x
netstat -n -I ppp0
ifconfig ppp0
```

To hang up the modem, execute `/etc/ppp/kermit.hup` , which should contain:

```
set line /dev/tty01 ; put your modem device here
set speed 19200
set file type binary
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
set term bytesize 8
set command bytesize 8
set flow none

pau 1
out +++
inp 5 OK
out ATH0\13
echo \13
```

```
exit
```

Here is an alternate method using `chat` instead of `kermit`:

The following two files are sufficient to accomplish a `pppd` connection.

`/etc/ppp/options` :

```
/dev/cuaa1 115200

crtscts  # enable hardware flow control
modem  # modem control line
connect "/usr/bin/chat -f /etc/ppp/login.chat.script"
noipdefault # remote PPP serve must supply your IP address
         # if the remote host doesn't send your IP during
                # IPCP negotiation, remove this option
passive         # wait for LCP packets
domain <your.domain> # put your domain name here

:  # put the IP of remote PPP host here
         # it will be used to route packets via PPP link
                # if you didn't specified the noipdefault option
                # change this line to <local_ip>:<remote_ip>

defaultroute # put this if you want that PPP server will be
         # your default router
```

`/etc/ppp/login.chat.script` :

注意

The following should go on a single line.

```
ABORT BUSY ABORT 'NO CARRIER' "" AT OK ATDT<phone.number>
  CONNECT "" TIMEOUT 10 ogin:-\\r-ogin: <login-id>
  TIMEOUT 5 sword: <password>
```

Once these are installed and modified correctly, all you need to do is run `pppd`, like so:

```
# pppd
```

26.3.3. Using `pppd` as a Server

`/etc/ppp/options` should contain something similar to the following:

```
crtscts                         # Hardware flow control
netmask 255.255.255.0           # netmask (not required)
192.114.208.20:192.114.208.165  # IP's of local and remote hosts
                                # local ip must be different from one
                                # you assigned to the Ethernet (or other)
                                # interface on your machine.
                                # remote IP is IP address that will be
                                # assigned to the remote machine
domain ppp.foo.com              # your domain
passive                         # wait for LCP
modem                           # modem line
```

The following `/etc/ppp/pppserv` script will tell pppd to behave as a server:

```
#!/bin/sh
```

```
ps ax |grep pppd |grep -v grep
pid=`ps ax |grep pppd |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing pppd, PID=' ${pid}
        kill ${pid}
fi
ps ax |grep kermit |grep -v grep
pid=`ps ax |grep kermit |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing kermit, PID=' ${pid}
        kill -9 ${pid}
fi

# reset ppp interface
ifconfig ppp0 down
ifconfig ppp0 delete

# enable autoanswer mode
kermit -y /etc/ppp/kermit.ans

# run ppp
pppd /dev/tty01 19200
```

Use this `/etc/ppp/pppservdown` script to stop the server:

```
#!/bin/sh
ps ax |grep pppd |grep -v grep
pid=`ps ax |grep pppd |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing pppd, PID=' ${pid}
        kill ${pid}
fi
ps ax |grep kermit |grep -v grep
pid=`ps ax |grep kermit |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" -] -; then
        echo 'killing kermit, PID=' ${pid}
        kill -9 ${pid}
fi
ifconfig ppp0 down
ifconfig ppp0 delete

kermit -y /etc/ppp/kermit.noans
```

The following Kermit script (`/etc/ppp/kermit.ans`) will enable/disable autoanswer mode on your modem. It should look like this:

```
set line /dev/tty01
set speed 19200
set file type binary
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
set term bytesize 8
set command bytesize 8
set flow none

pau 1
out +++
inp 5 OK
out ATH0\13
inp 5 OK
echo \13
out ATS0=1\13   -; change this to out ATS0=0\13 if you want to disable
                -; autoanswer mode
```

```
inp 5 OK
echo \13
exit
```

A script named `/etc/ppp/kermit.dial` is used for dialing and authenticating on the remote host. You will need to customize it for your needs. Put your login and password in this script; you will also need to change the input statement depending on responses from your modem and remote host.

```
;
; put the com line attached to the modem here:
;
set line /dev/tty01
;
; put the modem speed here:
;
set speed 19200
set file type binary            -; full 8 bit file xfer
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
set term bytesize 8
set command bytesize 8
set flow none
set modem hayes
set dial hangup off
set carrier auto                -; Then SET CARRIER if necessary,
set dial display on             -; Then SET DIAL if necessary,
set input echo on
set input timeout proceed
set input case ignore
def \%x 0                       -; login prompt counter
goto slhup

:slcmd                          -; put the modem in command mode
echo Put the modem in command mode.
clear                           -; Clear unread characters from input buffer
pause 1
output +++                      -; hayes escape sequence
input 1 OK\13\10                -; wait for OK
if success goto slhup
output \13
pause 1
output at\13
input 1 OK\13\10
if fail goto slcmd              -; if modem doesn't answer OK, try again

:slhup                          -; hang up the phone
clear                           -; Clear unread characters from input buffer
pause 1
echo Hanging up the phone.
output ath0\13                  -; hayes command for on hook
input 2 OK\13\10
if fail goto slcmd              -; if no OK answer, put modem in command mode

:sldial                         -; dial the number
pause 1
echo Dialing.
output atdt9,550311\13\10               -; put phone number here
assign \%x 0                    -; zero the time counter

:look
clear                           -; Clear unread characters from input buffer
increment \%x                   -; Count the seconds
input 1 {CONNECT }
```

```
if success goto sllogin
reinput 1 {NO CARRIER\13\10}
if success goto sldial
reinput 1 {NO DIALTONE\13\10}
if success goto slnodial
reinput 1 {\255}
if success goto slhup
reinput 1 {\127}
if success goto slhup
if < \%x 60 goto look
else goto slhup

:sllogin                        -; login
assign \%x 0                    -; zero the time counter
pause 1
echo Looking for login prompt.

:slloop
increment \%x                   -; Count the seconds
clear                           -; Clear unread characters from input buffer
output \13
;
; put your expected login prompt here:
;
input 1 {Username: }
if success goto sluid
reinput 1 {\255}
if success goto slhup
reinput 1 {\127}
if success goto slhup
if < \%x 10 goto slloop         -; try 10 times to get a login prompt
else goto slhup                 -; hang up and start again if 10 failures

:sluid
;
; put your userid here:
;
output ppp-login\13
input 1 {Password: }
;
; put your password here:
;
output ppp-password\13
input 1 {Entering SLIP mode.-}
echo
quit

:slnodial
echo \7No dialtone.  Check the telephone line!\7
exit 1

; local variables:
; mode: csh
; comment-start: "; "
; comment-start-skip: "; "
; end:
```

26.4. Troubleshooting PPP Connections

Contributed by Tom Rhodes.

This section covers a few issues which may arise when using PPP over a modem connection. For instance, perhaps you need to know exactly what prompts the system you are dialing into will present. Some ISPs present the `ssword` prompt, and others will present `password`; if the `ppp` script is not written accordingly, the login

attempt will fail. The most common way to debug ppp connections is by connecting manually. The following information will walk you through a manual connection step by step.

26.4.1. Check the Device Nodes

If you reconfigured your kernel then you recall the sio device. If you did not configure your kernel, there is no reason to worry. Just check the dmesg output for the modem device with:

```
# dmesg | grep sio
```

You should get some pertinent output about the sio devices. These are the COM ports we need. If your modem acts like a standard serial port then you should see it listed on sio1, or COM2. If so, you are not required to rebuild the kernel, you just need to make the serial device. You can do this by changing your directory to /dev and running the MAKEDEV script like above. Now make the serial devices with:

```
# sh MAKEDEV cuaa0 cuaa1 cuaa2 cuaa3
```

which will create the serial devices for your system. When matching up sio modem is on sio1 or COM2 if you are in DOS, then your modem device would be /dev/cuaa1 .

26.4.2. Connecting Manually

Connecting to the Internet by manually controlling ppp is quick, easy, and a great way to debug a connection or just get information on how your ISP treats ppp client connections. Lets start PPP from the command line. Note that in all of our examples we will use example as the hostname of the machine running PPP. You start ppp by just typing ppp:

```
# ppp
```

We have now started ppp.

```
ppp ON example> set device /dev/cuaa1
```

We set our modem device, in this case it is cuaa1.

```
ppp ON example> set speed 115200
```

Set the connection speed, in this case we are using 115,200 kbps.

```
ppp ON example> enable dns
```

Tell ppp to configure our resolver and add the nameserver lines to /etc/resolv.conf . If ppp cannot determine our hostname, we can set one manually later.

```
ppp ON example> term
```

Switch to “terminal” mode so that we can manually control the modem.

```
deflink: Entering terminal mode on /dev/cuaa1
type '~h' for help
```

```
at
OK
atdt123456789
```

Use at to initialize the modem, then use atdt and the number for your ISP to begin the dial in process.

```
CONNECT
```

Confirmation of the connection, if we are going to have any connection problems, unrelated to hardware, here is where we will attempt to resolve them.

```
ISP Login:myusername
```

Here you are prompted for a username, return the prompt with the username that was provided by the ISP.

```
ISP Pass:mypassword
```

This time we are prompted for a password, just reply with the password that was provided by the ISP. Just like logging into FreeBSD, the password will not echo.

```
Shell or PPP:ppp
```

Depending on your ISP this prompt may never appear. Here we are being asked if we wish to use a shell on the provider, or to start `ppp`. In this example, we have chosen to use `ppp` as we want an Internet connection.

```
Ppp ON example>
```

Notice that in this example the first `p` has been capitalized. This shows that we have successfully connected to the ISP.

```
PPp ON example>
```

We have successfully authenticated with our ISP and are waiting for the assigned IP address.

```
PPP ON example>
```

We have made an agreement on an IP address and successfully completed our connection.

```
PPP ON example>add default HISADDR
```

Here we add our default route, we need to do this before we can talk to the outside world as currently the only established connection is with the peer. If this fails due to existing routes you can put a bang character `!` in front of the `add`. Alternatively, you can set this before making the actual connection and it will negotiate a new route accordingly.

If everything went good we should now have an active connection to the Internet, which could be thrown into the background using CTRL+z If you notice the `PPP` return to `ppp` then we have lost our connection. This is good to know because it shows our connection status. Capital P's show that we have a connection to the ISP and lowercase p's show that the connection has been lost for whatever reason. `ppp` only has these 2 states.

26.4.2.1. Debugging

If you have a direct line and cannot seem to make a connection, then turn hardware flow CTS/RTS to off with the `set ctsrts off`. This is mainly the case if you are connected to some PPP capable terminal servers, where PPP hangs when it tries to write data to your communication link, so it would be waiting for a CTS, or Clear To Send signal which may never come. If you use this option however, you should also use the `set accmap` option, which may be required to defeat hardware dependent on passing certain characters from end to end, most of the time XON/XOFF. See the ppp(8) manual page for more information on this option, and how it is used.

If you have an older modem, you may need to use the `set parity even`. Parity is set at none be default, but is used for error checking (with a large increase in traffic) on older modems and some ISPs. You may need this option for the Compuserve ISP.

PPP may not return to the command mode, which is usually a negotiation error where the ISP is waiting for your side to start negotiating. At this point, using the `~p` command will force ppp to start sending the configuration information.

If you never obtain a login prompt, then most likely you need to use PAP or CHAP authentication instead of the UNIX® style in the example above. To use PAP or CHAP just add the following options to PPP before going into terminal mode:

```
ppp ON example> set authname myusername
```

Where *myusername* should be replaced with the username that was assigned by the ISP.

```
ppp ON example> set authkey mypassword
```

Where *mypassword* should be replaced with the password that was assigned by the ISP.

If you connect fine, but cannot seem to find any domain name, try to use ping(8) with an IP address and see if you can get any return information. If you experience 100 percent (100%) packet loss, then it is most likely that you were not assigned a default route. Double check that the option `add default HISADDR` was set during the connection. If you can connect to a remote IP address then it is possible that a resolver address has not been added to the `/etc/resolv.conf` . This file should look like:

```
domain example.com
nameserver x.x.x.x
nameserver y.y.y.y
```

Where *x.x.x.x* and *y.y.y.y* should be replaced with the IP address of your ISP's DNS servers. This information may or may not have been provided when you signed up, but a quick call to your ISP should remedy that.

You could also have syslog(3) provide a logging function for your PPP connection. Just add:

```
!ppp
*.*     /var/log/ppp.log
```

to `/etc/syslog.conf` . In most cases, this functionality already exists.

26.5. Using PPP over Ethernet (PPPoE)

Contributed (from http://node.to/freebsd/how-tos/how-to-freebsd-pppoe.html) by Jim Mock.

This section describes how to set up PPP over Ethernet (PPPoE).

26.5.1. Configuring the Kernel

No kernel configuration is necessary for PPPoE any longer. If the necessary netgraph support is not built into the kernel, it will be dynamically loaded by ppp.

26.5.2. Setting Up `ppp.conf`

Here is an example of a working `ppp.conf` :

```
default:
  set log Phase tun command # you can add more detailed logging if you wish
  set ifaddr 10.0.0.1/0 10.0.0.2/0

name_of_service_provider:
  set device PPPoE:xl1 # replace xl1 with your Ethernet device
  set authname YOURLOGINNAME
  set authkey YOURPASSWORD
  set dial
  set login
  add default HISADDR
```

26.5.3. Running ppp

As `root`, you can run:

```
# ppp -ddial name_of_service_provider
```

26.5.4. Starting ppp at Boot

Add the following to your `/etc/rc.conf` file:

```
ppp_enable="YES"
ppp_mode="ddial"
ppp_nat="YES" # if you want to enable nat for your local network, otherwise NO
ppp_profile="name_of_service_provider"
```

26.5.5. Using a PPPoE Service Tag

Sometimes it will be necessary to use a service tag to establish your connection. Service tags are used to distinguish between different PPPoE servers attached to a given network.

You should have been given any required service tag information in the documentation provided by your ISP. If you cannot locate it there, ask your ISP's tech support personnel.

As a last resort, you could try the method suggested by the Roaring Penguin PPPoE program which can be found in the Ports Collection. Bear in mind however, this may de-program your modem and render it useless, so think twice before doing it. Simply install the program shipped with the modem by your provider. Then, access the System menu from the program. The name of your profile should be listed there. It is usually ISP.

The profile name (service tag) will be used in the PPPoE configuration entry in `ppp.conf` as the provider part of the `set device` command (see the ppp(8) manual page for full details). It should look like this:

```
set device PPPoE:xl1:ISP
```

Do not forget to change *`xl1`* to the proper device for your Ethernet card.

Do not forget to change *`ISP`* to the profile you have just found above.

For additional information, see:

- Cheaper Broadband with FreeBSD on DSL by Renaud Waldura.
- Nutzung von T-DSL und T-Online mit FreeBSD by Udo Erdelhoff (in German).

26.5.6. PPPoE with a 3Com® HomeConnect® ADSL Modem Dual Link

This modem does not follow RFC 2516 (A Method for transmitting PPP over Ethernet (PPPoE), written by L. Mamakos, K. Lidl, J. Evarts, D. Carrel, D. Simone, and R. Wheeler). Instead, different packet type codes have been used for the Ethernet frames. Please complain to 3Com if you think it should comply with the PPPoE specification.

In order to make FreeBSD capable of communicating with this device, a sysctl must be set. This can be done automatically at boot time by updating `/etc/sysctl.conf` :

```
net.graph.nonstandard_pppoe=1
```

or can be done immediately with the command:

```
# sysctl net.graph.nonstandard_pppoe=1
```

Unfortunately, because this is a system-wide setting, it is not possible to talk to a normal PPPoE client or server and a 3Com® HomeConnect® ADSL Modem at the same time.

26.6. Using PPP over ATM (PPPoA)

The following describes how to set up PPP over ATM (PPPoA). PPPoA is a popular choice among European DSL providers.

26.6.1. Using PPPoA with the Alcatel SpeedTouch™ USB

PPPoA support for this device is supplied as a port in FreeBSD because the firmware is distributed under Alcatel's license agreement and can not be redistributed freely with the base system of FreeBSD.

To install the software, simply use the Ports Collection. Install the net/pppoa port and follow the instructions provided with it.

Like many USB devices, the Alcatel SpeedTouch™ USB needs to download firmware from the host computer to operate properly. It is possible to automate this process in FreeBSD so that this transfer takes place whenever the device is plugged into a USB port. The following information can be added to the `/etc/usbd.conf` file to enable this automatic firmware transfer. This file must be edited as the `root` user.

```
device "Alcatel SpeedTouch USB"
    devname "ugen[0-9]+"
    vendor 0x06b9
    product 0x4061
    attach "/usr/local/sbin/modem_run -f /usr/local/libdata/mgmt.o"
```

To enable the USB daemon, usbd, put the following the line into `/etc/rc.conf` :

```
usbd_enable="YES"
```

It is also possible to set up ppp to dial up at startup. To do this add the following lines to `/etc/rc.conf` . Again, for this procedure you will need to be logged in as the `root` user.

```
ppp_enable="YES"
ppp_mode="ddial"
ppp_profile="adsl"
```

For this to work correctly you will need to have used the sample `ppp.conf` which is supplied with the net/pppoa port.

26.6.2. Using mpd

You can use mpd to connect to a variety of services, in particular PPTP services. You can find mpd in the Ports Collection, net/mpd. Many ADSL modems require that a PPTP tunnel is created between the modem and computer, one such modem is the Alcatel SpeedTouch™ Home.

First you must install the port, and then you can configure mpd to suit your requirements and provider settings. The port places a set of sample configuration files which are well documented in `PREFIX/etc/mpd/` . Note here that *`PREFIX`* means the directory into which your ports are installed, this defaults to `/usr/local/` . A complete guide to configure mpd is available in HTML format once the port has been installed. It is placed in `PREFIX/share/doc/mpd/` . Here is a sample configuration for connecting to an ADSL service with mpd. The configuration is spread over two files, first the `mpd.conf` :

```
default:
    load adsl

adsl:
    new -i ng0 adsl adsl
    set bundle authname username ❶
    set bundle password password ❷
```

```
    set bundle disable multilink

    set link no pap acfcomp protocomp
    set link disable chap
    set link accept chap
    set link keep-alive 30 10

    set ipcp no vjcomp
    set ipcp ranges 0.0.0.0/0 0.0.0.0/0

    set iface route default
    set iface disable on-demand
    set iface enable proxy-arp
    set iface idle 0

    open
```

❶ The username used to authenticate with your ISP.
❷ The password used to authenticate with your ISP.

The `mpd.links` file contains information about the link, or links, you wish to establish. An example `mpd.links` to accompany the above example is given beneath:

```
adsl:
    set link type pptp
    set pptp mode active
    set pptp enable originate outcall
    set pptp self 10.0.0.1 ❶
    set pptp peer 10.0.0.138 ❷
```

❶ The IP address of your FreeBSD computer which you will be using mpd from.
❷ The IP address of your ADSL modem. For the Alcatel SpeedTouch™ Home this address defaults to `10.0.0.138`.

It is possible to initialize the connection easily by issuing the following command as `root`:

```
# mpd -b adsl
```

You can see the status of the connection with the following command:

```
% ifconfig ng0
ng0: flags=88d1<UP,POINTOPOINT,RUNNING,NOARP,SIMPLEX,MULTICAST> mtu 1500
     inet 216.136.204.117 --> 204.152.186.171 netmask 0xffffffff
```

Using mpd is the recommended way to connect to an ADSL service with FreeBSD.

26.6.3. Using pptpclient

It is also possible to use FreeBSD to connect to other PPPoA services using net/pptpclient.

To use net/pptpclient to connect to a DSL service, install the port or package and edit your `/etc/ppp/ppp.conf`. You will need to be `root` to perform both of these operations. An example section of `ppp.conf` is given below. For further information on `ppp.conf` options consult the ppp manual page, ppp(8).

```
adsl:
 set log phase chat lcp ipcp ccp tun command
 set timeout 0
 enable dns
 set authname username ❶
 set authkey password ❷
 set ifaddr 0 0
 add default HISADDR
```

❶ The username of your account with the DSL provider.
❷ The password for your account.

警告

Because you must put your account's password in the `ppp.conf` file in plain text form you should make sure than nobody can read the contents of this file. The following series of commands will make sure the file is only readable by the `root` account. Refer to the manual pages for chmod(1) and chown(8) for further information.

```
# chown root:wheel /etc/ppp/ppp.conf
# chmod 600 /etc/ppp/ppp.conf
```

This will open a tunnel for a PPP session to your DSL router. Ethernet DSL modems have a preconfigured LAN IP address which you connect to. In the case of the Alcatel SpeedTouch™ Home this address is `10.0.0.138` . Your router documentation should tell you which address your device uses. To open the tunnel and start a PPP session execute the following command:

```
# pptp address adsl
```

提示

You may wish to add an ampersand (“&”) to the end of the previous command because pptp will not return your prompt to you otherwise.

A `tun` virtual tunnel device will be created for interaction between the pptp and ppp processes. Once you have been returned to your prompt, or the pptp process has confirmed a connection you can examine the tunnel like so:

```
% ifconfig tun0
tun0: flags=8051<UP,POINTOPOINT,RUNNING,MULTICAST> mtu 1500
        inet 216.136.204.21 --> 204.152.186.171 netmask 0xffffff00
        Opened by PID 918
```

If you are unable to connect, check the configuration of your router, which is usually accessible via telnet or with a web browser. If you still cannot connect you should examine the output of the `pptp` command and the contents of the ppp log file, `/var/log/ppp.log` for clues.

26.7. Using SLIP

Originally contributed by Satoshi Asami.
With input from Guy Helmer # Piero Serini.

26.7.1. Setting Up a SLIP Client

The following is one way to set up a FreeBSD machine for SLIP on a static host network. For dynamic hostname assignments (your address changes each time you dial up), you probably need to have a more complex setup.

First, determine which serial port your modem is connected to. Many people set up a symbolic link, such as `/dev/modem`, to point to the real device name, `/dev/cuaaN` (or `/dev/cuadN` under FreeBSD 6.X). This allows you to abstract the actual device name should you ever need to move the modem to a different port. It can become quite cumbersome when you need to fix a bunch of files in `/etc` and `.kermrc` files all over the system!

注意

/dev/cuaa0 (or /dev/cuad0 under FreeBSD 6.X) is COM1, cuaa1 (or /dev/cuad1) is COM2, etc.

Make sure you have the following in your kernel configuration file:

```
device   sl
```

Under FreeBSD 4.X, use instead the following line:

```
pseudo-device   sl      1
```

It is included in the GENERIC kernel, so this should not be a problem unless you have deleted it.

26.7.1.1. Things You Have to Do Only Once

1. Add your home machine, the gateway and nameservers to your /etc/hosts file. Ours looks like this:

   ```
   127.0.0.1               localhost loghost
   136.152.64.181          water.CS.Example.EDU water.CS water
   136.152.64.1            inr-3.CS.Example.EDU inr-3 slip-gateway
   128.32.136.9            ns1.Example.EDU ns1
   128.32.136.12           ns2.Example.EDU ns2
   ```

2. Make sure you have hosts before bind in your /etc/host.conf on FreeBSD versions prior to 5.0. Since FreeBSD 5.0, the system uses the file /etc/nsswitch.conf instead, make sure you have files before dns in the hosts line of this file. Without these parameters funny things may happen.

3. Edit the /etc/rc.conf file.

   1. Set your hostname by editing the line that says:

      ```
      hostname="myname.my.domain"
      ```

      Your machine's full Internet hostname should be placed here.

   2. Designate the default router by changing the line:

      ```
      defaultrouter="NO"
      ```

      to:

      ```
      defaultrouter="slip-gateway"
      ```

4. Make a file /etc/resolv.conf which contains:

   ```
   domain CS.Example.EDU
   nameserver 128.32.136.9
   nameserver 128.32.136.12
   ```

   As you can see, these set up the nameserver hosts. Of course, the actual domain names and addresses depend on your environment.

5. Set the password for root and toor (and any other accounts that do not have a password).

6. Reboot your machine and make sure it comes up with the correct hostname.

26.7.1.2. Making a SLIP Connection

1. Dial up, type `slip` at the prompt, enter your machine name and password. What is required to be entered depends on your environment. If you use Kermit, you can try a script like this:

```
# kermit setup
set modem hayes
set line /dev/modem
set speed 115200
set parity none
set flow rts/cts
set terminal bytesize 8
set file type binary
# The next macro will dial up and login
define slip dial 643-9600, input 10 =>, if failure stop, -
output slip\x0d, input 10 Username:, if failure stop, -
output silvia\x0d, input 10 Password:, if failure stop, -
output ***\x0d, echo \x0aCONNECTED\x0a
```

   Of course, you have to change the username and password to fit yours. After doing so, you can just type `slip` from the Kermit prompt to connect.

注意

Leaving your password in plain text anywhere in the filesystem is generally a bad idea. Do it at your own risk.

2. Leave the Kermit there (you can suspend it by Ctrl+z) and as `root`, type:

```
# slattach -h -c -s 115200 /dev/modem
```

   If you are able to `ping` hosts on the other side of the router, you are connected! If it does not work, you might want to try `-a` instead of `-c` as an argument to `slattach`.

26.7.1.3. How to Shutdown the Connection

Do the following:

```
# kill -INT `cat /var/run/slattach.modem.pid`
```

to kill `slattach`. Keep in mind you must be `root` to do the above. Then go back to `kermit` (by running `fg` if you suspended it) and exit from it (q).

The slattach(8) manual page says you have to use `ifconfig sl0 down` to mark the interface down, but this does not seem to make any difference. (`ifconfig sl0` reports the same thing.)

Some times, your modem might refuse to drop the carrier. In that case, simply start `kermit` and quit it again. It usually goes out on the second try.

26.7.1.4. Troubleshooting

If it does not work, feel free to ask on freebsd-net mailing list. The things that people tripped over so far:

- Not using `-c` or `-a` in `slattach` (This should not be fatal, but some users have reported that this solves their problems.)
- Using `sl0` instead of `sl0` (might be hard to see the difference on some fonts).

- Try `ifconfig sl0` to see your interface status. For example, you might get:

```
# ifconfig sl0
sl0: flags=10<POINTOPOINT>
        inet 136.152.64.181 --> 136.152.64.1 netmask ffffff00
```

- If you get no route to host messages from ping(8), there may be a problem with your routing table. You can use the `netstat -r` command to display the current routes :

```
# netstat -r
Routing tables
Destination      Gateway            Flags     Refs     Use  IfaceMTU    Rtt    Netmasks:

(root node)
(root node)

Route Tree for Protocol Family inet:
(root node) =>
default          inr-3.Example.EDU  UG          8   224515  sl0 -      -
localhost.Exampl localhost.Example. UH          5    42127  lo0 -       0.438
inr-3.Example.ED water.CS.Example.E UH          1        0  sl0 -      -
water.CS.Example localhost.Example. UGH        34 47641234  lo0 -       0.438
(root node)
```

  The preceding examples are from a relatively busy system. The numbers on your system will vary depending on network activity.

26.7.2. Setting Up a SLIP Server

This document provides suggestions for setting up SLIP Server services on a FreeBSD system, which typically means configuring your system to automatically startup connections upon login for remote SLIP clients.

26.7.2.1. Prerequisites

This section is very technical in nature, so background knowledge is required. It is assumed that you are familiar with the TCP/IP network protocol, and in particular, network and node addressing, network address masks, subnetting, routing, and routing protocols, such as RIP. Configuring SLIP services on a dial-up server requires a knowledge of these concepts, and if you are not familiar with them, please read a copy of either Craig Hunt's TCP/IP Network Administration published by O'Reilly & Associates, Inc. (ISBN Number 0-937175-82-X), or Douglas Comer's books on the TCP/IP protocol.

It is further assumed that you have already set up your modem(s) and configured the appropriate system files to allow logins through your modems. If you have not prepared your system for this yet, please see 節 25.4, “Dial-in Service” for details on dialup services configuration. You may also want to check the manual pages for sio(4) for information on the serial port device driver and ttys(5), gettytab(5), getty(8), & init(8) for information relevant to configuring the system to accept logins on modems, and perhaps stty(1) for information on setting serial port parameters (such as `clocal` for directly-connected serial interfaces).

26.7.2.2. Quick Overview

In its typical configuration, using FreeBSD as a SLIP server works as follows: a SLIP user dials up your FreeBSD SLIP Server system and logs in with a special SLIP login ID that uses `/usr/sbin/sliplogin` as the special user's shell. The `sliplogin` program browses the file `/etc/sliphome/slip.hosts` to find a matching line for the special user, and if it finds a match, connects the serial line to an available SLIP interface and then runs the shell script `/etc/sliphome/slip.login` to configure the SLIP interface.

26.7.2.2.1. An Example of a SLIP Server Login

For example, if a SLIP user ID were `Shelmerg` , `Shelmerg` 's entry in `/etc/master.passwd` would look something like this:

```
Shelmerg:password:1964:89::0:0:Guy Helmer - SLIP:/usr/users/Shelmerg:/usr/sbin/sliplogin
```

When `Shelmerg` logs in, `sliplogin` will search `/etc/sliphome/slip.hosts` for a line that had a matching user ID; for example, there may be a line in `/etc/sliphome/slip.hosts` that reads:

```
Shelmerg        dc-slip sl-helmer       0xfffffc00      autocomp
```

`sliplogin` will find that matching line, hook the serial line into the next available SLIP interface, and then execute `/etc/sliphome/slip.login` like this:

```
/etc/sliphome/slip.login 0 19200 Shelmerg dc-slip sl-helmer 0xfffffc00 autocomp
```

If all goes well, `/etc/sliphome/slip.login` will issue an `ifconfig` for the SLIP interface to which `sliplogin` attached itself (SLIP interface 0, in the above example, which was the first parameter in the list given to `slip.login`) to set the local IP address (`dc-slip`), remote IP address (`sl-helmer`), network mask for the SLIP interface (`0xfffffc00`), and any additional flags (`autocomp`). If something goes wrong, `sliplogin` usually logs good informational messages via the syslogd daemon facility, which usually logs to `/var/log/messages` (see the manual pages for syslogd(8) and syslog.conf(5) and perhaps check `/etc/syslog.conf` to see to what syslogd is logging and where it is logging to).

26.7.2.3. Kernel Configuration

FreeBSD's default kernel (`GENERIC`) comes with SLIP (sl(4)) support; in case of a custom kernel, you have to add the following line to your kernel configuration file:

```
device    sl
```

Under FreeBSD 4.X, use instead the following line:

```
pseudo-device    sl      2
```

注意

The number at the end of the line is the maximum number of SLIP connections that may be operating simultaneously. Since FreeBSD 5.0, the sl(4) driver is “auto-cloning”.

By default, your FreeBSD machine will not forward packets. If you want your FreeBSD SLIP Server to act as a router, you will have to edit the `/etc/rc.conf` file and change the setting of the `gateway_enable` variable to `YES`.

You will then need to reboot for the new settings to take effect.

Please refer to 章 8, 設定 FreeBSD Kernel on Configuring the FreeBSD Kernel for help in reconfiguring your kernel.

26.7.2.4. Sliplogin Configuration

As mentioned earlier, there are three files in the `/etc/sliphome` directory that are part of the configuration for `/usr/sbin/sliplogin` (see sliplogin(8) for the actual manual page for `sliplogin`): `slip.hosts`, which defines the SLIP users and their associated IP addresses; `slip.login`, which usually just configures the SLIP interface; and (optionally) `slip.logout`, which undoes `slip.login`'s effects when the serial connection is terminated.

26.7.2.4.1. `slip.hosts` Configuration

`/etc/sliphome/slip.hosts` contains lines which have at least four items separated by whitespace:

- SLIP user's login ID

- Local address (local to the SLIP server) of the SLIP link
- Remote address of the SLIP link
- Network mask

The local and remote addresses may be host names (resolved to IP addresses by `/etc/hosts` or by the domain name service, depending on your specifications in the file `/etc/nsswitch.conf` , or in `/etc/host.conf` if you use FreeBSD 4.X), and the network mask may be a name that can be resolved by a lookup into `/etc/networks` . On a sample system, `/etc/sliphome/slip.hosts` looks like this:

```
#
# login local-addr      remote-addr     mask            opt1    opt2
#                                                (normal,compress,noicmp)
#
Shelmerg  dc-slip       sl-helmerg      0xfffffc00      autocomp
```

At the end of the line is one or more of the options:

- `normal` —— no header compression
- `compress` —— compress headers
- `autocomp` —— compress headers if the remote end allows it
- `noicmp` —— disable ICMP packets (so any “ping” packets will be dropped instead of using up your bandwidth)

Your choice of local and remote addresses for your SLIP links depends on whether you are going to dedicate a TCP/IP subnet or if you are going to use “proxy ARP” on your SLIP server (it is not “true” proxy ARP, but that is the terminology used in this section to describe it). If you are not sure which method to select or how to assign IP addresses, please refer to the TCP/IP books referenced in the SLIP Prerequisites (節 26.7.2.1, “Prerequisites”) and/or consult your IP network manager.

If you are going to use a separate subnet for your SLIP clients, you will need to allocate the subnet number out of your assigned IP network number and assign each of your SLIP client's IP numbers out of that subnet. Then, you will probably need to configure a static route to the SLIP subnet via your SLIP server on your nearest IP router.

Otherwise, if you will use the “proxy ARP” method, you will need to assign your SLIP client's IP addresses out of your SLIP server's Ethernet subnet, and you will also need to adjust your `/etc/sliphome/slip.login` and `/etc/sliphome/slip.logout` scripts to use arp(8) to manage the proxy-ARP entries in the SLIP server's ARP table.

26.7.2.4.2. `slip.login` Configuration

The typical `/etc/sliphome/slip.login` file looks like this:

```
#!/bin/sh -
#
#       @(#)slip.login  5.1 (Berkeley) 7/1/90

#
# generic login file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 inet $4 $5 netmask $6
```

This `slip.login` file merely runs `ifconfig` for the appropriate SLIP interface with the local and remote addresses and network mask of the SLIP interface.

If you have decided to use the "proxy ARP" method (instead of using a separate subnet for your SLIP clients), your `/etc/sliphome/slip.login` file will need to look something like this:

```
#!/bin/sh -
#
#       @(#)slip.login  5.1 (Berkeley) 7/1/90

#
# generic login file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 inet $4 $5 netmask $6
# Answer ARP requests for the SLIP client with our Ethernet addr
/usr/sbin/arp -s $5 00:11:22:33:44:55 pub
```

The additional line in this `slip.login`, `arp -s $5 00:11:22:33:44:55 pub`, creates an ARP entry in the SLIP server's ARP table. This ARP entry causes the SLIP server to respond with the SLIP server's Ethernet MAC address whenever another IP node on the Ethernet asks to speak to the SLIP client's IP address.

When using the example above, be sure to replace the Ethernet MAC address (`00:11:22:33:44:55`) with the MAC address of your system's Ethernet card, or your "proxy ARP" will definitely not work! You can discover your SLIP server's Ethernet MAC address by looking at the results of running `netstat -i`; the second line of the output should look something like:

```
ed0   1500  <Link>0.2.c1.28.5f.4a         191923 0   129457     0   116
```

This indicates that this particular system's Ethernet MAC address is `00:02:c1:28:5f:4a` —— the periods in the Ethernet MAC address given by `netstat -i` must be changed to colons and leading zeros should be added to each single-digit hexadecimal number to convert the address into the form that arp(8) desires; see the manual page on arp(8) for complete information on usage.

注意

When you create `/etc/sliphome/slip.login` and `/etc/sliphome/slip.logout`, the "execute" bit (i.e., `chmod 755 /etc/sliphome/slip.login /etc/sliphome/slip.logout`) must be set, or `sliplogin` will be unable to execute it.

26.7.2.4.3. `slip.logout` Configuration

`/etc/sliphome/slip.logout` is not strictly needed (unless you are implementing "proxy ARP"), but if you decide to create it, this is an example of a basic `slip.logout` script:

```
#!/bin/sh -
#
#       slip.logout

#
# logout file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 down
```

If you are using "proxy ARP", you will want to have `/etc/sliphome/slip.logout` remove the ARP entry for the SLIP client:

```
#!/bin/sh -
#
#       @(#)slip.logout

#
# logout file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 down
# Quit answering ARP requests for the SLIP client
/usr/sbin/arp -d $5
```

The `arp -d $5` removes the ARP entry that the "proxy ARP" `slip.login` added when the SLIP client logged in.

It bears repeating: make sure `/etc/sliphome/slip.logout` has the execute bit set after you create it (i.e., `chmod 755 /etc/sliphome/slip.logout`).

26.7.2.5. Routing Considerations

If you are not using the "proxy ARP" method for routing packets between your SLIP clients and the rest of your network (and perhaps the Internet), you will probably have to add static routes to your closest default router(s) to route your SLIP clients subnet via your SLIP server.

26.7.2.5.1. Static Routes

Adding static routes to your nearest default routers can be troublesome (or impossible if you do not have authority to do so...). If you have a multiple-router network in your organization, some routers, such as those made by Cisco and Proteon, may not only need to be configured with the static route to the SLIP subnet, but also need to be told which static routes to tell other routers about, so some expertise and troubleshooting/tweaking may be necessary to get static-route-based routing to work.

26.7.2.5.2. Running GateD®

注意

GateD® is proprietary software now and will not be available as source code to the public anymore (more info on the GateD® website). This section only exists to ensure backwards compatibility for those that are still using an older version.

An alternative to the headaches of static routes is to install GateD® on your FreeBSD SLIP server and configure it to use the appropriate routing protocols (RIP/OSPF/BGP/EGP) to tell other routers about your SLIP subnet. You will need to write a `/etc/gated.conf` file to configure your GateD®; here is a sample, similar to what the author used on a FreeBSD SLIP server:

```
#
# gated configuration file for dc.dsu.edu; for gated version 3.5alpha5
# Only broadcast RIP information for xxx.xxx.yy out the ed Ethernet interface
#
#
# tracing options
#
traceoptions "/var/tmp/gated.output" replace size 100k files 2 general -;

rip yes {
  interface sl noripout noripin -;
  interface ed ripin ripout version 1 -;
```

```
  traceoptions route -;
} -;

#
# Turn on a bunch of tracing info for the interface to the kernel:
kernel {
  traceoptions remnants request routes info interface -;
} -;

#
# Propagate the route to xxx.xxx.yy out the Ethernet interface via RIP
#

export proto rip interface ed {
  proto direct {
      xxx.xxx.yy  mask 255.255.252.0 metric 1; # SLIP connections
  } -;
} -;

#
# Accept routes from RIP via ed Ethernet interfaces

import proto rip interface ed {
  all -;
} -;
```

The above sample `gated.conf` file broadcasts routing information regarding the SLIP subnet *`xxx.xxx.yy`* via RIP onto the Ethernet; if you are using a different Ethernet driver than the `ed` driver, you will need to change the references to the `ed` interface appropriately. This sample file also sets up tracing to `/var/tmp/gated.output` for debugging GateD®'s activity; you can certainly turn off the tracing options if GateD® works correctly for you. You will need to change the *`xxx.xxx.yy`* 's into the network address of your own SLIP subnet (be sure to change the net mask in the `proto direct` clause as well).

Once you have installed and configured GateD® on your system, you will need to tell the FreeBSD startup scripts to run GateD® in place of routed. The easiest way to accomplish this is to set the `router` and `router_flags` variables in `/etc/rc.conf` . Please see the manual page for GateD® for information on command-line parameters.

章 27. 電子郵件

Original work by Bill Lloyd.
Rewritten by Jim Mock.

27.1. 概述

“電子郵件”或者俗稱的 email， 乃是現今使用最廣泛的溝通方式之一。 本章主要介紹如何在 FreeBSD 上安裝、 設定 email 服務，以及如何在 FreeBSD 收發信件； 然而這並不是完整的參考手冊， 實際上許多需考量的重要事項並未提及，若欲瞭解細節請參閱 附錄 B, 參考文獻 內的參考書籍。

讀完這章，您將了解：

- 哪些軟體元件與收發電子郵件有關。
- FreeBSD 內的 sendmail 基本設定檔在哪。
- 遠端信箱與本機信箱的區別。
- 如何阻擋 spammer(垃圾郵件製造者)非法運用您的郵件伺服器作為 relay(轉發中繼點)。
- 如何安裝、設定其他 Mail Transfer Agent(MTA) 來取代 sendmail。
- 如何處理常見的郵件伺服器問題。
- 如何使用 UUCP 來進行 SMTP。
- 如何設定系統，使其只能發送郵件。
- 如何在撥接上網環境中，收發郵件。
- 如何設定 SMTP 驗證，以加强安全性。
- 如何安裝、使用 Mail User Agent(MUA) 程式，比如 mutt 來收發郵件。
- 如何從遠端 POP 或 IMAP 主機去下載郵件。
- 如何在收信方面，自動套用郵件過濾。

在開始閱讀這章之前，您需要：

- 先設好你的網路 (章 30, 網路進階練功房)。
- 能正確為郵件伺服器設定 DNS (章 28, 網路伺服器)。
- 知道如何透過 port/package 安裝軟體 (章 4, 軟體套件管理篇：Packages 及 Ports 機制)。

27.2. 使用電子郵件

在 email 交換的過程中有 5 個主要部分，分別是：MUA、MTA、 DNS、 遠端或本機的信箱，當然還有 郵件主機本身 。

27.2.1. MUA 程式

包括一些文字介面的程式，像是 mutt、 pine、elm、 and mail，以及 GUI 介面的程式， 像是 balsa、xfmail 等等。 此外，還有更 “複雜的” 像是 WWW 瀏覽器。 這些程式會郵件處理交給 “郵件主機” ，或者透過呼叫 MTA(若有的話)或者是透過 TCP 來傳遞郵件。

27.2.2. Mailhost Server Daemon

FreeBSD ships with sendmail by default, but also support numerous other mail server daemons, just some of which include:

- exim;
- postfix;
- qmail.

The server daemon usually has two functions——it is responsible for receiving incoming mail as well as delivering outgoing mail. It is not responsible for the collection of mail using protocols such as POP or IMAP to read your email, nor does it allow connecting to local `mbox` or Maildir mailboxes. You may require an additional daemon for that.

警告

Older versions of sendmail have some serious security issues which may result in an attacker gaining local and/or remote access to your machine. Make sure that you are running a current version to avoid these problems. Optionally, install an alternative MTA from the FreeBSD Ports Collection.

27.2.3. Email and DNS

The Domain Name System (DNS) and its daemon `named` play a large role in the delivery of email. In order to deliver mail from your site to another, the server daemon will look up the remote site in the DNS to determine the host that will receive mail for the destination. This process also occurs when mail is sent from a remote host to your mail server.

DNS is responsible for mapping hostnames to IP addresses, as well as for storing information specific to mail delivery, known as MX records. The MX (Mail eXchanger) record specifies which host, or hosts, will receive mail for a particular domain. If you do not have an MX record for your hostname or domain, the mail will be delivered directly to your host provided you have an A record pointing your hostname to your IP address.

You may view the MX records for any domain by using the host(1) command, as seen in the example below:

```
% host -t mx FreeBSD.org
FreeBSD.org mail is handled (pri=10) by mx1.FreeBSD.org
```

27.2.4. Receiving Mail

Receiving mail for your domain is done by the mail host. It will collect all mail sent to your domain and store it either in `mbox` (the default method for storing mail) or Maildir format, depending on your configuration. Once mail has been stored, it may either be read locally using applications such as mail(1) or mutt, or remotely accessed and collected using protocols such as POP or IMAP. This means that should you only wish to read mail locally, you are not required to install a POP or IMAP server.

27.2.4.1. Accessing remote mailboxes using POP and IMAP

In order to access mailboxes remotely, you are required to have access to a POP or IMAP server. These protocols allow users to connect to their mailboxes from remote locations with ease. Though both POP and IMAP allow users to remotely access mailboxes, IMAP offers many advantages, some of which are:

- IMAP can store messages on a remote server as well as fetch them.
- IMAP supports concurrent updates.

- IMAP can be extremely useful over low-speed links as it allows users to fetch the structure of messages without downloading them; it can also perform tasks such as searching on the server in order to minimize data transfer between clients and servers.

In order to install a POP or IMAP server, the following steps should be performed:

1. Choose an IMAP or POP server that best suits your needs. The following POP and IMAP servers are well known and serve as some good examples:
   - qpopper;
   - teapop;
   - imap-uw;
   - courier-imap;
2. Install the POP or IMAP daemon of your choosing from the ports collection.
3. Where required, modify `/etc/inetd.conf` to load the POP or IMAP server.

警告

It should be noted that both POP and IMAP transmit information, including username and password credentials in clear-text. This means that if you wish to secure the transmission of information across these protocols, you should consider tunneling sessions over ssh(1). Tunneling sessions is described in 節 13.8.1.2, “SSH Tunneling”.

27.2.4.2. Accessing local mailboxes

Mailboxes may be accessed locally by directly utilizing MUAs on the server on which the mailbox resides. This can be done using applications such as mutt or mail(1).

27.2.5. The Mail Host

The mail host is the name given to a server that is responsible for delivering and receiving mail for your host, and possibly your network.

27.3. sendmail Configuration

Contributed by Christopher Shumway.

sendmail(8) is the default Mail Transfer Agent (MTA) in FreeBSD. sendmail's job is to accept mail from Mail User Agents (MUA) and deliver it to the appropriate mailer as defined by its configuration file. sendmail can also accept network connections and deliver mail to local mailboxes or deliver it to another program.

sendmail uses the following configuration files:

Filename	Function
`/etc/mail/access`	sendmail access database file
`/etc/mail/aliases`	Mailbox aliases
`/etc/mail/local-host-names`	Lists of hosts sendmail accepts mail for
`/etc/mail/mailer.conf`	Mailer program configuration

Filename	Function
/etc/mail/mailertable	Mailer delivery table
/etc/mail/sendmail.cf	sendmail master configuration file
/etc/mail/virtusertable	Virtual users and domain tables

27.3.1. /etc/mail/access

The access database defines what host(s) or IP addresses have access to the local mail server and what kind of access they have. Hosts can be listed as OK, REJECT , RELAY or simply passed to sendmail's error handling routine with a given mailer error. Hosts that are listed as OK, which is the default, are allowed to send mail to this host as long as the mail's final destination is the local machine. Hosts that are listed as REJECT are rejected for all mail connections. Hosts that have the RELAY option for their hostname are allowed to send mail for any destination through this mail server.

範例 27.1. Configuring the sendmail Access Database

```
cyberspammer.com                550 We do not accept mail from spammers
FREE.STEALTH.MAILER@            550 We do not accept mail from spammers
another.source.of.spam          REJECT
okay.cyberspammer.com           OK
128.32                          RELAY
```

In this example we have five entries. Mail senders that match the left hand side of the table are affected by the action on the right side of the table. The first two examples give an error code to sendmail's error handling routine. The message is printed to the remote host when a mail matches the left hand side of the table. The next entry rejects mail from a specific host on the Internet, another.source.of.spam . The next entry accepts mail connections from a host okay.cyberspammer.com , which is more exact than the cyberspammer.com line above. More specific matches override less exact matches. The last entry allows relaying of electronic mail from hosts with an IP address that begins with 128.32 . These hosts would be able to send mail through this mail server that are destined for other mail servers.

When this file is updated, you need to run make in /etc/mail/ to update the database.

27.3.2. /etc/mail/aliases

The aliases database contains a list of virtual mailboxes that are expanded to other user(s), files, programs or other aliases. Here are a few examples that can be used in /etc/mail/aliases :

範例 27.2. Mail Aliases

```
root: localuser
ftp-bugs: joe,eric,paul
bit.bucket:  /dev/null
procmail: "|/usr/local/bin/procmail"
```

The file format is simple; the mailbox name on the left side of the colon is expanded to the target(s) on the right. The first example simply expands the mailbox root to the mailbox localuser , which is then looked up again in the aliases database. If no match is found, then the message is delivered to the local user localuser . The next example shows a mail list. Mail to the mailbox ftp-bugs is expanded to the three local mailboxes joe, eric,

and `paul`. Note that a remote mailbox could be specified as `<user@example.com >`. The next example shows writing mail to a file, in this case `/dev/null` . The last example shows sending mail to a program, in this case the mail message is written to the standard input of `/usr/local/bin/procmail` through a UNIX® pipe.

When this file is updated, you need to run `make` in `/etc/mail/` to update the database.

27.3.3. `/etc/mail/local-host-names`

This is a list of hostnames sendmail(8) is to accept as the local host name. Place any domains or hosts that sendmail is to be receiving mail for. For example, if this mail server was to accept mail for the domain `example.com` and the host `mail.example.com` , its `local-host-names` might look something like this:

```
example.com
mail.example.com
```

When this file is updated, sendmail(8) needs to be restarted to read the changes.

27.3.4. `/etc/mail/sendmail.cf`

sendmail's master configuration file, `sendmail.cf` controls the overall behavior of sendmail, including everything from rewriting e-mail addresses to printing rejection messages to remote mail servers. Naturally, with such a diverse role, this configuration file is quite complex and its details are a bit out of the scope of this section. Fortunately, this file rarely needs to be changed for standard mail servers.

The master sendmail configuration file can be built from m4(1) macros that define the features and behavior of sendmail. Please see `/usr/src/contrib/sendmail/cf/README` for some of the details.

When changes to this file are made, sendmail needs to be restarted for the changes to take effect.

27.3.5. `/etc/mail/virtusertable`

The `virtusertable` maps mail addresses for virtual domains and mailboxes to real mailboxes. These mailboxes can be local, remote, aliases defined in `/etc/mail/aliases` or files.

範例 27.3. Example Virtual Domain Mail Map

```
root@example.com                root
postmaster@example.com          postmaster@noc.example.net
@example.com                    joe
```

In the above example, we have a mapping for a domain `example.com` . This file is processed in a first match order down the file. The first item maps `<root@example.com >` to the local mailbox `root`. The next entry maps `<postmaster@example.com >` to the mailbox `postmaster` on the host `noc.example.net` . Finally, if nothing from `example.com` has matched so far, it will match the last mapping, which matches every other mail message addressed to someone at `example.com` . This will be mapped to the local mailbox `joe`.

27.4. Changing Your Mail Transfer Agent

Written by Andrew Boothman.
Information taken from e-mails written by Gregory Neil Shapiro.

As already mentioned, FreeBSD comes with sendmail already installed as your MTA (Mail Transfer Agent). Therefore by default it is in charge of your outgoing and incoming mail.

However, for a variety of reasons, some system administrators want to change their system's MTA. These reasons range from simply wanting to try out another MTA to needing a specific feature or package which relies on another mailer. Fortunately, whatever the reason, FreeBSD makes it easy to make the change.

27.4.1. Install a New MTA

You have a wide choice of MTAs available. A good starting point is the FreeBSD Ports Collection where you will be able to find many. Of course you are free to use any MTA you want from any location, as long as you can make it run under FreeBSD.

Start by installing your new MTA. Once it is installed it gives you a chance to decide if it really fulfills your needs, and also gives you the opportunity to configure your new software before getting it to take over from sendmail. When doing this, you should be sure that installing the new software will not attempt to overwrite system binaries such as `/usr/bin/sendmail` . Otherwise, your new mail software has essentially been put into service before you have configured it.

Please refer to your chosen MTA's documentation for information on how to configure the software you have chosen.

27.4.2. Disable sendmail

The procedure used to start sendmail changed significantly between 4.5-RELEASE, 4.6-RELEASE, and later releases. Therefore, the procedure used to disable it is subtly different.

警告

If you disable sendmail's outgoing mail service, it is important that you replace it with an alternative mail delivery system. If you choose not to, system functions such as periodic(8) will be unable to deliver their results by e-mail as they would normally expect to. Many parts of your system may expect to have a functional sendmail-compatible system. If applications continue to use sendmail's binaries to try to send e-mail after you have disabled them, mail could go into an inactive sendmail queue, and never be delivered.

27.4.2.1. FreeBSD 4.5-STABLE before 2002/4/4 and Earlier (Including 4.5-RELEASE and Earlier)

Enter:

```
sendmail_enable="NO"
```

into `/etc/rc.conf` . This will disable sendmail's incoming mail service, but if `/etc/mail/mailer.conf` (see below) is not changed, sendmail will still be used to send e-mail.

27.4.2.2. FreeBSD 4.5-STABLE after 2002/4/4 (Including 4.6-RELEASE and Later)

In order to completely disable sendmail, including the outgoing mail service, you must use

```
sendmail_enable="NONE"
```

in `/etc/rc.conf.`

If you only want to disable sendmail's incoming mail service, you should set

```
sendmail_enable="NO"
```

in `/etc/rc.conf` . However, if incoming mail is disabled, local delivery will still function. More information on sendmail's startup options is available from the rc.sendmail(8) manual page.

27.4.2.3. FreeBSD 5.0-STABLE and Later

In order to completely disable sendmail, including the outgoing mail service, you must use

```
sendmail_enable="NO"
sendmail_submit_enable="NO"
sendmail_outbound_enable="NO"
sendmail_msp_queue_enable="NO"
```

in `/etc/rc.conf`.

If you only want to disable sendmail's incoming mail service, you should set

```
sendmail_enable="NO"
```

in `/etc/rc.conf` . More information on sendmail's startup options is available from the rc.sendmail(8) manual page.

27.4.3. Running Your New MTA on Boot

You may have a choice of two methods for running your new MTA on boot, again depending on what version of FreeBSD you are running.

27.4.3.1. FreeBSD 4.5-STABLE before 2002/4/11 (Including 4.5-RELEASE and Earlier)

Add a script to `/usr/local/etc/rc.d/` that ends in `.sh` and is executable by `root`. The script should accept `start` and `stop` parameters. At startup time the system scripts will execute the command

```
/usr/local/etc/rc.d/supermailer.sh start
```

which you can also use to manually start the server. At shutdown time, the system scripts will use the `stop` option, running the command

```
/usr/local/etc/rc.d/supermailer.sh stop
```

which you can also use to manually stop the server while the system is running.

27.4.3.2. FreeBSD 4.5-STABLE after 2002/4/11 (Including 4.6-RELEASE and Later)

With later versions of FreeBSD, you can use the above method or you can set

```
mta_start_script="filename"
```

in `/etc/rc.conf` , where *`filename`* is the name of some script that you want executed at boot to start your MTA.

27.4.4. Replacing sendmail as the System's Default Mailer

The program sendmail is so ubiquitous as standard software on UNIX® systems that some software just assumes it is already installed and configured. For this reason, many alternative MTA's provide their own compatible implementations of the sendmail command-line interface; this facilitates using them as “drop-in” replacements for sendmail.

Therefore, if you are using an alternative mailer, you will need to make sure that software trying to execute standard sendmail binaries such as `/usr/bin/sendmail` actually executes your chosen mailer instead. Fortunately, FreeBSD provides a system called mailwrapper(8) that does this job for you.

When sendmail is operating as installed, you will find something like the following in `/etc/mail/mailer.conf` :

```
sendmail  /usr/libexec/sendmail/sendmail
send-mail /usr/libexec/sendmail/sendmail
```

```
mailq  /usr/libexec/sendmail/sendmail
newaliases /usr/libexec/sendmail/sendmail
hoststat /usr/libexec/sendmail/sendmail
purgestat /usr/libexec/sendmail/sendmail
```

This means that when any of these common commands (such as `sendmail` itself) are run, the system actually invokes a copy of mailwrapper named `sendmail`, which checks `mailer.conf` and executes `/usr/libexec/sendmail/sendmail` instead. This system makes it easy to change what binaries are actually executed when these default `sendmail` functions are invoked.

Therefore if you wanted `/usr/local/supermailer/bin/sendmail-compat` to be run instead of sendmail, you could change `/etc/mail/mailer.conf` to read:

```
sendmail  /usr/local/supermailer/bin/sendmail-compat
send-mail /usr/local/supermailer/bin/sendmail-compat
mailq  /usr/local/supermailer/bin/mailq-compat
newaliases /usr/local/supermailer/bin/newaliases-compat
hoststat /usr/local/supermailer/bin/hoststat-compat
purgestat /usr/local/supermailer/bin/purgestat-compat
```

27.4.5. Finishing

Once you have everything configured the way you want it, you should either kill the sendmail processes that you no longer need and start the processes belonging to your new software, or simply reboot. Rebooting will also give you the opportunity to ensure that you have correctly configured your system to start your new MTA automatically on boot.

27.5. Troubleshooting

問： Why do I have to use the FQDN for hosts on my site?

答： You will probably find that the host is actually in a different domain; for example, if you are in `foo.bar.edu` and you wish to reach a host called `mumble` in the `bar.edu` domain, you will have to refer to it by the fully-qualified domain name, `mumble.bar.edu`, instead of just `mumble`.

Traditionally, this was allowed by BSD BIND resolvers. However the current version of BIND that ships with FreeBSD no longer provides default abbreviations for non-fully qualified domain names other than the domain you are in. So an unqualified host `mumble` must either be found as `mumble.foo.bar.edu`, or it will be searched for in the root domain.

This is different from the previous behavior, where the search continued across `mumble.bar.edu`, and `mumble.edu`. Have a look at RFC 1535 for why this was considered bad practice, or even a security hole.

As a good workaround, you can place the line:

```
search foo.bar.edu bar.edu
```

instead of the previous:

```
domain foo.bar.edu
```

into your `/etc/resolv.conf`. However, make sure that the search order does not go beyond the "boundary between local and public administration", as RFC 1535 calls it.

問： sendmail says mail loops back to myself

答： This is answered in the sendmail FAQ as follows:

```
I'm getting these error messages:
```

```
553 MX list for domain.net points back to relay.domain.net
554 <user@domain.net>... Local configuration error

How can I solve this problem?

You have asked mail to the domain (e.g., domain.net) to be
forwarded to a specific host (in this case, relay.domain.net)
by using an MX
record, but the relay machine does not recognize
itself as domain.net. Add domain.net to /etc/mail/local-host-names
[known as /etc/sendmail.cw prior to version 8.10]
(if you are using FEATURE(use_cw_file)) or add “Cw domain.net”
to /etc/mail/sendmail.cf.
```

The sendmail FAQ can be found at `http://www.sendmail.org/faq/` and is recommended reading if you want to do any “tweaking” of your mail setup.

問： How can I run a mail server on a dial-up PPP host?

答： You want to connect a FreeBSD box on a LAN to the Internet. The FreeBSD box will be a mail gateway for the LAN. The PPP connection is non-dedicated.

There are at least two ways to do this. One way is to use UUCP.

Another way is to get a full-time Internet server to provide secondary MX services for your domain. For example, if your company's domain is `example.com` and your Internet service provider has set `example.net` up to provide secondary MX services to your domain:

```
example.com.          MX      10      example.com.
                      MX      20      example.net.
```

Only one host should be specified as the final recipient (add `Cw example.com` in `/etc/mail/sendmail.cf` on `example.com`).

When the sending `sendmail` is trying to deliver the mail it will try to connect to you (`example.com`) over the modem link. It will most likely time out because you are not online. The program sendmail will automatically deliver it to the secondary MX site, i.e. your Internet provider (`example.net`). The secondary MX site will then periodically try to connect to your host and deliver the mail to the primary MX host (`example.com`).

You might want to use something like this as a login script:

```
#!/bin/sh
# Put me in /usr/local/bin/pppmyisp
( sleep 60 -; /usr/sbin/sendmail -q ) &
/usr/sbin/ppp -direct pppmyisp
```

If you are going to create a separate login script for a user you could use `sendmail -qRexample.com` instead in the script above. This will force all mail in your queue for `example.com` to be processed immediately.

A further refinement of the situation is as follows:

Message stolen from the FreeBSD Internet service provider's 郵遞論壇.

```
> we provide the secondary MX for a customer. The customer connects to
> our services several times a day automatically to get the mails to
> his primary MX (We do not call his site when a mail for his domains
> arrived). Our sendmail sends the mailqueue every 30 minutes. At the
> moment he has to stay 30 minutes online to be sure that all mail is
> gone to the primary MX.
```

```
>
> Is there a command that would initiate sendmail to send all the mails
> now? The user has not root-privileges on our machine of course.

In the “privacy flags” section of sendmail.cf, there is a
definition Opgoaway,restrictqrun

Remove restrictqrun to allow non-root users to start the queue processing.
You might also like to rearrange the MXs. We are the 1st MX for our
customers like this, and we have defined:

# If we are the best MX for a host, try directly instead of generating
# local config error.
OwTrue

That way a remote site will deliver straight to you, without trying
the customer connection.  You then send to your customer.  Only works for
“hosts”, so you need to get your customer to name their mail
machine “customer.com” as well as
“hostname.customer.com” in the DNS.  Just put an A record in
the DNS for “customer.com”.
```

問： Why do I keep getting Relaying Denied errors when sending mail from other hosts?

答： In default FreeBSD installations, sendmail is configured to only send mail from the host it is running on. For example, if a POP server is available, then users will be able to check mail from school, work, or other remote locations but they still will not be able to send outgoing emails from outside locations. Typically, a few moments after the attempt, an email will be sent from MAILER-DAEMON with a 5.7 Relaying Denied error message.

There are several ways to get around this. The most straightforward solution is to put your ISP's address in a relay-domains file at `/etc/mail/relay-domains` . A quick way to do this would be:

```
# echo "your.isp.example.com" > /etc/mail/relay-domains
```

After creating or editing this file you must restart sendmail. This works great if you are a server administrator and do not wish to send mail locally, or would like to use a point and click client/system on another machine or even another ISP. It is also very useful if you only have one or two email accounts set up. If there is a large number of addresses to add, you can simply open this file in your favorite text editor and then add the domains, one per line:

```
your.isp.example.com
other.isp.example.net
users-isp.example.org
www.example.org
```

Now any mail sent through your system, by any host in this list (provided the user has an account on your system), will succeed. This is a very nice way to allow users to send mail from your system remotely without allowing people to send SPAM through your system.

27.6. Advanced Topics

The following section covers more involved topics such as mail configuration and setting up mail for your entire domain.

27.6.1. Basic Configuration

Out of the box, you should be able to send email to external hosts as long as you have set up `/etc/resolv.conf` or are running your own name server. If you would like to have mail for your host delivered to the MTA (e.g., sendmail) on your own FreeBSD host, there are two methods:

- Run your own name server and have your own domain. For example, `FreeBSD.org`
- Get mail delivered directly to your host. This is done by delivering mail directly to the current DNS name for your machine. For example, `example.FreeBSD.org` .

Regardless of which of the above you choose, in order to have mail delivered directly to your host, it must have a permanent static IP address (not a dynamic address, as with most PPP dial-up configurations). If you are behind a firewall, it must pass SMTP traffic on to you. If you want to receive mail directly at your host, you need to be sure of either of two things:

- Make sure that the (lowest-numbered) MX record in your DNS points to your host's IP address.
- Make sure there is no MX entry in your DNS for your host.

Either of the above will allow you to receive mail directly at your host.

Try this:

```
# hostname
example.FreeBSD.org
# host example.FreeBSD.org
example.FreeBSD.org has address 204.216.27.XX
```

If that is what you see, mail directly to <yourlogin@example.FreeBSD.org > should work without problems (assuming sendmail is running correctly on `example.FreeBSD.org`).

If instead you see something like this:

```
# host example.FreeBSD.org
example.FreeBSD.org has address 204.216.27.XX
example.FreeBSD.org mail is handled (pri=10) by hub.FreeBSD.org
```

All mail sent to your host (`example.FreeBSD.org`) will end up being collected on `hub` under the same username instead of being sent directly to your host.

The above information is handled by your DNS server. The DNS record that carries mail routing information is the Mail eXchange entry. If no MX record exists, mail will be delivered directly to the host by way of its IP address.

The MX entry for `freefall.FreeBSD.org` at one time looked like this:

```
freefall  MX 30 mail.crl.net
freefall  MX 40 agora.rdrop.com
freefall  MX 10 freefall.FreeBSD.org
freefall  MX 20 who.cdrom.com
```

As you can see, `freefall` had many MX entries. The lowest MX number is the host that receives mail directly if available; if it is not accessible for some reason, the others (sometimes called “backup MXes”) accept messages temporarily, and pass it along when a lower-numbered host becomes available, eventually to the lowest-numbered host.

Alternate MX sites should have separate Internet connections from your own in order to be most useful. Your ISP or another friendly site should have no problem providing this service for you.

27.6.2. Mail for Your Domain

In order to set up a “mailhost” (a.k.a. mail server) you need to have any mail sent to various workstations directed to it. Basically, you want to “claim” any mail for any hostname in your domain (in this case `*.FreeBSD.org`) and divert it to your mail server so your users can receive their mail on the master mail server.

To make life easiest, a user account with the same username should exist on both machines. Use adduser(8) to do this.

The mailhost you will be using must be the designated mail exchanger for each workstation on the network. This is done in your DNS configuration like so:

```
example.FreeBSD.org A 204.216.27.XX  ; Workstation
   MX 10 hub.FreeBSD.org ; Mailhost
```

This will redirect mail for the workstation to the mailhost no matter where the A record points. The mail is sent to the MX host.

You cannot do this yourself unless you are running a DNS server. If you are not, or cannot run your own DNS server, talk to your ISP or whoever provides your DNS.

If you are doing virtual email hosting, the following information will come in handy. For this example, we will assume you have a customer with his own domain, in this case `customer1.org` , and you want all the mail for `customer1.org` sent to your mailhost, `mail.myhost.com` . The entry in your DNS should look like this:

```
customer1.org  MX 10 mail.myhost.com
```

You do not need an A record for `customer1.org` if you only want to handle email for that domain.

注意

Be aware that pinging `customer1.org` will not work unless an A record exists for it.

The last thing that you must do is tell sendmail on your mailhost what domains and/or hostnames it should be accepting mail for. There are a few different ways this can be done. Either of the following will work:

- Add the hosts to your `/etc/mail/local-host-names` file if you are using the `FEATURE(use_cw_file)` . If you are using a version of sendmail earlier than 8.10, the file is `/etc/sendmail.cw` .
- Add a `Cwyour.host.com` line to your `/etc/sendmail.cf` or `/etc/mail/sendmail.cf` if you are using sendmail 8.10 or higher.

27.7. SMTP with UUCP

The sendmail configuration that ships with FreeBSD is designed for sites that connect directly to the Internet. Sites that wish to exchange their mail via UUCP must install another sendmail configuration file.

Tweaking `/etc/mail/sendmail.cf` manually is an advanced topic. sendmail version 8 generates config files via m4(1) preprocessing, where the actual configuration occurs on a higher abstraction level. The m4(1) configuration files can be found under `/usr/share/sendmail/cf` . The file `README` in the `cf` directory can serve as a basic introduction to m4(1) configuration.

The best way to support UUCP delivery is to use the `mailertable` feature. This creates a database that sendmail can use to make routing decisions.

First, you have to create your `.mc` file. The directory `/usr/share/sendmail/cf/cf` contains a few examples. Assuming you have named your file `foo.mc`, all you need to do in order to convert it into a valid `sendmail.cf` is:

```
# cd /etc/mail
# make foo.cf
# cp foo.cf /etc/mail/sendmail.cf
```

A typical `.mc` file might look like:

```
VERSIONID(`Your version number ') OSTYPE(bsd4.4)

FEATURE(accept_unresolvable_domains)
FEATURE(nocanonify)
FEATURE(mailertable, `hash -o /etc/mail/mailertable')

define(`UUCP_RELAY', your.uucp.relay )
define(`UUCP_MAX_SIZE', 200000)
define(`confDONT_PROBE_INTERFACES')

MAILER(local)
MAILER(smtp)
MAILER(uucp)

Cw    your.alias.host.name
Cw    youruucpnodename.UUCP
```

The lines containing `accept_unresolvable_domains`, `nocanonify`, and `confDONT_PROBE_INTERFACES` features will prevent any usage of the DNS during mail delivery. The `UUCP_RELAY` clause is needed to support UUCP delivery. Simply put an Internet hostname there that is able to handle .UUCP pseudo-domain addresses; most likely, you will enter the mail relay of your ISP there.

Once you have this, you need an `/etc/mail/mailertable` file. If you have only one link to the outside that is used for all your mails, the following file will suffice:

```
#
# makemap hash /etc/mail/mailertable.db < /etc/mail/mailertable
.                           uucp-dom:your.uucp.relay
```

A more complex example might look like this:

```
#
# makemap hash /etc/mail/mailertable.db < /etc/mail/mailertable
#
horus.interface-business.de   uucp-dom:horus
.interface-business.de        uucp-dom:if-bus
interface-business.de         uucp-dom:if-bus
.heep.sax.de                  smtp8:%1
horus.UUCP                    uucp-dom:horus
if-bus.UUCP                   uucp-dom:if-bus
.                             uucp-dom:
```

The first three lines handle special cases where domain-addressed mail should not be sent out to the default route, but instead to some UUCP neighbor in order to “shortcut” the delivery path. The next line handles mail to the local Ethernet domain that can be delivered using SMTP. Finally, the UUCP neighbors are mentioned in the .UUCP pseudo-domain notation, to allow for a `uucp-neighbor !recipient` override of the default rules. The last line is always a single dot, matching everything else, with UUCP delivery to a UUCP neighbor that serves as your universal mail gateway to the world. All of the node names behind the `uucp-dom:` keyword must be valid UUCP neighbors, as you can verify using the command `uuname`.

As a reminder that this file needs to be converted into a DBM database file before use. The command line to accomplish this is best placed as a comment at the top of the `mailertable` file. You always have to execute this command each time you change your `mailertable` file.

Final hint: if you are uncertain whether some particular mail routing would work, remember the `-bt` option to sendmail. It starts sendmail in address test mode; simply enter `3,0`, followed by the address you wish to test for the mail routing. The last line tells you the used internal mail agent, the destination host this agent will be called with, and the (possibly translated) address. Leave this mode by typing Ctrl+D.

```
% sendmail -bt
```

```
ADDRESS TEST MODE (ruleset 3 NOT automatically invoked)
Enter <ruleset> <address>
> 3,0 foo@example.com
canonify           input: foo @ example . com
...
parse            returns: $# uucp-dom $@ your.uucp.relay  $: foo < @ example . com . >
> ^D
```

27.8. Setting Up to Send Only

Contributed by Bill Moran.

There are many instances where you may only want to send mail through a relay. Some examples are:

- Your computer is a desktop machine, but you want to use programs such as send-pr(1). To do so, you should use your ISP's mail relay.
- The computer is a server that does not handle mail locally, but needs to pass off all mail to a relay for processing.

Just about any MTA is capable of filling this particular niche. Unfortunately, it can be very difficult to properly configure a full-featured MTA just to handle offloading mail. Programs such as sendmail and postfix are largely overkill for this use.

Additionally, if you are using a typical Internet access service, your agreement may forbid you from running a "mail server".

The easiest way to fulfill those needs is to install the mail/ssmtp port. Execute the following commands as `root`:

```
# cd /usr/ports/mail/ssmtp
# make install replace clean
```

Once installed, mail/ssmtp can be configured with a four-line file located at `/usr/local/etc/ssmtp/ssmtp.conf`:

```
root=yourrealemail@example.com
mailhub=mail.example.com
rewriteDomain=example.com
hostname=_HOSTNAME_
```

Make sure you use your real email address for `root`. Enter your ISP's outgoing mail relay in place of `mail.example.com` (some ISPs call this the "outgoing mail server" or "SMTP server").

Make sure you disable sendmail, including the outgoing mail service. See 節 27.4.2, "Disable sendmail" for details.

mail/ssmtp has some other options available. See the example configuration file in `/usr/local/etc/ssmtp` or the manual page of ssmtp for some examples and more information.

Setting up ssmtp in this manner will allow any software on your computer that needs to send mail to function properly, while not violating your ISP's usage policy or allowing your computer to be hijacked for spamming.

27.9. Using Mail with a Dialup Connection

If you have a static IP address, you should not need to adjust anything from the defaults. Set your host name to your assigned Internet name and sendmail will do the rest.

If you have a dynamically assigned IP number and use a dialup PPP connection to the Internet, you will probably have a mailbox on your ISPs mail server. Let's assume your ISP's domain is `example.net`, and that your

user name is `user`, you have called your machine `bsd.home`, and your ISP has told you that you may use `relay.example.net` as a mail relay.

In order to retrieve mail from your mailbox, you must install a retrieval agent. The fetchmail utility is a good choice as it supports many different protocols. This program is available as a package or from the Ports Collection (mail/fetchmail). Usually, your ISP will provide POP. If you are using user PPP, you can automatically fetch your mail when an Internet connection is established with the following entry in `/etc/ppp/ppp.linkup`:

```
MYADDR:
!bg su user -c fetchmail
```

If you are using sendmail (as shown below) to deliver mail to non-local accounts, you probably want to have sendmail process your mailqueue as soon as your Internet connection is established. To do this, put this command after the `fetchmail` command in `/etc/ppp/ppp.linkup`:

```
  !bg su user -c "sendmail -q"
```

Assume that you have an account for `user` on `bsd.home`. In the home directory of `user` on `bsd.home`, create a `.fetchmailrc` file:

```
poll example.net protocol pop3 fetchall pass MySecret
```

This file should not be readable by anyone except `user` as it contains the password `MySecret`.

In order to send mail with the correct `from:` header, you must tell sendmail to use `<user@example.net>` rather than `<user@bsd.home>`. You may also wish to tell sendmail to send all mail via `relay.example.net`, allowing quicker mail transmission.

The following `.mc` file should suffice:

```
VERSIONID(`bsd.home.mc version 1.0')
OSTYPE(bsd4.4)dnl
FEATURE(nouucp)dnl
MAILER(local)dnl
MAILER(smtp)dnl
Cwlocalhost
Cwbsd.home
MASQUERADE_AS(`example.net')dnl
FEATURE(allmasquerade)dnl
FEATURE(masquerade_envelope)dnl
FEATURE(nocanonify)dnl
FEATURE(nodns)dnl
define(`SMART_HOST', `relay.example.net')
Dmbsd.home
define(`confDOMAIN_NAME',`bsd.home')dnl
define(`confDELIVERY_MODE',`deferred')dnl
```

Refer to the previous section for details of how to turn this `.mc` file into a `sendmail.cf` file. Also, do not forget to restart sendmail after updating `sendmail.cf`.

27.10. SMTP Authentication

Written by James Gorham.

Having SMTP Authentication in place on your mail server has a number of benefits. SMTP Authentication can add another layer of security to sendmail, and has the benefit of giving mobile users who switch hosts the ability to use the same mail server without the need to reconfigure their mail client settings each time.

1. Install security/cyrus-sasl2 from the ports. You can find this port in security/cyrus-sasl2. The security/cyrus-sasl2 port supports a number of compile-time options. For the SMTP Authentication method we will be using here, make sure that the `LOGIN` option is not disabled.

2. After installing security/cyrus-sasl2, edit `/usr/local/lib/sasl2/Sendmail.conf` (or create it if it does not exist) and add the following line:

```
pwcheck_method: saslauthd
```

3. Next, install security/cyrus-sasl2-saslauthd, edit `/etc/rc.conf` to add the following line:

```
saslauthd_enable="YES"
```

and finally start the saslauthd daemon:

```
# /usr/local/etc/rc.d/saslauthd start
```

This daemon serves as a broker for sendmail to authenticate against your FreeBSD `passwd` database. This saves the trouble of creating a new set of usernames and passwords for each user that needs to use SMTP authentication, and keeps the login and mail password the same.

4. Now edit `/etc/make.conf` and add the following lines:

```
SENDMAIL_CFLAGS=-I/usr/local/include/sasl -DSASL
SENDMAIL_LDFLAGS=-L/usr/local/lib
SENDMAIL_LDADD=-lsasl2
```

These lines will give sendmail the proper configuration options for linking to cyrus-sasl2 at compile time. Make sure that cyrus-sasl2 has been installed before recompiling sendmail.

5. Recompile sendmail by executing the following commands:

```
# cd /usr/src/lib/libsmutil
# make cleandir && make obj && make
# cd /usr/src/lib/libsm
# make cleandir && make obj && make
# cd /usr/src/usr.sbin/sendmail
# make cleandir && make obj && make && make install
```

The compile of sendmail should not have any problems if `/usr/src` has not been changed extensively and the shared libraries it needs are available.

6. After sendmail has been compiled and reinstalled, edit your `/etc/mail/freebsd.mc` file (or whichever file you use as your `.mc` file. Many administrators choose to use the output from hostname(1) as the `.mc` file for uniqueness). Add these lines to it:

```
dnl set SASL options
TRUST_AUTH_MECH(`GSSAPI DIGEST-MD5 CRAM-MD5 LOGIN')dnl
define(`confAUTH_MECHANISMS', `GSSAPI DIGEST-MD5 CRAM-MD5 LOGIN')dnl
```

These options configure the different methods available to sendmail for authenticating users. If you would like to use a method other than pwcheck, please see the included documentation.

7. Finally, run make(1) while in `/etc/mail`. That will run your new `.mc` file and create a `.cf` file named `freebsd.cf` (or whatever name you have used for your `.mc` file). Then use the command `make install restart`, which will copy the file to `sendmail.cf`, and will properly restart sendmail. For more information about this process, you should refer to `/etc/mail/Makefile`.

If all has gone correctly, you should be able to enter your login information into the mail client and send a test message. For further investigation, set the `LogLevel` of sendmail to 13 and watch `/var/log/maillog` for any errors.

For more information, please see the sendmail page regarding SMTP authentication.

27.11. Mail User Agents

Contributed by Marc Silver.

A Mail User Agent (MUA) is an application that is used to send and receive email. Furthermore, as email "evolves" and becomes more complex, MUA's are becoming increasingly powerful in the way they interact with email; this gives users increased functionality and flexibility. FreeBSD contains support for numerous mail user agents, all of which can be easily installed using the FreeBSD Ports Collection. Users may choose between graphical email clients such as evolution or balsa, console based clients such as mutt, pine or `mail`, or the web interfaces used by some large organizations.

27.11.1. mail

mail(1) is the default Mail User Agent (MUA) in FreeBSD. It is a console based MUA that offers all the basic functionality required to send and receive text-based email, though it is limited in interaction abilities with attachments and can only support local mailboxes.

Although `mail` does not natively support interaction with POP or IMAP servers, these mailboxes may be downloaded to a local `mbox` file using an application such as fetchmail, which will be discussed later in this chapter (節 27.12, "Using fetchmail").

In order to send and receive email, simply invoke the `mail` command as per the following example:

```
% mail
```

The contents of the user mailbox in `/var/mail` are automatically read by the `mail` utility. Should the mailbox be empty, the utility exits with a message indicating that no mails could be found. Once the mailbox has been read, the application interface is started, and a list of messages will be displayed. Messages are automatically numbered, as can be seen in the following example:

```
Mail version 8.1 6/6/93.  Type ? for help.
"/var/mail/marcs": 3 messages 3 new
>N  1 root@localhost        Mon Mar  8 14:05  14/510   "test"
 N  2 root@localhost        Mon Mar  8 14:05  14/509   "user account"
 N  3 root@localhost        Mon Mar  8 14:05  14/509   "sample"
```

Messages can now be read by using the t `mail` command, suffixed by the message number that should be displayed. In this example, we will read the first email:

```
& t 1
Message 1:
From root@localhost  Mon Mar  8 14:05:52 2004
X-Original-To: marcs@localhost
Delivered-To: marcs@localhost
To: marcs@localhost
Subject: test
Date: Mon,  8 Mar 2004 14:05:52 +0200 (SAST)
From: root@localhost (Charlie Root)

This is a test message, please reply if you receive it.
```

As can be seen in the example above, the t key will cause the message to be displayed with full headers. To display the list of messages again, the h key should be used.

If the email requires a response, you may use `mail` to reply, by using either the R or r `mail` keys. The R key instructs `mail` to reply only to the sender of the email, while r replies not only to the sender, but also to other recipients of the message. You may also suffix these commands with the mail number which you would like make a reply to. Once this has been done, the response should be entered, and the end of the message should be marked by a single . on a new line. An example can be seen below:

```
& R 1
To: root@localhost
Subject: Re: test

Thank you, I did get your email.
.
EOT
```

In order to send new email, the m key should be used, followed by the recipient email address. Multiple recipients may also be specified by separating each address with the , delimiter. The subject of the message may then be entered, followed by the message contents. The end of the message should be specified by putting a single . on a new line.

```
& mail root@localhost
Subject: I mastered mail

Now I can send and receive email using mail ... :)
.
EOT
```

While inside the `mail` utility, the ? command may be used to display help at any time, the mail(1) manual page should also be consulted for more help with `mail`.

注意

As previously mentioned, the mail(1) command was not originally designed to handle attachments, and thus deals with them very poorly. Newer MUAs such as mutt handle attachments in a much more intelligent way. But should you still wish to use the `mail` command, the converters/mpack port may be of considerable use.

27.11.2. mutt

mutt is a small yet very powerful Mail User Agent, with excellent features, just some of which include:

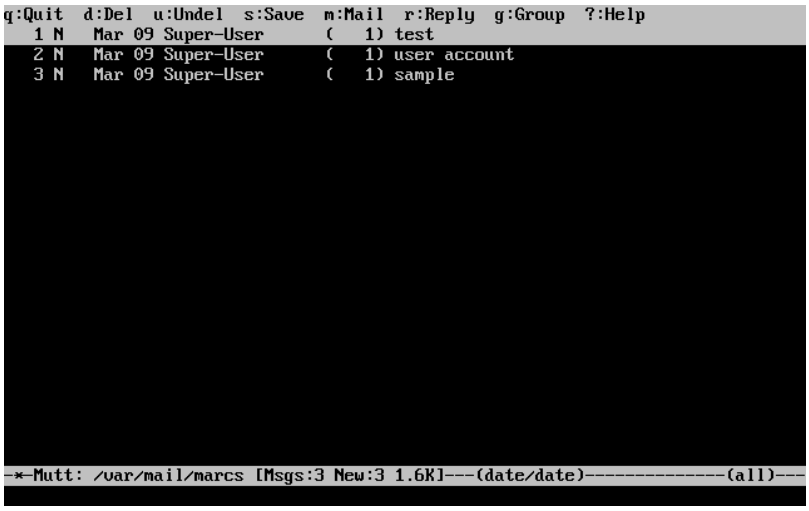
- The ability to thread messages;
- PGP support for digital signing and encryption of email;
- MIME Support;
- Maildir Support;
- Highly customizable.

All of these features help to make mutt one of the most advanced mail user agents available. See `http://www.mutt.org` for more information on mutt.

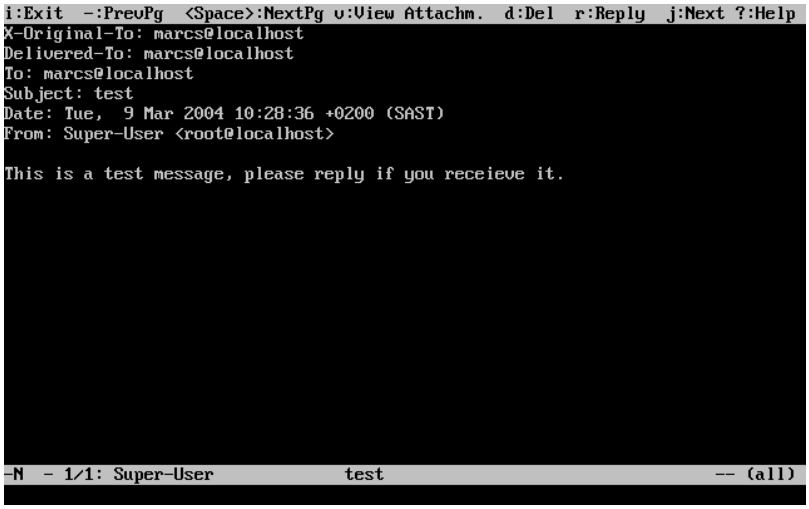
The stable version of mutt may be installed using the mail/mutt port, while the current development version may be installed via the mail/mutt-devel port. After the port has been installed, mutt can be started by issuing the following command:

```
% mutt
```

mutt will automatically read the contents of the user mailbox in `/var/mail` and display the contents if applicable. If no mails are found in the user mailbox, then mutt will wait for commands from the user. The example below shows mutt displaying a list of messages:



In order to read an email, simply select it using the cursor keys, and press the Enter key. An example of mutt displaying email can be seen below:

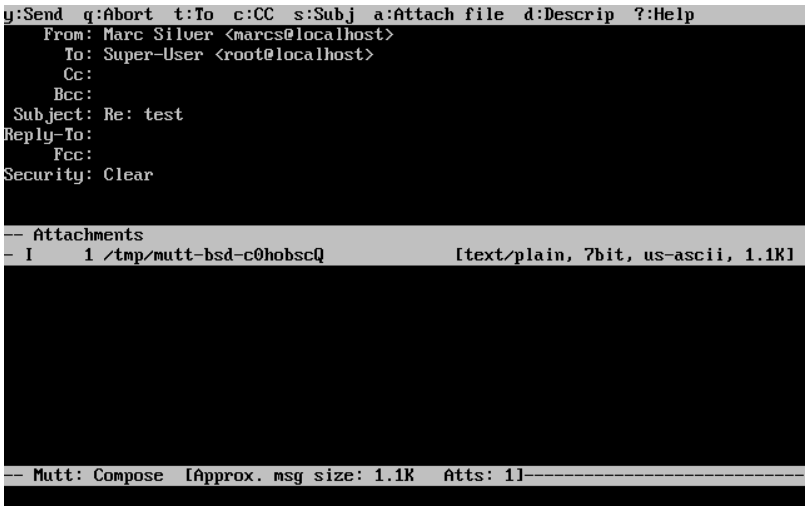


As with the mail(1) command, mutt allows users to reply only to the sender of the message as well as to all recipients. To reply only to the sender of the email, use the r keyboard shortcut. To send a group reply, which will be sent to the original sender as well as all the message recipients, use the g shortcut.

注意

mutt makes use of the vi(1) command as an editor for creating and replying to emails. This may be customized by the user by creating or editing their own `.muttrc` file in their home directory and setting the `editor` variable or by setting the `EDITOR` environment variable. See `http://www.mutt.org/` for more information about configuring mutt.

In order to compose a new mail message, press m. After a valid subject has been given, mutt will start vi(1) and the mail can be written. Once the contents of the mail are complete, save and quit from `vi` and mutt will resume, displaying a summary screen of the mail that is to be delivered. In order to send the mail, press y. An example of the summary screen can be seen below:



mutt also contains extensive help, which can be accessed from most of the menus by pressing the ? key. The top line also displays the keyboard shortcuts where appropriate.

27.11.3. pine

pine is aimed at a beginner user, but also includes some advanced features.

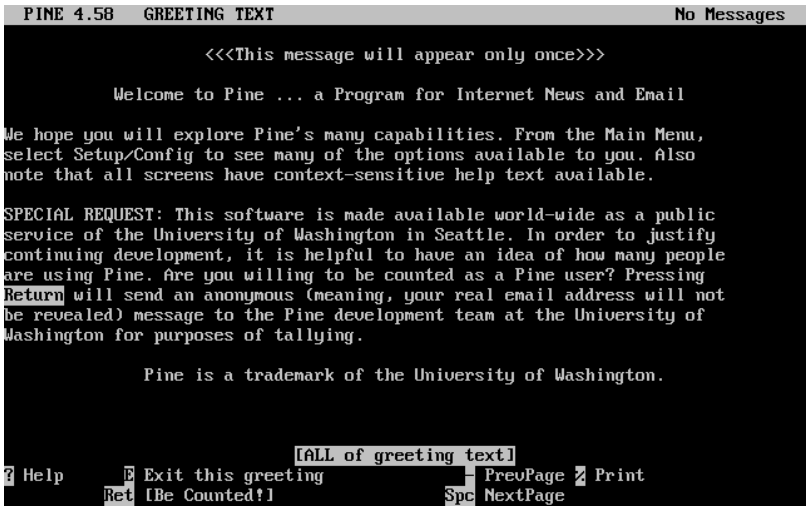
警告

The pine software has had several remote vulnerabilities discovered in the past, which allowed remote attackers to execute arbitrary code as users on the local system, by the action of sending a specially-prepared email. All such known problems have been fixed, but the pine code is written in a very insecure style and the FreeBSD Security Officer believes there are likely to be other undiscovered vulnerabilities. You install pine at your own risk.

The current version of pine may be installed using the mail/pine4 port. Once the port has installed, pine can be started by issuing the following command:

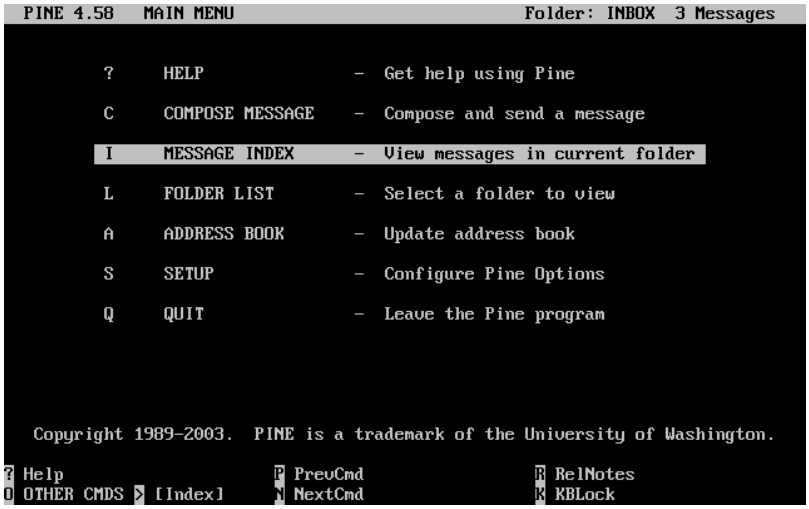
```
% pine
```

The first time that pine is run it displays a greeting page with a brief introduction, as well as a request from the pine development team to send an anonymous email message allowing them to judge how many users are using their client. To send this anonymous message, press Enter, or alternatively press E to exit the greeting without sending an anonymous message. An example of the greeting page can be seen below:



Users are then presented with the main menu, which can be easily navigated using the cursor keys. This main menu provides shortcuts for the composing new mails, browsing of mail directories, and even the administration of address book entries. Below the main menu, relevant keyboard shortcuts to perform functions specific to the task at hand are shown.

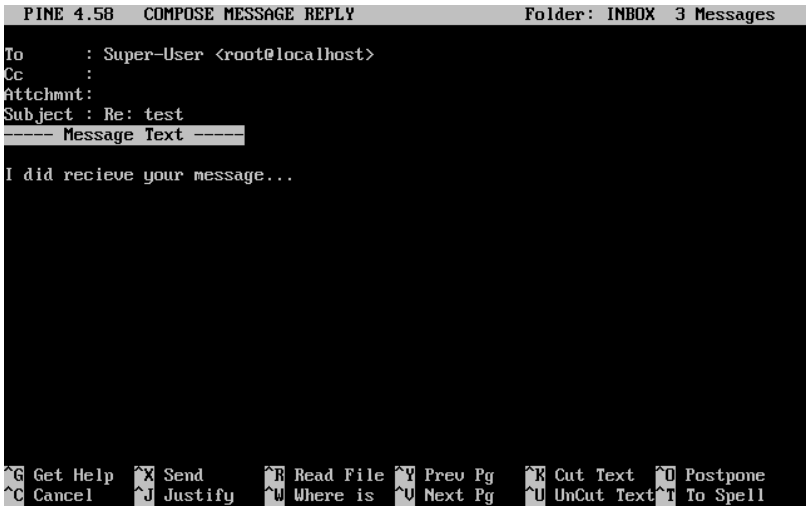
The default directory opened by pine is the `inbox`. To view the message index, press I, or select the MESSAGE INDEX option as seen below:



The message index shows messages in the current directory, and can be navigated by using the cursor keys. Highlighted messages can be read by pressing the Enter key.

In the screenshot below, a sample message is displayed by pine. Keyboard shortcuts are displayed as a reference at the bottom of the screen. An example of one of these shortcuts is the r key, which tells the MUA to reply to the current message being displayed.

Replying to an email in pine is done using the pico editor, which is installed by default with pine. The pico utility makes it easy to navigate around the message and is slightly more forgiving on novice users than vi(1) or mail(1). Once the reply is complete, the message can be sent by pressing Ctrl+X. The pine application will ask for confirmation.



The pine application can be customized using the SETUP option from the main menu. Consult `http://www.washington.edu/pine/` for more information.

27.12. Using fetchmail

Contributed by Marc Silver.

fetchmail is a full-featured IMAP and POP client which allows users to automatically download mail from remote IMAP and POP servers and save it into local mailboxes; there it can be accessed more easily. fetchmail can be installed using the mail/fetchmail port, and offers various features, some of which include:

- Support of POP3, APOP, KPOP, IMAP, ETRN and ODMR protocols.
- Ability to forward mail using SMTP, which allows filtering, forwarding, and aliasing to function normally.
- May be run in daemon mode to check periodically for new messages.
- Can retrieve multiple mailboxes and forward them based on configuration, to different local users.

While it is outside the scope of this document to explain all of fetchmail's features, some basic features will be explained. The fetchmail utility requires a configuration file known as `.fetchmailrc` , in order to run correctly. This file includes server information as well as login credentials. Due to the sensitive nature of the contents of this file, it is advisable to make it readable only by the owner, with the following command:

```
% chmod 600 .fetchmailrc
```

The following `.fetchmailrc` serves as an example for downloading a single user mailbox using POP. It tells fetchmail to connect to `example.com` using a username of `joesoap` and a password of XXX. This example assumes that the user `joesoap` is also a user on the local system.

```
poll example.com protocol pop3 username "joesoap" password "XXX"
```

The next example connects to multiple POP and IMAP servers and redirects to different local usernames where applicable:

```
poll example.com proto pop3:
user "joesoap", with password "XXX", is "jsoap" here;
user "andrea", with password "XXXX";
poll example2.net proto imap:
user "john", with password "XXXXX", is "myth" here;
```

The fetchmail utility can be run in daemon mode by running it with the `-d` flag, followed by the interval (in seconds) that fetchmail should poll servers listed in the `.fetchmailrc` file. The following example would cause fetchmail to poll every 600 seconds:

```
% fetchmail -d 600
```

More information on fetchmail can be found at `http://fetchmail.berlios.de/` .

27.13. Using procmail

Contributed by Marc Silver.

The procmail utility is an incredibly powerful application used to filter incoming mail. It allows users to define "rules" which can be matched to incoming mails to perform specific functions or to reroute mail to alternative mailboxes and/or email addresses. procmail can be installed using the mail/procmail port. Once installed, it can be directly integrated into most MTAs; consult your MTA documentation for more information. Alternatively, procmail can be integrated by adding the following line to a `.forward` in the home directory of the user utilizing procmail features:

```
"|exec /usr/local/bin/procmail || exit 75"
```

The following section will display some basic procmail rules, as well as brief descriptions on what they do. These rules, and others must be inserted into a `.procmailrc` file, which must reside in the user's home directory.

The majority of these rules can also be found in the procmailex(5) manual page.

Forward all mail from `<user@example.com >` to an external address of `<goodmail@example2.com >`:

```
:0
* ^From.*user@example.com
! goodmail@example2.com
```

Forward all mails shorter than 1000 bytes to an external address of `<goodmail@example2.com >`:

```
:0
* < 1000
! goodmail@example2.com
```

Send all mail sent to `<alternate@example.com >` into a mailbox called `alternate` :

```
:0
* ^TOalternate@example.com
alternate
```

Send all mail with a subject of "Spam" to `/dev/null` :

```
:0
^Subject:.*Spam
/dev/null
```

A useful recipe that parses incoming `FreeBSD.org` mailing lists and places each list in its own mailbox:

```
:0
* ^Sender:.owner-freebsd-\/[^@]+@FreeBSD.ORG
{
 LISTNAME=${MATCH}
 :0
 * LISTNAME??^\/[^@]+
 FreeBSD-${MATCH}
}
```

章 28. 網路伺服器

28.1. 概述

This chapter covers some of the more frequently used network services on UNIX® systems. This includes installing, configuring, testing, and maintaining many different types of network services. Example configuration files are included throughout this chapter for reference.

By the end of this chapter, readers will know:

- How to manage the inetd daemon.
- How to set up the Network File System (NFS).
- How to set up the Network Information Server (NIS) for centralizing and sharing user accounts.
- How to set FreeBSD up to act as an LDAP server or client
- How to set up automatic network settings using DHCP.
- How to set up a Domain Name Server (DNS).
- How to set up the Apache HTTP Server.
- How to set up a File Transfer Protocol (FTP) server.
- How to set up a file and print server for Windows® clients using Samba.
- How to synchronize the time and date, and set up a time server using the Network Time Protocol (NTP).
- How to set up iSCSI.

This chapter assumes a basic knowledge of:

- `/etc/rc` scripts.
- Network terminology.
- Installation of additional third-party software (章 4, 軟體套件管理篇：Packages 及 Ports 機制).

28.2. The inetd Super-Server

The inetd(8) daemon is sometimes referred to as a Super-Server because it manages connections for many services. Instead of starting multiple applications, only the inetd service needs to be started. When a connection is received for a service that is managed by inetd, it determines which program the connection is destined for, spawns a process for that program, and delegates the program a socket. Using inetd for services that are not heavily used can reduce system load, when compared to running each daemon individually in stand-alone mode.

Primarily, inetd is used to spawn other daemons, but several trivial protocols are handled internally, such as chargen, auth, time, echo, discard, and daytime.

This section covers the basics of configuring inetd.

28.2.1. Configuration File

Configuration of inetd is done by editing `/etc/inetd.conf` . Each line of this configuration file represents an application which can be started by inetd. By default, every line starts with a comment (**#**), meaning that inetd is

not listening for any applications. To configure inetd to listen for an application's connections, remove the **#** at the beginning of the line for that application.

After saving your edits, configure inetd to start at system boot by editing `/etc/rc.conf` :

```
inetd_enable="YES"
```

To start inetd now, so that it listens for the service you configured, type:

```
# service inetd start
```

Once inetd is started, it needs to be notified whenever a modification is made to `/etc/inetd.conf` :

範例 28.1. Reloading the inetd Configuration File

```
# service inetd reload
```

Typically, the default entry for an application does not need to be edited beyond removing the **#**. In some situations, it may be appropriate to edit the default entry.

As an example, this is the default entry for ftpd(8) over IPv4:

```
ftp     stream  tcp     nowait  root    /usr/libexec/ftpd       ftpd -l
```

The seven columns in an entry are as follows:

```
service-name
socket-type
protocol
{wait|nowait}[/max-child[/max-connections-per-ip-per-minute[/max-child-per-ip]]]
user[:group][/login-class]
server-program
server-program-arguments
```

where:

service-name
: The service name of the daemon to start. It must correspond to a service listed in `/etc/services` . This determines which port inetd listens on for incoming connections to that service. When using a custom service, it must first be added to `/etc/services` .

socket-type
: Either `stream`, `dgram`, `raw`, or `seqpacket` . Use `stream` for TCP connections and `dgram` for UDP services.

protocol
: Use one of the following protocol names:

Protocol Name	Explanation
tcp or tcp4	TCP IPv4
udp or udp4	UDP IPv4
tcp6	TCP IPv6
udp6	UDP IPv6

Protocol Name	Explanation
tcp46	Both TCP IPv4 and IPv6
udp46	Both UDP IPv4 and IPv6

{wait|nowait}[/max-child[/max-connections-per-ip-per-minute[/max-child-per-ip]]]
: In this field, `wait` or `nowait` must be specified. `max-child`, `max-connections-per-ip-per-minute` and `max-child-per-ip` are optional.

  `wait|nowait` indicates whether or not the service is able to handle its own socket. `dgram` socket types must use `wait` while `stream` daemons, which are usually multi-threaded, should use `nowait`. `wait` usually hands off multiple sockets to a single daemon, while `nowait` spawns a child daemon for each new socket.

  The maximum number of child daemons inetd may spawn is set by `max-child`. For example, to limit ten instances of the daemon, place a `/10` after `nowait`. Specifying `/0` allows an unlimited number of children.

  `max-connections-per-ip-per-minute` limits the number of connections from any particular IP address per minute. Once the limit is reached, further connections from this IP address will be dropped until the end of the minute. For example, a value of `/10` would limit any particular IP address to ten connection attempts per minute. `max-child-per-ip` limits the number of child processes that can be started on behalf on any single IP address at any moment. These options can limit excessive resource consumption and help to prevent Denial of Service attacks.

  An example can be seen in the default settings for fingerd(8):

```
finger stream  tcp     nowait/3/10 nobody /usr/libexec/fingerd fingerd -k -s
```

user
: The username the daemon will run as. Daemons typically run as `root`, `daemon`, or `nobody`.

server-program
: The full path to the daemon. If the daemon is a service provided by inetd internally, use `internal`.

server-program-arguments
: Used to specify any command arguments to be passed to the daemon on invocation. If the daemon is an internal service, use `internal`.

28.2.2. Command-Line Options

Like most server daemons, inetd has a number of options that can be used to modify its behaviour. By default, inetd is started with `-wW -C 60`. These options enable TCP wrappers for all services, including internal services, and prevent any IP address from requesting any service more than 60 times per minute.

To change the default options which are passed to inetd, add an entry for `inetd_flags` in `/etc/rc.conf`. If inetd is already running, restart it with `service inetd restart`.

The available rate limiting options are:

-c maximum
: Specify the default maximum number of simultaneous invocations of each service, where the default is unlimited. May be overridden on a per-service basis by using `max-child` in `/etc/inetd.conf`.

-C rate
: Specify the default maximum number of times a service can be invoked from a single IP address per minute. May be overridden on a per-service basis by using `max-connections-per-ip-per-minute` in `/etc/inetd.conf`.

-R rate
: Specify the maximum number of times a service can be invoked in one minute, where the default is `256`. A rate of `0` allows an unlimited number.

-s maximum
: Specify the maximum number of times a service can be invoked from a single IP address at any one time, where the default is unlimited. May be overridden on a per-service basis by using `max-child-per-ip` in `/etc/inetd.conf` .

Additional options are available. Refer to inetd(8) for the full list of options.

28.2.3. Security Considerations

Many of the daemons which can be managed by inetd are not security-conscious. Some daemons, such as fingerd, can provide information that may be useful to an attacker. Only enable the services which are needed and monitor the system for excessive connection attempts. `max-connections-per-ip-per-minute` , `max-child` and `max-child-per-ip` can be used to limit such attacks.

By default, TCP wrappers is enabled. Consult hosts_access(5) for more information on placing TCP restrictions on various inetd invoked daemons.

28.3. Network File System (NFS)

Reorganized and enhanced by Tom Rhodes.
Written by Bill Swingle.

FreeBSD supports the Network File System (NFS), which allows a server to share directories and files with clients over a network. With NFS, users and programs can access files on remote systems as if they were stored locally.

NFS has many practical uses. Some of the more common uses include:

- Data that would otherwise be duplicated on each client can be kept in a single location and accessed by clients on the network.
- Several clients may need access to the `/usr/ports/distfiles` directory. Sharing that directory allows for quick access to the source files without having to download them to each client.
- On large networks, it is often more convenient to configure a central NFS server on which all user home directories are stored. Users can log into a client anywhere on the network and have access to their home directories.
- Administration of NFS exports is simplified. For example, there is only one file system where security or backup policies must be set.
- Removable media storage devices can be used by other machines on the network. This reduces the number of devices throughout the network and provides a centralized location to manage their security. It is often more convenient to install software on multiple machines from a centralized installation media.

NFS consists of a server and one or more clients. The client remotely accesses the data that is stored on the server machine. In order for this to function properly, a few processes have to be configured and running.

These daemons must be running on the server:

Daemon	Description
nfsd	The NFS daemon which services requests from NFS clients.
mountd	The NFS mount daemon which carries out requests received from nfsd.
rpcbind	This daemon allows NFS clients to discover which port the NFS server is using.

Running nfsiod(8) on the client can improve performance, but is not required.

28.3.1. Configuring the Server

The file systems which the NFS server will share are specified in `/etc/exports`. Each line in this file specifies a file system to be exported, which clients have access to that file system, and any access options. When adding entries to this file, each exported file system, its properties, and allowed hosts must occur on a single line. If no clients are listed in the entry, then any client on the network can mount that file system.

The following `/etc/exports` entries demonstrate how to export file systems. The examples can be modified to match the file systems and client names on the reader's network. There are many options that can be used in this file, but only a few will be mentioned here. See exports(5) for the full list of options.

This example shows how to export `/cdrom` to three hosts named *`alpha`*, *`bravo`*, and *`charlie`*:

```
/cdrom -ro alpha bravo charlie
```

The `-ro` flag makes the file system read-only, preventing clients from making any changes to the exported file system. This example assumes that the host names are either in DNS or in `/etc/hosts`. Refer to hosts(5) if the network does not have a DNS server.

The next example exports `/home` to three clients by IP address. This can be useful for networks without DNS or `/etc/hosts` entries. The `-alldirs` flag allows subdirectories to be mount points. In other words, it will not automatically mount the subdirectories, but will permit the client to mount the directories that are required as needed.

```
/home  -alldirs  10.0.0.2 10.0.0.3 10.0.0.4
```

This next example exports `/a` so that two clients from different domains may access that file system. The `-maproot=root` allows `root` on the remote system to write data on the exported file system as `root`. If `-maproot=root` is not specified, the client's `root` user will be mapped to the server's `nobody` account and will be subject to the access limitations defined for `nobody`.

```
/a  -maproot=root  host.example.com box.example.org
```

A client can only be specified once per file system. For example, if `/usr` is a single file system, these entries would be invalid as both entries specify the same host:

```
# Invalid when /usr is one file system
/usr/src   client
/usr/ports client
```

The correct format for this situation is to use one entry:

```
/usr/src /usr/ports  client
```

The following is an example of a valid export list, where `/usr` and `/exports` are local file systems:

```
# Export src and ports to client01 and client02, but only
# client01 has root privileges on it
/usr/src /usr/ports -maproot=root    client01
/usr/src /usr/ports              client02
# The client machines have root and can mount anywhere
# on /exports. Anyone in the world can mount /exports/obj read-only
/exports -alldirs -maproot=root      client01 client02
/exports/obj -ro
```

To enable the processes required by the NFS server at boot time, add these options to `/etc/rc.conf`:

```
rpcbind_enable="YES"
nfs_server_enable="YES"
mountd_flags="-r"
```

The server can be started now by running this command:

```
# service nfsd start
```

Whenever the NFS server is started, mountd also starts automatically. However, mountd only reads `/etc/exports` when it is started. To make subsequent `/etc/exports` edits take effect immediately, force mountd to reread it:

```
# service mountd reload
```

28.3.2. Configuring the Client

To enable NFS clients, set this option in each client's `/etc/rc.conf` :

```
nfs_client_enable="YES"
```

Then, run this command on each NFS client:

```
# service nfsclient start
```

The client now has everything it needs to mount a remote file system. In these examples, the server's name is `server` and the client's name is `client`. To mount `/home` on `server` to the `/mnt` mount point on `client`:

```
# mount server:/home /mnt
```

The files and directories in `/home` will now be available on `client`, in the `/mnt` directory.

To mount a remote file system each time the client boots, add it to `/etc/fstab` :

```
server:/home /mnt nfs rw 0 0
```

Refer to fstab(5) for a description of all available options.

28.3.3. Locking

Some applications require file locking to operate correctly. To enable locking, add these lines to `/etc/rc.conf` on both the client and server:

```
rpc_lockd_enable="YES"
rpc_statd_enable="YES"
```

Then start the applications:

```
# service lockd start
# service statd start
```

If locking is not required on the server, the NFS client can be configured to lock locally by including `-L` when running mount. Refer to mount_nfs(8) for further details.

28.3.4. Automating Mounts with amd(8)

Contributed by Wylie Stilwell.
Rewritten by Chern Lee.

The automatic mounter daemon, amd, automatically mounts a remote file system whenever a file or directory within that file system is accessed. File systems that are inactive for a period of time will be automatically unmounted by amd.

This daemon provides an alternative to modifying `/etc/fstab` to list every client. It operates by attaching itself as an NFS server to the `/host` and `/net` directories. When a file is accessed within one of these directories, amd looks up the corresponding remote mount and automatically mounts it. `/net` is used to mount an exported file system from an IP address while `/host` is used to mount an export from a remote hostname. For instance, an

attempt to access a file within `/host/foobar/usr` would tell amd to mount the `/usr` export on the host `foobar`.

範例 28.2. Mounting an Export with amd

In this example, `showmount -e` shows the exported file systems that can be mounted from the NFS server, `foobar`:

```
% showmount -e foobar
Exports list on foobar:
/usr                               10.10.10.0
/a                                 10.10.10.0
% cd /host/foobar/usr
```

The output from `showmount` shows `/usr` as an export. When changing directories to `/host/foobar/usr`, amd intercepts the request and attempts to resolve the hostname `foobar`. If successful, amd automatically mounts the desired export.

To enable amd at boot time, add this line to `/etc/rc.conf` :

```
amd_enable="YES"
```

To start amd now:

```
# service amd start
```

Custom flags can be passed to amd from the `amd_flags` environment variable. By default, `amd_flags` is set to:

```
amd_flags="-a /.amd_mnt -l syslog /host /etc/amd.map /net /etc/amd.map"
```

The default options with which exports are mounted are defined in `/etc/amd.map` . Some of the more advanced features of amd are defined in `/etc/amd.conf` .

Consult amd(8) and amd.conf(5) for more information.

28.3.5. Automating Mounts with autofs(5)

注意

The autofs(5) automount facility is supported starting with FreeBSD 10.1-RELEASE. To use the automounter functionality in older versions of FreeBSD, use amd(8) instead. This chapter only describes the autofs(5) automounter.

The autofs(5) facility is a common name for several components that, together, allow for automatic mounting of remote and local filesystems whenever a file or directory within that file system is accessed. It consists of the kernel component, autofs(5), and several userspace applications: automount(8), automountd(8) and autounmountd(8). It serves as an alternative for amd(8) from previous FreeBSD releases. Amd is still provided for backward compatibility purposes, as the two use different map format; the one used by autofs is the same as with other SVR4 automounters, such as the ones in Solaris, MacOS X, and Linux.

The autofs(5) virtual filesystem is mounted on specified mountpoints by automount(8), usually invoked during boot.

Whenever a process attempts to access file within the autofs(5) mountpoint, the kernel will notify automountd(8) daemon and pause the triggering process. The automountd(8) daemon will handle kernel requests by finding the proper map and mounting the filesystem according to it, then signal the kernel to release blocked process. The autounmountd(8) daemon automatically unmounts automounted filesystems after some time, unless they are still being used.

The primary autofs configuration file is `/etc/auto_master` . It assigns individual maps to top-level mounts. For an explanation of `auto_master` and the map syntax, refer to auto_master(5).

There is a special automounter map mounted on `/net`. When a file is accessed within this directory, autofs(5) looks up the corresponding remote mount and automatically mounts it. For instance, an attempt to access a file within `/net/foobar/usr` would tell automountd(8) to mount the `/usr` export from the host `foobar`.

範例 28.3. Mounting an Export with autofs(5)

In this example, `showmount -e` shows the exported file systems that can be mounted from the NFS server, `foobar`:

```
% showmount -e foobar
Exports list on foobar:
/usr                               10.10.10.0
/a                                 10.10.10.0
% cd /net/foobar/usr
```

The output from `showmount` shows `/usr` as an export. When changing directories to `/host/foobar/usr` , automountd(8) intercepts the request and attempts to resolve the hostname `foobar`. If successful, automountd(8) automatically mounts the source export.

To enable autofs(5) at boot time, add this line to `/etc/rc.conf` :

```
autofs_enable="YES"
```

Then autofs(5) can be started by running:

```
# service automount start
# service automountd start
# service autounmountd start
```

The autofs(5) map format is the same as in other operating systems, it might be desirable to consult information from other operating systems, such as the Mac OS X document.

Consult the automount(8), automountd(8), autounmountd(8), and auto_master(5) manual pages for more information.

28.4. Network Information System (NIS)

Network Information System (NIS) is designed to centralize administration of UNIX®-like systems such as Solaris™, HP-UX, AIX®, Linux, NetBSD, OpenBSD, and FreeBSD. NIS was originally known as Yellow Pages but the name was changed due to trademark issues. This is the reason why NIS commands begin with `yp`.

NIS is a Remote Procedure Call (RPC)-based client/server system that allows a group of machines within an NIS domain to share a common set of configuration files. This permits a system administrator to set up NIS client systems with only minimal configuration data and to add, remove, or modify configuration data from a single location.

FreeBSD uses version 2 of the NIS protocol.

28.4.1. NIS Terms and Processes

Table 28.1 summarizes the terms and important processes used by NIS:

表格 28.1. NIS Terminology

Term	Description
NIS domain name	NIS servers and clients share an NIS domain name. Typically, this name does not have anything to do with DNS.
rpcbind(8)	This service enables RPC and must be running in order to run an NIS server or act as an NIS client.
ypbind(8)	This service binds an NIS client to its NIS server. It will take the NIS domain name and use RPC to connect to the server. It is the core of client/server communication in an NIS environment. If this service is not running on a client machine, it will not be able to access the NIS server.
ypserv(8)	This is the process for the NIS server. If this service stops running, the server will no longer be able to respond to NIS requests so hopefully, there is a slave server to take over. Some non-FreeBSD clients will not try to reconnect using a slave server and the ypbind process may need to be restarted on these clients.
rpc.yppasswdd(8)	This process only runs on NIS master servers. This daemon allows NIS clients to change their NIS passwords. If this daemon is not running, users will have to login to the NIS master server and change their passwords there.

28.4.2. Machine Types

There are three types of hosts in an NIS environment:

- NIS master server

  This server acts as a central repository for host configuration information and maintains the authoritative copy of the files used by all of the NIS clients. The `passwd`, `group`, and other various files used by NIS clients are stored on the master server. While it is possible for one machine to be an NIS master server for more than one NIS domain, this type of configuration will not be covered in this chapter as it assumes a relatively small-scale NIS environment.

- NIS slave servers

  NIS slave servers maintain copies of the NIS master's data files in order to provide redundancy. Slave servers also help to balance the load of the master server as NIS clients always attach to the NIS server which responds first.

- NIS clients

  NIS clients authenticate against the NIS server during log on.

Information in many files can be shared using NIS. The `master.passwd`, `group`, and `hosts` files are commonly shared via NIS. Whenever a process on a client needs information that would normally be found in these files locally, it makes a query to the NIS server that it is bound to instead.

28.4.3. Planning Considerations

This section describes a sample NIS environment which consists of 15 FreeBSD machines with no centralized point of administration. Each machine has its own `/etc/passwd` and `/etc/master.passwd`. These files are kept in sync with each other only through manual intervention. Currently, when a user is added to the lab, the process must be repeated on all 15 machines.

The configuration of the lab will be as follows:

Machine name	IP address	Machine role
`ellington`	`10.0.0.2`	NIS master
`coltrane`	`10.0.0.3`	NIS slave
`basie`	`10.0.0.4`	Faculty workstation
`bird`	`10.0.0.5`	Client machine
`cli[1-11]`	`10.0.0.[6-17]`	Other client machines

If this is the first time an NIS scheme is being developed, it should be thoroughly planned ahead of time. Regardless of network size, several decisions need to be made as part of the planning process.

28.4.3.1. Choosing a NIS Domain Name

When a client broadcasts its requests for info, it includes the name of the NIS domain that it is part of. This is how multiple servers on one network can tell which server should answer which request. Think of the NIS domain name as the name for a group of hosts.

Some organizations choose to use their Internet domain name for their NIS domain name. This is not recommended as it can cause confusion when trying to debug network problems. The NIS domain name should be unique within the network and it is helpful if it describes the group of machines it represents. For example, the Art department at Acme Inc. might be in the "acme-art" NIS domain. This example will use the domain name `test-domain` .

However, some non-FreeBSD operating systems require the NIS domain name to be the same as the Internet domain name. If one or more machines on the network have this restriction, the Internet domain name must be used as the NIS domain name.

28.4.3.2. Physical Server Requirements

There are several things to keep in mind when choosing a machine to use as a NIS server. Since NIS clients depend upon the availability of the server, choose a machine that is not rebooted frequently. The NIS server should ideally be a stand alone machine whose sole purpose is to be an NIS server. If the network is not heavily used, it is acceptable to put the NIS server on a machine running other services. However, if the NIS server becomes unavailable, it will adversely affect all NIS clients.

28.4.4. Configuring the NIS Master Server

The canonical copies of all NIS files are stored on the master server. The databases used to store the information are called NIS maps. In FreeBSD, these maps are stored in `/var/yp/[domainname]` where `[domainname]` is the name of the NIS domain. Since multiple domains are supported, it is possible to have several directories, one for each domain. Each domain will have its own independent set of maps.

NIS master and slave servers handle all NIS requests through ypserv(8). This daemon is responsible for receiving incoming requests from NIS clients, translating the requested domain and map name to a path to the corresponding database file, and transmitting data from the database back to the client.

Setting up a master NIS server can be relatively straight forward, depending on environmental needs. Since FreeBSD provides built-in NIS support, it only needs to be enabled by adding the following lines to `/etc/rc.conf`:

```
nisdomainname="test-domain" ❶
nis_server_enable="YES"  ❷
nis_yppasswdd_enable="YES" ❸
```

❶ This line sets the NIS domain name to `test-domain` .
❷ This automates the start up of the NIS server processes when the system boots.
❸ This enables the rpc.yppasswdd(8) daemon so that users can change their NIS password from a client machine.

Care must be taken in a multi-server domain where the server machines are also NIS clients. It is generally a good idea to force the servers to bind to themselves rather than allowing them to broadcast bind requests and possibly become bound to each other. Strange failure modes can result if one server goes down and others are dependent upon it. Eventually, all the clients will time out and attempt to bind to other servers, but the delay involved can be considerable and the failure mode is still present since the servers might bind to each other all over again.

A server that is also a client can be forced to bind to a particular server by adding these additional lines to `/etc/rc.conf`:

```
nis_client_enable="YES" # run client stuff as well
nis_client_flags="-S NIS domain,server"
```

After saving the edits, type `/etc/netstart` to restart the network and apply the values defined in `/etc/rc.conf`. Before initializing the NIS maps, start ypserv(8):

```
# service ypserv start
```

28.4.4.1. Initializing the NIS Maps

NIS maps are generated from the configuration files in `/etc` on the NIS master, with one exception: `/etc/master.passwd`. This is to prevent the propagation of passwords to all the servers in the NIS domain. Therefore, before the NIS maps are initialized, configure the primary password files:

```
# cp /etc/master.passwd /var/yp/master.passwd
# cd /var/yp
# vi master.passwd
```

It is advisable to remove all entries for system accounts as well as any user accounts that do not need to be propagated to the NIS clients, such as the `root` and any other administrative accounts.

注意

Ensure that the `/var/yp/master.passwd` is neither group or world readable by setting its permissions to `600`.

After completing this task, initialize the NIS maps. FreeBSD includes the ypinit(8) script to do this. When generating maps for the master server, include `-m` and specify the NIS domain name:

```
ellington# ypinit -m test-domain
Server Type: MASTER Domain: test-domain
Creating an YP server will require that you answer a few questions.
Questions will all be asked at the beginning of the procedure.
Do you want this procedure to quit on non-fatal errors? [y/n: n] n
Ok, please remember to go back and redo manually whatever fails.
If not, something might not work.
At this point, we have to construct a list of this domains YP servers.
rod.darktech.org is already known as master server.
Please continue to add any slave servers, one per line. When you are
done with the list, type a <control D>.
master server   :  ellington
next host to add:  coltrane
next host to add:  ^D
The current list of NIS servers looks like this:
ellington
coltrane
Is this correct?  [y/n: y] y

[..output from map generation..-]
```

```
NIS Map update completed.
ellington has been setup as an YP master server without any errors.
```

This will create `/var/yp/Makefile` from `/var/yp/Makefile.dist`. By default, this file assumes that the environment has a single NIS server with only FreeBSD clients. Since `test-domain` has a slave server, edit this line in `/var/yp/Makefile` so that it begins with a comment (`#`):

```
NOPUSH = "True"
```

28.4.4.2. Adding New Users

Every time a new user is created, the user account must be added to the master NIS server and the NIS maps rebuilt. Until this occurs, the new user will not be able to login anywhere except on the NIS master. For example, to add the new user `jsmith` to the `test-domain` domain, run these commands on the master server:

```
# pw useradd jsmith
# cd /var/yp
# make test-domain
```

The user could also be added using `adduser jsmith` instead of `pw useradd smith`.

28.4.5. Setting up a NIS Slave Server

To set up an NIS slave server, log on to the slave server and edit `/etc/rc.conf` as for the master server. Do not generate any NIS maps, as these already exist on the master server. When running `ypinit` on the slave server, use `-s` (for slave) instead of `-m` (for master). This option requires the name of the NIS master in addition to the domain name, as seen in this example:

```
coltrane# ypinit -s ellington test-domain

Server Type: SLAVE Domain: test-domain Master: ellington

Creating an YP server will require that you answer a few questions.
Questions will all be asked at the beginning of the procedure.

Do you want this procedure to quit on non-fatal errors? [y/n: n]  n

Ok, please remember to go back and redo manually whatever fails.
If not, something might not work.
There will be no further questions. The remainder of the procedure
should take a few minutes, to copy the databases from ellington.
Transferring netgroup...
ypxfr: Exiting: Map successfully transferred
Transferring netgroup.byuser...
ypxfr: Exiting: Map successfully transferred
Transferring netgroup.byhost...
ypxfr: Exiting: Map successfully transferred
Transferring master.passwd.byuid...
ypxfr: Exiting: Map successfully transferred
Transferring passwd.byuid...
ypxfr: Exiting: Map successfully transferred
Transferring passwd.byname...
ypxfr: Exiting: Map successfully transferred
Transferring group.bygid...
ypxfr: Exiting: Map successfully transferred
Transferring group.byname...
ypxfr: Exiting: Map successfully transferred
Transferring services.byname...
ypxfr: Exiting: Map successfully transferred
Transferring rpc.bynumber...
ypxfr: Exiting: Map successfully transferred
Transferring rpc.byname...
```

```
ypxfr: Exiting: Map successfully transferred
Transferring protocols.byname...
ypxfr: Exiting: Map successfully transferred
Transferring master.passwd.byname...
ypxfr: Exiting: Map successfully transferred
Transferring networks.byname...
ypxfr: Exiting: Map successfully transferred
Transferring networks.byaddr...
ypxfr: Exiting: Map successfully transferred
Transferring netid.byname...
ypxfr: Exiting: Map successfully transferred
Transferring hosts.byaddr...
ypxfr: Exiting: Map successfully transferred
Transferring protocols.bynumber...
ypxfr: Exiting: Map successfully transferred
Transferring ypservers...
ypxfr: Exiting: Map successfully transferred
Transferring hosts.byname...
ypxfr: Exiting: Map successfully transferred

coltrane has been setup as an YP slave server without any errors.
Remember to update map ypservers on ellington.
```

This will generate a directory on the slave server called `/var/yp/test-domain` which contains copies of the NIS master server's maps. Adding these `/etc/crontab` entries on each slave server will force the slaves to sync their maps with the maps on the master server:

```
20      *       *       *       *       root    /usr/libexec/ypxfr passwd.byname
21      *       *       *       *       root    /usr/libexec/ypxfr passwd.byuid
```

These entries are not mandatory because the master server automatically attempts to push any map changes to its slaves. However, since clients may depend upon the slave server to provide correct password information, it is recommended to force frequent password map updates. This is especially important on busy networks where map updates might not always complete.

To finish the configuration, run `/etc/netstart` on the slave server in order to start the NIS services.

28.4.6. Setting Up an NIS Client

An NIS client binds to an NIS server using ypbind(8). This daemon broadcasts RPC requests on the local network. These requests specify the domain name configured on the client. If an NIS server in the same domain receives one of the broadcasts, it will respond to ypbind, which will record the server's address. If there are several servers available, the client will use the address of the first server to respond and will direct all of its NIS requests to that server. The client will automatically ping the server on a regular basis to make sure it is still available. If it fails to receive a reply within a reasonable amount of time, ypbind will mark the domain as unbound and begin broadcasting again in the hopes of locating another server.

To configure a FreeBSD machine to be an NIS client:

1. Edit `/etc/rc.conf` and add the following lines in order to set the NIS domain name and start ypbind(8) during network startup:

   ```
   nisdomainname="test-domain"
   nis_client_enable="YES"
   ```

2. To import all possible password entries from the NIS server, use `vipw` to remove all user accounts except one from `/etc/master.passwd`. When removing the accounts, keep in mind that at least one local account should remain and this account should be a member of `wheel`. If there is a problem with NIS, this local account can be used to log in remotely, become the superuser, and fix the problem. Before saving the edits, add the following line to the end of the file:

   ```
   +:::::::::
   ```

This line configures the client to provide anyone with a valid account in the NIS server's password maps an account on the client. There are many ways to configure the NIS client by modifying this line. One method is described in 節 28.4.8, “Using Netgroups”. For more detailed reading, refer to the book `Managing NFS and NIS`, published by O'Reilly Media.

3. To import all possible group entries from the NIS server, add this line to `/etc/group` :

```
+:*::
```

To start the NIS client immediately, execute the following commands as the superuser:

```
# /etc/netstart
# service ypbind start
```

After completing these steps, running `ypcat passwd` on the client should show the server's `passwd` map.

28.4.7. NIS Security

Since RPC is a broadcast-based service, any system running ypbind within the same domain can retrieve the contents of the NIS maps. To prevent unauthorized transactions, ypserv(8) supports a feature called “securenets” which can be used to restrict access to a given set of hosts. By default, this information is stored in `/var/yp/securenets` , unless ypserv(8) is started with `-p` and an alternate path. This file contains entries that consist of a network specification and a network mask separated by white space. Lines starting with `#` are considered to be comments. A sample `securenets` might look like this:

```
# allow connections from local host -- mandatory
127.0.0.1     255.255.255.255
# allow connections from any host
# on the 192.168.128.0 network
192.168.128.0 255.255.255.0
# allow connections from any host
# between 10.0.0.0 to 10.0.15.255
# this includes the machines in the testlab
10.0.0.0      255.255.240.0
```

If ypserv(8) receives a request from an address that matches one of these rules, it will process the request normally. If the address fails to match a rule, the request will be ignored and a warning message will be logged. If the `securenets` does not exist, `ypserv` will allow connections from any host.

節 13.4, “TCP Wrapper” is an alternate mechanism for providing access control instead of `securenets` . While either access control mechanism adds some security, they are both vulnerable to “IP spoofing” attacks. All NIS-related traffic should be blocked at the firewall.

Servers using `securenets` may fail to serve legitimate NIS clients with archaic TCP/IP implementations. Some of these implementations set all host bits to zero when doing broadcasts or fail to observe the subnet mask when calculating the broadcast address. While some of these problems can be fixed by changing the client configuration, other problems may force the retirement of these client systems or the abandonment of `securenets` .

The use of TCP Wrapper increases the latency of the NIS server. The additional delay may be long enough to cause timeouts in client programs, especially in busy networks with slow NIS servers. If one or more clients suffer from latency, convert those clients into NIS slave servers and force them to bind to themselves.

28.4.7.1. Barring Some Users

In this example, the `basie` system is a faculty workstation within the NIS domain. The `passwd` map on the master NIS server contains accounts for both faculty and students. This section demonstrates how to allow faculty logins on this system while refusing student logins.

To prevent specified users from logging on to a system, even if they are present in the NIS database, use `vipw` to add `-username` with the correct number of colons towards the end of `/etc/master.passwd` on the client,

where *username* is the username of a user to bar from logging in. The line with the blocked user must be before the **+** line that allows NIS users. In this example, `bill` is barred from logging on to `basie`:

```
basie# cat /etc/master.passwd
root:[password]:0:0::0:0:The super-user:/root:/bin/csh
toor:[password]:0:0::0:0:The other super-user:/root:/bin/sh
daemon:*:1:1::0:0:Owner of many system processes:/root:/sbin/nologin
operator:*:2:5::0:0:System &:/:/sbin/nologin
bin:*:3:7::0:0:Binaries Commands and Source,,,:/:/sbin/nologin
tty:*:4:65533::0:0:Tty Sandbox:/:/sbin/nologin
kmem:*:5:65533::0:0:KMem Sandbox:/:/sbin/nologin
games:*:7:13::0:0:Games pseudo-user:/usr/games:/sbin/nologin
news:*:8:8::0:0:News Subsystem:/:/sbin/nologin
man:*:9:9::0:0:Mister Man Pages:/usr/share/man:/sbin/nologin
bind:*:53:53::0:0:Bind Sandbox:/:/sbin/nologin
uucp:*:66:66::0:0:UUCP pseudo-user:/var/spool/uucppublic:/usr/libexec/uucp/uucico
xten:*:67:67::0:0:X-10 daemon:/usr/local/xten:/sbin/nologin
pop:*:68:6::0:0:Post Office Owner:/nonexistent:/sbin/nologin
nobody:*:65534:65534::0:0:Unprivileged user:/nonexistent:/sbin/nologin
-bill:::::::::
+:::::::::

basie#
```

28.4.8. Using Netgroups

Barring specified users from logging on to individual systems becomes unscaleable on larger networks and quickly loses the main benefit of NIS: centralized administration.

Netgroups were developed to handle large, complex networks with hundreds of users and machines. Their use is comparable to UNIX® groups, where the main difference is the lack of a numeric ID and the ability to define a netgroup by including both user accounts and other netgroups.

To expand on the example used in this chapter, the NIS domain will be extended to add the users and systems shown in Tables 28.2 and 28.3:

表格 28.2. Additional Users

User Name(s)	Description
`alpha`, `beta`	IT department employees
`charlie`, `delta`	IT department apprentices
`echo`, `foxtrott`, `golf`, ...	employees
`able`, `baker`, ...	interns

表格 28.3. Additional Systems

Machine Name(s)	Description
`war`, `death`, `famine`, `pollution`	Only IT employees are allowed to log onto these servers.
`pride`, `greed`, `envy`, `wrath`, `lust`, `sloth`	All members of the IT department are allowed to login onto these servers.
`one`, `two`, `three`, `four`, ...	Ordinary workstations used by employees.
`trashcan`	A very old machine without any critical data. Even interns are allowed to use this system.

When using netgroups to configure this scenario, each user is assigned to one or more netgroups and logins are then allowed or forbidden for all members of the netgroup. When adding a new machine, login restrictions must be defined for all netgroups. When a new user is added, the account must be added to one or more netgroups. If

the NIS setup is planned carefully, only one central configuration file needs modification to grant or deny access to machines.

The first step is the initialization of the NIS `netgroup` map. In FreeBSD, this map is not created by default. On the NIS master server, use an editor to create a map named `/var/yp/netgroup`.

This example creates four netgroups to represent IT employees, IT apprentices, employees, and interns:

```
IT_EMP  (,alpha,test-domain)    (,beta,test-domain)
IT_APP  (,charlie,test-domain)  (,delta,test-domain)
USERS   (,echo,test-domain)     (,foxtrott,test-domain) \
        (,golf,test-domain)
INTERNS (,able,test-domain)     (,baker,test-domain)
```

Each entry configures a netgroup. The first column in an entry is the name of the netgroup. Each set of brackets represents either a group of one or more users or the name of another netgroup. When specifying a user, the three comma-delimited fields inside each group represent:

1. The name of the host(s) where the other fields representing the user are valid. If a hostname is not specified, the entry is valid on all hosts.
2. The name of the account that belongs to this netgroup.
3. The NIS domain for the account. Accounts may be imported from other NIS domains into a netgroup.

If a group contains multiple users, separate each user with whitespace. Additionally, each field may contain wildcards. See netgroup(5) for details.

Netgroup names longer than 8 characters should not be The names are case sensitive and using capital letters for netgroup names is an easy way to distinguish between user, machine and netgroup names.

Some non-FreeBSD NIS clients cannot handle netgroups containing more than 15 entries. This limit may be circumvented by creating several sub-netgroups with 15 users or fewer and a real netgroup consisting of the sub-netgroups, as seen in this example:

```
BIGGRP1  (,joe1,domain)  (,joe2,domain)  (,joe3,domain) [...-]
BIGGRP2  (,joe16,domain)  (,joe17,domain) [...-]
BIGGRP3  (,joe31,domain)  (,joe32,domain)
BIGGROUP  BIGGRP1 BIGGRP2 BIGGRP3
```

Repeat this process if more than 225 (15 times 15) users exist within a single netgroup.

To activate and distribute the new NIS map:

```
ellington# cd /var/yp
ellington# make
```

This will generate the three NIS maps `netgroup`, `netgroup.byhost` and `netgroup.byuser`. Use the map key option of ypcat(1) to check if the new NIS maps are available:

```
ellington% ypcat -k netgroup
ellington% ypcat -k netgroup.byhost
ellington% ypcat -k netgroup.byuser
```

The output of the first command should resemble the contents of `/var/yp/netgroup`. The second command only produces output if host-specific netgroups were created. The third command is used to get the list of netgroups for a user.

To configure a client, use vipw(8) to specify the name of the netgroup. For example, on the server named `war`, replace this line:

```
+::::::::::
```

with

```
+@IT_EMP:::::::::
```

This specifies that only the users defined in the netgroup `IT_EMP` will be imported into this system's password database and only those users are allowed to login to this system.

This configuration also applies to the ~ function of the shell and all routines which convert between user names and numerical user IDs. In other words, `cd ~user` will not work, `ls -l` will show the numerical ID instead of the username, and `find . -user joe -print` will fail with the message No such user. To fix this, import all user entries without allowing them to login into the servers. This can be achieved by adding an extra line:

```
+:::::::::/sbin/nologin
```

This line configures the client to import all entries but to replace the shell in those entries with `/sbin/nologin`.

Make sure that extra line is placed after `+@IT_EMP:::::::::`. Otherwise, all user accounts imported from NIS will have `/sbin/nologin` as their login shell and no one will be able to login to the system.

To configure the less important servers, replace the old `+:::::::::` on the servers with these lines:

```
+@IT_EMP:::::::::
+@IT_APP:::::::::
+:::::::::/sbin/nologin
```

The corresponding lines for the workstations would be:

```
+@IT_EMP:::::::::
+@USERS:::::::::
+:::::::::/sbin/nologin
```

NIS supports the creation of netgroups from other netgroups which can be useful if the policy regarding user access changes. One possibility is the creation of role-based netgroups. For example, one might create a netgroup called `BIGSRV` to define the login restrictions for the important servers, another netgroup called `SMALLSRV` for the less important servers, and a third netgroup called `USERBOX` for the workstations. Each of these netgroups contains the netgroups that are allowed to login onto these machines. The new entries for the NIS `netgroup` map would look like this:

```
BIGSRV    IT_EMP  IT_APP
SMALLSRV  IT_EMP  IT_APP  ITINTERN
USERBOX   IT_EMP  ITINTERN USERS
```

This method of defining login restrictions works reasonably well when it is possible to define groups of machines with identical restrictions. Unfortunately, this is the exception and not the rule. Most of the time, the ability to define login restrictions on a per-machine basis is required.

Machine-specific netgroup definitions are another possibility to deal with the policy changes. In this scenario, the `/etc/master.passwd` of each system contains two lines starting with "+". The first line adds a netgroup with the accounts allowed to login onto this machine and the second line adds all other accounts with `/sbin/nologin` as shell. It is recommended to use the "ALL-CAPS" version of the hostname as the name of the netgroup:

```
+@BOXNAME:::::::::
+:::::::::/sbin/nologin
```

Once this task is completed on all the machines, there is no longer a need to modify the local versions of `/etc/master.passwd` ever again. All further changes can be handled by modifying the NIS map. Here is an example of a possible `netgroup` map for this scenario:

```
# Define groups of users first
IT_EMP    (,alpha,test-domain)    (,beta,test-domain)
IT_APP    (,charlie,test-domain)  (,delta,test-domain)
DEPT1     (,echo,test-domain)     (,foxtrott,test-domain)
DEPT2     (,golf,test-domain)     (,hotel,test-domain)
DEPT3     (,india,test-domain)    (,juliet,test-domain)
```

```
ITINTERN  (,kilo,test-domain)     (,lima,test-domain)
D_INTERNS (,able,test-domain)     (,baker,test-domain)
#
# Now, define some groups based on roles
USERS     DEPT1   DEPT2     DEPT3
BIGSRV    IT_EMP  IT_APP
SMALLSRV  IT_EMP  IT_APP    ITINTERN
USERBOX   IT_EMP  ITINTERN  USERS
#
# And a groups for a special tasks
# Allow echo and golf to access our anti-virus-machine
SECURITY  IT_EMP  (,echo,test-domain)  (,golf,test-domain)
#
# machine-based netgroups
# Our main servers
WAR       BIGSRV
FAMINE    BIGSRV
# User india needs access to this server
POLLUTION  BIGSRV  (,india,test-domain)
#
# This one is really important and needs more access restrictions
DEATH     IT_EMP
#
# The anti-virus-machine mentioned above
ONE       SECURITY
#
# Restrict a machine to a single user
TWO       (,hotel,test-domain)
# [...more groups to follow]
```

It may not always be advisable to use machine-based netgroups. When deploying a couple of dozen or hundreds of systems, role-based netgroups instead of machine-based netgroups may be used to keep the size of the NIS map within reasonable limits.

28.4.9. Password Formats

NIS requires that all hosts within an NIS domain use the same format for encrypting passwords. If users have trouble authenticating on an NIS client, it may be due to a differing password format. In a heterogeneous network, the format must be supported by all operating systems, where DES is the lowest common standard.

To check which format a server or client is using, look at this section of `/etc/login.conf` :

```
default:\
 :passwd_format=des:\
 :copyright=/etc/COPYRIGHT:\
 [Further entries elided]
```

In this example, the system is using the DES format. Other possible values are `blf` for Blowfish and `md5` for MD5 encrypted passwords.

If the format on a host needs to be edited to match the one being used in the NIS domain, the login capability database must be rebuilt after saving the change:

```
# cap_mkdb /etc/login.conf
```

注意

The format of passwords for existing user accounts will not be updated until each user changes their password after the login capability database is rebuilt.

28.5. Lightweight Directory Access Protocol (LDAP)

Written by Tom Rhodes.

The Lightweight Directory Access Protocol (LDAP) is an application layer protocol used to access, modify, and authenticate objects using a distributed directory information service. Think of it as a phone or record book which stores several levels of hierarchical, homogeneous information. It is used in Active Directory and OpenLDAP networks and allows users to access to several levels of internal information utilizing a single account. For example, email authentication, pulling employee contact information, and internal website authentication might all make use of a single user account in the LDAP server's record base.

This section provides a quick start guide for configuring an LDAP server on a FreeBSD system. It assumes that the administrator already has a design plan which includes the type of information to store, what that information will be used for, which users should have access to that information, and how to secure this information from unauthorized access.

28.5.1. LDAP Terminology and Structure

LDAP uses several terms which should be understood before starting the configuration. All directory entries consist of a group of attributes. Each of these attribute sets contains a unique identifier known as a Distinguished Name (DN) which is normally built from several other attributes such as the common or Relative Distinguished Name (RDN). Similar to how directories have absolute and relative paths, consider a DN as an absolute path and the RDN as the relative path.

An example LDAP entry looks like the following. This example searches for the entry for the specified user account (`uid`), organizational unit (`ou`), and organization (`o`):

```
% ldapsearch -xb "uid=trhodes,ou=users,o=example.com"
# extended LDIF
#
# LDAPv3
# base <uid=trhodes,ou=users,o=example.com> with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# trhodes, users, example.com
dn: uid=trhodes,ou=users,o=example.com
mail: trhodes@example.com
cn: Tom Rhodes
uid: trhodes
telephoneNumber: (123) 456-7890

# search result
search: 2
result: 0 Success

# numResponses: 2
# numEntries: 1
```

This example entry shows the values for the `dn`, `mail`, `cn`, `uid`, and `telephoneNumber` attributes. The cn attribute is the RDN.

More information about LDAP and its terminology can be found at `http://www.openldap.org/doc/admin24/intro.html` .

28.5.2. Configuring an LDAP Server

FreeBSD does not provide a built-in LDAP server. Begin the configuration by installing the net/openldap24-server package or port. Since the port has many configurable options, it is recommended that the default options are

reviewed to see if the package is sufficient, and to instead compile the port if any options should be changed. In most cases, the defaults are fine. However, if SQL support is needed, this option must be enabled and the port compiled using the instructions in 節 4.5, “使用 Ports 管理機制”.

Next, create the directories to hold the data and to store the certificates:

```
# mkdir /var/db/openldap-data
# mkdir /usr/local/etc/openldap/private
```

Copy over the database configuration file:

```
# cp /usr/local/etc/openldap/DB_CONFIG.example /var/db/openldap-data/
DB_CONFIG
```

The next phase is to configure the certificate authority. The following commands must be executed from `/usr/local/etc/openldap/private`. This is important as the file permissions need to be restrictive and users should not have access to these files. To create the certificate authority, start with this command and follow the prompts:

```
# openssl req -days 365 -nodes -new -x509 -keyout ca.key -out ../ca.crt
```

The entries for the prompts may be generic except for the `Common Name`. This entry must be different than the system hostname. If this will be a self signed certificate, prefix the hostname with `CA` for certificate authority.

The next task is to create a certificate signing request and a private key. Input this command and follow the prompts:

```
# openssl req -days 365 -nodes -new -keyout server.key -out server.csr
```

During the certificate generation process, be sure to correctly set the `Common Name` attribute. Once complete, sign the key:

```
# openssl x509 -req -days 365 -in server.csr -out ../server.crt -CA ../
ca.crt -CAkey ca.key -CAcreateserial
```

The final part of the certificate generation process is to generate and sign the client certificates:

```
# openssl req -days 365 -nodes -new -keyout client.key -out client.csr
# openssl x509 -req -days 3650 -in client.csr -out ../client.crt -CA ../
ca.crt -CAkey ca.key
```

Remember to use the same `Common Name` attribute when prompted. When finished, ensure that a total of eight (8) new files have been generated through the proceeding commands. If so, the next step is to edit `/usr/local/etc/openldap/slapd.conf` and add the following options:

```
TLSCipherSuite HIGH:MEDIUM:+SSLv3
TLSCertificateFile /usr/local/etc/openldap/server.crt
TLSCertificateKeyFile /usr/local/etc/openldap/private/server.key
TLSCACertificateFile /usr/local/etc/openldap/ca.crt
```

Then, edit `/usr/local/etc/openldap/ldap.conf` and add the following lines:

```
TLS_CACERT /usr/local/etc/openldap/ca.crt
TLS_CIPHER_SUITE HIGH:MEDIUM:+SSLv3
```

While editing this file, uncomment the following entries and set them to the desired values: `BASE`, `URI`, `SIZELIMIT` and `TIMELIMIT`. Set the `URI` to contain `ldap://` and `ldaps://`. Then, add two entries pointing to the certificate authority. When finished, the entries should look similar to the following:

```
BASE    dc=example,dc=com
URI     ldap:// ldaps://
```

```
SIZELIMIT       12
TIMELIMIT       15

TLS_CACERT /usr/local/etc/openldap/ca.crt
TLS_CIPHER_SUITE HIGH:MEDIUM:+SSLv3
```

The default password for the server should then be changed:

```
# slappasswd -h "{SHA}" >> /usr/local/etc/openldap/slapd.conf
```

This command will prompt for the password and, if the process does not fail, a password hash will be added to the end of `slapd.conf` . Several hashing formats are supported. Refer to the manual page for `slappasswd` for more information.

Next, edit `/usr/local/etc/openldap/slapd.conf` and add the following lines:

```
password-hash {sha}
allow bind_v2
```

The `suffix` in this file must be updated to match the `BASE` used in `/usr/local/etc/openldap/ldap.conf` and `rootdn` should also be set. A recommended value for `rootdn` is something like `cn=Manager` . Before saving this file, place the `rootpw` in front of the password output from `slappasswd` and delete the old `rootpw` . The end result should look similar to this:

```
TLSCipherSuite HIGH:MEDIUM:+SSLv3
TLSCertificateFile /usr/local/etc/openldap/server.crt
TLSCertificateKeyFile /usr/local/etc/openldap/private/server.key
TLSCACertificateFile /usr/local/etc/openldap/ca.crt
rootpw  {SHA}W6ph5Mm5Pz8GgiULbPgzG37mj9g=
```

Finally, enable the OpenLDAP service in `/etc/rc.conf` and set the URI:

```
slapd_enable="YES"
slapd_flags="-4 -h ldaps:///"
```

At this point the server can be started and tested:

```
# service slapd start
```

If everything is configured correctly, a search of the directory should show a successful connection with a single response as in this example:

```
# ldapsearch -Z
# extended LDIF
#
# LDAPv3
# base <dc=example,dc=com> (default) with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# search result
search: 3
result: 32 No such object

# numResponses: 1
```

注意

If the command fails and the configuration looks correct, stop the `slapd` service and restart it with debugging options:

```
# service slapd stop
# /usr/local/libexec/slapd -d -1
```

Once the service is responding, the directory can be populated using `ldapadd`. In this example, a file containing this list of users is first created. Each user should use the following format:

```
dn: dc=example,dc=com
objectclass: dcObject
objectclass: organization
o: Example
dc: Example

dn: cn=Manager,dc=example,dc=com
objectclass: organizationalRole
cn: Manager
```

To import this file, specify the file name. The following command will prompt for the password specified earlier and the output should look something like this:

```
# ldapadd -Z -D "cn=Manager,dc=example,dc=com" -W -f import.ldif
Enter LDAP Password:
adding new entry "dc=example,dc=com"

adding new entry "cn=Manager,dc=example,dc=com"
```

Verify the data was added by issuing a search on the server using `ldapsearch`:

```
% ldapsearch -Z
# extended LDIF
#
# LDAPv3
# base <dc=example,dc=com> (default) with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# example.com
dn: dc=example,dc=com
objectClass: dcObject
objectClass: organization
o: Example
dc: Example

# Manager, example.com
dn: cn=Manager,dc=example,dc=com
objectClass: organizationalRole
cn: Manager

# search result
search: 3
result: 0 Success

# numResponses: 3
# numEntries: 2
```

At this point, the server should be configured and functioning properly.

28.6. Dynamic Host Configuration Protocol (DHCP)

The Dynamic Host Configuration Protocol (DHCP) allows a system to connect to a network in order to be assigned the necessary addressing information for communication on that network. FreeBSD includes the OpenBSD version of `dhclient` which is used by the client to obtain the addressing information. FreeBSD does not install a DHCP server, but several servers are available in the FreeBSD Ports Collection. The DHCP protocol is fully described in RFC 2131. Informational resources are also available at isc.org/downloads/dhcp/.

This section describes how to use the built-in DHCP client. It then describes how to install and configure a DHCP server.

注意

In FreeBSD, the bpf(4) device is needed by both the DHCP server and DHCP client. This device is included in the `GENERIC` kernel that is installed with FreeBSD. Users who prefer to create a custom kernel need to keep this device if DHCP is used.

It should be noted that `bpf` also allows privileged users to run network packet sniffers on that system.

28.6.1. Configuring a DHCP Client

DHCP client support is included in the FreeBSD installer, making it easy to configure a newly installed system to automatically receive its networking addressing information from an existing DHCP server. Refer to 節 2.8, “Post-Installation” for examples of network configuration.

When `dhclient` is executed on the client machine, it begins broadcasting requests for configuration information. By default, these requests use UDP port 68. The server replies on UDP port 67, giving the client an IP address and other relevant network information such as a subnet mask, default gateway, and DNS server addresses. This information is in the form of a DHCP “lease” and is valid for a configurable time. This allows stale IP addresses for clients no longer connected to the network to automatically be reused. DHCP clients can obtain a great deal of information from the server. An exhaustive list may be found in dhcp-options(5).

By default, when a FreeBSD system boots, its DHCP client runs in the background, or asynchronously. Other startup scripts continue to run while the DHCP process completes, which speeds up system startup.

Background DHCP works well when the DHCP server responds quickly to the client's requests. However, DHCP may take a long time to complete on some systems. If network services attempt to run before DHCP has assigned the network addressing information, they will fail. Using DHCP in synchronous mode prevents this problem as it pauses startup until the DHCP configuration has completed.

This line in `/etc/rc.conf` is used to configure background or asynchronous mode:

```
ifconfig_fxp0="DHCP"
```

This line may already exist if the system was configured to use DHCP during installation. Replace the *`fxp0`* shown in these examples with the name of the interface to be dynamically configured, as described in 節 11.7, “設定網路卡”.

To instead configure the system to use synchronous mode, and to pause during startup while DHCP completes, use “`SYNCDHCP`”:

```
ifconfig_fxp0="SYNCDHCP"
```

Additional client options are available. Search for `dhclient` in rc.conf(5) for details.

The DHCP client uses the following files:

- `/etc/dhclient.conf`

The configuration file used by `dhclient`. Typically, this file contains only comments as the defaults are suitable for most clients. This configuration file is described in dhclient.conf(5).

- `/sbin/dhclient`

  More information about the command itself can be found in dhclient(8).

- `/sbin/dhclient-script`

  The FreeBSD-specific DHCP client configuration script. It is described in dhclient-script(8), but should not need any user modification to function properly.

- `/var/db/dhclient.leases.` *`interface`*

  The DHCP client keeps a database of valid leases in this file, which is written as a log and is described in dhclient.leases(5).

28.6.2. Installing and Configuring a DHCP Server

This section demonstrates how to configure a FreeBSD system to act as a DHCP server using the Internet Systems Consortium (ISC) implementation of the DHCP server. This implementation and its documentation can be installed using the net/isc-dhcp42-server package or port.

The installation of net/isc-dhcp42-server installs a sample configuration file. Copy `/usr/local/etc/dhcpd.conf.example` to `/usr/local/etc/dhcpd.conf` and make any edits to this new file.

The configuration file is comprised of declarations for subnets and hosts which define the information that is provided to DHCP clients. For example, these lines configure the following:

```
option domain-name "example.org";❶
option domain-name-servers ns1.example.org;❷
option subnet-mask 255.255.255.0;❸

default-lease-time 600;❹
max-lease-time 72400;❺
ddns-update-style none;❻

subnet 10.254.239.0 netmask 255.255.255.224 {
  range 10.254.239.10 10.254.239.20;❼
  option routers rtr-239-0-1.example.org, rtr-239-0-2.example.org;❽
}

host fantasia {
  hardware ethernet 08:00:07:26:c0:a5;❾
  fixed-address fantasia.fugue.com;❿
}
```

❶ This option specifies the default search domain that will be provided to clients. Refer to resolv.conf(5) for more information.

❷ This option specifies a comma separated list of DNS servers that the client should use. They can be listed by their Fully Qualified Domain Names (FQDN), as seen in the example, or by their IP addresses.

❸ The subnet mask that will be provided to clients.

❹ The default lease expiry time in seconds. A client can be configured to override this value.

❺ The maximum allowed length of time, in seconds, for a lease. Should a client request a longer lease, a lease will still be issued, but it will only be valid for `max-lease-time`.

❻ The default of `none` disables dynamic DNS updates. Changing this to `interim` configures the DHCP server to update a DNS server whenever it hands out a lease so that the DNS server knows which IP addresses are associated with which computers in the network. Do not change the default setting unless the DNS server has been configured to support dynamic DNS.

❼ This line creates a pool of available IP addresses which are reserved for allocation to DHCP clients. The range of addresses must be valid for the network or subnet specified in the previous line.
❽ Declares the default gateway that is valid for the network or subnet specified before the opening `{` bracket.
❾ Specifies the hardware MAC address of a client so that the DHCP server can recognize the client when it makes a request.
❿ Specifies that this host should always be given the same IP address. Using the hostname is correct, since the DHCP server will resolve the hostname before returning the lease information.

This configuration file supports many more options. Refer to dhcpd.conf(5), installed with the server, for details and examples.

Once the configuration of `dhcpd.conf` is complete, enable the DHCP server in `/etc/rc.conf` :

```
dhcpd_enable="YES"
dhcpd_ifaces="dc0"
```

Replace the `dc0` with the interface (or interfaces, separated by whitespace) that the DHCP server should listen on for DHCP client requests.

Start the server by issuing the following command:

```
# service isc-dhcpd start
```

Any future changes to the configuration of the server will require the dhcpd service to be stopped and then started using service(8).

The DHCP server uses the following files. Note that the manual pages are installed with the server software.

- `/usr/local/sbin/dhcpd`

  More information about the dhcpd server can be found in dhcpd(8).

- `/usr/local/etc/dhcpd.conf`

  The server configuration file needs to contain all the information that should be provided to clients, along with information regarding the operation of the server. This configuration file is described in dhcpd.conf(5).

- `/var/db/dhcpd.leases`

  The DHCP server keeps a database of leases it has issued in this file, which is written as a log. Refer to dhcpd.leases(5), which gives a slightly longer description.

- `/usr/local/sbin/dhcrelay`

  This daemon is used in advanced environments where one DHCP server forwards a request from a client to another DHCP server on a separate network. If this functionality is required, install the net/isc-dhcp42-relay package or port. The installation includes dhcrelay(8) which provides more detail.

28.7. Domain Name System (DNS)

Domain Name System (DNS) is the protocol through which domain names are mapped to IP addresses, and vice versa. DNS is coordinated across the Internet through a somewhat complex system of authoritative root, Top Level Domain (TLD), and other smaller-scale name servers, which host and cache individual domain information. It is not necessary to run a name server to perform DNS lookups on a system.

In FreeBSD 10, the Berkeley Internet Name Domain (BIND) has been removed from the base system and replaced with Unbound. Unbound as configured in the FreeBSD Base is a local caching resolver. BIND is still available from The Ports Collection as dns/bind99 or dns/bind98. In FreeBSD 9 and lower, BIND is included in FreeBSD Base.

The FreeBSD version provides enhanced security features, a new file system layout, and automated chroot(8) configuration. BIND is maintained by the Internet Systems Consortium.

The following table describes some of the terms associated with DNS:

表格 28.4. DNS Terminology

Term	Definition
Forward DNS	Mapping of hostnames to IP addresses.
Origin	Refers to the domain covered in a particular zone file.
named, BIND	Common names for the BIND name server package within FreeBSD.
Resolver	A system process through which a machine queries a name server for zone information.
Reverse DNS	Mapping of IP addresses to hostnames.
Root zone	The beginning of the Internet zone hierarchy. All zones fall under the root zone, similar to how all files in a file system fall under the root directory.
Zone	An individual domain, subdomain, or portion of the DNS administered by the same authority.

Examples of zones:

- `.` is how the root zone is usually referred to in documentation.
- `org.` is a Top Level Domain (TLD) under the root zone.
- `example.org.` is a zone under the `org.` TLD.
- `1.168.192.in-addr.arpa` is a zone referencing all IP addresses which fall under the `192.168.1.*` IP address space.

As one can see, the more specific part of a hostname appears to its left. For example, `example.org.` is more specific than `org.`, as `org.` is more specific than the root zone. The layout of each part of a hostname is much like a file system: the `/dev` directory falls within the root, and so on.

28.7.1. Reasons to Run a Name Server

Name servers generally come in two forms: authoritative name servers, and caching (also known as resolving) name servers.

An authoritative name server is needed when:

- One wants to serve DNS information to the world, replying authoritatively to queries.
- A domain, such as `example.org` , is registered and IP addresses need to be assigned to hostnames under it.
- An IP address block requires reverse DNS entries (IP to hostname).
- A backup or second name server, called a slave, will reply to queries.

A caching name server is needed when:

- A local DNS server may cache and respond more quickly than querying an outside name server.

When one queries for `www.FreeBSD.org` , the resolver usually queries the uplink ISP's name server, and retrieves the reply. With a local, caching DNS server, the query only has to be made once to the outside world by the caching DNS server. Additional queries will not have to go outside the local network, since the information is cached locally.

28.7.2. DNS Server Configuration in FreeBSD 10.0 and Later

In FreeBSD 10.0, BIND has been replaced with Unbound. Unbound is a validating caching resolver only. If an authoritative server is needed, many are available from the Ports Collection.

Unbound is provided in the FreeBSD base system. By default, it will provide DNS resolution to the local machine only. While the base system package can be configured to provide resolution services beyond the local machine, it is recommended that such requirements be addressed by installing Unbound from the FreeBSD Ports Collection.

To enable Unbound, add the following to `/etc/rc.conf` :

```
local_unbound_enable="YES"
```

Any existing nameservers in `/etc/resolv.conf` will be configured as forwarders in the new Unbound configuration.

注意

If any of the listed nameservers do not support DNSSEC, local DNS resolution will fail. Be sure to test each nameserver and remove any that fail the test. The following command will show the trust tree or a failure for a nameserver running on `192.168.1.1` :

```
% drill -S FreeBSD.org @ 192.168.1.1
```

Once each nameserver is confirmed to support DNSSEC, start Unbound:

```
# service local_unbound onestart
```

This will take care of updating `/etc/resolv.conf` so that queries for DNSSEC secured domains will now work. For example, run the following to validate the FreeBSD.org DNSSEC trust tree:

```
% drill -S FreeBSD.org
;; Number of trusted keys: 1
;; Chasing: freebsd.org. A

DNSSEC Trust tree:
freebsd.org. (A)
|---freebsd.org. (DNSKEY keytag: 36786 alg: 8 flags: 256)
    |---freebsd.org. (DNSKEY keytag: 32659 alg: 8 flags: 257)
    |---freebsd.org. (DS keytag: 32659 digest type: 2)
        |---org. (DNSKEY keytag: 49587 alg: 7 flags: 256)
            |---org. (DNSKEY keytag: 9795 alg: 7 flags: 257)
            |---org. (DNSKEY keytag: 21366 alg: 7 flags: 257)
            |---org. (DS keytag: 21366 digest type: 1)
            |   |---. (DNSKEY keytag: 40926 alg: 8 flags: 256)
            |       |---. (DNSKEY keytag: 19036 alg: 8 flags: 257)
            |---org. (DS keytag: 21366 digest type: 2)
                |---. (DNSKEY keytag: 40926 alg: 8 flags: 256)
                    |---. (DNSKEY keytag: 19036 alg: 8 flags: 257)
;; Chase successful
```

28.7.3. DNS Server Configuration in FreeBSD 9.X and Earlier

In FreeBSD, the BIND daemon is called named.

File	Description
named(8)	The BIND daemon.
rndc(8)	Name server control utility.

File	Description
`/etc/namedb`	Directory where BIND zone information resides.
`/etc/namedb/named.conf`	Configuration file of the daemon.

Depending on how a given zone is configured on the server, the files related to that zone can be found in the `master`, `slave`, or `dynamic` subdirectories of the `/etc/namedb` directory. These files contain the DNS information that will be given out by the name server in response to queries.

28.7.3.1. Starting BIND

Since BIND is installed by default, configuring it is relatively simple.

The default named configuration is that of a basic resolving name server, running in a chroot(8) environment, and restricted to listening on the local IPv4 loopback address (127.0.0.1). To start the server one time with this configuration, use the following command:

```
# service named onestart
```

To ensure the named daemon is started at boot each time, put the following line into the `/etc/rc.conf` :

```
named_enable="YES"
```

There are many configuration options for `/etc/namedb/named.conf` that are beyond the scope of this document. Other startup options for named on FreeBSD can be found in the `named_*` flags in `/etc/defaults/rc.conf` and in rc.conf(5). The 節 11.6, “在 FreeBSD 使用 rc” section is also a good read.

28.7.3.2. Configuration Files

Configuration files for named currently reside in `/etc/namedb` directory and will need modification before use unless all that is needed is a simple resolver. This is where most of the configuration will be performed.

28.7.3.2.1. `/etc/namedb/named.conf`

```
// $FreeBSD$
//
// Refer to the named.conf(5) and named(8) man pages, and the documentation
// in /usr/share/doc/bind9 for more details.
//
// If you are going to set up an authoritative server, make sure you
// understand the hairy details of how DNS works.  Even with
// simple mistakes, you can break connectivity for affected parties,
// or cause huge amounts of useless Internet traffic.

options {
 // All file and path names are relative to the chroot directory,
 // if any, and should be fully qualified.
 directory "/etc/namedb/working";
 pid-file "/var/run/named/pid";
 dump-file "/var/dump/named_dump.db";
 statistics-file "/var/stats/named.stats";

// If named is being used only as a local resolver, this is a safe default.
// For named to be accessible to the network, comment this option, specify
// the proper IP address, or delete this option.
 listen-on { 127.0.0.1; };

// If you have IPv6 enabled on this system, uncomment this option for
// use as a local resolver.  To give access to the network, specify
// an IPv6 address, or the keyword "any".
// listen-on-v6 { ::1; };

// These zones are already covered by the empty zones listed below.
// If you remove the related empty zones below, comment these lines out.
```

```
 disable-empty-zone "255.255.255.255.IN-ADDR.ARPA";
 disable-empty-zone "0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.↺
IP6.ARPA";
 disable-empty-zone "1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.↺
IP6.ARPA";

// If you've got a DNS server around at your upstream provider, enter
// its IP address here, and enable the line below.  This will make you
// benefit from its cache, thus reduce overall DNS traffic in the Internet.
/*
 forwarders {
  127.0.0.1;
 };
*/

// If the 'forwarders' clause is not empty the default is to 'forward first'
// which will fall back to sending a query from your local server if the name
// servers in 'forwarders' do not have the answer.  Alternatively you can
// force your name server to never initiate queries of its own by enabling the
// following line:
// forward only;

// If you wish to have forwarding configured automatically based on
// the entries in /etc/resolv.conf, uncomment the following line and
// set named_auto_forward=yes in /etc/rc.conf.  You can also enable
// named_auto_forward_only (the effect of which is described above).
// include "/etc/namedb/auto_forward.conf";
```

Just as the comment says, to benefit from an uplink's cache, `forwarders` can be enabled here. Under normal circumstances, a name server will recursively query the Internet looking at certain name servers until it finds the answer it is looking for. Having this enabled will have it query the uplink's name server (or name server provided) first, taking advantage of its cache. If the uplink name server in question is a heavily trafficked, fast name server, enabling this may be worthwhile.

警告

`127.0.0.1` will not work here. Change this IP address to a name server at the uplink.

```
 /*
    Modern versions of BIND use a random UDP port for each outgoing
    query by default in order to dramatically reduce the possibility
    of cache poisoning.  All users are strongly encouraged to utilize
    this feature, and to configure their firewalls to accommodate it.

    AS A LAST RESORT in order to get around a restrictive firewall
    policy you can try enabling the option below.  Use of this option
    will significantly reduce your ability to withstand cache poisoning
    attacks, and should be avoided if at all possible.

    Replace NNNNN in the example with a number between 49160 and 65530.
 */
 // query-source address * port NNNNN;
};

// If you enable a local name server, don't forget to enter 127.0.0.1
// first in your /etc/resolv.conf so this server will be queried.
// Also, make sure to enable it in /etc/rc.conf.

// The traditional root hints mechanism. Use this, OR the slave zones below.
zone "." { type hint; file "/etc/namedb/named.root"; };
```

```
/* Slaving the following zones from the root name servers has some
 significant advantages:
 1. Faster local resolution for your users
 2. No spurious traffic will be sent from your network to the roots
 3. Greater resilience to any potential root server failure/DDoS

 On the other hand, this method requires more monitoring than the
 hints file to be sure that an unexpected failure mode has not
 incapacitated your server.  Name servers that are serving a lot
 of clients will benefit more from this approach than individual
 hosts.  Use with caution.

 To use this mechanism, uncomment the entries below, and comment
 the hint zone above.

 As documented at http://dns.icann.org/services/axfr/ these zones:
 "." (the root), ARPA, IN-ADDR.ARPA, IP6.ARPA, and ROOT-SERVERS.NET
 are available for AXFR from these servers on IPv4 and IPv6:
 xfr.lax.dns.icann.org, xfr.cjr.dns.icann.org
*/
/*
zone "." {
 type slave;
 file "/etc/namedb/slave/root.slave";
 masters {
  192.5.5.241; // F.ROOT-SERVERS.NET.
 };
 notify no;
};
zone "arpa" {
 type slave;
 file "/etc/namedb/slave/arpa.slave";
 masters {
  192.5.5.241; // F.ROOT-SERVERS.NET.
 };
 notify no;
};
*/

/* Serving the following zones locally will prevent any queries
 for these zones leaving your network and going to the root
 name servers.  This has two significant advantages:
 1. Faster local resolution for your users
 2. No spurious traffic will be sent from your network to the roots
*/
// RFCs 1912 and 5735 (and BCP 32 for localhost)
zone "localhost" { type master; file "/etc/namedb/master/localhost-forward.db"; };
zone "127.in-addr.arpa" { type master; file "/etc/namedb/master/localhost-reverse.db"; };
zone "255.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// RFC 1912-style zone for IPv6 localhost address
zone "0.ip6.arpa" { type master; file "/etc/namedb/master/localhost-reverse.db"; };

// "This" Network (RFCs 1912 and 5735)
zone "0.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// Private Use Networks (RFCs 1918 and 5735)
zone "10.in-addr.arpa"     { type master; file "/etc/namedb/master/empty.db"; };
zone "16.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "17.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "18.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "19.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "20.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "21.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "22.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "23.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
```

```
zone "24.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "25.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "26.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "27.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "28.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "29.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "30.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "31.172.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "168.192.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// Link-local/APIPA (RFCs 3927 and 5735)
zone "254.169.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IETF protocol assignments (RFCs 5735 and 5736)
zone "0.0.192.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// TEST-NET-[1-3] for Documentation (RFCs 5735 and 5737)
zone "2.0.192.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "100.51.198.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "113.0.203.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IPv6 Range for Documentation (RFC 3849)
zone "8.b.d.0.1.0.0.2.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// Domain Names for Documentation and Testing (BCP 32)
zone "test" { type master; file "/etc/namedb/master/empty.db"; };
zone "example" { type master; file "/etc/namedb/master/empty.db"; };
zone "invalid" { type master; file "/etc/namedb/master/empty.db"; };
zone "example.com" { type master; file "/etc/namedb/master/empty.db"; };
zone "example.net" { type master; file "/etc/namedb/master/empty.db"; };
zone "example.org" { type master; file "/etc/namedb/master/empty.db"; };

// Router Benchmark Testing (RFCs 2544 and 5735)
zone "18.198.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "19.198.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IANA Reserved - Old Class E Space (RFC 5735)
zone "240.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "241.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "242.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "243.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "244.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "245.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "246.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "247.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "248.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "249.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "250.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "251.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "252.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "253.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "254.in-addr.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IPv6 Unassigned Addresses (RFC 4291)
zone "1.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "3.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "4.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "5.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "6.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "7.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "8.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "9.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "a.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "b.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "c.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "d.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
```

```
zone "e.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "0.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "1.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "2.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "3.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "4.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "5.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "6.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "7.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "8.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "9.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "a.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "b.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "0.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "1.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "2.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "3.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "4.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "5.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "6.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "7.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IPv6 ULA (RFC 4193)
zone "c.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "d.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IPv6 Link Local (RFC 4291)
zone "8.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "9.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "a.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "b.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IPv6 Deprecated Site-Local Addresses (RFC 3879)
zone "c.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "d.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "e.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };
zone "f.e.f.ip6.arpa" { type master; file "/etc/namedb/master/empty.db"; };

// IP6.INT is Deprecated (RFC 4159)
zone "ip6.int"  { type master; file "/etc/namedb/master/empty.db"; };

// NB: Do not use the IP addresses below, they are faked, and only
// serve demonstration/documentation purposes!
//
// Example slave zone config entries.  It can be convenient to become
// a slave at least for the zone your own domain is in.  Ask
// your network administrator for the IP address of the responsible
// master name server.
//
// Do not forget to include the reverse lookup zone!
// This is named after the first bytes of the IP address, in reverse
// order, with ".IN-ADDR.ARPA" appended, or ".IP6.ARPA" for IPv6.
//
// Before starting to set up a master zone, make sure you fully
// understand how DNS and BIND work.  There are sometimes
// non-obvious pitfalls.  Setting up a slave zone is usually simpler.
//
// NB: Don't blindly enable the examples below. :-)  Use actual names
// and addresses instead.

/* An example dynamic zone
key "exampleorgkey" {
 algorithm hmac-md5;
 secret "sf87HJqjkqh8ac87a02lla==";
};
zone "example.org" {
```

```
 type master;
 allow-update {
  key "exampleorgkey";
 };
 file "/etc/namedb/dynamic/example.org";
};
*/

/* Example of a slave reverse zone
zone "1.168.192.in-addr.arpa" {
 type slave;
 file "/etc/namedb/slave/1.168.192.in-addr.arpa";
 masters {
  192.168.1.1;
 };
};
*/
```

In `named.conf` , these are examples of slave entries for a forward and reverse zone.

For each new zone served, a new zone entry must be added to `named.conf` .

For example, the simplest zone entry for `example.org` can look like:

```
zone "example.org" {
 type master;
 file "master/example.org";
};
```

The zone is a master, as indicated by the `type` statement, holding its zone information in `/etc/namedb/master/example.org` indicated by the `file` statement.

```
zone "example.org" {
 type slave;
 file "slave/example.org";
};
```

In the slave case, the zone information is transferred from the master name server for the particular zone, and saved in the file specified. If and when the master server dies or is unreachable, the slave name server will have the transferred zone information and will be able to serve it.

28.7.3.2.2. Zone Files

An example master zone file for `example.org` (existing within `/etc/namedb/master/example.org`) is as follows:

```
$TTL 3600        -; 1 hour default TTL
example.org.    IN      SOA      ns1.example.org. admin.example.org. (
                                2006051501      -; Serial
                                10800           -; Refresh
                                3600            -; Retry
                                604800          -; Expire
                                300             -; Negative Response TTL
                        )

; DNS Servers
                IN      NS      ns1.example.org.
                IN      NS      ns2.example.org.

; MX Records
                IN      MX 10   mx.example.org.
                IN      MX 20   mail.example.org.

                IN      A       192.168.1.1
```

```
; Machine Names
localhost       IN      A       127.0.0.1
ns1             IN      A       192.168.1.2
ns2             IN      A       192.168.1.3
mx              IN      A       192.168.1.4
mail            IN      A       192.168.1.5

; Aliases
www             IN      CNAME   example.org.
```

Note that every hostname ending in a "." is an exact hostname, whereas everything without a trailing "." is relative to the origin. For example, `ns1` is translated into `ns1.example.org.`

The format of a zone file follows:

```
recordname      IN recordtype   value
```

The most commonly used DNS records:

SOA
: start of zone authority

NS
: an authoritative name server

A
: a host address

CNAME
: the canonical name for an alias

MX
: mail exchanger

PTR
: a domain name pointer (used in reverse DNS)

```
example.org. IN SOA ns1.example.org. admin.example.org. (
                        2006051501      -; Serial
                        10800           -; Refresh after 3 hours
                        3600            -; Retry after 1 hour
                        604800          -; Expire after 1 week
                        300 )           -; Negative Response TTL
```

`example.org.`
: the domain name, also the origin for this zone file.

`ns1.example.org.`
: the primary/authoritative name server for this zone.

`admin.example.org.`
: the responsible person for this zone, email address with "@" replaced. (`<admin@example.org >` becomes `admin.example.org`)

`2006051501`
: the serial number of the file. This must be incremented each time the zone file is modified. Nowadays, many admins prefer a `yyyymmddrr` format for the serial number. `2006051501` would mean last modified 05/15/2006, the latter `01` being the first time the zone file has been modified this day. The serial number is important as it alerts slave name servers for a zone when it is updated.

```
       IN NS           ns1.example.org.
```

This is an NS entry. Every name server that is going to reply authoritatively for the zone must have one of these entries.

```
localhost       IN      A       127.0.0.1
ns1             IN      A       192.168.1.2
ns2             IN      A       192.168.1.3
mx              IN      A       192.168.1.4
mail            IN      A       192.168.1.5
```

The A record indicates machine names. As seen above, `ns1.example.org` would resolve to `192.168.1.2`.

```
                IN      A       192.168.1.1
```

This line assigns IP address `192.168.1.1` to the current origin, in this case `example.org`.

```
www             IN CNAME        @
```

The canonical name record is usually used for giving aliases to a machine. In the example, `www` is aliased to the "master" machine whose name happens to be the same as the domain name `example.org` (`192.168.1.1`). CNAMEs can never be used together with another kind of record for the same hostname.

```
               IN MX   10      mail.example.org.
```

The MX record indicates which mail servers are responsible for handling incoming mail for the zone. `mail.example.org` is the hostname of a mail server, and 10 is the priority of that mail server.

One can have several mail servers, with priorities of 10, 20 and so on. A mail server attempting to deliver to `example.org` would first try the highest priority MX (the record with the lowest priority number), then the second highest, etc, until the mail can be properly delivered.

For in-addr.arpa zone files (reverse DNS), the same format is used, except with PTR entries instead of A or CNAME.

```
$TTL 3600

1.168.192.in-addr.arpa. IN SOA ns1.example.org. admin.example.org. (
                        2006051501      -; Serial
                        10800           -; Refresh
                        3600            -; Retry
                        604800          -; Expire
                        300 )           -; Negative Response TTL

        IN      NS      ns1.example.org.
        IN      NS      ns2.example.org.

1       IN      PTR     example.org.
2       IN      PTR     ns1.example.org.
3       IN      PTR     ns2.example.org.
4       IN      PTR     mx.example.org.
5       IN      PTR     mail.example.org.
```

This file gives the proper IP address to hostname mappings for the above fictitious domain.

It is worth noting that all names on the right side of a PTR record need to be fully qualified (i.e., end in a ".").

28.7.3.3. Caching Name Server

A caching name server is a name server whose primary role is to resolve recursive queries. It simply asks queries of its own, and remembers the answers for later use.

28.7.3.4. DNSSEC

Domain Name System Security Extensions, or DNSSEC for short, is a suite of specifications to protect resolving name servers from forged DNS data, such as spoofed DNS records. By using digital signatures, a resolver can verify the integrity of the record. Note that DNSSEC only provides integrity via digitally signing the Resource Records (RRs). It provides neither confidentiality nor protection against false end-user assumptions. This means that it cannot protect against people going to `example.net` instead of `example.com`. The only thing DNSSEC does is authenticate that the data has not been compromised in transit. The security of DNS is an important step in securing the Internet in general. For more in-depth details of how DNSSEC works, the relevant RFCs are a good place to start. See the list in 節 28.7.3.6, “Further Reading”.

The following sections will demonstrate how to enable DNSSEC for an authoritative DNS server and a recursive (or caching) DNS server running BIND 9. While all versions of BIND 9 support DNSSEC, it is necessary to have at least version 9.6.2 in order to be able to use the signed root zone when validating DNS queries. This is because earlier versions lack the required algorithms to enable validation using the root zone key. It is strongly recommended to use the latest version of BIND 9.7 or later to take advantage of automatic key updating for the root key, as well as other features to automatically keep zones signed and signatures up to date. Where configurations differ between 9.6.2 and 9.7 and later, differences will be pointed out.

28.7.3.4.1. Recursive DNS Server Configuration

Enabling DNSSEC validation of queries performed by a recursive DNS server requires a few changes to `named.conf`. Before making these changes the root zone key, or trust anchor, must be acquired. Currently the root zone key is not available in a file format BIND understands, so it has to be manually converted into the proper format. The key itself can be obtained by querying the root zone for it using dig. By running

```
% dig +multi +noall +answer DNSKEY . > root.dnskey
```

the key will end up in `root.dnskey`. The contents should look something like this:

```
. 93910 IN DNSKEY 257 3 8 (
 AwEAAagAIKlVZrpC6Ia7gEzahOR+9W29euxhJhVVLOyQ
 bSEW0O8gcCjFFVQUTf6v58fLjwBd0YI0EzrAcQqBGCzh
 /RStIoO8g0NfnfL2MTJRkxoXbfDaUeVPQuYEhg37NZWA
 JQ9VnMVDxP/VHL496M/QZxkjf5/Efucp2gaDX6RS6CXp
 oY68LsvPVjR0ZSwzz1apAzvN9dlzEheX7ICJBBtuA6G3
 LQpzW5hOA2hzCTMjJPJ8LbqF6dsV6DoBQzgul0sGIcGO
 Yl7OyQdXfZ57relSQageu+ipAdTTJ25AsRTAoub8ONGc
 LmqrAmRLKBP1dfwhYB4N7knNnulqQxA+Uk1ihz0=
 ) -; key id = 19036
. 93910 IN DNSKEY 256 3 8 (
 AwEAAcaGQEA+OJmOzfzVfoYN249JId7gx+OZMbxy69Hf
 UyuGBbRN0+HuTOpBxxBCkNOL+EJB9qJxt+0FEY6ZUVjE
 g58sRr4ZQ6Iu6b1xTBKgc193zUARk4mmQ/PPGxn7Cn5V
 EGJ/1h6dNaiXuRHwR+7oWh7DnzkIJChcTqlFrXDW3tjt
) -; key id = 34525
```

Do not be alarmed if the obtained keys differ from this example. They might have changed since these instructions were last updated. This output actually contains two keys. The first key in the listing, with the value 257 after the DNSKEY record type, is the one needed. This value indicates that this is a Secure Entry Point (SEP), commonly known as a Key Signing Key (KSK). The second key, with value 256, is a subordinate key, commonly called a Zone Signing Key (ZSK). More on the different key types later in 節 28.7.3.4.2, “Authoritative DNS Server Configuration”.

Now the key must be verified and formatted so that BIND can use it. To verify the key, generate a DS RR set. Create a file containing these RRs with

```
% dnssec-dsfromkey -f root.dnskey . > root.ds
```

These records use SHA-1 and SHA-256 respectively, and should look similar to the following example, where the longer is using SHA-256.

```
.  IN DS 19036 8 1
 B256BD09DC8DD59F0E0F0D8541B8328DD986DF6E
```

```
. IN DS 19036 8 2 49AAC11D7B6F6446702E54A1607371607A1A41855200FD2CE1CDDE32F24E8FB5
```

The SHA-256 RR can now be compared to the digest in https://data.iana.org/root-anchors/root-anchors.xml. To be absolutely sure that the key has not been tampered with the data in the XML file can be verified using the PGP signature in https://data.iana.org/root-anchors/root-anchors.asc.

Next, the key must be formatted properly. This differs a little between BIND versions 9.6.2 and 9.7 and later. In version 9.7 support was added to automatically track changes to the key and update it as necessary. This is done using `managed-keys` as seen in the example below. When using the older version, the key is added using a `trusted-keys` statement and updates must be done manually. For BIND 9.6.2 the format should look like:

```
trusted-keys {
 "." 257 3 8
 "AwEAAagAIKlVZrpC6Ia7gEzahOR+9W29euxhJhVVLOyQbSEW0O8gcCjF
 FVQUTf6v58fLjwBd0YI0EzrAcQqBGCzh/RStIoO8g0NfnfL2MTJRkxoX
 bfDaUeVPQuYEhg37NZWAJQ9VnMVDxP/VHL496M/QZxkjf5/Efucp2gaD
 X6RS6CXpoY68LsvPVjR0ZSwzz1apAzvN9dlzEheX7ICJBBtuA6G3LQpz
 W5hOA2hzCTMjJPJ8LbqF6dsV6DoBQzgul0sGIcGOYl7OyQdXfZ57relS
 Qageu+ipAdTTJ25AsRTAoub8ONGcLmqrAmRLKBP1dfwhYB4N7knNnulq
 QxA+Uk1ihz0=";
};
```

For 9.7 the format will instead be:

```
managed-keys {
 "." initial-key 257 3 8
 "AwEAAagAIKlVZrpC6Ia7gEzahOR+9W29euxhJhVVLOyQbSEW0O8gcCjF
 FVQUTf6v58fLjwBd0YI0EzrAcQqBGCzh/RStIoO8g0NfnfL2MTJRkxoX
 bfDaUeVPQuYEhg37NZWAJQ9VnMVDxP/VHL496M/QZxkjf5/Efucp2gaD
 X6RS6CXpoY68LsvPVjR0ZSwzz1apAzvN9dlzEheX7ICJBBtuA6G3LQpz
 W5hOA2hzCTMjJPJ8LbqF6dsV6DoBQzgul0sGIcGOYl7OyQdXfZ57relS
 Qageu+ipAdTTJ25AsRTAoub8ONGcLmqrAmRLKBP1dfwhYB4N7knNnulq
 QxA+Uk1ihz0=";
};
```

The root key can now be added to `named.conf` either directly or by including a file containing the key. After these steps, configure BIND to do DNSSEC validation on queries by editing `named.conf` and adding the following to the `options` directive:

```
dnssec-enable yes;
dnssec-validation yes;
```

To verify that it is actually working use dig to make a query for a signed zone using the resolver just configured. A successful reply will contain the AD flag to indicate the data was authenticated. Running a query such as

```
% dig @resolver +dnssec se ds
```

should return the DS RR for the `.se` zone. In the `flags:` section the AD flag should be set, as seen in:

```
...
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 3, AUTHORITY: 0, ADDITIONAL: 1
...
```

The resolver is now capable of authenticating DNS queries.

28.7.3.4.2. Authoritative DNS Server Configuration

In order to get an authoritative name server to serve a DNSSEC signed zone a little more work is required. A zone is signed using cryptographic keys which must be generated. It is possible to use only one key for this. The preferred method however is to have a strong well-protected Key Signing Key (KSK) that is not rotated very often and a Zone Signing Key (ZSK) that is rotated more frequently. Information on recommended operational practices can be found in RFC 4641: DNSSEC Operational Practices. Practices regarding the root zone can be found in DNSSEC

Practice Statement for the Root Zone KSK operator and DNSSEC Practice Statement for the Root Zone ZSK operator. The KSK is used to build a chain of authority to the data in need of validation and as such is also called a Secure Entry Point (SEP) key. A message digest of this key, called a Delegation Signer (DS) record, must be published in the parent zone to establish the trust chain. How this is accomplished depends on the parent zone owner. The ZSK is used to sign the zone, and only needs to be published there.

To enable DNSSEC for the `example.com` zone depicted in previous examples, the first step is to use dnssec-keygen to generate the KSK and ZSK key pair. This key pair can utilize different cryptographic algorithms. It is recommended to use RSA/SHA256 for the keys and 2048 bits key length should be enough. To generate the KSK for `example.com` , run

```
% dnssec-keygen -f KSK -a RSASHA256 -b 2048 -n ZONE example.com
```

and to generate the ZSK, run

```
% dnssec-keygen -a RSASHA256 -b 2048 -n ZONE example.com
```

dnssec-keygen outputs two files, the public and the private keys in files named similar to `Kexample.com.+005+nnnnn.key` (public) and `Kexample.com.+005+nnnnn.private` (private). The `nnnnn` part of the file name is a five digit key ID. Keep track of which key ID belongs to which key. This is especially important when having more than one key in a zone. It is also possible to rename the keys. For each KSK file do:

```
% mv Kexample.com.+005+nnnnn.key Kexample.com.+005+nnnnn.KSK.key
% mv Kexample.com.+005+nnnnn.private Kexample.com.+005+nnnnn.KSK.private
```

For the ZSK files, substitute `KSK` for `ZSK` as necessary. The files can now be included in the zone file, using the `$include` statement. It should look something like this:

```
$include Kexample.com.+005+nnnnn.KSK.key -; KSK
$include Kexample.com.+005+nnnnn.ZSK.key    -; ZSK
```

Finally, sign the zone and tell BIND to use the signed zone file. To sign a zone dnssec-signzone is used. The command to sign the zone `example.com` , located in `example.com.db` would look similar to

```
% dnssec-signzone -o
 example.com -k Kexample.com.+005+nnnnn.KSK example.com.db
 Kexample.com.+005+nnnnn.ZSK.key
```

The key supplied to the `-k` argument is the KSK and the other key file is the ZSK that should be used in the signing. It is possible to supply more than one KSK and ZSK, which will result in the zone being signed with all supplied keys. This can be needed to supply zone data signed using more than one algorithm. The output of dnssec-signzone is a zone file with all RRs signed. This output will end up in a file with the extension `.signed` , such as `example.com.db.signed` . The DS records will also be written to a separate file `dsset-example.com` . To use this signed zone just modify the zone directive in `named.conf` to use `example.com.db.signed` . By default, the signatures are only valid 30 days, meaning that the zone needs to be resigned in about 15 days to be sure that resolvers are not caching records with stale signatures. It is possible to make a script and a cron job to do this. See relevant manuals for details.

Be sure to keep private keys confidential, as with all cryptographic keys. When changing a key it is best to include the new key into the zone, while still signing with the old one, and then move over to using the new key to sign. After these steps are done the old key can be removed from the zone. Failure to do this might render the DNS data unavailable for a time, until the new key has propagated through the DNS hierarchy. For more information on key rollovers and other DNSSEC operational issues, see RFC 4641: DNSSEC Operational practices.

28.7.3.4.3. Automation Using BIND 9.7 or Later

Beginning with BIND version 9.7 a new feature called Smart Signing was introduced. This feature aims to make the key management and signing process simpler by automating parts of the task. By putting the keys into a directory

called a key repository, and using the new option `auto-dnssec` , it is possible to create a dynamic zone which will be resigned as needed. To update this zone use nsupdate with the new option `-l`. rndc has also grown the ability to sign zones with keys in the key repository, using the option `sign`. To tell BIND to use this automatic signing and zone updating for `example.com` , add the following to `named.conf` :

```
zone example.com {
 type master;
 key-directory "/etc/named/keys";
 update-policy local;
 auto-dnssec maintain;
 file "/etc/named/dynamic/example.com.zone";
};
```

After making these changes, generate keys for the zone as explained in 節 28.7.3.4.2, “Authoritative DNS Server Configuration”, put those keys in the key repository given as the argument to the `key-directory` in the zone configuration and the zone will be signed automatically. Updates to a zone configured this way must be done using nsupdate, which will take care of re-signing the zone with the new data added. For further details, see 節 28.7.3.6, “Further Reading” and the BIND documentation.

28.7.3.5. Security

Although BIND is the most common implementation of DNS, there is always the issue of security. Possible and exploitable security holes are sometimes found.

While FreeBSD automatically drops named into a chroot(8) environment; there are several other security mechanisms in place which could help to lure off possible DNS service attacks.

It is always good idea to read CERT's security advisories and to subscribe to the FreeBSD security notifications 郵遞論壇 to stay up to date with the current Internet and FreeBSD security issues.

提示

If a problem arises, keeping sources up to date and having a fresh build of named may help.

28.7.3.6. Further Reading

BIND/named manual pages: rndc(8) named(8) named.conf(5) nsupdate(1) dnssec-signzone(8) dnssec-keygen(8)

- Official ISC BIND Page
- Official ISC BIND Forum
- O'Reilly DNS and BIND 5th Edition
- Root DNSSEC
- DNSSEC Trust Anchor Publication for the Root Zone
- RFC1034 - Domain Names - Concepts and Facilities
- RFC1035 - Domain Names - Implementation and Specification
- RFC4033 - DNS Security Introduction and Requirements
- RFC4034 - Resource Records for the DNS Security Extensions
- RFC4035 - Protocol Modifications for the DNS Security Extensions

- RFC4641 - DNSSEC Operational Practices
- RFC 5011 - Automated Updates of DNS Security (DNSSEC Trust Anchors

28.8. Apache HTTP Server

Contributed by Murray Stokely.

The open source Apache HTTP Server is the most widely used web server. FreeBSD does not install this web server by default, but it can be installed from the www/apache24 package or port.

This section summarizes how to configure and start version 2.*X* of the Apache HTTP Server on FreeBSD. For more detailed information about Apache 2.X and its configuration directives, refer to httpd.apache.org.

28.8.1. Configuring and Starting Apache

In FreeBSD, the main Apache HTTP Server configuration file is installed as `/usr/local/etc/apache2 x/httpd.conf` , where *x* represents the version number. This ASCII text file begins comment lines with a #. The most frequently modified directives are:

`ServerRoot "/usr/local"`
: Specifies the default directory hierarchy for the Apache installation. Binaries are stored in the `bin` and `sbin` subdirectories of the server root and configuration files are stored in the `etc/apache2` *x* subdirectory.

`ServerAdmin you@example.com`
: Change this to the email address to receive problems with the server. This address also appears on some server-generated pages, such as error documents.

`ServerName www.example.com:80`
: Allows an administrator to set a hostname which is sent back to clients for the server. For example, `www` can be used instead of the actual hostname. If the system does not have a registered DNS name, enter its IP address instead. If the server will listen on an alternate report, change `80` to the alternate port number.

`DocumentRoot "/usr/local/www/apache2 x/data"`
: The directory where documents will be served from. By default, all requests are taken from this directory, but symbolic links and aliases may be used to point to other locations.

It is always a good idea to make a backup copy of the default Apache configuration file before making changes. When the configuration of Apache is complete, save the file and verify the configuration using `apachectl` . Running `apachectl configtest` should return `Syntax OK`.

To launch Apache at system startup, add the following line to `/etc/rc.conf` :

```
apache24_enable="YES"
```

If Apache should be started with non-default options, the following line may be added to `/etc/rc.conf` to specify the needed flags:

```
apache24_flags=""
```

If apachectl does not report configuration errors, start `httpd` now:

```
# service apache 24 start
```

The `httpd` service can be tested by entering `http://localhost` in a web browser, replacing `localhost` with the fully-qualified domain name of the machine running `httpd`. The default web page that is displayed is `/usr/local/www/apache 24/data/index.html` .

The Apache configuration can be tested for errors after making subsequent configuration changes while `httpd` is running using the following command:

```
# service apache24 configtest
```

注意

It is important to note that `configtest` is not an rc(8) standard, and should not be expected to work for all startup scripts.

28.8.2. Virtual Hosting

Virtual hosting allows multiple websites to run on one Apache server. The virtual hosts can be IP-based or name-based. IP-based virtual hosting uses a different IP address for each website. Name-based virtual hosting uses the clients HTTP/1.1 headers to figure out the hostname, which allows the websites to share the same IP address.

To setup Apache to use name-based virtual hosting, add a `VirtualHost` block for each website. For example, for the webserver named `www.domain.tld` with a virtual domain of `www.someotherdomain.tld` , add the following entries to `httpd.conf` :

```
<VirtualHost *>
ServerName www.domain.tld
DocumentRoot /www/domain.tld
</VirtualHost>

<VirtualHost *>
ServerName www.someotherdomain.tld
DocumentRoot /www/someotherdomain.tld
</VirtualHost>
```

For each virtual host, replace the values for `ServerName` and `DocumentRoot` with the values to be used.

For more information about setting up virtual hosts, consult the official Apache documentation at: `http://httpd.apache.org/docs/vhosts/` .

28.8.3. Apache Modules

Apache uses modules to augment the functionality provided by the basic server. Refer to `http://httpd.apache.org/docs/current/mod/` for a complete listing of and the configuration details for the available modules.

In FreeBSD, some modules can be compiled with the www/apache24 port. Type `make config` within `/usr/ports/www/apache24` to see which modules are available and which are enabled by default. If the module is not compiled with the port, the FreeBSD Ports Collection provides an easy way to install many modules. This section describes three of the most commonly used modules.

28.8.3.1. `mod_ssl`

The `mod_ssl` module uses the OpenSSL library to provide strong cryptography via the Secure Sockets Layer (SSLv3) and Transport Layer Security (TLSv1) protocols. This module provides everything necessary to request a signed certificate from a trusted certificate signing authority to run a secure web server on FreeBSD.

In FreeBSD, `mod_ssl` module is enabled by default in both the package and the port. The available configuration directives are explained at `http://httpd.apache.org/docs/current/mod/mod_ssl.html` .

28.8.3.2. `mod_perl`

The `mod_perl` module makes it possible to write Apache modules in Perl. In addition, the persistent interpreter embedded in the server avoids the overhead of starting an external interpreter and the penalty of Perl start-up time.

The `mod_perl` can be installed using the www/mod_perl2 package or port. Documentation for using this module can be found at `http://perl.apache.org/docs/2.0/index.html` .

28.8.3.3. mod_php

Written by Tom Rhodes.

PHP: Hypertext Preprocessor (PHP) is a general-purpose scripting language that is especially suited for web development. Capable of being embedded into HTML, its syntax draws upon C, Java™, and Perl with the intention of allowing web developers to write dynamically generated webpages quickly.

To gain support for PHP5 for the Apache web server, install the www/mod_php5 package or port. This will install and configure the modules required to support dynamic PHP applications. The installation will automatically add this line to `/usr/local/etc/apache2 4/httpd.conf` :

```
LoadModule php5_module        libexec/apache24/libphp5.so
```

Then, perform a graceful restart to load the PHP module:

```
# apachectl graceful
```

The PHP support provided by www/mod_php5 is limited. Additional support can be installed using the lang/php5-extensions port which provides a menu driven interface to the available PHP extensions.

Alternatively, individual extensions can be installed using the appropriate port. For instance, to add PHP support for the MySQL database server, install `databases/php5-mysql` .

After installing an extension, the Apache server must be reloaded to pick up the new configuration changes:

```
# apachectl graceful
```

28.8.4. Dynamic Websites

In addition to mod_perl and mod_php, other languages are available for creating dynamic web content. These include Django and Ruby on Rails.

28.8.4.1. Django

Django is a BSD-licensed framework designed to allow developers to write high performance, elegant web applications quickly. It provides an object-relational mapper so that data types are developed as Python objects. A rich dynamic database-access API is provided for those objects without the developer ever having to write SQL. It also provides an extensible template system so that the logic of the application is separated from the HTML presentation.

Django depends on `mod_python` , and an SQL database engine. In FreeBSD, the www/py-django port automatically installs `mod_python` and supports the PostgreSQL, MySQL, or SQLite databases, with the default being SQLite. To change the database engine, type `make config` within `/usr/ports/www/py-django` , then install the port.

Once Django is installed, the application will need a project directory along with the Apache configuration in order to use the embedded Python interpreter. This interpreter is used to call the application for specific URLs on the site.

To configure Apache to pass requests for certain URLs to the web application, add the following to `httpd.conf` , specifying the full path to the project directory:

```
<Location "/">
```

```
    SetHandler python-program
    PythonPath "['/dir/to/the/django/packages/ '] + sys.path"
    PythonHandler django.core.handlers.modpython
    SetEnv DJANGO_SETTINGS_MODULE mysite.settings
    PythonAutoReload On
    PythonDebug On
</Location>
```

Refer to `https://docs.djangoproject.com/en/1.6/` for more information on how to use Django.

28.8.4.2. Ruby on Rails

Ruby on Rails is another open source web framework that provides a full development stack. It is optimized to make web developers more productive and capable of writing powerful applications quickly. On FreeBSD, it can be installed using the www/rubygem-rails package or port.

Refer to `http://rubyonrails.org/documentation` for more information on how to use Ruby on Rails.

28.9. File Transfer Protocol (FTP)

The File Transfer Protocol (FTP) provides users with a simple way to transfer files to and from an FTP server. FreeBSD includes FTP server software, ftpd, in the base system.

FreeBSD provides several configuration files for controlling access to the FTP server. This section summarizes these files. Refer to ftpd(8) for more details about the built-in FTP server.

28.9.1. Configuration

The most important configuration step is deciding which accounts will be allowed access to the FTP server. A FreeBSD system has a number of system accounts which should not be allowed FTP access. The list of users disallowed any FTP access can be found in `/etc/ftpusers` . By default, it includes system accounts. Additional users that should not be allowed access to FTP can be added.

In some cases it may be desirable to restrict the access of some users without preventing them completely from using FTP. This can be accomplished be creating `/etc/ftpchroot` as described in ftpchroot(5). This file lists users and groups subject to FTP access restrictions.

To enable anonymous FTP access to the server, create a user named `ftp` on the FreeBSD system. Users will then be able to log on to the FTP server with a username of `ftp` or `anonymous` . When prompted for the password, any input will be accepted, but by convention, an email address should be used as the password. The FTP server will call chroot(2) when an anonymous user logs in, to restrict access to only the home directory of the `ftp` user.

There are two text files that can be created to specify welcome messages to be displayed to FTP clients. The contents of `/etc/ftpwelcome` will be displayed to users before they reach the login prompt. After a successful login, the contents of `/etc/ftpmotd` will be displayed. Note that the path to this file is relative to the login environment, so the contents of `~ftp/etc/ftpmotd` would be displayed for anonymous users.

Once the FTP server has been configured, set the appropriate variable in `/etc/rc.conf` to start the service during boot:

```
ftpd_enable="YES"
```

To start the service now:

```
# service ftpd start
```

Test the connection to the FTP server by typing:

```
% ftp localhost
```

The ftpd daemon uses syslog(3) to log messages. By default, the system log daemon will write messages related to FTP in `/var/log/xferlog` . The location of the FTP log can be modified by changing the following line in `/etc/syslog.conf` :

```
ftp.info       /var/log/xferlog
```

注意

Be aware of the potential problems involved with running an anonymous FTP server. In particular, think twice about allowing anonymous users to upload files. It may turn out that the FTP site becomes a forum for the trade of unlicensed commercial software or worse. If anonymous FTP uploads are required, then verify the permissions so that these files can not be read by other anonymous users until they have been reviewed by an administrator.

28.10. File and Print Services for Microsoft® Windows® Clients (Samba)

Samba is a popular open source software package that provides file and print services using the SMB/CIFS protocol. This protocol is built into Microsoft® Windows® systems. It can be added to non-Microsoft® Windows® systems by installing the Samba client libraries. The protocol allows clients to access shared data and printers. These shares can be mapped as a local disk drive and shared printers can be used as if they were local printers.

On FreeBSD, the Samba client libraries can be installed using the net/samba-smbclient port or package. The client provides the ability for a FreeBSD system to access SMB/CIFS shares in a Microsoft® Windows® network.

A FreeBSD system can also be configured to act as a Samba server. This allows the administrator to create SMB/CIFS shares on the FreeBSD system which can be accessed by clients running Microsoft® Windows® or the Samba client libraries. In order to configure a Samba server on FreeBSD, the net/samba36 port or package must first be installed. The rest of this section provides an overview of how to configure a Samba server on FreeBSD.

28.10.1. Configuration

A default Samba configuration file is installed as `/usr/local/share/examples/samba36/smb.conf.default` . This file must be copied to `/usr/local/etc/smb.conf` and customized before Samba can be used.

Runtime configuration information for Samba is found in `smb.conf` , such as definitions of the printers and "file system shares" that will be shared with Windows® clients. The Samba package includes a web based tool called swat which provides a simple way for configuring `smb.conf` .

28.10.1.1. Using the Samba Web Administration Tool (SWAT)

The Samba Web Administration Tool (SWAT) runs as a daemon from inetd. Therefore, inetd must be enabled as shown in 節 28.2, "The inetd Super-Server". To enable swat, uncomment the following line in `/etc/inetd.conf` :

```
swat    stream  tcp     nowait/400      root    /usr/local/sbin/swat    swat
```

As explained in 範例 28.1, "Reloading the inetd Configuration File", the inetd configuration must be reloaded after this configuration file is changed.

Once swat has been enabled, use a web browser to connect to `http://localhost:901` . At first login, enter the credentials for `root`.

Once logged in, the main Samba configuration page and the system documentation will be available. Begin configuration by clicking on the Globals tab. The Globals section corresponds to the variables that are set in the `[global]` section of `/usr/local/etc/smb.conf` .

28.10.1.2. Global Settings

Whether swat is used or `/usr/local/etc/smb.conf` is edited directly, the first directives encountered when configuring Samba are:

`workgroup`
: The domain name or workgroup name for the computers that will be accessing this server.

`netbios name`
: The NetBIOS name by which a Samba server is known. By default it is the same as the first component of the host's DNS name.

`server string`
: The string that will be displayed in the output of `net view` and some other networking tools that seek to display descriptive text about the server.

28.10.1.3. Security Settings

Two of the most important settings in `/usr/local/etc/smb.conf` are the security model and the backend password format for client users. The following directives control these options:

`security`
: The two most common options are `security = share` and `security = user` . If the clients use usernames that are the same as their usernames on the FreeBSD machine, user level security should be used. This is the default security policy and it requires clients to first log on before they can access shared resources.

  In share level security, clients do not need to log onto the server with a valid username and password before attempting to connect to a shared resource. This was the default security model for older versions of Samba.

`passdb backend`
: Samba has several different backend authentication models. Clients may be authenticated with LDAP, NIS+, an SQL database, or a modified password file. The default authentication method is `smbpasswd` , and that is all that will be covered here.

Assuming that the default `smbpasswd` backend is used, `/usr/local/etc/samba/smbpasswd` must be created to allow Samba to authenticate clients. To provide UNIX® user accounts access from Windows® clients, use the following command to add each required user to that file:

```
# smbpasswd -a username
```

注意

The recommended backend is now `tdbsam`. If this backend is selected, use the following command to add user accounts:

```
# pdbedit -a -u username
```

This section has only mentioned the most commonly used settings. Refer to the Official Samba HOWTO for additional information about the available configuration options.

28.10.2. Starting Samba

To enable Samba at boot time, add the following line to `/etc/rc.conf` :

```
samba_enable="YES"
```

Alternately, its services can be started separately:

```
nmbd_enable="YES"
```

```
smbd_enable="YES"
```

To start Samba now:

```
# service samba start
Starting SAMBA: removing stale tdbs :
Starting nmbd.
Starting smbd.
```

Samba consists of three separate daemons. Both the nmbd and smbd daemons are started by `samba_enable` . If winbind name resolution services are enabled in `smb.conf` , the winbindd daemon is started as well.

Samba may be stopped at any time by typing:

```
# service samba stop
```

Samba is a complex software suite with functionality that allows broad integration with Microsoft® Windows® networks. For more information about functionality beyond the basic configuration described here, refer to `http://www.samba.org` .

28.11. Clock Synchronization with NTP

Over time, a computer's clock is prone to drift. This is problematic as many network services require the computers on a network to share the same accurate time. Accurate time is also needed to ensure that file timestamps stay consistent. The Network Time Protocol (NTP) is one way to provide clock accuracy in a network.

FreeBSD includes ntpd(8) which can be configured to query other NTP servers in order to synchronize the clock on that machine or to provide time services to other computers in the network. The servers which are queried can be local to the network or provided by an ISP. In addition, an online list of publicly accessible NTP servers is available. When choosing a public NTP server, select one that is geographically close and review its usage policy.

Choosing several NTP servers is recommended in case one of the servers becomes unreachable or its clock proves unreliable. As ntpd receives responses, it favors reliable servers over the less reliable ones.

This section describes how to configure ntpd on FreeBSD. Further documentation can be found in `/usr/share/doc/ntp/` in HTML format.

28.11.1. NTP Configuration

On FreeBSD, the built-in ntpd can be used to synchronize a system's clock. To enable ntpd at boot time, add `ntpd_enable="YES"` to `/etc/rc.conf` . Additional variables can be specified in `/etc/rc.conf` . Refer to rc.conf(5) and ntpd(8) for details.

This application reads `/etc/ntp.conf` to determine which NTP servers to query. Here is a simple example of an `/etc/ntp.conf` :

範例 28.4. Sample `/etc/ntp.conf`

```
server ntplocal.example.com prefer
server timeserver.example.org
server ntp2a.example.net

driftfile /var/db/ntp.drift
```

The format of this file is described in ntp.conf(5). The `server` option specifies which servers to query, with one server listed on each line. If a server entry includes `prefer`, that server is preferred over other servers. A response from a preferred server will be discarded if it differs significantly from other servers' responses; otherwise it will be used. The `prefer` argument should only be used for NTP servers that are known to be highly accurate, such as those with special time monitoring hardware.

The `driftfile` entry specifies which file is used to store the system clock's frequency offset. ntpd uses this to automatically compensate for the clock's natural drift, allowing it to maintain a reasonably correct setting even if it is cut off from all external time sources for a period of time. This file also stores information about previous responses from NTP servers. Since this file contains internal information for NTP, it should not be modified.

By default, an NTP server is accessible to any network host. The `restrict` option in `/etc/ntp.conf` can be used to control which systems can access the server. For example, to deny all machines from accessing the NTP server, add the following line to `/etc/ntp.conf`:

```
restrict default ignore
```

注意

This will also prevent access from other NTP servers. If there is a need to synchronize with an external NTP server, allow only that specific server. Refer to ntp.conf(5) for more information.

To allow machines within the network to synchronize their clocks with the server, but ensure they are not allowed to configure the server or be used as peers to synchronize against, instead use:

```
restrict 192.168.1.0 mask 255.255.255.0 nomodify notrap
```

where `192.168.1.0` is the local network address and `255.255.255.0` is the network's subnet mask.

Multiple `restrict` entries are supported. For more details, refer to the `Access Control Support` subsection of ntp.conf(5).

Once `ntpd_enable="YES"` has been added to `/etc/rc.conf`, ntpd can be started now without rebooting the system by typing:

```
# service ntpd start
```

28.11.2. Using NTP with a PPP Connection

ntpd does not need a permanent connection to the Internet to function properly. However, if a PPP connection is configured to dial out on demand, NTP traffic should be prevented from triggering a dial out or keeping the connection alive. This can be configured with `filter` directives in `/etc/ppp/ppp.conf`. For example:

```
set filter dial 0 deny udp src eq 123
# Prevent NTP traffic from initiating dial out
set filter dial 1 permit 0 0
set filter alive 0 deny udp src eq 123
# Prevent incoming NTP traffic from keeping the connection open
set filter alive 1 deny udp dst eq 123
# Prevent outgoing NTP traffic from keeping the connection open
set filter alive 2 permit 0/0 0/0
```

For more details, refer to the `PACKET FILTERING` section in ppp(8) and the examples in `/usr/share/examples/ppp/` .

注意

Some Internet access providers block low-numbered ports, preventing NTP from functioning since replies never reach the machine.

28.12. iSCSI Initiator and Target Configuration

iSCSI is a way to share storage over a network. Unlike NFS, which works at the file system level, iSCSI works at the block device level.

In iSCSI terminology, the system that shares the storage is known as the target. The storage can be a physical disk, or an area representing multiple disks or a portion of a physical disk. For example, if the disk(s) are formatted with ZFS, a zvol can be created to use as the iSCSI storage.

The clients which access the iSCSI storage are called initiators. To initiators, the storage available through iSCSI appears as a raw, unformatted disk known as a LUN. Device nodes for the disk appear in `/dev/` and the device must be separately formatted and mounted.

Beginning with 10.0-RELEASE, FreeBSD provides a native, kernel-based iSCSI target and initiator. This section describes how to configure a FreeBSD system as a target or an initiator.

28.12.1. Configuring an iSCSI Target

注意

The native iSCSI target is supported starting with FreeBSD 10.0-RELEASE. To use iSCSI in older versions of FreeBSD, install a userspace target from the Ports Collection, such as net/istgt. This chapter only describes the native target.

To configure an iSCSI target, create the `/etc/ctl.conf` configuration file, add a line to `/etc/rc.conf` to make sure the ctld(8) daemon is automatically started at boot, and then start the daemon.

The following is an example of a simple `/etc/ctl.conf` configuration file. Refer to ctl.conf(5) for a more complete description of this file's available options.

```
portal-group pg0 {
 discovery-auth-group no-authentication
 listen 0.0.0.0
 listen [::]
}
```

```
target iqn.2012-06.com.example:target0 {
 auth-group no-authentication
 portal-group pg0

 lun 0 {
  path /data/target0-0
  size 4G
 }
}
```

The first entry defines the `pg0` portal group. Portal groups define which network addresses the ctld(8) daemon will listen on. The `discovery-auth-group no-authentication` entry indicates that any initiator is allowed to perform iSCSI target discovery without authentication. Lines three and four configure ctld(8) to listen on all IPv4 (`listen 0.0.0.0`) and IPv6 (`listen [::]`) addresses on the default port of 3260.

It is not necessary to define a portal group as there is a built-in portal group called `default`. In this case, the difference between `default` and `pg0` is that with `default`, target discovery is always denied, while with `pg0`, it is always allowed.

The second entry defines a single target. Target has two possible meanings: a machine serving iSCSI or a named group of LUNs. This example uses the latter meaning, where `iqn.2012-06.com.example:target0` is the target name. This target name is suitable for testing purposes. For actual use, change `com.example` to the real domain name, reversed. The `2012-06` represents the year and month of acquiring control of that domain name, and `target0` can be any value. Any number of targets can be defined in this configuration file.

The `auth-group no-authentication` line allows all initiators to connect to the specified target and `portal-group pg0` makes the target reachable through the `pg0` portal group.

The next section defines the LUN. To the initiator, each LUN will be visible as a separate disk device. Multiple LUNs can be defined for each target. Each LUN is identified by a number, where LUN 0 is mandatory. The `path /data/target0-0` line defines the full path to a file or zvol backing the LUN. That path must exist before starting ctld(8). The second line is optional and specifies the size of the LUN.

Next, to make sure the ctld(8) daemon is started at boot, add this line to `/etc/rc.conf`:

```
ctld_enable="YES"
```

To start ctld(8) now, run this command:

```
# service ctld start
```

As the ctld(8) daemon is started, it reads `/etc/ctl.conf`. If this file is edited after the daemon starts, use this command so that the changes take effect immediately:

```
# service ctld reload
```

28.12.1.1. Authentication

The previous example is inherently insecure as it uses no authentication, granting anyone full access to all targets. To require a username and password to access targets, modify the configuration as follows:

```
auth-group ag0 {
 chap username1 secretsecret
 chap username2 anothersecret
}

portal-group pg0 {
 discovery-auth-group no-authentication
 listen 0.0.0.0
 listen [::]
```

```
}

target iqn.2012-06.com.example:target0 {
 auth-group ag0
 portal-group pg0
 lun 0 {
  path /data/target0-0
  size 4G
 }
}
```

The `auth-group` section defines username and password pairs. An initiator trying to connect to `iqn.2012-06.com.example:target0` must first specify a defined username and secret. However, target discovery is still permitted without authentication. To require target discovery authentication, set `discovery-auth-group` to a defined `auth-group` name instead of `no-authentication` .

It is common to define a single exported target for every initiator. As a shorthand for the syntax above, the username and password can be specified directly in the target entry:

```
target iqn.2012-06.com.example:target0 {
 portal-group pg0
 chap username1 secretsecret

 lun 0 {
  path /data/target0-0
  size 4G
 }
}
```

28.12.2. Configuring an iSCSI Initiator

注意

The iSCSI initiator described in this section is supported starting with FreeBSD 10.0-RELEASE. To use the iSCSI initiator available in older versions, refer to iscontrol(8).

The iSCSI initiator requires that the iscsid(8) daemon is running. This daemon does not use a configuration file. To start it automatically at boot, add this line to `/etc/rc.conf` :

```
iscsid_enable="YES"
```

To start iscsid(8) now, run this command:

```
# service iscsid start
```

Connecting to a target can be done with or without an `/etc/iscsi.conf` configuration file. This section demonstrates both types of connections.

28.12.2.1. Connecting to a Target Without a Configuration File

To connect an initiator to a single target, specify the IP address of the portal and the name of the target:

```
# iscsictl -A -p 10.10.10.10 -t iqn.2012-06.com.example:target0
```

To verify if the connection succeeded, run `iscsictl` without any arguments. The output should look similar to this:

```
Target name                                    Target portal   State
iqn.2012-06.com.example:target0                10.10.10.10     Connected: da0
```

In this example, the iSCSI session was successfully established, with `/dev/da0` representing the attached LUN. If the `iqn.2012-06.com.example:target0` target exports more than one LUN, multiple device nodes will be shown in that section of the output:

```
Connected: da0 da1 da2.
```

Any errors will be reported in the output, as well as the system logs. For example, this message usually means that the iscsid(8) daemon is not running:

```
Target name                                     Target portal   State
iqn.2012-06.com.example:target0                 10.10.10.10     Waiting for iscsid(8)
```

The following message suggests a networking problem, such as a wrong IP address or port:

```
Target name                                     Target portal   State
iqn.2012-06.com.example:target0                 10.10.10.11     Connection refused
```

This message means that the specified target name is wrong:

```
Target name                                     Target portal   State
iqn.2012-06.com.example:atrget0                 10.10.10.10     Not found
```

This message means that the target requires authentication:

```
Target name                                     Target portal   State
iqn.2012-06.com.example:target0                 10.10.10.10     Authentication failed
```

To specify a CHAP username and secret, use this syntax:

```
# iscsictl -A -p 10.10.10.10 -t iqn.2012-06.com.example:target0 -u user
 -s secretsecret
```

28.12.2.2. Connecting to a Target with a Configuration File

To connect using a configuration file, create `/etc/iscsi.conf` with contents like this:

```
t0 {
 TargetAddress   = 10.10.10.10
 TargetName      = iqn.2012-06.com.example:target0
 AuthMethod      = CHAP
 chapIName       = user
 chapSecret      = secretsecret
}
```

The `t0` specifies a nickname for the configuration file section. It will be used by the initiator to specify which configuration to use. The other lines specify the parameters to use during connection. The `TargetAddress` and `TargetName` are mandatory, whereas the other options are optional. In this example, the CHAP username and secret are shown.

To connect to the defined target, specify the nickname:

```
# iscsictl -An t0
```

Alternately, to connect to all targets defined in the configuration file, use:

```
# iscsictl -Aa
```

To make the initiator automatically connect to all targets in `/etc/iscsi.conf`, add the following to `/etc/rc.conf`:

```
iscsictl_enable="YES"
iscsictl_flags="-Aa"
```

章 29. 防火牆

Contributed by Joseph J. Barbish.
Converted to SGML and updated by Brad Davis.

29.1. 概述

防火牆能夠過濾你的系統中進出的流量。 防火牆也能藉由設置一或多組「規則(rules)」 來檢查你的網路連結中進出的網路封包(network packets)， 並且能允許或阻擋其通過。 這些防火牆的規則可以檢查封包中的特徵， 這些特徵涵蓋，但不限於某些通訊協定類型、主機位址的來源或目的， 以及連接埠(port)的來源及目的。

防火牆能夠大幅地增強主機或是網路的安全性。 它也能夠用來執行下列事項：

- 保護或隔離你內部網路的應用程式、服務以及機器， 免於被來自 Internet 中你不想要的傳輸所影響
- 限制或禁止內部網路對 Internet 的存取服務
- 支援「網路位址轉換」(network address translation , NAT)，它可以允許你的內部網路使用 private IP 位址並可以共同分享一個單一連線到網際網路上（可同時用單一IP位址或是一組公共網址）

讀完這章之後，你將會知道：

- 如何適當地訂出封包過濾的規則。
- FreeBSD 中內建的防火牆之間的差異。
- 如何使用及設定 OpenBSD 的 PF 防火牆。
- 如何使用及設定 IPFILTER。
- 如何使用及設定 IPFW。

在閱讀這章之前，你必須：

- 了解基本的 FreeBSD 和 Internet 觀念

29.2. 淺談防火牆概念

基本上防火牆規則可分為兩種型態，分別為：「exclusive」以及 「inclusive」。 「exclusive」類似「黑名單」，它先允許所有封包通過， 然後違反規則的封包則禁止通過防火牆。 相反的，「inclusive」類似「白名單」，它先擋住所有封包通過， 然後只允許有符合規則的才可通過防火牆。

整體來說，「inclusive」式防火牆會比「exclusive」式防火牆安全些。 因為「inclusive」明顯降低了不必要的風險。

此外，使用「stateful firewall」可讓安全性更嚴密。 它會持續記錄通過防火牆開放的連線， 並且只允許符合現存或開啓新的連線才能通過防火牆。 狀態防火牆的缺點是如果在非常快的速度下開啓許多新連線， 就可能會受到阻絕式服務攻擊(DoS, Denial of Service)。 在大多數的防火牆方案中，也可以交叉運用「stateful」及「non-stateful」 防火牆的組合，讓該網站的防火牆達到最佳化。

29.3. 防火牆相關軟體

在 FreeBSD 基本系統中內建有三種不同的防火牆軟體套件。 它們分別是 IPFILTER （也就是 IPF）、IPFIREWALL（也就是 IPFW）， 以及 OpenBSD 的 PacketFilter（即有名的 PF）。 FreeBSD 也有兩個內建的流量控

管套件(基本上是控制頻寬的使用)： altq(4) 以及 dummynet(4)。 通常我們習慣把 Dummynet 與 IPFW 一併運用， 而 ALTQ 則是搭配 IPF/PF 一同使用。 雖然 IPF、IPFW 以及 PF 是使用不同的實做方式及規則語法，但是它們都使用規則來控制是否允許資料封包進出你的系統。

FreeBSD 為何會內建許多不同的防火牆軟體套件，這是因為不同人會有不同的需求 、偏好，很難說哪一個防火牆軟體套件是最好的。

而筆者偏好 IPFILTER 的原因，是因為運用在 NAT 環境的時候，它的狀態規則是相對簡單許多的。 而且它內建的 FTP 代理，也簡化了如何設定安全的對外 FTP 服務規則。

正由於所有的防火牆都是以「檢查、控制所選定之封包」的實作，所以， 制定防火牆規則的人就更必須了解 TCP/IP 如何運作， 以及如何控制封包在正常 session 的各種作用。 更詳盡的說明，請參閱： `http://www.ipprimer.com/overview.cfm` 。

29.4. OpenBSD 封包過濾器 (Packet Filter, PF)及 ALTQ

在 2003 年 6 月份，OpenBSD 的防火牆軟體 PF 被移植到 FreeBSD 中，並且收錄於 Ports Collection 內。 而 2004 年 11 月份所發行的 FreeBSD 5.3 版也是第一次將 PF 整合為基礎系統的一部分。 PF是個完備、全功能的防火牆， 並且具有選擇性 ALTQ(交錯佇列，Alternate Queuing) 的功能。 ALTQ提供了「QoS」 (Quality of Service) 頻寬管制功能， 它可以用過濾規則的方式來保障各種不同服務的頻寬。 另外，OpenBSD 計劃中已經對 PF 的使用指南提供了詳盡的解說， 因此在這本手冊中我們不會作重複的贅述，而只介紹概要。

更多關於 PF 的資訊可於下列網址查詢：`http://pf4freebsd.love2party.net/` .

29.4.1. 啓用 PF

PF 在 FreeBSD 5.3 之後的系統中，就可以輕鬆使用 kernel 動態模組來載入。 在 rc.conf 中加入 `pf_enable="YES"` 後， 系統就會載入 PF 的 kernel 動態模組。這模組會在建立時也啓用 pflog(4) 記錄功能。

注意

這個模組會假設 kernel 內已有 `options INET` 和 `device bpf`。 除非編譯 kernel 時已在像是 make.conf(5) 設定檔中加入 `NOINET6`(FreeBSD 6.0 以後的版本則是 `NO_INET6`) 這樣才會避免不打開 IPv6 支援， 否則 pf 模組同時也需要 `options INET6`，也就是 IPv6 支援。

一旦載入 PF 的 kernel 模組或是靜態編譯入 kernel 內， 就可以使用 `pfctl` 來啓動或關閉 pf。

下面這個例子示範如何啓動 pf：

```
# pfctl -e
```

`pfctl` 是使用 pf 防火牆的指令。 若要了解更詳盡的 `pfctl` 運用，請查閱 pfctl(8) 線上手冊。

29.4.2. kernel 選項

在編譯 FreeBSD kernel 時，並不必完全加入下列的選項來啓用 PF。 在這裡只是要列出給你參考的一些資訊而已。 將 PF 編譯入 kernel 中，會導致無法使用 kernel 的動態載入模組。

設定 PF 的 kernel 選項範例在 kernel 原始碼中的 `/usr/src/sys/conf/NOTES` ，轉貼內容如下：

```
device pf
device pflog
device pfsync
```

`device pf` 是用來啓動「packet filter(封包過濾)」 的防火牆支援。

而 `device pflog` ，此功能要裝不裝皆可，它會啓動 pflog(4)，以 bpf(4) 格式來記錄網路流量。 pflogd(8) daemon 則是用來紀錄這些訊息，並存在硬碟上。

`device pfsync` ，此功能要裝不裝皆可，它會啓動 pfsync(4)，可以用來監控「狀態的改變」。 請注意：`device pfsync` 並不是 kernel 動態模組，要使用的話， 必須要編入自訂的 kernel 中才行。

這些設定將會在你編譯及安裝好新 kernel 後才會生效。

29.4.3. rc.conf 其他相關的選項

你需要在 `/etc/rc.conf` 中加入下列的設定，以便在系統啓動時啓用 PF：

```
pf_enable="YES"                 # ## PF (##########)
pf_rules="/etc/pf.conf"         # PF ########
pf_flags=""                     # pfctl ########
pflog_enable="YES"              # ## pflogd(8)
pflog_logfile="/var/log/pflog"  # pflogd #########
pflog_flags=""                  # pflogd ########
```

如果您的防火牆後面有個 LAN(區域網路)，並要透過它來轉送封包， 就必須要設定下列選項：

```
gateway_enable="YES"            # ## LAN Gateway
```

29.4.4. 啓用 ALTQ

ALTQ 只有在編入 FreeBSD kernel 中才能生效。 不是所有的網路卡驅動程式都支援 ALTQ。 請看 altq(4) 線上手冊來了解你使用的 FreeBSD 版本中支援驅動程式的清單。 下面所列的將會啓用 ALTQ 及其他附加功能：

```
options         ALTQ
options         ALTQ_CBQ        # Class Bases Queuing (CBQ)
options         ALTQ_RED        # Random Early Detection (RED)
options         ALTQ_RIO        # RED In/Out
options         ALTQ_HFSC       # Hierarchical Packet Scheduler (HFSC)
options         ALTQ_PRIQ       # Priority Queuing (PRIQ)
options         ALTQ_NOPCC      # Required for SMP build
```

`options ALTQ` 是啓用 ALTQ 主架構。

`options ALTQ_CBQ` 會啓用「CBQ」 (Class Based Queuing)支援。 CBQ 允許你 divide a connection's bandwidth into different classes or queues to prioritize traffic based on filter rules.

`options ALTQ_RED` enables Random Early Detection (RED). RED is used to avoid network congestion. RED does this by measuring the length of the queue and comparing it to the minimum and maximum thresholds for the queue. If the queue is over the maximum all new packets will be dropped. True to its name, RED drops packets from different connections randomly.

`options ALTQ_RIO` enables Random Early Detection In and Out.

`options ALTQ_HFSC` enables the Hierarchical Fair Service Curve Packet Scheduler. For more information about HFSC see: `http://www-2.cs.cmu.edu/~hzhang/HFSC/main.html` .

`options ALTQ_PRIQ` enables Priority Queuing (PRIQ). PRIQ will always pass traffic that is in a higher queue first.

`options ALTQ_NOPCC` enables SMP support for ALTQ. This option is required on SMP systems.

29.4.5. Creating Filtering Rules

The Packet Filter reads its configuration rules from the pf.conf(5) file and it modifies, drops or passes packets according to the rules or definitions specified there. The FreeBSD installation comes with a default `/etc/pf.conf` which contains useful examples and explanations.

Although FreeBSD has its own `/etc/pf.conf` the syntax is the same as one used in OpenBSD. A great resource for configuring the pf firewall has been written by OpenBSD team and is available at `http://www.openbsd.org/faq/pf/` .

警告

When browsing the pf user's guide, please keep in mind that different versions of FreeBSD contain different versions of pf. The pf firewall in FreeBSD 5.X is at the level of OpenBSD version 3.5 and in FreeBSD 6.X is at the level of OpenBSD version 3.7.

The FreeBSD packet filter 郵遞論壇 is a good place to ask questions about configuring and running the pf firewall. Do not forget to check the mailing list archives before asking questions.

29.5. IPFILTER (IPF) 防火牆

注意

此一節的內容仍在陸續補充、更新，所以本節內容可能並未完全符合現況。

IPFILTER 的作者為 Darren Reed。IPFILTER 並非得綁某特定作業系統才行： 它是個跨 OS 平台的 open source 應用程式，且已被移植到 FreeBSD、NetBSD、OpenBSD、SunOS™、HP/UX 以及 Solaris™ 這些作業系統上。此外，IPFILTER 的支援、維護也相當積極，也有定期釋出的更新版。

IPFILTER is based on a kernel-side firewall and NAT mechanism that can be controlled and monitored by userland interface programs. The firewall rules can be set or deleted with the ipf(8) utility. The NAT rules can be set or deleted with the ipnat(1) utility. The ipfstat(8) utility can print run-time statistics for the kernel parts of IPFILTER. The ipmon(8) program can log IPFILTER actions to the system log files.

IPF was originally written using a rule processing logic of 「the last matching rule wins」 and used only stateless type of rules. Over time IPF has been enhanced to include a 「quick」 option and a stateful 「keep state」 option which drastically modernized the rules processing logic. IPF's official documentation covers the legacy rule coding parameters and the legacy rule file processing logic. The modernized functions are only included as additional options, completely understating their benefits in producing a far superior secure firewall.

The instructions contained in this section are based on using rules that contain the 「quick」 option and the stateful 「keep state」 option. This is the basic framework for coding an inclusive firewall rule set.

An inclusive firewall only allows packets matching the rules to pass through. This way you can control what services can originate behind the firewall destined for the public Internet and also control the services which can originate from the public Internet accessing your private network. Everything else is blocked and logged by default design. Inclusive firewalls are much, much more secure than exclusive firewall rule sets and is the only rule set type covered herein.

For detailed explanation of the legacy rules processing method see: `http://www.obfuscation.org/ipf/ipf-howto.html#TOC_1` and `http://coombs.anu.edu.au/~avalon/ip-filter.html` .

IPF 的 FAQ 位於 `http://www.phildev.net/ipf/index.html` .

29.5.1. 啓用 IPF

IPF is included in the basic FreeBSD install as a separate run time loadable module. The system will dynamically load the IPF kernel loadable module when the rc.conf statement `ipfilter_enable="YES"` is used. The loadable module was created with logging enabled and the `default pass all` options. You do not need to compile IPF into the FreeBSD kernel just to change the default to `block all`, you can do that by just coding a block all rule at the end of your rule set.

29.5.2. kernel 選項

在編譯 FreeBSD kernel 時，並不必完全加入下列的選項來啓用 IPF。 在這裡只是要列出給你參考的一些資訊而已。 將 IPF 編譯入 kernel 中，會導致無法使用 kernel 的動態載入模組。

Sample kernel config IPF option statements are in the `/usr/src/sys/conf/NOTES` kernel source (`/usr/src/sys/arch/conf/LINT` for FreeBSD 4.X) and are reproduced here:

```
options IPFILTER
options IPFILTER_LOG
options IPFILTER_DEFAULT_BLOCK
```

`options IPFILTER` enables support for the 「IPFILTER」 firewall.

`options IPFILTER_LOG` enables the option to have IPF log traffic by writing to the `ipl` packet logging pseudo——device for every rule that has the `log` keyword.

`options IPFILTER_DEFAULT_BLOCK` changes the default behavior so any packet not matching a firewall `pass` rule gets blocked.

These settings will take effect only after you have built and installed a kernel with them set.

29.5.3. 可用的 rc.conf 選項

須在 `/etc/rc.conf` 內加入下列內容，以便在開機時就會啓用 IPF：

```
ipfilter_enable="YES"             # Start ipf firewall
ipfilter_rules="/etc/ipf.rules"   # IPF ########
ipmon_enable="YES"                # ## IP ####
ipmon_flags="-Ds"                 # D = ###### (daemon) ##
                                  # s = ## syslog ##
                                  # v = ### tcp window, ack, seq
                                  # n = # IP # port ######
```

If you have a LAN behind this firewall that uses the reserved private IP address ranges, then you need to add the following to enable NAT functionality:

```
gateway_enable="YES"              # ## LAN Gateway
ipnat_enable="YES"                # Start ipnat function
ipnat_rules="/etc/ipnat.rules"    # rules definition file for ipnat
```

29.5.4. IPF

The ipf command is used to load your rules file. Normally you create a file containing your custom rules and use this command to replace in mass the currently running firewall internal rules:

```
# ipf -Fa -f /etc/ipf.rules
```

`-Fa` means flush all internal rules tables.

`-f` means this is the file to read for the rules to load.

This gives you the ability to make changes to your custom rules file, run the above IPF command, and thus update the running firewall with a fresh copy of all the rules without having to reboot the system. This method is very convenient for testing new rules as the procedure can be executed as many times as needed.

See the ipf(8) manual page for details on the other flags available with this command.

The ipf(8) command expects the rules file to be a standard text file. It will not accept a rules file written as a script with symbolic substitution.

There is a way to build IPF rules that utilizes the power of script symbolic substitution. For more information, see 節 29.5.9, “Building the Rule Script with Symbolic Substitution”.

29.5.5. IPFSTAT

The default behavior of ipfstat(8) is to retrieve and display the totals of the accumulated statistics gathered as a result of applying the user coded rules against packets going in and out of the firewall since it was last started, or since the last time the accumulators were reset to zero by the `ipf -Z` command.

See the ipfstat(8) manual page for details.

The default ipfstat(8) command output will look something like this:

```
input packets: blocked 99286 passed 1255609 nomatch 14686 counted 0
 output packets: blocked 4200 passed 1284345 nomatch 14687 counted 0
 input packets logged: blocked 99286 passed 0
 output packets logged: blocked 0 passed 0
 packets logged: input 0 output 0
 log failures: input 3898 output 0
 fragment state(in): kept 0 lost 0
 fragment state(out): kept 0 lost 0
 packet state(in): kept 169364 lost 0
 packet state(out): kept 431395 lost 0
 ICMP replies: 0 TCP RSTs sent: 0
 Result cache hits(in): 1215208 (out): 1098963
 IN Pullups succeeded: 2 failed: 0
 OUT Pullups succeeded: 0 failed: 0
 Fastroute successes: 0 failures: 0
 TCP cksum fails(in): 0 (out): 0
 Packet log flags set: (0)
```

When supplied with either `-i` for inbound or `-o` for outbound, it will retrieve and display the appropriate list of filter rules currently installed and in use by the kernel.

`ipfstat -in` displays the inbound internal rules table with rule number.

`ipfstat -on` displays the outbound internal rules table with the rule number.

The output will look something like this:

```
@1 pass out on xl0 from any to any
@2 block out on dc0 from any to any
@3 pass out quick on dc0 proto tcp/udp from any to any keep state
```

`ipfstat -ih` displays the inbound internal rules table, prefixing each rule with a count of how many times the rule was matched.

`ipfstat -oh` displays the outbound internal rules table, prefixing each rule with a count of how many times the rule was matched.

The output will look something like this:

```
2451423 pass out on xl0 from any to any
354727 block out on dc0 from any to any
430918 pass out quick on dc0 proto tcp/udp from any to any keep state
```

One of the most important functions of the `ipfstat` command is the `-t` flag which displays the state table in a way similar to the way top(1) shows the FreeBSD running process table. When your firewall is under attack this function gives you the ability to identify, drill down to, and see the attacking packets. The optional sub-flags give the ability to select the destination or source IP, port, or protocol that you want to monitor in real time. See the ipfstat(8) manual page for details.

29.5.6. IPMON

In order for `ipmon` to work properly, the kernel option IPFILTER_LOG must be turned on. This command has two different modes that it can be used in. Native mode is the default mode when you type the command on the command line without the `-D` flag.

Daemon mode is for when you want to have a continuous system log file available so that you can review logging of past events. This is how FreeBSD and IPFILTER are configured to work together. FreeBSD has a built in facility to automatically rotate system logs. That is why outputting the log information to syslogd is better than the default of outputting to a regular file. In the default `rc.conf` file you see the ipmon_flags statement uses the `-Ds` flags:

```
ipmon_flags="-Ds" # D = start as daemon
                  # s = log to syslog
                  # v = log tcp window, ack, seq
                  # n = map IP & port to names
```

The benefits of logging are obvious. It provides the ability to review, after the fact, information such as which packets had been dropped, what addresses they came from and where they were going. These all give you a significant edge in tracking down attackers.

Even with the logging facility enabled, IPF will not generate any rule logging on its own. The firewall administrator decides what rules in the rule set he wants to log and adds the log keyword to those rules. Normally only deny rules are logged.

It is very customary to include a default deny everything rule with the log keyword included as your last rule in the rule set. This way you get to see all the packets that did not match any of the rules in the rule set.

29.5.7. IPMON Logging

Syslogd uses its own special method for segregation of log data. It uses special groupings called 「`facility`」 and "level". IPMON in `-Ds` mode uses `security` (`local0` in 4.X) as the 「`facility`」 name. All IPMON logged data goes to `security` (`local0` in 4.X). The following levels can be used to further segregate the logged data if desired:

```
LOG_INFO - packets logged using the "log" keyword as the action rather than pass or ↺
block.
LOG_NOTICE - packets logged which are also passed
LOG_WARNING - packets logged which are also blocked
LOG_ERR - packets which have been logged and which can be considered short
```

To setup IPFILTER to log all data to `/var/log/ipfilter.log` , you will need to create the file. The following command will do that:

```
# touch /var/log/ipfilter.log
```

The syslog function is controlled by definition statements in the `/etc/syslog.conf` file. The `syslog.conf` file offers considerable flexibility in how syslog will deal with system messages issued by software applications like IPF.

Add the following statement to `/etc/syslog.conf` for FreeBSD 5.X and later:

```
security.* /var/log/ipfilter.log
```

Or add the following statement to `/etc/syslog.conf` for FreeBSD 4.X:

```
local0.* /var/log/ipfilter.log
```

The `security.*` (`local0` for 4.X) means to write all the logged messages to the coded file location.

To activate the changes to `/etc/syslog.conf` you can reboot or bump the syslog task into re-reading `/etc/syslog.conf` by running `/etc/rc.d/syslogd reload` (`killall -HUP syslogd` in FreeBSD 4.X).

Do not forget to change `/etc/newsyslog.conf` to rotate the new log you just created above.

29.5.8. The Format of Logged Messages

Messages generated by `ipmon` consist of data fields separated by white space. Fields common to all messages are:

1. The date of packet receipt.
2. The time of packet receipt. This is in the form HH:MM:SS.F, for hours, minutes, seconds, and fractions of a second (which can be several digits long).
3. The name of the interface the packet was processed on, e.g. `dc0`.
4. The group and rule number of the rule, e.g. `@0:17`.

These can be viewed with `ipfstat -in`.

1. The action: p for passed, b for blocked, S for a short packet, n did not match any rules, L for a log rule. The order of precedence in showing flags is: S, p, b, n, L. A capital P or B means that the packet has been logged due to a global logging setting, not a particular rule.
2. The addresses. This is actually three fields: the source address and port (separated by a comma), the -> symbol, and the destination address and port. 209.53.17.22,80 -> 198.73.220.17,1722.
3. `PR` followed by the protocol name or number, e.g. PR tcp.
4. `len` followed by the header length and total length of the packet, e.g. len 20 40.

If the packet is a TCP packet, there will be an additional field starting with a hyphen followed by letters corresponding to any flags that were set. See the ipmon(8) manual page for a list of letters and their flags.

If the packet is an ICMP packet, there will be two fields at the end, the first always being 「ICMP」, and the next being the ICMP message and sub-message type, separated by a slash, e.g. ICMP 3/3 for a port unreachable message.

29.5.9. Building the Rule Script with Symbolic Substitution

Some experienced IPF users create a file containing the rules and code them in a manner compatible with running them as a script with symbolic substitution. The major benefit of doing this is that you only have to change the value associated with the symbolic name and when the script is run all the rules containing the symbolic name

will have the value substituted in the rules. Being a script, you can use symbolic substitution to code frequently used values and substitute them in multiple rules. You will see this in the following example.

The script syntax used here is compatible with the sh, csh, and tcsh shells.

Symbolic substitution fields are prefixed with a dollar sign: `$`.

Symbolic fields do not have the `$` prefix.

The value to populate the symbolic field must be enclosed with double quotes (`"`).

Start your rule file with something like this:

```
############ IPF ########  ########################

oif="dc0"            # #########
odns="192.0.2.11"    # ISP # DNS ### IP ##
myip="192.0.2.7"     # ### ISP ##### IP
ks="keep state"
fks="flags S keep state"

# You can choose between building /etc/ipf.rules file
# from this script or running this script "as is".
#
# Uncomment only one line and comment out another.
#
# 1) This can be used for building /etc/ipf.rules:
#cat > /etc/ipf.rules << EOF
#
# 2) This can be used to run script "as is":
/sbin/ipf -Fa -f - << EOF

# Allow out access to my ISP's Domain name server.
pass out quick on $oif proto tcp from any to $odns port = 53 $fks
pass out quick on $oif proto udp from any to $odns port = 53 $ks

# Allow out non-secure standard www function
pass out quick on $oif proto tcp from $myip to any port = 80 $fks

# Allow out secure www function https over TLS SSL
pass out quick on $oif proto tcp from $myip to any port = 443 $fks
EOF
################## End of IPF rules script ########################
```

That is all there is to it. The rules are not important in this example; how the symbolic substitution fields are populated and used are. If the above example was in a file named `/etc/ipf.rules.script` , you could reload these rules by entering the following command:

```
# sh /etc/ipf.rules.script
```

There is one problem with using a rules file with embedded symbolics: IPF does not understand symbolic substitution, and cannot read such scripts directly.

This script can be used in one of two ways:

- Uncomment the line that begins with `cat`, and comment out the line that begins with `/sbin/ipf` . Place `ipfilter_enable="YES"` into `/etc/rc.conf` as usual, and run script once after each modification to create or update `/etc/ipf.rules` .
- Disable IPFILTER in system startup scripts by adding `ipfilter_enable="NO"` (this is default value) into `/etc/rc.conf` file.

  Add a script like the following to your `/usr/local/etc/rc.d/` startup directory. The script should have an obvious name like `ipf.loadrules.sh` . The `.sh` extension is mandatory.

```
#!/bin/sh
sh /etc/ipf.rules.script
```

The permissions on this script file must be read, write, execute for owner `root`.

```
# chmod 700 /usr/local/etc/rc.d/ipf.loadrules.sh
```

從現在起，當系統開機時就會載入你所設的 IPF 規則。

29.5.10. IPF 規則

A rule set is a group of ipf rules coded to pass or block packets based on the values contained in the packet. The bi-directional exchange of packets between hosts comprises a session conversation. The firewall rule set processes the packet two times, once on its arrival from the public Internet host and again as it leaves for its return trip back to the public Internet host. Each TCP/IP service (i.e. telnet, www, mail, etc.) is predefined by its protocol, source and destination IP address, or the source and destination port number. This is the basic selection criteria used to create rules which will pass or block services.

IPF was originally written using a rules processing logic of 「the last matching rule wins」 and used only stateless rules. Over time IPF has been enhanced to include a 「quick」 option and a stateful 「keep state」 option which drastically modernized the rule processing logic.

The instructions contained in this section are based on using rules that contain the 「quick」 option and the stateful 「keep state」 option. This is the basic framework for coding an inclusive firewall rule set.

An inclusive firewall only allows services matching the rules through. This way you can control what services can originate behind the firewall destined for the public Internet and also control the services which can originate from the public Internet accessing your private network. Everything else is blocked and logged by default design. Inclusive firewalls are much, much securer than exclusive firewall rule sets and is the only rule set type covered herein.

警告

When working with the firewall rules, be very careful. Some configurations will lock you out of the server. To be on the safe side, you may wish to consider performing the initial firewall configuration from the local console rather than doing it remotely e.g. via ssh.

29.5.11. Rule Syntax

The rule syntax presented here has been simplified to only address the modern stateful rule context and 「first matching rule wins」 logic. For the complete legacy rule syntax description see the ipf(8) manual page.

A **#** character is used to mark the start of a comment and may appear at the end of a rule line or on its own line. Blank lines are ignored.

Rules contain keywords. These keywords have to be coded in a specific order from left to right on the line. Keywords are identified in bold type. Some keywords have sub-options which may be keywords themselves and also include more sub-options. Each of the headings in the below syntax has a bold section header which expands on the content.

ACTION IN-OUT OPTIONS SELECTION STATEFUL PROTO SRC_ADDR,DST_ADDR OBJECT PORT_NUM TCP_FLAG STATEFUL

ACTION = block | pass

IN-OUT = in | out

OPTIONS = log | quick | on interface-name

SELECTION = proto value | source/destination IP | port = number | flags flag-value

PROTO = tcp/udp | udp | tcp | icmp

SRC_ADD,DST_ADDR = all | from object to object

OBJECT = IP address | any

PORT_NUM = port number

TCP_FLAG = S

STATEFUL = keep state

29.5.11.1. ACTION

The action indicates what to do with the packet if it matches the rest of the filter rule. Each rule must have a action. The following actions are recognized:

`block` indicates that the packet should be dropped if the selection parameters match the packet.

`pass` indicates that the packet should exit the firewall if the selection parameters match the packet.

29.5.11.2. IN-OUT

A mandatory requirement is that each filter rule explicitly state which side of the I/O it is to be used on. The next keyword must be either in or out and one or the other has to be coded or the rule will not pass syntax checks.

`in` means this rule is being applied against an inbound packet which has just been received on the interface facing the public Internet.

`out` means this rule is being applied against an outbound packet destined for the interface facing the public Internet.

29.5.11.3. OPTIONS

注意

These options must be used in the order shown here.

`log` indicates that the packet header will be written to the `ipl` log (as described in the LOGGING section below) if the selection parameters match the packet.

`quick` indicates that if the selection parameters match the packet, this rule will be the last rule checked, allowing a 「`short-circuit`」 path to avoid processing any following rules for this packet. This option is a mandatory requirement for the modernized rules processing logic.

`on` indicates the interface name to be incorporated into the selection parameters. Interface names are as displayed by ifconfig(8). Using this option, the rule will only match if the packet is going through that interface in the specified direction (in/out). This option is a mandatory requirement for the modernized rules processing logic.

When a packet is logged, the headers of the packet are written to the IPL packet logging pseudo-device. Immediately following the log keyword, the following qualifiers may be used (in this order):

`body` indicates that the first 128 bytes of the packet contents will be logged after the headers.

`first` If the `log` keyword is being used in conjunction with a 「`keep state`」 option, it is recommended that this option is also applied so that only the triggering packet is logged and not every packet which thereafter matches the 「`keep state`」 information.

29.5.11.4. SELECTION

The keywords described in this section are used to describe attributes of the packet to be interrogated when determining whether rules match or not. There is a keyword subject, and it has sub-option keywords, one of which has to be selected. The following general-purpose attributes are provided for matching, and must be used in this order:

29.5.11.5. PROTO

`proto` is the subject keyword and must be coded along with one of its corresponding keyword sub-option values. The value allows a specific protocol to be matched against. This option is a mandatory requirement for the modernized rules processing logic.

`tcp/udp | udp | tcp | icmp` or any protocol names found in `/etc/protocols` are recognized and may be used. The special protocol keyword `tcp/udp` may be used to match either a TCP or a UDP packet, and has been added as a convenience to save duplication of otherwise identical rules.

29.5.11.6. SRC_ADDR/DST_ADDR

The `all` keyword is essentially a synonym for 「`from` any to `any`」 with no other match parameters.

`from src to dst` : the from and to keywords are used to match against IP addresses. Rules must specify BOTH source and destination parameters. `any` is a special keyword that matches any IP address. Examples of use: 「`from` any to `any`」 or 「`from` 0.0.0.0/0 to `any`」 or “from any to `0.0.0.0/0`」 or 「`from` 0.0.0.0 to any” or 「`from` any to `0.0.0.0`」 .

IP addresses may be specified as a dotted IP address numeric form/mask-length, or as single dotted IP address numeric form.

There is no way to match ranges of IP addresses which do not express themselves easily as mask-length. See this web page for help on writing mask-length: `http://jodies.de/ipcalc` .

29.5.11.7. PORT

If a port match is included, for either or both of source and destination, then it is only applied to TCP and UDP packets. When composing port comparisons, either the service name from `/etc/services` or an integer port number may be used. When the port appears as part of the from object, it matches the source port number; when it appears as part of the to object, it matches the destination port number. The use of the port option with the `to` object is a mandatory requirement for the modernized rules processing logic. Example of use: 「`from` any to any port = `80`」

Port comparisons may be done in a number of forms, with a number of comparison operators, or port ranges may be specified.

port "=" | "!=" | "<" | ">" | "<=" | ">=" | "eq" | "ne" | "lt" | "gt" | "le" | "ge".

To specify port ranges, port "<>" | "><"

警告

Following the source and destination matching parameters, the following two parameters are mandatory requirements for the modernized rules processing logic.

29.5.11.8. TCP_FLAG

Flags are only effective for TCP filtering. The letters represents one of the possible flags that can be interrogated in the TCP packet header.

The modernized rules processing logic uses the `flags S` parameter to identify the tcp session start request.

29.5.11.9. STATEFUL

`keep state` indicates that on a pass rule, any packets that match the rules selection parameters should activate the stateful filtering facility.

注意

This option is a mandatory requirement for the modernized rules processing logic.

29.5.12. Stateful Filtering

Stateful filtering treats traffic as a bi-directional exchange of packets comprising a session conversation. When activated, keep-state dynamically generates internal rules for each anticipated packet being exchanged during the bi-directional session conversation. It has the interrogation abilities to determine if the session conversation between the originating sender and the destination are following the valid procedure of bi-directional packet exchange. Any packets that do not properly fit the session conversation template are automatically rejected as impostors.

Keep state will also allow ICMP packets related to a TCP or UDP session through. So if you get ICMP type 3 code 4 in response to some web surfing allowed out by a keep state rule, they will be automatically allowed in. Any packet that IPF can be certain is part of an active session, even if it is a different protocol, will be let in.

What happens is:

Packets destined to go out the interface connected to the public Internet are first checked against the dynamic state table, if the packet matches the next expected packet comprising in a active session conversation, then it exits the firewall and the state of the session conversation flow is updated in the dynamic state table, the remaining packets get checked against the outbound rule set.

Packets coming in to the interface connected to the public Internet are first checked against the dynamic state table, if the packet matches the next expected packet comprising a active session conversation, then it exits the firewall and the state of the session conversation flow is updated in the dynamic state table, the remaining packets get checked against the inbound rule set.

When the conversation completes it is removed from the dynamic state table.

Stateful filtering allows you to focus on blocking/passing new sessions. If the new session is passed, all its subsequent packets will be allowed through automatically and any impostors automatically rejected. If a new session is blocked, none of its subsequent packets will be allowed through. Stateful filtering has technically

advanced interrogation abilities capable of defending against the flood of different attack methods currently employed by attackers.

29.5.13. Inclusive Rule Set Example

The following rule set is an example of how to code a very secure inclusive type of firewall. An inclusive firewall only allows services matching pass rules through and blocks all other by default. All firewalls have at the minimum two interfaces which have to have rules to allow the firewall to function.

All UNIX® flavored systems including FreeBSD are designed to use interface `lo0` and IP address `127.0.0.1` for internal communication within the operating system. The firewall rules must contain rules to allow free unmolested movement of these special internally used packets.

The interface which faces the public Internet is the one where you place your rules to authorize and control access out to the public Internet and access requests arriving from the public Internet. This can be your user PPP `tun0` interface or your NIC that is connected to your DSL or cable modem.

In cases where one or more NICs are cabled to private LANs behind the firewall, those interfaces must have a rule coded to allow free unmolested movement of packets originating from those LAN interfaces.

The rules should be first organized into three major sections: all the free unmolested interfaces, the public interface outbound, and the public interface inbound.

The rules in each of the public interface sections should have the most frequently matched rules placed before less commonly matched rules, with the last rule in the section blocking and logging all packets on that interface and direction.

The Outbound section in the following rule set only contains 'pass' rules which contain selection values that uniquely identify the service that is authorized for public Internet access. All the rules have the 'quick', 'on', 'proto', 'port', and 'keep state' option coded. The 'proto tcp' rules have the 'flag' option included to identify the session start request as the triggering packet to activate the stateful facility.

The Inbound section has all the blocking of undesirable packets first, for two different reasons. The first is that these things being blocked may be part of an otherwise valid packet which may be allowed in by the later authorized service rules. The second reason is that by having a rule that explicitly blocks selected packets that I receive on an infrequent basis and that I do not want to see in the log, they will not be caught by the last rule in the section which blocks and logs all packets which have fallen through the rules. The last rule in the section which blocks and logs all packets is how you create the legal evidence needed to prosecute the people who are attacking your system.

Another thing you should take note of, is there is no response returned for any of the undesirable stuff, their packets just get dropped and vanish. This way the attacker has no knowledge if his packets have reached your system. The less the attackers can learn about your system, the more time they must invest before actually doing something bad. The inbound 'nmap OS fingerprint' attempts rule I log the first occurrence because this is something a attacker would do.

Any time you see log messages on a rule with 'log first'. You should do an `ipfstat -hio` command to see the number of times the rule has been matched so you know if you are being flooded, i.e. under attack.

When you log packets with port numbers you do not recognize, look it up in `/etc/services` or go to `http://www.securitystats.com/tools/portsearch.php` and do a port number lookup to find what the purpose of that port number is.

Check out this link for port numbers used by Trojans `http://www.simovits.com/trojans/trojans.html` .

The following rule set is a complete very secure 'inclusive' type of firewall rule set that I have used on my system. You can not go wrong using this rule set for your own. Just comment out any pass rules for services that you do not want to authorize.

If you see messages in your log that you want to stop seeing just add a block rule in the inbound section.

You have to change the `dc0` interface name in every rule to the interface name of the Nic card that connects your system to the public Internet. For user PPP it would be `tun0`.

Add the following statements to `/etc/ipf.rules` :

```
#####################################################################
# No restrictions on Inside LAN Interface for private network
# Not needed unless you have LAN
#####################################################################

#pass out quick on xl0 all
#pass in quick on xl0 all

#####################################################################
# No restrictions on Loopback Interface
#####################################################################
pass in quick on lo0 all
pass out quick on lo0 all

#####################################################################
# Interface facing Public Internet (Outbound Section)
# Interrogate session start requests originating from behind the
# firewall on the private network
# or from this gateway server destine for the public Internet.
#####################################################################

# Allow out access to my ISP's Domain name server.
# xxx must be the IP address of your ISP's DNS.
# Dup these lines if your ISP has more than one DNS server
# Get the IP addresses from /etc/resolv.conf file
pass out quick on dc0 proto tcp from any to xxx port = 53 flags S keep state
pass out quick on dc0 proto udp from any to xxx port = 53 keep state

# Allow out access to my ISP's DHCP server for cable or DSL networks.
# This rule is not needed for 'user ppp' type connection to the
# public Internet, so you can delete this whole group.
# Use the following rule and check log for IP address.
# Then put IP address in commented out rule & delete first rule
pass out log quick on dc0 proto udp from any to any port = 67 keep state
#pass out quick on dc0 proto udp from any to z.z.z.z port = 67 keep state


# Allow out non-secure standard www function
pass out quick on dc0 proto tcp from any to any port = 80 flags S keep state

# Allow out secure www function https over TLS SSL
pass out quick on dc0 proto tcp from any to any port = 443 flags S keep state

# Allow out send & get email function
pass out quick on dc0 proto tcp from any to any port = 110 flags S keep state
pass out quick on dc0 proto tcp from any to any port = 25 flags S keep state

# Allow out Time
pass out quick on dc0 proto tcp from any to any port = 37 flags S keep state

# Allow out nntp news
pass out quick on dc0 proto tcp from any to any port = 119 flags S keep state

# Allow out gateway & LAN users non-secure FTP ( both passive & active modes)
# This function uses the IPNAT built in FTP proxy function coded in
# the nat rules file to make this single rule function correctly.
# If you want to use the pkg_add command to install application packages
# on your gateway system you need this rule.
pass out quick on dc0 proto tcp from any to any port = 21 flags S keep state

# Allow out secure FTP, Telnet, and SCP
```

```
# This function is using SSH (secure shell)
pass out quick on dc0 proto tcp from any to any port = 22 flags S keep state

# Allow out non-secure Telnet
pass out quick on dc0 proto tcp from any to any port = 23 flags S keep state

# Allow out FBSD CVSUP function
pass out quick on dc0 proto tcp from any to any port = 5999 flags S keep state

# Allow out ping to public Internet
pass out quick on dc0 proto icmp from any to any icmp-type 8 keep state

# Allow out whois for LAN PC to public Internet
pass out quick on dc0 proto tcp from any to any port = 43 flags S keep state

# Block and log only the first occurrence of everything
# else that's trying to get out.
# This rule enforces the block all by default logic.
block out log first quick on dc0 all

################################################################
# Interface facing Public Internet (Inbound Section)
# Interrogate packets originating from the public Internet
# destine for this gateway server or the private network.
################################################################

# Block all inbound traffic from non-routable or reserved address spaces
block in quick on dc0 from 192.168.0.0/16 to any    #RFC 1918 private IP
block in quick on dc0 from 172.16.0.0/12 to any     #RFC 1918 private IP
block in quick on dc0 from 10.0.0.0/8 to any        #RFC 1918 private IP
block in quick on dc0 from 127.0.0.0/8 to any       #loopback
block in quick on dc0 from 0.0.0.0/8 to any         #loopback
block in quick on dc0 from 169.254.0.0/16 to any    #DHCP auto-config
block in quick on dc0 from 192.0.2.0/24 to any      #reserved for docs
block in quick on dc0 from 204.152.64.0/23 to any   #Sun cluster interconnect
block in quick on dc0 from 224.0.0.0/3 to any       #Class D & E multicast

##### Block a bunch of different nasty things. ############
# That I do not want to see in the log

# Block frags
block in quick on dc0 all with frags

# Block short tcp packets
block in quick on dc0 proto tcp all with short

# block source routed packets
block in quick on dc0 all with opt lsrr
block in quick on dc0 all with opt ssrr

# Block nmap OS fingerprint attempts
# Log first occurrence of these so I can get their IP address
block in log first quick on dc0 proto tcp from any to any flags FUP

# Block anything with special options
block in quick on dc0 all with ipopts

# Block public pings
block in quick on dc0 proto icmp all icmp-type 8

# Block ident
block in quick on dc0 proto tcp from any to any port = 113

# Block all Netbios service. 137=name, 138=datagram, 139=session
# Netbios is MS/Windows sharing services.
# Block MS/Windows hosts2 name server requests 81
```

```
block in log first quick on dc0 proto tcp/udp from any to any port = 137
block in log first quick on dc0 proto tcp/udp from any to any port = 138
block in log first quick on dc0 proto tcp/udp from any to any port = 139
block in log first quick on dc0 proto tcp/udp from any to any port = 81

# Allow traffic in from ISP's DHCP server. This rule must contain
# the IP address of your ISP's DHCP server as it's the only
# authorized source to send this packet type. Only necessary for
# cable or DSL configurations. This rule is not needed for
# 'user ppp' type connection to the public Internet.
# This is the same IP address you captured and
# used in the outbound section.
pass in quick on dc0 proto udp from z.z.z.z to any port = 68 keep state

# Allow in standard www function because I have apache server
pass in quick on dc0 proto tcp from any to any port = 80 flags S keep state

# Allow in non-secure Telnet session from public Internet
# labeled non-secure because ID/PW passed over public Internet as clear text.
# Delete this sample group if you do not have telnet server enabled.
#pass in quick on dc0 proto tcp from any to any port = 23 flags S keep state

# Allow in secure FTP, Telnet, and SCP from public Internet
# This function is using SSH (secure shell)
pass in quick on dc0 proto tcp from any to any port = 22 flags S keep state

# Block and log only first occurrence of all remaining traffic
# coming into the firewall. The logging of only the first
# occurrence stops a .denial of service. attack targeted
# at filling up your log file space.
# This rule enforces the block all by default logic.
block in log first quick on dc0 all
################## End of rules file ####################################
```

29.5.14. NAT

NAT stands for Network Address Translation. To those familiar with Linux®, this concept is called IP Masquerading; NAT and IP Masquerading are the same thing. One of the many things the IPF NAT function enables is the ability to have a private Local Area Network (LAN) behind the firewall sharing a single ISP assigned IP address on the public Internet.

You may ask why would someone want to do this. ISPs normally assign a dynamic IP address to their non-commercial users. Dynamic means that the IP address can be different each time you dial in and log on to your ISP, or for cable and DSL modem users when you power off and then power on your modems you can get assigned a different IP address. This IP address is how you are known to the public Internet.

Now lets say you have five PCs at home and each one needs Internet access. You would have to pay your ISP for an individual Internet account for each PC and have five phone lines.

With NAT you only need a single account with your ISP, then cable your other four PCs to a switch and the switch to the NIC in your FreeBSD system which is going to service your LAN as a gateway. NAT will automatically translate the private LAN IP address for each separate PC on the LAN to the single public IP address as it exits the firewall bound for the public Internet. It also does the reverse translation for returning packets.

NAT is most often accomplished without the approval, or knowledge, of your ISP and in most cases is grounds for your ISP terminating your account if found out. Commercial users pay a lot more for their Internet connection and usually get assigned a block of static IP address which never change. The ISP also expects and consents to their Commercial customers using NAT for their internal private LANs.

There is a special range of IP addresses reserved for NATed private LAN IP address. According to RFC 1918, you can use the following IP ranges for private nets which will never be routed directly to the public Internet:

Start IP `10.0.0.0`	-	Ending IP `10.255.255.255`
Start IP `172.16.0.0`	-	Ending IP `172.31.255.255`
Start IP `192.168.0.0`	-	Ending IP `192.168.255.255`

29.5.15. IPNAT

NAT rules are loaded by using the `ipnat` command. Typically the NAT rules are stored in `/etc/ipnat.rules` . See ipnat(1) for details.

When changing the NAT rules after NAT has been started, make your changes to the file containing the NAT rules, then run ipnat command with the `-CF` flags to delete the internal in use NAT rules and flush the contents of the translation table of all active entries.

To reload the NAT rules issue a command like this:

```
# ipnat -CF -f /etc/ipnat.rules
```

To display some statistics about your NAT, use this command:

```
# ipnat -s
```

To list the NAT table's current mappings, use this command:

```
# ipnat -l
```

To turn verbose mode on, and display information relating to rule processing and active rules/table entries:

```
# ipnat -v
```

29.5.16. IPNAT Rules

NAT rules are very flexible and can accomplish many different things to fit the needs of commercial and home users.

The rule syntax presented here has been simplified to what is most commonly used in a non-commercial environment. For a complete rule syntax description see the ipnat(5) manual page.

The syntax for a NAT rule looks something like this:

```
map IF LAN_IP_RANGE -> PUBLIC_ADDRESS
```

The keyword `map` starts the rule.

Replace *`IF`* with the external interface.

The *`LAN_IP_RANGE`* is what your internal clients use for IP Addressing, usually this is something like `192.168.1.0/24` .

The *`PUBLIC_ADDRESS`* can either be the external IP address or the special keyword `0/32`, which means to use the IP address assigned to *`IF`*.

29.5.17. How NAT works

A packet arrives at the firewall from the LAN with a public destination. It passes through the outbound filter rules, NAT gets his turn at the packet and applies its rules top down, first matching rule wins. NAT tests each of its rules against the packets interface name and source IP address. When a packets interface name matches a NAT rule then the [source IP address, i.e. private LAN IP address] of the packet is checked to see if it falls within the IP address range specified to the left of the arrow symbol on the NAT rule. On a match the packet has its source IP address

rewritten with the public IP address obtained by the `0/32` keyword. NAT posts a entry in its internal NAT table so when the packet returns from the public Internet it can be mapped back to its original private IP address and then passed to the filter rules for processing.

29.5.18. Enabling IPNAT

To enable IPNAT add these statements to `/etc/rc.conf` .

To enable your machine to route traffic between interfaces:

```
gateway_enable="YES"
```

To start IPNAT automatically each time:

```
ipnat_enable="YES"
```

To specify where to load the IPNAT rules from:

```
ipnat_rules="/etc/ipnat.rules"
```

29.5.19. NAT for a very large LAN

For networks that have large numbers of PC's on the LAN or networks with more than a single LAN, the process of funneling all those private IP addresses into a single public IP address becomes a resource problem that may cause problems with the same port numbers being used many times across many NATed LAN PC's, causing collisions. There are two ways to relieve this resource problem.

29.5.19.1. Assigning Ports to Use

A normal NAT rule would look like:

```
map dc0 192.168.1.0/24 -> 0/32
```

In the above rule the packet's source port is unchanged as the packet passes through IPNAT. By adding the portmap keyword you can tell IPNAT to only use source ports in a range. For example the following rule will tell IPNAT to modify the source port to be within that range:

```
map dc0 192.168.1.0/24 -> 0/32 portmap tcp/udp 20000:60000
```

Additionally we can make things even easier by using the `auto` keyword to tell IPNAT to determine by itself which ports are available to use:

```
map dc0 192.168.1.0/24 -> 0/32 portmap tcp/udp auto
```

29.5.19.2. Using a pool of public addresses

In very large LANs there comes a point where there are just too many LAN addresses to fit into a single public address. By changing the following rule:

```
map dc0 192.168.1.0/24 -> 204.134.75.1
```

Currently this rule maps all connections through `204.134.75.1` . This can be changed to specify a range:

```
map dc0 192.168.1.0/24 -> 204.134.75.1-10
```

Or a subnet using CIDR notation such as:

```
map dc0 192.168.1.0/24 -> 204.134.75.0/24
```

29.5.20. Port Redirection

A very common practice is to have a web server, email server, database server and DNS server each segregated to a different PC on the LAN. In this case the traffic from these servers still have to be NATed, but there has to be some

way to direct the inbound traffic to the correct LAN PCs. IPNAT has the redirection facilities of NAT to solve this problem. Lets say you have your web server on LAN address `10.0.10.25` and your single public IP address is `20.20.20.5` you would code the rule like this:

```
rdr dc0 20.20.20.5/32 port 80 -> 10.0.10.25 port 80
```

or:

```
rdr dc0 0/32 port 80 -> 10.0.10.25 port 80
```

or for a LAN DNS Server on LAN address of `10.0.10.33` that needs to receive public DNS requests:

```
rdr dc0 20.20.20.5/32 port 53 -> 10.0.10.33 port 53 udp
```

29.5.21. FTP and NAT

FTP is a dinosaur left over from the time before the Internet as it is known today, when research universities were leased lined together and FTP was used to share files among research Scientists. This was a time when data security was not a consideration. Over the years the FTP protocol became buried into the backbone of the emerging Internet and its username and password being sent in clear text was never changed to address new security concerns. FTP has two flavors, it can run in active mode or passive mode. The difference is in how the data channel is acquired. Passive mode is more secure as the data channel is acquired be the ordinal ftp session requester. For a real good explanation of FTP and the different modes see `http://www.slacksite.com/other/ftp.html` .

29.5.21.1. IPNAT Rules

IPNAT has a special built in FTP proxy option which can be specified on the NAT map rule. It can monitor all outbound packet traffic for FTP active or passive start session requests and dynamically create temporary filter rules containing only the port number really in use for the data channel. This eliminates the security risk FTP normally exposes the firewall to from having large ranges of high order port numbers open.

This rule will handle all the traffic for the internal LAN:

```
map dc0 10.0.10.0/29 -> 0/32 proxy port 21 ftp/tcp
```

This rule handles the FTP traffic from the gateway:

```
map dc0 0.0.0.0/0 -> 0/32 proxy port 21 ftp/tcp
```

This rule handles all non-FTP traffic from the internal LAN:

```
map dc0 10.0.10.0/29 -> 0/32
```

The FTP map rule goes before our regular map rule. All packets are tested against the first rule from the top. Matches on interface name, then private LAN source IP address, and then is it a FTP packet. If all that matches then the special FTP proxy creates temp filter rules to let the FTP session packets pass in and out, in addition to also NATing the FTP packets. All LAN packets that are not FTP do not match the first rule and fall through to the third rule and are tested, matching on interface and source IP, then are NATed.

29.5.21.2. IPNAT FTP Filter Rules

Only one filter rule is needed for FTP if the NAT FTP proxy is used.

Without the FTP Proxy you will need the following three rules:

```
# Allow out LAN PC client FTP to public Internet
# Active and passive modes
pass out quick on rl0 proto tcp from any to any port = 21 flags S keep state

# Allow out passive mode data channel high order port numbers
pass out quick on rl0 proto tcp from any to any port > 1024 flags S keep state
```

```
# Active mode let data channel in from FTP server
pass in quick on rl0 proto tcp from any to any port = 20 flags S keep state
```

29.5.21.3. FTP NAT Proxy Bug

As of FreeBSD 4.9 which includes IPFILTER version 3.4.31 the FTP proxy works as documented during the FTP session until the session is told to close. When the close happens packets returning from the remote FTP server are blocked and logged coming in on port 21. The NAT FTP/proxy appears to remove its temp rules prematurely, before receiving the response from the remote FTP server acknowledging the close. A problem report was posted to the IPF mailing list.

The solution is to add a filter rule to get rid of these unwanted log messages or do nothing and ignore FTP inbound error messages in your log. Most people do not use outbound FTP too often.

```
block in quick on rl0 proto tcp from any to any port = 21
```

29.6. IPFW

注意

此一節的內容仍在陸續補充、更新，所以本節內容可能並未完全符合現況。.

The IPFIREWALL (IPFW) is a FreeBSD sponsored firewall software application authored and maintained by FreeBSD volunteer staff members. It uses the legacy stateless rules and a legacy rule coding technique to achieve what is referred to as Simple Stateful logic.

The IPFW sample rule set (found in `/etc/rc.firewall`) in the standard FreeBSD install is rather simple and it is not expected that it used directly without modifications. The example does not use stateful filtering, which is beneficial in most setups, so it will not be used as base for this section.

The IPFW stateless rule syntax is empowered with technically sophisticated selection capabilities which far surpasses the knowledge level of the customary firewall installer. IPFW is targeted at the professional user or the advanced technical computer hobbyist who have advanced packet selection requirements. A high degree of detailed knowledge into how different protocols use and create their unique packet header information is necessary before the power of the IPFW rules can be unleashed. Providing that level of explanation is out of the scope of this section of the handbook.

IPFW is composed of seven components, the primary component is the kernel firewall filter rule processor and its integrated packet accounting facility, the logging facility, the 'divert' rule which triggers the NAT facility, and the advanced special purpose facilities, the dummynet traffic shaper facilities, the 'fwd rule' forward facility, the bridge facility, and the ipstealth facility.

29.6.1. Enabling IPFW

IPFW is included in the basic FreeBSD install as a separate run time loadable module. The system will dynamically load the kernel module when the `rc.conf` statement `firewall_enable="YES"` is used. You do not need to compile IPFW into the FreeBSD kernel unless you want NAT function enabled.

After rebooting your system with `firewall_enable="YES"` in `rc.conf` the following white highlighted message is displayed on the screen as part of the boot process:

```
ipfw2 initialized, divert disabled, rule-based forwarding disabled, default to deny, ↺
logging disabled
```

The loadable module does have logging ability compiled in. To enable logging and set the verbose logging limit, there is a knob you can set in `/etc/sysctl.conf` by adding these statements, logging will be enabled on future reboots:

```
net.inet.ip.fw.verbose=1
net.inet.ip.fw.verbose_limit=5
```

29.6.2. Kernel Options

It is not a mandatory requirement that you enable IPFW by compiling the following options into the FreeBSD kernel unless you need NAT function. It is presented here as background information.

```
options    IPFIREWALL
```

This option enables IPFW as part of the kernel

```
options    IPFIREWALL_VERBOSE
```

Enables logging of packets that pass through IPFW and have the 'log' keyword specified in the rule set.

```
options    IPFIREWALL_VERBOSE_LIMIT=5
```

Limits the number of packets logged through syslogd(8) on a per entry basis. You may wish to use this option in hostile environments which you want to log firewall activity. This will close a possible denial of service attack via syslog flooding.

```
options    IPFIREWALL_DEFAULT_TO_ACCEPT
```

This option will allow everything to pass through the firewall by default, which is a good idea when you are first setting up your firewall.

```
options    IPV6FIREWALL
options    IPV6FIREWALL_VERBOSE
options    IPV6FIREWALL_VERBOSE_LIMIT
options    IPV6FIREWALL_DEFAULT_TO_ACCEPT
```

These options are exactly the same as the IPv4 options but they are for IPv6. If you do not use IPv6 you might want to use IPV6FIREWALL without any rules to block all IPv6

```
options    IPDIVERT
```

This enables the use of NAT functionality.

注意

If you do not include IPFIREWALL_DEFAULT_TO_ACCEPT or set your rules to allow incoming packets you will block all packets going to and from this machine.

29.6.3. `/etc/rc.conf` Options

If you do not have IPFW compiled into your kernel you will need to load it with the following statement in your `/etc/rc.conf` :

```
firewall_enable="YES"
```

Set the script to run to activate your rules:

```
firewall_script="/etc/ipfw.rules"
```

Enable logging:

```
firewall_logging="YES"
```

警告

The only thing that the `firewall_logging` variable will do is setting the `net.inet.ip.fw.verbose` sysctl variable to the value of `1` (see 節 29.6.1, "Enabling IPFW"). There is no `rc.conf` variable to set log limitations, but it can be set via sysctl variable, manually or from the `/etc/sysctl.conf` file:

```
net.inet.ip.fw.verbose_limit=5
```

If your machine is acting as a gateway, i.e. providing Network Address Translation (NAT) via natd(8), please refer to 節 30.9, "Network Address Translation" for information regarding the required `/etc/rc.conf` options.

29.6.4. The IPFW Command

The ipfw command is the normal vehicle for making manual single rule additions or deletions to the firewall active internal rules while it is running. The problem with using this method is once your system is shutdown or halted all the rules you added or changed or deleted are lost. Writing all your rules in a file and using that file to load the rules at boot time, or to replace in mass the currently running firewall rules with changes you made to the files content is the recommended method used here.

The ipfw command is still a very useful to display the running firewall rules to the console screen. The IPFW accounting facility dynamically creates a counter for each rule that counts each packet that matches the rule. During the process of testing a rule, listing the rule with its counter is the one of the ways of determining if the rule is functioning.

To list all the rules in sequence:

```
# ipfw list
```

To list all the rules with a time stamp of when the last time the rule was matched:

```
# ipfw -t list
```

To list the accounting information, packet count for matched rules along with the rules themselves. The first column is the rule number, followed by the number of outgoing matched packets, followed by the number of incoming matched packets, and then the rule itself.

```
# ipfw -a list
```

List the dynamic rules in addition to the static rules:

```
# ipfw -d list
```

Also show the expired dynamic rules:

```
# ipfw -d -e list
```

Zero the counters:

```
# ipfw zero
```

Zero the counters for just rule *NUM*:

```
# ipfw zero NUM
```

29.6.5. IPFW Rule Sets

A rule set is a group of ipfw rules coded to allow or deny packets based on the values contained in the packet. The bi-directional exchange of packets between hosts comprises a session conversation. The firewall rule set processes the packet twice: once on its arrival from the public Internet host and again as it leaves for its return trip back to the public Internet host. Each tcp/ip service (i.e. telnet, www, mail, etc.) is predefined by its protocol, and port number. This is the basic selection criteria used to create rules which will allow or deny services.

When a packet enters the firewall it is compared against the first rule in the rule set and progress one rule at a time moving from top to bottom of the set in ascending rule number sequence order. When the packet matches a rule selection parameters, the rules action field value is executed and the search of the rule set terminates for that packet. This is referred to as 「the first match wins」 search method. If the packet does not match any of the rules, it gets caught by the mandatory ipfw default rule, number 65535 which denies all packets and discards them without any reply back to the originating destination.

注意

The search continues after `count`, `skipto` and `tee` rules.

The instructions contained here are based on using rules that contain the stateful 'keep state', 'limit', 'in'/'out', and via options. This is the basic framework for coding an inclusive type firewall rule set.

An inclusive firewall only allows services matching the rules through. This way you can control what services can originate behind the firewall destine for the public Internet and also control the services which can originate from the public Internet accessing your private network. Everything else is denied by default design. Inclusive firewalls are much, much more secure than exclusive firewall rule sets and is the only rule set type covered here in.

警告

When working with the firewall rules be careful, you can end up locking your self out.

29.6.5.1. Rule Syntax

The rule syntax presented here has been simplified to what is necessary to create a standard inclusive type firewall rule set. For a complete rule syntax description see the ipfw(8) manual page.

Rules contain keywords: these keywords have to be coded in a specific order from left to right on the line. Keywords are identified in bold type. Some keywords have sub-options which may be keywords them selves and also include more sub-options.

is used to mark the start of a comment and may appear at the end of a rule line or on its own lines. Blank lines are ignored.

CMD RULE_NUMBER ACTION LOGGING SELECTION STATEFUL

29.6.5.1.1. CMD

Each new rule has to be prefixed with ***add*** to add the rule to the internal table.

29.6.5.1.2. RULE_NUMBER

Each rule has to have a rule number to go with it.

29.6.5.1.3. ACTION

A rule can be associated with one of the following actions, which will be executed when the packet matches the selection criterion of the rule.

allow | accept | pass | permit

These all mean the same thing which is to allow packets that match the rule to exit the firewall rule processing. The search terminates at this rule.

check-state

Checks the packet against the dynamic rules table. If a match is found, execute the action associated with the rule which generated this dynamic rule, otherwise move to the next rule. The check-state rule does not have selection criterion. If no check-state rule is present in the rule set, the dynamic rules table is checked at the first keep-state or limit rule.

deny | drop

Both words mean the same thing which is to discard packets that match this rule. The search terminates.

29.6.5.1.4. Logging

log or *logamount*

When a packet matches a rule with the log keyword, a message will be logged to syslogd with a facility name of SECURITY. The logging only occurs if the number of packets logged so far for that particular rule does not exceed the logamount parameter. If no logamount is specified, the limit is taken from the sysctl variable net.inet.ip.fw.verbose_limit. In both cases, a value of zero removes the logging limit. Once the limit is reached, logging can be re-enabled by clearing the logging counter or the packet counter for that rule, see the ipfw reset log command.

注意

Logging is done after all other packet matching conditions have been successfully verified, and before performing the final action (accept, deny) on the packet. It is up to you to decide which rules you want to enable logging on.

29.6.5.1.5. Selection

The keywords described in this section are used to describe attributes of the packet to be interrogated when determining whether rules match the packet or not. The following general-purpose attributes are provided for matching, and must be used in this order:

udp | tcp | icmp

or any protocol names found in `/etc/protocols` are recognized and may be used. The value specified is protocol to be matched against. This is a mandatory requirement.

from src to dst

The from and to keywords are used to match against IP addresses. Rules must specify BOTH source and destination parameters. `any` is a special keyword that matches any IP address. `me` is a special keyword that matches any IP address configured on an interface in your FreeBSD system to represent the PC the firewall is running on (i.e. this box) as in 'from me to any' or 'from any to me' or 'from 0.0.0.0/0 to any' or 'from any to 0.0.0.0/0' or 'from 0.0.0.0 to any' or 'from any to 0.0.0.0' or 'from me to 0.0.0.0'. IP addresses are specified as a dotted IP address numeric form/mask-length, or as single dotted IP address numeric form. This is a mandatory requirement. See this link for help on writing mask-lengths. `http://jodies.de/ipcalc`

port number

For protocols which support port numbers (such as TCP and UDP). It is mandatory that you code the port number of the service you want to match on. Service names (from `/etc/services`) may be used instead of numeric port values.

in | out

Matches incoming or outgoing packets, respectively. The in and out are keywords and it is mandatory that you code one or the other as part of your rule matching criterion.

via IF

Matches packets going through the interface specified by exact name. The `via` keyword causes the interface to always be checked as part of the match process.

setup

This is a mandatory keyword that identifies the session start request for TCP packets.

keep-state

This is a mandatory> keyword. Upon a match, the firewall will create a dynamic rule, whose default behavior is to match bidirectional traffic between source and destination IP/port using the same protocol.

limit {src-addr | src-port | dst-addr | dst-port}

The firewall will only allow ***N*** connections with the same set of parameters as specified in the rule. One or more of source and destination addresses and ports can be specified. The 'limit' and 'keep-state' can not be used on same rule. Limit provides the same stateful function as 'keep-state' plus its own functions.

29.6.5.2. Stateful Rule Option

Stateful filtering treats traffic as a bi-directional exchange of packets comprising a session conversation. It has the interrogation abilities to determine if the session conversation between the originating sender and the destination are following the valid procedure of bi-directional packet exchange. Any packets that do not properly fit the session conversation template are automatically rejected as impostors.

'check-state' is used to identify where in the IPFW rules set the packet is to be tested against the dynamic rules facility. On a match the packet exits the firewall to continue on its way and a new rule is dynamic created for the next anticipated packet being exchanged during this bi-directional session conversation. On a no match the packet advances to the next rule in the rule set for testing.

The dynamic rules facility is vulnerable to resource depletion from a SYN-flood attack which would open a huge number of dynamic rules. To counter this attack, FreeBSD version 4.5 added another new option named limit. This option is used to limit the number of simultaneous session conversations by interrogating the rules source or destinations fields as directed by the limit option and using the packet's IP address found there, in a search of the open dynamic rules counting the number of times this rule and IP address combination occurred, if this count is greater that the value specified on the limit option, the packet is discarded.

29.6.5.3. Logging Firewall Messages

The benefits of logging are obvious: it provides the ability to review after the fact the rules you activated logging on which provides information like, what packets had been dropped, what addresses they came from, where they were going, giving you a significant edge in tracking down attackers.

Even with the logging facility enabled, IPFW will not generate any rule logging on it's own. The firewall administrator decides what rules in the rule set he wants to log and adds the log verb to those rules. Normally only deny rules are logged, like the deny rule for incoming ICMP pings. It is very customary to duplicate the ipfw default deny everything rule with the log verb included as your last rule in the rule set. This way you get to see all the packets that did not match any of the rules in the rule set.

Logging is a two edged sword, if you are not careful, you can lose yourself in the over abundance of log data and fill your disk up with growing log files. DoS attacks that fill up disk drives is one of the oldest attacks around. These log message are not only written to syslogd, but also are displayed on the root console screen and soon become very annoying.

The `IPFIREWALL_VERBOSE_LIMIT=5` kernel option limits the number of consecutive messages sent to the system logger syslogd, concerning the packet matching of a given rule. When this option is enabled in the kernel, the number of consecutive messages concerning a particular rule is capped at the number specified. There is nothing to be gained from 200 log messages saying the same identical thing. For instance, five consecutive messages concerning a particular rule would be logged to syslogd, the remainder identical consecutive messages would be counted and posted to the syslogd with a phrase like this:

```
last message repeated 45 times
```

All logged packets messages are written by default to `/var/log/security` file, which is defined in the `/etc/syslog.conf` file.

29.6.5.4. Building a Rule Script

Most experienced IPFW users create a file containing the rules and code them in a manner compatible with running them as a script. The major benefit of doing this is the firewall rules can be refreshed in mass without the need of rebooting the system to activate the new rules. This method is very convenient in testing new rules as the procedure can be executed as many times as needed. Being a script, you can use symbolic substitution to code frequent used values and substitution them in multiple rules. You will see this in the following example.

The script syntax used here is compatible with the 'sh', 'csh', 'tcsh' shells. Symbolic substitution fields are prefixed with a dollar sign $. Symbolic fields do not have the $ prefix. The value to populate the Symbolic field must be enclosed to "double quotes".

Start your rules file like this:

```
############### start of example ipfw rules script #############
#
ipfw -q -f flush       # Delete all rules
# Set defaults
oif="tun0"             # out interface
odns="192.0.2.11"      # ISP's DNS server IP address
cmd="ipfw -q add "     # build rule prefix
ks="keep-state"        # just too lazy to key this each time
$cmd 00500 check-state
$cmd 00502 deny all from any to any frag
$cmd 00501 deny tcp from any to any established
$cmd 00600 allow tcp from any to any 80 out via $oif setup $ks
$cmd 00610 allow tcp from any to $odns 53 out via $oif setup $ks
$cmd 00611 allow udp from any to $odns 53 out via $oif $ks
################### End of example ipfw rules script ############
```

That is all there is to it. The rules are not important in this example, how the Symbolic substitution field are populated and used are.

If the above example was in `/etc/ipfw.rules` file, you could reload these rules by entering on the command line.

```
# sh /etc/ipfw.rules
```

The `/etc/ipfw.rules` file could be located anywhere you want and the file could be named any thing you would like.

The same thing could also be accomplished by running these commands by hand:

```
# ipfw -q -f flush
# ipfw -q add check-state
# ipfw -q add deny all from any to any frag
```

```
# ipfw -q add deny tcp from any to any established
# ipfw -q add allow tcp from any to any 80 out via tun0 setup keep-state
# ipfw -q add allow tcp from any to 192.0.2.11 53 out via tun0 setup ↺
keep-state
# ipfw -q add 00611 allow udp from any to 192.0.2.11 53 out via tun0 ↺
keep-state
```

29.6.5.5. Stateful Ruleset

The following non-NATed rule set is an example of how to code a very secure 'inclusive' type of firewall. An inclusive firewall only allows services matching pass rules through and blocks all other by default. All firewalls have at the minimum two interfaces which have to have rules to allow the firewall to function.

All UNIX® flavored operating systems, FreeBSD included, are designed to use interface `lo0` and IP address `127.0.0.1` for internal communication with in the operating system. The firewall rules must contain rules to allow free unmolested movement of these special internally used packets.

The interface which faces the public Internet, is the one which you code your rules to authorize and control access out to the public Internet and access requests arriving from the public Internet. This can be your ppp `tun0` interface or your NIC that is connected to your DSL or cable modem.

In cases where one or more than one NIC are connected to a private LANs behind the firewall, those interfaces must have rules coded to allow free unmolested movement of packets originating from those LAN interfaces.

The rules should be first organized into three major sections, all the free unmolested interfaces, public interface outbound, and the public interface inbound.

The order of the rules in each of the public interface sections should be in order of the most used rules being placed before less often used rules with the last rule in the section being a block log all packets on that interface and direction.

The Outbound section in the following rule set only contains 'allow' rules which contain selection values that uniquely identify the service that is authorized for public Internet access. All the rules have the, proto, port, in/out, via and keep state option coded. The 'proto tcp' rules have the 'setup' option included to identify the start session request as the trigger packet to be posted to the keep state stateful table.

The Inbound section has all the blocking of undesirable packets first for two different reasons. First is these things being blocked may be part of an otherwise valid packet which may be allowed in by the later authorized service rules. Second reason is that by having a rule that explicitly blocks selected packets that I receive on an infrequent bases and do not want to see in the log, this keeps them from being caught by the last rule in the section which blocks and logs all packets which have fallen through the rules. The last rule in the section which blocks and logs all packets is how you create the legal evidence needed to prosecute the people who are attacking your system.

Another thing you should take note of, is there is no response returned for any of the undesirable stuff, their packets just get dropped and vanish. This way the attackers has no knowledge if his packets have reached your system. The less the attackers can learn about your system the more secure it is. When you log packets with port numbers you do not recognize, look the numbers up in `/etc/services/` or go to `http://www.securitystats.com/tools/portsearch.php` and do a port number lookup to find what the purpose of that port number is. Check out this link for port numbers used by Trojans: `http://www.simovits.com/trojans/trojans.html` .

29.6.5.6. An Example Inclusive Ruleset

The following non-NATed rule set is a complete inclusive type ruleset. You can not go wrong using this rule set for you own. Just comment out any pass rules for services you do not want. If you see messages in your log that you want to stop seeing just add a deny rule in the inbound section. You have to change the 'dc0' interface name in every rule to the interface name of the NIC that connects your system to the public Internet. For user ppp it would be 'tun0'.

You will see a pattern in the usage of these rules.

- All statements that are a request to start a session to the public Internet use keep-state.
- All the authorized services that originate from the public Internet have the limit option to stop flooding.
- All rules use in or out to clarify direction.
- All rules use via interface name to specify the interface the packet is traveling over.

The following rules go into `/etc/ipfw.rules` .

```
################ Start of IPFW rules file ###############################
# Flush out the list before we begin.
ipfw -q -f flush

# Set rules command prefix
cmd="ipfw -q add"
pif="dc0"     # public interface name of NIC
              # facing the public Internet

######################################################################
# No restrictions on Inside LAN Interface for private network
# Not needed unless you have LAN.
# Change xl0 to your LAN NIC interface name
######################################################################
#$cmd 00005 allow all from any to any via xl0

######################################################################
# No restrictions on Loopback Interface
######################################################################
$cmd 00010 allow all from any to any via lo0

######################################################################
# Allow the packet through if it has previous been added to the
# the "dynamic" rules table by a allow keep-state statement.
######################################################################
$cmd 00015 check-state

######################################################################
# Interface facing Public Internet (Outbound Section)
# Interrogate session start requests originating from behind the
# firewall on the private network or from this gateway server
# destine for the public Internet.
######################################################################

# Allow out access to my ISP's Domain name server.
# x.x.x.x must be the IP address of your ISP.s DNS
# Dup these lines if your ISP has more than one DNS server
# Get the IP addresses from /etc/resolv.conf file
$cmd 00110 allow tcp from any to x.x.x.x 53 out via $pif setup keep-state
$cmd 00111 allow udp from any to x.x.x.x 53 out via $pif keep-state

# Allow out access to my ISP's DHCP server for cable/DSL configurations.
# This rule is not needed for .user ppp. connection to the public Internet.
# so you can delete this whole group.
# Use the following rule and check log for IP address.
# Then put IP address in commented out rule & delete first rule
$cmd 00120 allow log udp from any to any 67 out via $pif keep-state
#$cmd 00120 allow udp from any to x.x.x.x 67 out via $pif keep-state

# Allow out non-secure standard www function
$cmd 00200 allow tcp from any to any 80 out via $pif setup keep-state

# Allow out secure www function https over TLS SSL
$cmd 00220 allow tcp from any to any 443 out via $pif setup keep-state

# Allow out send & get email function
```

```
$cmd 00230 allow tcp from any to any 25 out via $pif setup keep-state
$cmd 00231 allow tcp from any to any 110 out via $pif setup keep-state

# Allow out FBSD (make install & CVSUP) functions
# Basically give user root "GOD" privileges.
$cmd 00240 allow tcp from me to any out via $pif setup keep-state uid root

# Allow out ping
$cmd 00250 allow icmp from any to any out via $pif keep-state

# Allow out Time
$cmd 00260 allow tcp from any to any 37 out via $pif setup keep-state

# Allow out nntp news (i.e. news groups)
$cmd 00270 allow tcp from any to any 119 out via $pif setup keep-state

# Allow out secure FTP, Telnet, and SCP
# This function is using SSH (secure shell)
$cmd 00280 allow tcp from any to any 22 out via $pif setup keep-state

# Allow out whois
$cmd 00290 allow tcp from any to any 43 out via $pif setup keep-state

# deny and log everything else that.s trying to get out.
# This rule enforces the block all by default logic.
$cmd 00299 deny log all from any to any out via $pif

#################################################################
# Interface facing Public Internet (Inbound Section)
# Interrogate packets originating from the public Internet
# destine for this gateway server or the private network.
#################################################################

# Deny all inbound traffic from non-routable reserved address spaces
$cmd 00300 deny all from 192.168.0.0/16 to any in via $pif  #RFC 1918 private IP
$cmd 00301 deny all from 172.16.0.0/12 to any in via $pif     #RFC 1918 private IP
$cmd 00302 deny all from 10.0.0.0/8 to any in via $pif          #RFC 1918 private IP
$cmd 00303 deny all from 127.0.0.0/8 to any in via $pif        #loopback
$cmd 00304 deny all from 0.0.0.0/8 to any in via $pif            #loopback
$cmd 00305 deny all from 169.254.0.0/16 to any in via $pif   #DHCP auto-config
$cmd 00306 deny all from 192.0.2.0/24 to any in via $pif       #reserved for docs
$cmd 00307 deny all from 204.152.64.0/23 to any in via $pif  #Sun cluster interconnect
$cmd 00308 deny all from 224.0.0.0/3 to any in via $pif         #Class D & E multicast

# Deny public pings
$cmd 00310 deny icmp from any to any in via $pif

# Deny ident
$cmd 00315 deny tcp from any to any 113 in via $pif

# Deny all Netbios service. 137=name, 138=datagram, 139=session
# Netbios is MS/Windows sharing services.
# Block MS/Windows hosts2 name server requests 81
$cmd 00320 deny tcp from any to any 137 in via $pif
$cmd 00321 deny tcp from any to any 138 in via $pif
$cmd 00322 deny tcp from any to any 139 in via $pif
$cmd 00323 deny tcp from any to any 81 in via $pif

# Deny any late arriving packets
$cmd 00330 deny all from any to any frag in via $pif

# Deny ACK packets that did not match the dynamic rule table
$cmd 00332 deny tcp from any to any established in via $pif

# Allow traffic in from ISP's DHCP server. This rule must contain
# the IP address of your ISP.s DHCP server as it.s the only
```

```
# authorized source to send this packet type.
# Only necessary for cable or DSL configurations.
# This rule is not needed for .user ppp. type connection to
# the public Internet. This is the same IP address you captured
# and used in the outbound section.
#$cmd 00360 allow udp from any to x.x.x.x 67 in via $pif keep-state

# Allow in standard www function because I have apache server
$cmd 00400 allow tcp from any to me 80 in via $pif setup limit src-addr 2

# Allow in secure FTP, Telnet, and SCP from public Internet
$cmd 00410 allow tcp from any to me 22 in via $pif setup limit src-addr 2

# Allow in non-secure Telnet session from public Internet
# labeled non-secure because ID & PW are passed over public
# Internet as clear text.
# Delete this sample group if you do not have telnet server enabled.
$cmd 00420 allow tcp from any to me 23 in via $pif setup limit src-addr 2

# Reject & Log all incoming connections from the outside
$cmd 00499 deny log all from any to any in via $pif

# Everything else is denied by default
# deny and log all packets that fell through to see what they are
$cmd 00999 deny log all from any to any
################ End of IPFW rules file ################################
```

29.6.5.7. An Example NAT and Stateful Ruleset

There are some additional configuration statements that need to be enabled to activate the NAT function of IPFW. The kernel source needs 'option divert' statement added to the other IPFIREWALL statements compiled into a custom kernel.

In addition to the normal IPFW options in `/etc/rc.conf` , the following are needed.

```
natd_enable="YES"                   # Enable NATD function
natd_interface="rl0"                # interface name of public Internet NIC
natd_flags="-dynamic -m"            # -m = preserve port numbers if possible
```

Utilizing stateful rules with divert natd rule (Network Address Translation) greatly complicates the rule set coding logic. The positioning of the check-state, and 'divert natd' rules in the rule set becomes very critical. This is no longer a simple fall-through logic flow. A new action type is used, called 'skipto'. To use the skipto command it is mandatory that you number each rule so you know exactly where the skipto rule number is you are really jumping to.

The following is an uncommented example of one coding method, selected here to explain the sequence of the packet flow through the rule sets.

The processing flow starts with the first rule from the top of the rule file and progress one rule at a time deeper into the file until the end is reach or the packet being tested to the selection criteria matches and the packet is released out of the firewall. It is important to take notice of the location of rule numbers 100 101, 450, 500, and 510. These rules control the translation of the outbound and inbound packets so their entries in the keep-state dynamic table always register the private LAN IP address. Next notice that all the allow and deny rules specified the direction the packet is going (IE outbound or inbound) and the interface. Also notice that all the start outbound session requests all skipto rule 500 for the network address translation.

Lets say a LAN user uses their web browser to get a web page. Web pages use port 80 to communicate over. So the packet enters the firewall, It does not match 100 because it is headed out not in. It passes rule 101 because this is the first packet so it has not been posted to the keep-state dynamic table yet. The packet finally comes to rule 125 a matches. It is outbound through the NIC facing the public Internet. The packet still has it's source IP address as a private LAN IP address. On the match to this rule, two actions take place. The keep-state option will post this rule into the keep-state dynamic rules table and the specified action is executed. The action is part of the info posted to

the dynamic table. In this case it is "skipto rule 500". Rule 500 NATs the packet IP address and out it goes. Remember this, this is very important. This packet makes its way to the destination and returns and enters the top of the rule set. This time it does match rule 100 and has it destination IP address mapped back to its corresponding LAN IP address. It then is processed by the check-state rule, it's found in the table as an existing session conversation and released to the LAN. It goes to the LAN PC that sent it and a new packet is sent requesting another segment of the data from the remote server. This time it gets checked by the check-state rule and its outbound entry is found, the associated action, 'skipto 500', is executed. The packet jumps to rule 500 gets NATed and released on it's way out.

On the inbound side, everything coming in that is part of an existing session conversation is being automatically handled by the check-state rule and the properly placed divert natd rules. All we have to address is denying all the bad packets and only allowing in the authorized services. Lets say there is a apache server running on the firewall box and we want people on the public Internet to be able to access the local web site. The new inbound start request packet matches rule 100 and its IP address is mapped to LAN IP for the firewall box. The packet is them matched against all the nasty things we want to check for and finally matches against rule 425. On a match two things occur. The packet rule is posted to the keep-state dynamic table but this time any new session requests originating from that source IP address is limited to 2. This defends against DoS attacks of service running on the specified port number. The action is allow so the packet is released to the LAN. On return the check-state rule recognizes the packet as belonging to an existing session conversation sends it to rule 500 for NATing and released to outbound interface.

Example Ruleset #1:

```
#!/bin/sh
cmd="ipfw -q add"
skip="skipto 500"
pif=rl0
ks="keep-state"
good_tcpo="22,25,37,43,53,80,443,110,119"

ipfw -q -f flush

$cmd 002 allow all from any to any via xl0  # exclude LAN traffic
$cmd 003 allow all from any to any via lo0  # exclude loopback traffic

$cmd 100 divert natd ip from any to any in via $pif
$cmd 101 check-state

# Authorized outbound packets
$cmd 120 $skip udp from any to xx.168.240.2 53 out via $pif $ks
$cmd 121 $skip udp from any to xx.168.240.5 53 out via $pif $ks
$cmd 125 $skip tcp from any to any $good_tcpo out via $pif setup $ks
$cmd 130 $skip icmp from any to any out via $pif $ks
$cmd 135 $skip udp from any to any 123 out via $pif $ks


# Deny all inbound traffic from non-routable reserved address spaces
$cmd 300 deny all from 192.168.0.0/16  to any in via $pif  #RFC 1918 private IP
$cmd 301 deny all from 172.16.0.0/12   to any in via $pif  #RFC 1918 private IP
$cmd 302 deny all from 10.0.0.0/8      to any in via $pif  #RFC 1918 private IP
$cmd 303 deny all from 127.0.0.0/8     to any in via $pif  #loopback
$cmd 304 deny all from 0.0.0.0/8       to any in via $pif  #loopback
$cmd 305 deny all from 169.254.0.0/16  to any in via $pif  #DHCP auto-config
$cmd 306 deny all from 192.0.2.0/24    to any in via $pif  #reserved for docs
$cmd 307 deny all from 204.152.64.0/23 to any in via $pif  #Sun cluster
$cmd 308 deny all from 224.0.0.0/3     to any in via $pif  #Class D & E multicast

# Authorized inbound packets
$cmd 400 allow udp from xx.70.207.54 to any 68 in $ks
$cmd 420 allow tcp from any to me 80 in via $pif setup limit src-addr 1


$cmd 450 deny log ip from any to any
```

```
# This is skipto location for outbound stateful rules
$cmd 500 divert natd ip from any to any out via $pif
$cmd 510 allow ip from any to any

######################## end of rules  #################
```

The following is pretty much the same as above, but uses a self documenting coding style full of description comments to help the inexperienced IPFW rule writer to better understand what the rules are doing.

Example Ruleset #2:

```
#!/bin/sh
################ Start of IPFW rules file ###############################
# Flush out the list before we begin.
ipfw -q -f flush

# Set rules command prefix
cmd="ipfw -q add"
skip="skipto 800"
pif="rl0"     # public interface name of NIC
              # facing the public Internet

#####################################################################
# No restrictions on Inside LAN Interface for private network
# Change xl0 to your LAN NIC interface name
#####################################################################
$cmd 005 allow all from any to any via xl0

#####################################################################
# No restrictions on Loopback Interface
#####################################################################
$cmd 010 allow all from any to any via lo0

#####################################################################
# check if packet is inbound and nat address if it is
#####################################################################
$cmd 014 divert natd ip from any to any in via $pif

#####################################################################
# Allow the packet through if it has previous been added to the
# the "dynamic" rules table by a allow keep-state statement.
#####################################################################
$cmd 015 check-state

#####################################################################
# Interface facing Public Internet (Outbound Section)
# Interrogate session start requests originating from behind the
# firewall on the private network or from this gateway server
# destine for the public Internet.
#####################################################################

# Allow out access to my ISP's Domain name server.
# x.x.x.x must be the IP address of your ISP's DNS
# Dup these lines if your ISP has more than one DNS server
# Get the IP addresses from /etc/resolv.conf file
$cmd 020 $skip tcp from any to x.x.x.x 53 out via $pif setup keep-state


# Allow out access to my ISP's DHCP server for cable/DSL configurations.
$cmd 030 $skip udp from any to x.x.x.x 67 out via $pif keep-state

# Allow out non-secure standard www function
$cmd 040 $skip tcp from any to any 80 out via $pif setup keep-state

# Allow out secure www function https over TLS SSL
$cmd 050 $skip tcp from any to any 443 out via $pif setup keep-state
```

```
# Allow out send & get email function
$cmd 060 $skip tcp from any to any 25 out via $pif setup keep-state
$cmd 061 $skip tcp from any to any 110 out via $pif setup keep-state

# Allow out FreeBSD (make install & CVSUP) functions
# Basically give user root "GOD" privileges.
$cmd 070 $skip tcp from me to any out via $pif setup keep-state uid root

# Allow out ping
$cmd 080 $skip icmp from any to any out via $pif keep-state

# Allow out Time
$cmd 090 $skip tcp from any to any 37 out via $pif setup keep-state

# Allow out nntp news (i.e. news groups)
$cmd 100 $skip tcp from any to any 119 out via $pif setup keep-state

# Allow out secure FTP, Telnet, and SCP
# This function is using SSH (secure shell)
$cmd 110 $skip tcp from any to any 22 out via $pif setup keep-state

# Allow out whois
$cmd 120 $skip tcp from any to any 43 out via $pif setup keep-state

# Allow ntp time server
$cmd 130 $skip udp from any to any 123 out via $pif keep-state

################################################################
# Interface facing Public Internet (Inbound Section)
# Interrogate packets originating from the public Internet
# destine for this gateway server or the private network.
################################################################

# Deny all inbound traffic from non-routable reserved address spaces
$cmd 300 deny all from 192.168.0.0/16  to any in via $pif  #RFC 1918 private IP
$cmd 301 deny all from 172.16.0.0/12   to any in via $pif  #RFC 1918 private IP
$cmd 302 deny all from 10.0.0.0/8      to any in via $pif  #RFC 1918 private IP
$cmd 303 deny all from 127.0.0.0/8     to any in via $pif  #loopback
$cmd 304 deny all from 0.0.0.0/8       to any in via $pif  #loopback
$cmd 305 deny all from 169.254.0.0/16  to any in via $pif  #DHCP auto-config
$cmd 306 deny all from 192.0.2.0/24    to any in via $pif  #reserved for docs
$cmd 307 deny all from 204.152.64.0/23 to any in via $pif  #Sun cluster
$cmd 308 deny all from 224.0.0.0/3     to any in via $pif  #Class D & E multicast

# ## ident
$cmd 315 deny tcp from any to any 113 in via $pif

# ##### Netbios ##. 137=name, 138=datagram, 139=session
# Netbios # MS/Windows ######
# ##### MS/Windows #######hosts2 name server requests 81
$cmd 320 deny tcp from any to any 137 in via $pif
$cmd 321 deny tcp from any to any 138 in via $pif
$cmd 322 deny tcp from any to any 139 in via $pif
$cmd 323 deny tcp from any to any 81  in via $pif

# ############
$cmd 330 deny all from any to any frag in via $pif

# Deny ACK packets that did not match the dynamic rule table
$cmd 332 deny tcp from any to any established in via $pif

# Allow traffic in from ISP's DHCP server. This rule must contain
# the IP address of your ISP's DHCP server as it's the only
# authorized source to send this packet type.
# Only necessary for cable or DSL configurations.
```

```
# This rule is not needed for 'user ppp' type connection to
# the public Internet. This is the same IP address you captured
# and used in the outbound section.
$cmd 360 allow udp from x.x.x.x to any 68 in via $pif keep-state

# Allow in standard www function because I have Apache server
$cmd 370 allow tcp from any to me 80 in via $pif setup limit src-addr 2

# Allow in secure FTP, Telnet, and SCP from public Internet
$cmd 380 allow tcp from any to me 22 in via $pif setup limit src-addr 2

# Allow in non-secure Telnet session from public Internet
# labeled non-secure because ID & PW are passed over public
# Internet as clear text.
# Delete this sample group if you do not have telnet server enabled.
$cmd 390 allow tcp from any to me 23 in via $pif setup limit src-addr 2

# Reject & Log all unauthorized incoming connections from the public Internet
$cmd 400 deny log all from any to any in via $pif

# Reject & Log all unauthorized out going connections to the public Internet
$cmd 450 deny log all from any to any out via $pif

# This is skipto location for outbound stateful rules
$cmd 800 divert natd ip from any to any out via $pif
$cmd 801 allow ip from any to any

# Everything else is denied by default
# deny and log all packets that fell through to see what they are
$cmd 999 deny log all from any to any
################ End of IPFW rules file ################################
```

章 30. 網路進階練功房

30.1. 概述

本章將介紹一些進階的網路設定主題。

讀完這章，您將了解：

- gateway(閘道)及 route(路由)的概念。
- 如何設定 IEEE 802.11 以及藍芽(Bluetooth®)設備。
- 如何以 FreeBSD 作為 bridge(橋接)。
- 如何為無碟系統設定網路開機。
- 如何設定 NAT(Network Address Translation)。
- 如何透過 PLIP 方式來連接兩台電腦。
- 如何在 FreeBSD 內設定 IPv6。
- 如何設定 ATM。
- 如何去善用 FreeBSD 的 CARP(Common Access Redundancy Protocol)功能 。

在開始閱讀這章之前，您需要：

- 瞭解 /etc/rc 相關 script 的概念。
- 熟悉基本常用的網路術語。
- 知道如何設定、安裝新的 FreeBSD kernel (章 8, 設定 FreeBSD Kernel)。
- 知道如何透過 port/package 安裝軟體 (章 4, 軟體套件管理篇：Packages 及 Ports 機制) 。

30.2. Gateways and Routes

Contributed by Coranth Gryphon.

為了讓一部電腦能找到另一部電腦，因此必需要有一種機制， 讓這部電腦知道該怎麼做，這個機制就是路由選擇 (routing)。 一條路由(“route”)是由一對位址所定義的：一個是 “目的地(destination)”以及另一個則是閘道 (“gateway”)。 這對位址表示要送到目的地的封包， 必須經過閘道。 目的地分為三種類型：主機、子網路(subnet)、預設路由(“default route”。 若都沒有其它的路由可以使用， 這時就會使用預設路由，稍後我們會對預設路由作進一步的說明。 此外， 閘道也可分為三種類型：主機、傳輸介面(interface，也稱為 “links”)、乙太網路硬體位址(MAC addresses)。

30.2.1. 範例

為了方便說明不同類型的路由選擇(routing)，以下使用 netstat 指令的結果作為介紹範例：

```
% netstat -r
Routing tables
```

```
Destination      Gateway            Flags     Refs     Use     Netif Expire

default          outside-gw         UGSc       37      418      ppp0
localhost        localhost          UH          0      181       lo0
test0            0:e0:b5:36:cf:4f   UHLW        5    63288       ed0     77
10.20.30.255     link#1             UHLW        1     2421
example.com      link#1             UC          0        0
host1            0:e0:a8:37:8:1e    UHLW        3     4601       lo0
host2            0:e0:a8:37:8:1e    UHLW        0        5       lo0 =>
host2.example.com link#1             UC         0        0
224              link#1             UC          0        0
```

The first two lines specify the default route (which we will cover in the next section) and the `localhost` route.

The interface (`Netif` column) that this routing table specifies to use for `localhost` is `lo0`, also known as the loopback device. This says to keep all traffic for this destination internal, rather than sending it out over the LAN, since it will only end up back where it started.

The next thing that stands out are the addresses beginning with `0:e0:`. These are Ethernet hardware addresses, which are also known as MAC addresses. FreeBSD will automatically identify any hosts (`test0` in the example) on the local Ethernet and add a route for that host, directly to it over the Ethernet interface, `ed0`. There is also a timeout (`Expire` column) associated with this type of route, which is used if we fail to hear from the host in a specific amount of time. When this happens, the route to this host will be automatically deleted. These hosts are identified using a mechanism known as RIP (Routing Information Protocol), which figures out routes to local hosts based upon a shortest path determination.

FreeBSD will also add subnet routes for the local subnet (`10.20.30.255` is the broadcast address for the subnet `10.20.30`, and `example.com` is the domain name associated with that subnet). The designation `link#1` refers to the first Ethernet card in the machine. You will notice no additional interface is specified for those.

Both of these groups (local network hosts and local subnets) have their routes automatically configured by a daemon called routed. If this is not run, then only routes which are statically defined (i.e. entered explicitly) will exist.

The `host1` line refers to our host, which it knows by Ethernet address. Since we are the sending host, FreeBSD knows to use the loopback interface (`lo0`) rather than sending it out over the Ethernet interface.

The two `host2` lines are an example of what happens when we use an ifconfig(8) alias (see the section on Ethernet for reasons why we would do this). The `=>` symbol after the `lo0` interface says that not only are we using the loopback (since this address also refers to the local host), but specifically it is an alias. Such routes only show up on the host that supports the alias; all other hosts on the local network will simply have a `link#1` line for such routes.

The final line (destination subnet `224`) deals with multicasting, which will be covered in another section.

Finally, various attributes of each route can be seen in the `Flags` column. Below is a short table of some of these flags and their meanings:

U	Up: The route is active.
H	Host: The route destination is a single host.
G	Gateway: Send anything for this destination on to this remote system, which will figure out from there where to send it.
S	Static: This route was configured manually, not automatically generated by the system.
C	Clone: Generates a new route based upon this route for machines we connect to. This type of route is normally used for local networks.

W	WasCloned: Indicated a route that was auto-configured based upon a local area network (Clone) route.
L	Link: Route involves references to Ethernet hardware.

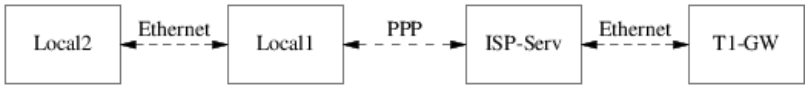
30.2.2. Default Routes

When the local system needs to make a connection to a remote host, it checks the routing table to determine if a known path exists. If the remote host falls into a subnet that we know how to reach (Cloned routes), then the system checks to see if it can connect along that interface.

If all known paths fail, the system has one last option: the "default" route. This route is a special type of gateway route (usually the only one present in the system), and is always marked with a `c` in the flags field. For hosts on a local area network, this gateway is set to whatever machine has a direct connection to the outside world (whether via PPP link, DSL, cable modem, T1, or another network interface).

If you are configuring the default route for a machine which itself is functioning as the gateway to the outside world, then the default route will be the gateway machine at your Internet Service Provider's (ISP) site.

Let us look at an example of default routes. This is a common configuration:



The hosts `Local1` and `Local2` are at your site. `Local1` is connected to an ISP via a dial up PPP connection. This PPP server computer is connected through a local area network to another gateway computer through an external interface to the ISPs Internet feed.

The default routes for each of your machines will be:

Host	Default Gateway	Interface
Local2	Local1	Ethernet
Local1	T1-GW	PPP

A common question is "Why (or how) would we set the `T1-GW` to be the default gateway for `Local1`, rather than the ISP server it is connected to?".

Remember, since the PPP interface is using an address on the ISP's local network for your side of the connection, routes for any other machines on the ISP's local network will be automatically generated. Hence, you will already know how to reach the `T1-GW` machine, so there is no need for the intermediate step of sending traffic to the ISP server.

It is common to use the address `X.X.X.1` as the gateway address for your local network. So (using the same example), if your local class-C address space was `10.20.30` and your ISP was using `10.9.9` then the default routes would be:

Host	Default Route
Local2 (10.20.30.2)	Local1 (10.20.30.1)
Local1 (10.20.30.1, 10.9.9.30)	T1-GW (10.9.9.1)

You can easily define the default route via the `/etc/rc.conf` file. In our example, on the `Local2` machine, we added the following line in `/etc/rc.conf` :

```
defaultrouter="10.20.30.1"
```

It is also possible to do it directly from the command line with the route(8) command:

```
# route add default 10.20.30.1
```

For more information on manual manipulation of network routing tables, consult route(8) manual page.

30.2.3. Dual Homed Hosts

There is one other type of configuration that we should cover, and that is a host that sits on two different networks. Technically, any machine functioning as a gateway (in the example above, using a PPP connection) counts as a dual-homed host. But the term is really only used to refer to a machine that sits on two local-area networks.

In one case, the machine has two Ethernet cards, each having an address on the separate subnets. Alternately, the machine may only have one Ethernet card, and be using ifconfig(8) aliasing. The former is used if two physically separate Ethernet networks are in use, the latter if there is one physical network segment, but two logically separate subnets.

Either way, routing tables are set up so that each subnet knows that this machine is the defined gateway (inbound route) to the other subnet. This configuration, with the machine acting as a router between the two subnets, is often used when we need to implement packet filtering or firewall security in either or both directions.

If you want this machine to actually forward packets between the two interfaces, you need to tell FreeBSD to enable this ability. See the next section for more details on how to do this.

30.2.4. Building a Router

A network router is simply a system that forwards packets from one interface to another. Internet standards and good engineering practice prevent the FreeBSD Project from enabling this by default in FreeBSD. You can enable this feature by changing the following variable to YES in rc.conf(5):

```
gateway_enable=YES          # Set to YES if this host will be a gateway
```

This option will set the sysctl(8) variable `net.inet.ip.forwarding` to `1`. If you should need to stop routing temporarily, you can reset this to `0` temporarily.

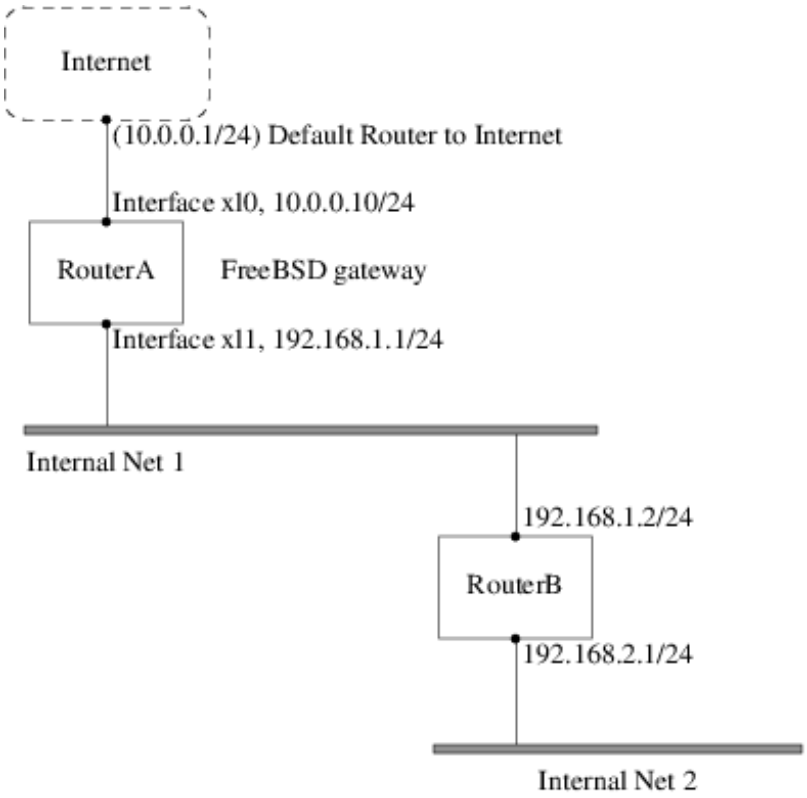
Your new router will need routes to know where to send the traffic. If your network is simple enough you can use static routes. FreeBSD also comes with the standard BSD routing daemon routed(8), which speaks RIP (both version 1 and version 2) and IRDP. Support for BGP v4, OSPF v2, and other sophisticated routing protocols is available with the net/zebra package. Commercial products such as GateD® are also available for more complex network routing solutions.

30.2.5. Setting Up Static Routes

Contributed by Al Hoang.

30.2.5.1. Manual Configuration

Let us assume we have a network as follows:



In this scenario, `RouterA` is our FreeBSD machine that is acting as a router to the rest of the Internet. It has a default route set to `10.0.0.1` which allows it to connect with the outside world. We will assume that `RouterB` is already configured properly and knows how to get wherever it needs to go. (This is simple in this picture. Just add a default route on `RouterB` using `192.168.1.1` as the gateway.)

If we look at the routing table for `RouterA` we would see something like the following:

```
% netstat -nr
Routing tables

Internet:
Destination        Gateway            Flags    Refs      Use  Netif  Expire
default            10.0.0.1           UGS         0    49378    xl0
127.0.0.1          127.0.0.1          UH          0        6    lo0
10.0.0/24          link#1             UC          0        0    xl0
192.168.1/24       link#2             UC          0        0    xl1
```

With the current routing table `RouterA` will not be able to reach our Internal Net 2. It does not have a route for `192.168.2.0/24` . One way to alleviate this is to manually add the route. The following command would add the Internal Net 2 network to `RouterA` 's routing table using `192.168.1.2` as the next hop:

```
# route add -net 192.168.2.0/24 192.168.1.2
```

Now `RouterA` can reach any hosts on the `192.168.2.0/24` network.

30.2.5.2. Persistent Configuration

The above example is perfect for configuring a static route on a running system. However, one problem is that the routing information will not persist if you reboot your FreeBSD machine. The way to handle the addition of a static route is to put it in your `/etc/rc.conf` file:

```
# Add Internal Net 2 as a static route
```

```
static_routes="internalnet2"
route_internalnet2="-net 192.168.2.0/24 192.168.1.2"
```

The `static_routes` configuration variable is a list of strings separated by a space. Each string references to a route name. In our above example we only have one string in `static_routes` . This string is *`internalnet2`* . We then add a configuration variable called `route_internalnet2` where we put all of the configuration parameters we would give to the route(8) command. For our example above we would have used the command:

```
# route add -net 192.168.2.0/24 192.168.1.2
```

so we need `"-net 192.168.2.0/24 192.168.1.2"` .

As said above, we can have more than one string in `static_routes` . This allows us to create multiple static routes. The following lines shows an example of adding static routes for the `192.168.0.0/24` and `192.168.1.0/24` networks on an imaginary router:

```
static_routes="net1 net2"
route_net1="-net 192.168.0.0/24 192.168.0.1"
route_net2="-net 192.168.1.0/24 192.168.1.1"
```

30.2.6. Routing Propagation

We have already talked about how we define our routes to the outside world, but not about how the outside world finds us.

We already know that routing tables can be set up so that all traffic for a particular address space (in our examples, a class-C subnet) can be sent to a particular host on that network, which will forward the packets inbound.

When you get an address space assigned to your site, your service provider will set up their routing tables so that all traffic for your subnet will be sent down your PPP link to your site. But how do sites across the country know to send to your ISP?

There is a system (much like the distributed DNS information) that keeps track of all assigned address-spaces, and defines their point of connection to the Internet Backbone. The “Backbone” are the main trunk lines that carry Internet traffic across the country, and around the world. Each backbone machine has a copy of a master set of tables, which direct traffic for a particular network to a specific backbone carrier, and from there down the chain of service providers until it reaches your network.

It is the task of your service provider to advertise to the backbone sites that they are the point of connection (and thus the path inward) for your site. This is known as route propagation.

30.2.7. Troubleshooting

Sometimes, there is a problem with routing propagation, and some sites are unable to connect to you. Perhaps the most useful command for trying to figure out where routing is breaking down is the traceroute(8) command. It is equally useful if you cannot seem to make a connection to a remote machine (i.e. ping(8) fails).

The traceroute(8) command is run with the name of the remote host you are trying to connect to. It will show the gateway hosts along the path of the attempt, eventually either reaching the target host, or terminating because of a lack of connection.

For more information, see the manual page for traceroute(8).

30.2.8. Multicast Routing

FreeBSD supports both multicast applications and multicast routing natively. Multicast applications do not require any special configuration of FreeBSD; applications will generally run out of the box. Multicast routing requires that support be compiled into the kernel:

```
options MROUTING
```

In addition, the multicast routing daemon, mrouted(8) must be configured to set up tunnels and DVMRP via `/etc/mrouted.conf` . More details on multicast configuration may be found in the manual page for mrouted(8).

30.3. Wireless Networking

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30.3.1. Wireless Networking Basics

Most wireless networks are based on the IEEE 802.11 standards. A basic wireless network consists of multiple stations communicating with radios that broadcast in either the 2.4GHz or 5GHz band (though this varies according to the locale and is also changing to enable communication in the 2.3GHz and 4.9GHz ranges).

802.11 networks are organized in two ways: in infrastructure mode one station acts as a master with all the other stations associating to it; the network is known as a BSS and the master station is termed an access point (AP). In a BSS all communication passes through the AP; even when one station wants to communicate with another wireless station messages must go through the AP. In the second form of network there is no master and stations communicate directly. This form of network is termed an IBSS and is commonly known as an ad-hoc network.

802.11 networks were first deployed in the 2.4GHz band using protocols defined by the IEEE 802.11 and 802.11b standard. These specifications include the operating frequencies, MAC layer characteristics including framing and transmission rates (communication can be done at various rates). Later the 802.11a standard defined operation in the 5GHz band, including different signalling mechanisms and higher transmission rates. Still later the 802.11g standard was defined to enable use of 802.11a signalling and transmission mechanisms in the 2.4GHz band in such a way as to be backwards compatible with 802.11b networks.

Separate from the underlying transmission techniques 802.11 networks have a variety of security mechanisms. The original 802.11 specifications defined a simple security protocol called WEP. This protocol uses a fixed pre-shared key and the RC4 cryptographic cipher to encode data transmitted on a network. Stations must all agree on the fixed key in order to communicate. This scheme was shown to be easily broken and is now rarely used except to discourage transient users from joining networks. Current security practice is given by the IEEE 802.11i specification that defines new cryptographic ciphers and an additional protocol to authenticate stations to an access point and exchange keys for doing data communication. Further, cryptographic keys are periodically refreshed and there are mechanisms for detecting intrusion attempts (and for countering intrusion attempts). Another security protocol specification commonly used in wireless networks is termed WPA. This was a precursor to 802.11i defined by an industry group as an interim measure while waiting for 802.11i to be ratified. WPA specifies a subset of the requirements found in 802.11i and is designed for implementation on legacy hardware. Specifically WPA requires only the TKIP cipher that is derived from the original WEP cipher. 802.11i permits use of TKIP but also requires support for a stronger cipher, AES-CCM, for encrypting data. (The AES cipher was not required in WPA because it was deemed too computationally costly to be implemented on legacy hardware.)

Other than the above protocol standards the other important standard to be aware of is 802.11e. This defines protocols for deploying multi-media applications such as streaming video and voice over IP (VoIP) in an 802.11 network. Like 802.11i, 802.11e also has a precursor specification termed WME (later renamed WMM) that has been defined by an industry group as a subset of 802.11e that can be deployed now to enable multi-media applications while waiting for the final ratification of 802.11e. The most important thing to know about 802.11e and WME/WMM is that it enables prioritized traffic use of a wireless network through Quality of Service (QoS) protocols and enhanced media access protocols. Proper implementation of these protocols enable high speed bursting of data and prioritized traffic flow.

Since the 6.0 version, FreeBSD supports networks that operate using 802.11a, 802.11b, and 802.11g. The WPA and 802.11i security protocols are likewise supported (in conjunction with any of 11a, 11b, and 11g) and QoS and traffic prioritization required by the WME/WMM protocols are supported for a limited set of wireless devices.

30.3.2. Basic Setup

30.3.2.1. Kernel Configuration

To use wireless networking you need a wireless networking card and to configure the kernel with the appropriate wireless networking support. The latter is separated into multiple modules so that you only need to configure the software you are actually going to use.

The first thing you need is a wireless device. The most commonly used devices are those that use parts made by Atheros. These devices are supported by the ath(4) driver and require the following line to be added to the `/boot/loader.conf` file:

```
if_ath_load="YES"
```

The Atheros driver is split up into three separate pieces: the driver proper (ath(4)), the hardware support layer that handles chip-specific functions (ath_hal(4)), and an algorithm for selecting which of several possible rates for transmitting frames (ath_rate_sample here). When you load this support as modules these dependencies are automatically handled for you. If instead of an Atheros device you had another device you would select the module for that device; e.g.:

```
if_wi_load="YES"
```

for devices based on the Intersil Prism parts (wi(4) driver).

注意

In the rest of this document, we will use an ath(4) device, the device name in the examples must be changed according to your configuration. A list of available wireless drivers can be found at the beginning of the wlan(4) manual page. If a native FreeBSD driver for your wireless device does not exist, it may be possible to directly use the Windows® driver with the help of the NDIS driver wrapper.

With a device driver configured you need to also bring in the 802.11 networking support required by the driver. For the ath(4) driver this is at least the wlan(4) module; this module is automatically loaded with the wireless device driver. With that you will need the modules that implement cryptographic support for the security protocols you intend to use. These are intended to be dynamically loaded on demand by the wlan(4) module but for now they must be manually configured. The following modules are available: wlan_wep(4), wlan_ccmp(4) and wlan_tkip(4). Both wlan_ccmp(4) and wlan_tkip(4) drivers are only needed if you intend to use the WPA and/or 802.11i security protocols. If your network is to run totally open (i.e., with no encryption) then you do not even need the wlan_wep(4) support. To load these modules at boot time, add the following lines to `/boot/loader.conf` :

```
wlan_wep_load="YES"
wlan_ccmp_load="YES"
wlan_tkip_load="YES"
```

With this information in the system bootstrap configuration file (i.e., `/boot/loader.conf`), you have to reboot your FreeBSD box. If you do not want to reboot your machine for the moment, you can just load the modules by hand using kldload(8).

注意

If you do not want to use modules, it is possible to compile these drivers into the kernel by adding the following lines to your kernel configuration file:

```
device ath              # Atheros IEEE 802.11 wireless network driver
```

```
device ath_hal          # Atheros Hardware Access Layer
device ath_rate_sample  # John Bicket's SampleRate control algorithm.
device wlan             # 802.11 support (Required)
device wlan_wep         # WEP crypto support for 802.11 devices
device wlan_ccmp        # AES-CCMP crypto support for 802.11 devices
device wlan_tkip        # TKIP and Michael crypto support for 802.11 ↺
devices
```

With this information in the kernel configuration file, recompile the kernel and reboot your FreeBSD machine.

When the system is up, we could find some information about the wireless device in the boot messages, like this:

```
ath0: <Atheros 5212> mem 0xff9f0000-0xff9fffff irq 17 at device 2.0 on pci2
ath0: Ethernet address: 00:11:95:d5:43:62
ath0: mac 7.9 phy 4.5 radio 5.6
```

30.3.3. Infrastructure Mode

The infrastructure mode or BSS mode is the mode that is typically used. In this mode, a number of wireless access points are connected to a wired network. Each wireless network has its own name, this name is called the SSID of the network. Wireless clients connect to the wireless access points.

30.3.3.1. FreeBSD Clients

30.3.3.1.1. How to Find Access Points

To scan for networks, use the `ifconfig` command. This request may take a few moments to complete as it requires that the system switches to each available wireless frequency and probes for available access points. Only the super-user can initiate such a scan:

```
# ifconfig ath0 up scan
SSID            BSSID              CHAN RATE  S:N   INT CAPS
dlinkap         00:13:46:49:41:76    6   54M 29:0   100 EPS  WPA WME
freebsdap       00:11:95:c3:0d:ac    1   54M 22:0   100 EPS  WPA
```

注意

You must mark the interface `up` before you can scan. Subsequent scan requests do not require you to mark the interface up again.

The output of a scan request lists each BSS/IBSS network found. Beside the name of the network, `SSID`, we find the `BSSID` which is the MAC address of the access point. The `CAPS` field identifies the type of each network and the capabilities of the stations operating there:

`E`
: Extended Service Set (ESS). Indicates that the station is part of an infrastructure network (in contrast to an IBSS/ad-hoc network).

`I`
: IBSS/ad-hoc network. Indicates that the station is part of an ad-hoc network (in contrast to an ESS network).

`P`
: Privacy. Data confidentiality is required for all data frames exchanged within the BSS. This means that this BSS requires the station to use cryptographic means such as WEP, TKIP or AES-CCMP to encrypt/decrypt data frames being exchanged with others.

`S`
: Short Preamble. Indicates that the network is using short preambles (defined in 802.11b High Rate/DSSS PHY, short preamble utilizes a 56 bit sync field in contrast to a 128 bit field used in long preamble mode).

`s`
: Short slot time. Indicates that the 802.11g network is using a short slot time because there are no legacy (802.11b) stations present.

One can also display the current list of known networks with:

```
# ifconfig ath0 list scan
```

This information may be updated automatically by the adapter or manually with a `scan` request. Old data is automatically removed from the cache, so over time this list may shrink unless more scans are done.

30.3.3.1.2. Basic Settings

This section provides a simple example of how to make the wireless network adapter work in FreeBSD without encryption. After you are familiar with these concepts, we strongly recommend using WPA to set up your wireless network.

There are three basic steps to configure a wireless network: selecting an access point, authenticating your station, and configuring an IP address. The following sections discuss each step.

30.3.3.1.2.1. Selecting an Access Point

Most of time it is sufficient to let the system choose an access point using the builtin heuristics. This is the default behaviour when you mark an interface up or otherwise configure an interface by listing it in `/etc/rc.conf` , e.g.:

```
ifconfig_ath0="DHCP"
```

If there are multiple access points and you want to select a specific one, you can select it by its SSID:

```
ifconfig_ath0="ssid your_ssid_here DHCP"
```

In an environment where there are multiple access points with the same SSID (often done to simplify roaming) it may be necessary to associate to one specific device. In this case you can also specify the BSSID of the access point (you can also leave off the SSID):

```
ifconfig_ath0="ssid your_ssid_here bssid xx:xx:xx:xx:xx:xx DHCP"
```

There are other ways to constrain the choice of an access point such as limiting the set of frequencies the system will scan on. This may be useful if you have a multi-band wireless card as scanning all the possible channels can be time-consuming. To limit operation to a specific band you can use the `mode` parameter; e.g.:

```
ifconfig_ath0="mode 11g ssid your_ssid_here DHCP"
```

will force the card to operate in 802.11g which is defined only for 2.4GHz frequencies so any 5GHz channels will not be considered. Other ways to do this are the `channel` parameter, to lock operation to one specific frequency, and the `chanlist` parameter, to specify a list of channels for scanning. More information about these parameters can be found in the ifconfig(8) manual page.

30.3.3.1.2.2. Authentication

Once you have selected an access point your station needs to authenticate before it can pass data. Authentication can happen in several ways. The most common scheme used is termed open authentication and allows any station

to join the network and communicate. This is the authentication you should use for test purpose the first time you set up a wireless network. Other schemes require cryptographic handshakes be completed before data traffic can flow; either using pre-shared keys or secrets, or more complex schemes that involve backend services such as RADIUS. Most users will use open authentication which is the default setting. Next most common setup is WPA-PSK, also known as WPA Personal, which is described below.

注意

If you have an Apple® AirPort® Extreme base station for an access point you may need to configure shared-key authentication together with a WEP key. This can be done in the `/etc/rc.conf` file or using the wpa_supplicant(8) program. If you have a single AirPort® base station you can setup access with something like:

```
ifconfig_ath0="authmode shared wepmode on weptxkey 1 wepkey 01234567 ↺
DHCP"
```

In general shared key authentication is to be avoided because it uses the WEP key material in a highly-constrained manner making it even easier to crack the key. If WEP must be used (e.g., for compatibility with legacy devices) it is better to use WEP with `open` authentication. More information regarding WEP can be found in the 節 30.3.3.1.4, “WEP”.

30.3.3.1.2.3. Getting an IP Address with DHCP

Once you have selected an access point and set the authentication parameters, you will have to get an IP address to communicate. Most of time you will obtain your wireless IP address via DHCP. To achieve that, simply edit `/etc/rc.conf` and add `DHCP` to the configuration for your device as shown in various examples above:

```
ifconfig_ath0="DHCP"
```

At this point, you are ready to bring up the wireless interface:

```
# /etc/rc.d/netif start
```

Once the interface is running, use `ifconfig` to see the status of the interface `ath0`:

```
# ifconfig ath0
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
        inet 192.168.1.100 netmask 0xffffff00 broadcast 192.168.1.255
        ether 00:11:95:d5:43:62
        media: IEEE 802.11 Wireless Ethernet autoselect (OFDM/54Mbps)
        status: associated
        ssid dlinkap channel 6 bssid 00:13:46:49:41:76
        authmode OPEN privacy OFF txpowmax 36 protmode CTS bintval 100
```

The `status: associated` means you are connected to the wireless network (to the `dlinkap` network in our case). The `bssid 00:13:46:49:41:76` part is the MAC address of your access point; the `authmode` line informs you that the communication is not encrypted (`OPEN`).

30.3.3.1.2.4. Static IP Address

In the case you cannot obtain an IP address from a DHCP server, you can set a fixed IP address. Replace the `DHCP` keyword shown above with the address information. Be sure to retain any other parameters you have set up for selecting an access point:

```
ifconfig_ath0="inet 192.168.1.100 netmask 255.255.255.0 ssid your_ssid_here "
```

30.3.3.1.3. WPA

WPA (Wi-Fi Protected Access) is a security protocol used together with 802.11 networks to address the lack of proper authentication and the weakness of WEP. WPA leverages the 802.1X authentication protocol and uses one of several ciphers instead of WEP for data integrity. The only cipher required by WPA is TKIP (Temporary Key Integrity Protocol) which is a cipher that extends the basic RC4 cipher used by WEP by adding integrity checking, tamper detection, and measures for responding to any detected intrusions. TKIP is designed to work on legacy hardware with only software modification; it represents a compromise that improves security but is still not entirely immune to attack. WPA also specifies the AES-CCMP cipher as an alternative to TKIP and that is preferred when possible; for this specification the term WPA2 (or RSN) is commonly used.

WPA defines authentication and encryption protocols. Authentication is most commonly done using one of two techniques: by 802.1X and a backend authentication service such as RADIUS, or by a minimal handshake between the station and the access point using a pre-shared secret. The former is commonly termed WPA Enterprise with the latter known as WPA Personal. Since most people will not set up a RADIUS backend server for wireless network, WPA-PSK is by far the most commonly encountered configuration for WPA.

The control of the wireless connection and the authentication (key negotiation or authentication with a server) is done with the wpa_supplicant(8) utility. This program requires a configuration file, `/etc/wpa_supplicant.conf` , to run. More information regarding this file can be found in the wpa_supplicant.conf(5) manual page.

30.3.3.1.3.1. WPA-PSK

WPA-PSK also known as WPA-Personal is based on a pre-shared key (PSK) generated from a given password and that will be used as the master key in the wireless network. This means every wireless user will share the same key. WPA-PSK is intended for small networks where the use of an authentication server is not possible or desired.

警告

Always use strong passwords that are sufficiently long and made from a rich alphabet so they will not be guessed and/or attacked.

The first step is the configuration of the `/etc/wpa_supplicant.conf` file with the SSID and the pre-shared key of your network:

```
network={
  ssid="freebsdap"
  psk="freebsdmall"
}
```

Then, in `/etc/rc.conf` , we indicate that the wireless device configuration will be done with WPA and the IP address will be obtained with DHCP:

```
ifconfig_ath0="WPA DHCP"
```

Then, we can bring up the interface:

```
# /etc/rc.d/netif start
Starting wpa_supplicant.
DHCPDISCOVER on ath0 to 255.255.255.255 port 67 interval 5
DHCPDISCOVER on ath0 to 255.255.255.255 port 67 interval 6
DHCPOFFER from 192.168.0.1
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPACK from 192.168.0.1
bound to 192.168.0.254 -- renewal in 300 seconds.
```

```
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.254 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (OFDM/36Mbps)
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA privacy ON deftxkey UNDEF TKIP 2:128-bit txpowmax 36
      protmode CTS roaming MANUAL bintval 100
```

Or you can try to configure it manually using the same `/etc/wpa_supplicant.conf` above, and run:

```
# wpa_supplicant -i ath0 -c /etc/wpa_supplicant.conf
Trying to associate with 00:11:95:c3:0d:ac (SSID='freebsdap' freq=2412 MHz)
Associated with 00:11:95:c3:0d:ac
WPA: Key negotiation completed with 00:11:95:c3:0d:ac [PTK=TKIP GTK=TKIP]
```

The next operation is the launch of the `dhclient` command to get the IP address from the DHCP server:

```
# dhclient ath0
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPACK from 192.168.0.1
bound to 192.168.0.254 -- renewal in 300 seconds.
# ifconfig ath0
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.254 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (OFDM/48Mbps)
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA privacy ON deftxkey UNDEF TKIP 2:128-bit txpowmax 36
      protmode CTS roaming MANUAL bintval 100
```

注意

If the `/etc/rc.conf` is set up with the line `ifconfig_ath0="DHCP"` then it is no need to run the `dhclient` command manually, `dhclient` will be launched after `wpa_supplicant` plumbs the keys.

In the case where the use of DHCP is not possible, you can set a static IP address after `wpa_supplicant` has authenticated the station:

```
# ifconfig ath0 inet 192.168.0.100 netmask 255.255.255.0
# ifconfig ath0
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.100 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (OFDM/36Mbps)
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA privacy ON deftxkey UNDEF TKIP 2:128-bit txpowmax 36
      protmode CTS roaming MANUAL bintval 100
```

When DHCP is not used, you also have to manually set up the default gateway and the nameserver:

```
# route add default your_default_router
# echo "nameserver your_DNS_server" >> /etc/resolv.conf
```

30.3.3.1.3.2. WPA with EAP-TLS

The second way to use WPA is with an 802.1X backend authentication server, in this case WPA is called WPA-Enterprise to make difference with the less secure WPA-Personal with its pre-shared key. The authentication in WPA-Enterprise is based on EAP (Extensible Authentication Protocol).

EAP does not come with an encryption method, it was decided to embed EAP inside an encrypted tunnel. Many types of EAP authentication methods have been designed, the most common methods are EAP-TLS, EAP-TTLS and EAP-PEAP.

EAP-TLS (EAP with Transport Layer Security) is a very well-supported authentication protocol in the wireless world since it was the first EAP method to be certified by the Wi-Fi alliance. EAP-TLS will require three certificates to run: the CA certificate (installed on all machines), the server certificate for your authentication server, and one client certificate for each wireless client. In this EAP method, both authentication server and wireless client authenticate each other in presenting their respective certificates, and they verify that these certificates were signed by your organization's certificate authority (CA).

As previously, the configuration is done via `/etc/wpa_supplicant.conf` :

```
network={
  ssid="freebsdap" ❶
  proto=RSN  ❷
  key_mgmt=WPA-EAP ❸
  eap=TLS ❹
  identity="loader" ❺
  ca_cert="/etc/certs/cacert.pem" ❻
  client_cert="/etc/certs/clientcert.pem" ❼
  private_key="/etc/certs/clientkey.pem" ❽
  private_key_passwd="freebsdmallclient" ❾
}
```

❶ This field indicates the network name (SSID).
❷ Here, we use RSN (IEEE 802.11i) protocol, i.e., WPA2.
❸ The `key_mgmt` line refers to the key management protocol we use. In our case it is WPA using EAP authentication: `WPA-EAP`.
❹ In this field, we mention the EAP method for our connection.
❺ The `identity` field contains the identity string for EAP.
❻ The `ca_cert` field indicates the pathname of the CA certificate file. This file is needed to verify the server certificat.
❼ The `client_cert` line gives the pathname to the client certificate file. This certificate is unique to each wireless client of the network.
❽ The `private_key` field is the pathname to the client certificate private key file.
❾ The `private_key_passwd` field contains the passphrase for the private key.

Then add the following line to `/etc/rc.conf` :

```
ifconfig_ath0="WPA DHCP"
```

The next step is to bring up the interface with the help of the `rc.d` facility:

```
# /etc/rc.d/netif start
Starting wpa_supplicant.
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPACK from 192.168.0.20
bound to 192.168.0.254 -- renewal in 300 seconds.
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.254 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (DS/11Mbps)
```

```
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA2/802.11i privacy ON deftxkey UNDEF TKIP 2:128-bit
      txpowmax 36 protmode CTS roaming MANUAL bintval 100
```

As previously shown, it is also possible to bring up the interface manually with both `wpa_supplicant` and `ifconfig` commands.

30.3.3.1.3.3. WPA with EAP-TTLS

With EAP-TLS both the authentication server and the client need a certificate, with EAP-TTLS (EAP-Tunneled Transport Layer Security) a client certificate is optional. This method is close to what some secure web sites do , where the web server can create a secure SSL tunnel even if the visitors do not have client-side certificates. EAP-TTLS will use the encrypted TLS tunnel for safe transport of the authentication data.

The configuration is done via the `/etc/wpa_supplicant.conf` file:

```
network={
  ssid="freebsdap"
  proto=RSN
  key_mgmt=WPA-EAP
  eap=TTLS ❶
  identity="test" ❷
  password="test" ❸
  ca_cert="/etc/certs/cacert.pem" ❹
  phase2="auth=MD5" ❺
}
```

❶ In this field, we mention the EAP method for our connection.
❷ The `identity` field contains the identity string for EAP authentication inside the encrypted TLS tunnel.
❸ The `password` field contains the passphrase for the EAP authentication.
❹ The `ca_cert` field indicates the pathname of the CA certificate file. This file is needed to verify the server certificat.
❺ In this field, we mention the authentication method used in the encrypted TLS tunnel. In our case, EAP with MD5-Challenge has been used. The “inner authentication” phase is often called “phase2”.

You also have to add the following line to `/etc/rc.conf` :

```
ifconfig_ath0="WPA DHCP"
```

The next step is to bring up the interface:

```
# /etc/rc.d/netif start
Starting wpa_supplicant.
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPACK from 192.168.0.20
bound to 192.168.0.254 -- renewal in 300 seconds.
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.254 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (DS/11Mbps)
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA2/802.11i privacy ON deftxkey UNDEF TKIP 2:128-bit
      txpowmax 36 protmode CTS roaming MANUAL bintval 100
```

30.3.3.1.3.4. WPA with EAP-PEAP

PEAP (Protected EAP) has been designed as an alternative to EAP-TTLS. There are two types of PEAP methods, the most common one is PEAPv0/EAP-MSCHAPv2. In the rest of this document, we will use the PEAP term to refer to

that EAP method. PEAP is the most used EAP standard after EAP-TLS, in other words if you have a network with mixed OSes, PEAP should be the most supported standard after EAP-TLS.

PEAP is similar to EAP-TTLS: it uses a server-side certificate to authenticate clients by creating an encrypted TLS tunnel between the client and the authentication server, which protects the ensuing exchange of authentication information. In term of security the difference between EAP-TTLS and PEAP is that PEAP authentication broadcasts the username in clear, only the password is sent in the encrypted TLS tunnel. EAP-TTLS will use the TLS tunnel for both username and password.

We have to edit the `/etc/wpa_supplicant.conf` file and add the EAP-PEAP related settings:

```
network={
  ssid="freebsdap"
  proto=RSN
  key_mgmt=WPA-EAP
  eap=PEAP ❶
  identity="test" ❷
  password="test" ❸
  ca_cert="/etc/certs/cacert.pem" ❹
  phase1="peaplabel=0" ❺
  phase2="auth=MSCHAPV2" ❻
}
```

❶ In this field, we mention the EAP method for our connection.
❷ The `identity` field contains the identity string for EAP authentication inside the encrypted TLS tunnel.
❸ The `password` field contains the passphrase for the EAP authentication.
❹ The `ca_cert` field indicates the pathname of the CA certificate file. This file is needed to verify the server certificat.
❺ This field contains the parameters for the first phase of the authentication (the TLS tunnel). According to the authentication server used, you will have to specify a specific label for the authentication. Most of time, the label will be "client EAP encryption" which is set by using `peaplabel=0` . More information can be found in the wpa_supplicant.conf(5) manual page.
❻ In this field, we mention the authentication protocol used in the encrypted TLS tunnel. In the case of PEAP, it is `auth=MSCHAPV2` .

The following must be added to `/etc/rc.conf` :

```
ifconfig_ath0="WPA DHCP"
```

Then, we can bring up the interface:

```
# /etc/rc.d/netif start
Starting wpa_supplicant.
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPREQUEST on ath0 to 255.255.255.255 port 67
DHCPACK from 192.168.0.20
bound to 192.168.0.254 -- renewal in 300 seconds.
ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
      inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
      inet 192.168.0.254 netmask 0xffffff00 broadcast 192.168.0.255
      ether 00:11:95:d5:43:62
      media: IEEE 802.11 Wireless Ethernet autoselect (DS/11Mbps)
      status: associated
      ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
      authmode WPA2/802.11i privacy ON deftxkey UNDEF TKIP 2:128-bit
      txpowmax 36 protmode CTS roaming MANUAL bintval 100
```

30.3.3.1.4. WEP

WEP (Wired Equivalent Privacy) is part of the original 802.11 standard. There is no authentication mechanism, only a weak form of access control, and it is easily to be cracked.

WEP can be set up with `ifconfig`:

```
# ifconfig ath0 inet 192.168.1.100 netmask 255.255.255.0 ssid my_net \
     wepmode on weptxkey 3 wepkey 3:0x3456789012
```

- The `weptxkey` means which WEP key will be used in the transmission. Here we used the third key. This must match the setting in the access point.
- The `wepkey` means setting the selected WEP key. It should in the format *`index:key`*, if the index is not given, key `1` is set. That is to say we need to set the index if we use keys other than the first key.

注意

You must replace the `0x3456789012` with the key configured for use on the access point.

You are encouraged to read ifconfig(8) manual page for further information.

The `wpa_supplicant` facility also can be used to configure your wireless interface with WEP. The example above can be set up by adding the following lines to `/etc/wpa_supplicant.conf`:

```
network={
  ssid="my_net"
  key_mgmt=NONE
  wep_key3=3456789012
  wep_tx_keyidx=3
}
```

Then:

```
# wpa_supplicant -i ath0 -c /etc/wpa_supplicant.conf
Trying to associate with 00:13:46:49:41:76 (SSID='dlinkap' freq=2437 MHz)
Associated with 00:13:46:49:41:76
```

30.3.4. Ad-hoc Mode

IBSS mode, also called ad-hoc mode, is designed for point to point connections. For example, to establish an ad-hoc network between the machine A and the machine B we will just need to choose two IP adresses and a SSID.

On the box A:

```
# ifconfig ath0 inet 192.168.0.1 netmask 255.255.255.0 ssid freebsdap ↺
mediaopt adhoc
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
   inet 192.168.0.1 netmask 0xffffff00 broadcast 192.168.0.255
   inet6 fe80::211:95ff:fec3:dac%ath0 prefixlen 64 scopeid 0x4
   ether 00:11:95:c3:0d:ac
   media: IEEE 802.11 Wireless Ethernet autoselect <adhoc> (autoselect <adhoc>)
   status: associated
   ssid freebsdap channel 2 bssid 02:11:95:c3:0d:ac
   authmode OPEN privacy OFF txpowmax 36 protmode CTS bintval 100
```

The `adhoc` parameter indicates the interface is running in the IBSS mode.

On B, we should be able to detect A:

```
# ifconfig ath0 up scan
```

```
  SSID            BSSID              CHAN RATE  S:N   INT CAPS
  freebsdap       02:11:95:c3:0d:ac    2   54M 19:0   100 IS
```

The `I` in the output confirms the machine A is in ad-hoc mode. We just have to configure B with a different IP address:

```
# ifconfig ath0 inet 192.168.0.2 netmask 255.255.255.0 ssid freebsdap ↺
mediaopt adhoc
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
   inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
   inet 192.168.0.2 netmask 0xffffff00 broadcast 192.168.0.255
   ether 00:11:95:d5:43:62
   media: IEEE 802.11 Wireless Ethernet autoselect <adhoc> (autoselect <adhoc>)
   status: associated
   ssid freebsdap channel 2 bssid 02:11:95:c3:0d:ac
   authmode OPEN privacy OFF txpowmax 36 protmode CTS bintval 100
```

Both A and B are now ready to exchange informations.

30.3.5. FreeBSD Host Access Points

FreeBSD can act as an Access Point (AP) which eliminates the need to buy a hardware AP or run an ad-hoc network. This can be particularly useful when your FreeBSD machine is acting as a gateway to another network (e.g., the Internet).

30.3.5.1. Basic Settings

Before configuring your FreeBSD machine as an AP, the kernel must be configured with the appropriate wireless networking support for your wireless card. You also have to add the support for the security protocols you intend to use. For more details, see 節 30.3.2, “Basic Setup”.

注意

The use of the NDIS driver wrapper and the Windows® drivers do not allow currently the AP operation. Only native FreeBSD wireless drivers support AP mode.

Once the wireless networking support is loaded, you can check if your wireless device supports the host-based access point mode (also know as hostap mode):

```
# ifconfig ath0 list caps
ath0=783ed0f<WEP,TKIP,AES,AES_CCM,IBSS,HOSTAP,AHDEMO,TXPMGT,SHSLOT,SHPREAMBLE,MONITOR,TKIPMIC,WPA1,WPA2,BURST
```

This output displays the card capabilities; the `HOSTAP` word confirms this wireless card can act as an Access Point. Various supported ciphers are also mentioned: WEP, TKIP, WPA2, etc., these informations are important to know what security protocols could be set on the Access Point.

The wireless device can now be put into hostap mode and configured with the correct SSID and IP address:

```
# ifconfig ath0 ssid freebsdap mode 11g mediaopt hostap  inet 192.168.0.1 ↺
netmask 255.255.255.0
```

Use again `ifconfig` to see the status of the `ath0` interface:

```
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
   inet 192.168.0.1 netmask 0xffffff00 broadcast 192.168.0.255
   inet6 fe80::211:95ff:fec3:dac%ath0 prefixlen 64 scopeid 0x4
```

```
   ether 00:11:95:c3:0d:ac
   media: IEEE 802.11 Wireless Ethernet autoselect mode 11g <hostap>
   status: associated
   ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
   authmode OPEN privacy OFF txpowmax 38 bmiss 7 protmode CTS burst dtimperiod 1 ↺
bintval 100
```

The `hostap` parameter indicates the interface is running in the host-based access point mode.

The interface configuration can be done automatically at boot time by adding the following line to `/etc/rc.conf`:

```
ifconfig_ath0="ssid freebsdap mode 11g mediaopt hostap inet 192.168.0.1 ↺
netmask 255.255.255.0 "
```

30.3.5.2. Host-based Access Point without Authentication or Encryption

Although it is not recommended to run an AP without any authentication or encryption, this is a simple way to check if your AP is working. This configuration is also important for debugging client issues.

Once the AP configured as previously shown, it is possible from another wireless machine to initiate a scan to find the AP:

```
# ifconfig ath0 up scan
SSID            BSSID              CHAN RATE  S:N   INT CAPS
freebsdap       00:11:95:c3:0d:ac    1   54M 22:1   100 ES
```

The client machine found the Access Point and can be associated with it:

```
# ifconfig ath0 ssid freebsdap inet 192.168.0.2 netmask 255.255.255.0
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
   inet6 fe80::211:95ff:fed5:4362%ath0 prefixlen 64 scopeid 0x1
   inet 192.168.0.2 netmask 0xffffff00 broadcast 192.168.0.255
   ether 00:11:95:d5:43:62
   media: IEEE 802.11 Wireless Ethernet autoselect (OFDM/54Mbps)
   status: associated
   ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
   authmode OPEN privacy OFF txpowmax 36 protmode CTS bintval 100
```

30.3.5.3. WPA Host-based Access Point

This section will focus on setting up FreeBSD Access Point using the WPA security protocol. More details regarding WPA and the configuration of WPA-based wireless clients can be found in the 節 30.3.3.1.3, “WPA”.

The hostapd daemon is used to deal with client authentication and keys management on the WPA enabled Access Point.

In the following, all the configuration operations will be performed on the FreeBSD machine acting as AP. Once the AP is correctly working, hostapd should be automatically enabled at boot with the following line in `/etc/rc.conf`:

```
hostapd_enable="YES"
```

Before trying to configure hostapd, be sure you have done the basic settings introduced in the 節 30.3.5.1, “Basic Settings”.

30.3.5.3.1. WPA-PSK

WPA-PSK is intended for small networks where the use of an backend authentication server is not possible or desired.

The configuration is done in the `/etc/hostapd.conf` file:

```
interface=ath0 ❶
debug=1 ❷
ctrl_interface=/var/run/hostapd ❸
ctrl_interface_group=wheel ❹
ssid=freebsdap ❺
wpa=1 ❻
wpa_passphrase=freebsdmall ❼
wpa_key_mgmt=WPA-PSK ❽
wpa_pairwise=CCMP TKIP ❾
```

❶ This field indicates the wireless interface used for the Access Point.
❷ This field sets the level of verbosity during the execution of hostapd. A value of `1` represents the minimal level.
❸ The `ctrl_interface` field gives the pathname of the directory used by hostapd to stores its domain socket files for the communication with external programs such as hostapd_cli(8). The default value is used here.
❹ The `ctrl_interface_group` line sets the group (here, it is the `wheel` group) allowed to access to the control interface files.
❺ This field sets the network name.
❻ The `wpa` field enables WPA and specifies which WPA authentication protocol will be required. A value of `1` configures the AP for WPA-PSK.
❼ The `wpa_passphrase` field contains the ASCII passphrase for the WPA authentication.

警告

Always use strong passwords that are sufficiently long and made from a rich alphabet so they will not be guessed and/or attacked.

❽ The `wpa_key_mgmt` line refers to the key management protocol we use. In our case it is WPA-PSK.
❾ The `wpa_pairwise` field indicates the set of accepted encryption algorithms by the Access Point. Here both TKIP (WPA) and CCMP (WPA2) ciphers are accepted. CCMP cipher is an alternative to TKIP and that is strongly preferred when possible; TKIP should be used solely for stations incapable of doing CCMP.

The next step is to start hostapd:

```
# /etc/rc.d/hostapd forcestart
```

```
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 2290
   inet 192.168.0.1 netmask 0xffffff00 broadcast 192.168.0.255
   inet6 fe80::211:95ff:fec3:dac%ath0 prefixlen 64 scopeid 0x4
   ether 00:11:95:c3:0d:ac
   media: IEEE 802.11 Wireless Ethernet autoselect mode 11g <hostap>
   status: associated
   ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
   authmode WPA2/802.11i privacy MIXED deftxkey 2 TKIP 2:128-bit txpowmax 36 protmode ↺
CTS dtimperiod 1 bintval 100
```

The Access Point is running, the clients can now be associated with it, see 節 30.3.3.1.3, “WPA” for more details. It is possible to see the stations associated with the AP using the `ifconfig ath0 list sta` command.

30.3.5.4. WEP Host-based Access Point

It is not recommended to use WEP for setting up an Access Point since there is no authentication mechanism and it is easily to be cracked. Some legacy wireless cards only support WEP as security protocol, these cards will only allow to set up AP without authentication or encryption or using the WEP protocol.

The wireless device can now be put into hostap mode and configured with the correct SSID and IP address:

```
# ifconfig ath0 ssid freebsdap wepmode on weptxkey 3 wepkey ↺
3:0x3456789012 mode 11g mediaopt hostap \
 inet 192.168.0.1 netmask 255.255.255.0
```

- The `weptxkey` means which WEP key will be used in the transmission. Here we used the third key (note that the key numbering starts with `1`). This parameter must be specified to really encrypt the data.
- The `wepkey` means setting the selected WEP key. It should in the format *`index:key`* , if the index is not given, key `1` is set. That is to say we need to set the index if we use keys other than the first key.

Use again `ifconfig` to see the status of the `ath0` interface:

```
# ifconfig ath0
  ath0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
   inet 192.168.0.1 netmask 0xffffff00 broadcast 192.168.0.255
   inet6 fe80::211:95ff:fec3:dac%ath0 prefixlen 64 scopeid 0x4
   ether 00:11:95:c3:0d:ac
   media: IEEE 802.11 Wireless Ethernet autoselect mode 11g <hostap>
   status: associated
   ssid freebsdap channel 1 bssid 00:11:95:c3:0d:ac
   authmode OPEN privacy ON deftxkey 3 wepkey 3:40-bit txpowmax 36 protmode CTS ↺
dtimperiod 1 bintval 100
```

From another wireless machine, it is possible to initiate a scan to find the AP:

```
# ifconfig ath0 up scan
SSID            BSSID              CHAN RATE  S:N   INT CAPS
freebsdap       00:11:95:c3:0d:ac    1   54M 22:1   100 EPS
```

The client machine found the Access Point and can be associated with it using the correct parameters (key, etc.), see 節 30.3.3.1.4, “WEP” for more details.

30.3.6. Troubleshooting

If you are having trouble with wireless networking, there are a number of steps you can take to help troubleshoot the problem.

- If you do not see the access point listed when scanning be sure you have not configured your wireless device to a limited set of channels.
- If you cannot associate to an access point verify the configuration of your station matches the one of the access point. This includes the authentication scheme and any security protocols. Simplify your configuration as much as possible. If you are using a security protocol such as WPA or WEP configure the access point for open authentication and no security to see if you can get traffic to pass.
- Once you can associate to the access point diagnose any security configuration using simple tools like ping(8).

  The `wpa_supplicant` has much debugging support; try running it manually with the `-dd` option and look at the system logs.
- There are also many lower-level debugging tools. You can enable debugging messages in the 802.11 protocol support layer using the `wlandebug` program found in `/usr/src/tools/tools/net80211` . For example:

  ```
  # wlandebug -i ath0 +scan+auth+debug+assoc
    net.wlan.0.debug: 0 => 0xc80000<assoc,auth,scan>
  ```

  can be used to enable console messages related to scanning for access points and doing the 802.11 protocol handshakes required to arrange communication.

There are also many useful statistics maintained by the 802.11 layer; the `wlanstats` tool will dump these informations. These statistics should identify all errors identified by the 802.11 layer. Beware however that some errors are identified in the device drivers that lie below the 802.11 layer so they may not show up. To diagnose device-specific problems you need to refer to the drivers' documentation.

If the above information does not help to clarify the problem, please submit a problem report and include output from the above tools.

30.4. Bluetooth

Written by Pav Lucistnik.

30.4.1. Introduction

Bluetooth is a wireless technology for creating personal networks operating in the 2.4 GHz unlicensed band, with a range of 10 meters. Networks are usually formed ad-hoc from portable devices such as cellular phones, handhelds and laptops. Unlike the other popular wireless technology, Wi-Fi, Bluetooth offers higher level service profiles, e.g. FTP-like file servers, file pushing, voice transport, serial line emulation, and more.

The Bluetooth stack in FreeBSD is implemented using the Netgraph framework (see netgraph(4)). A broad variety of Bluetooth USB dongles is supported by the ng_ubt(4) driver. The Broadcom BCM2033 chip based Bluetooth devices are supported via the ubtbcmfw(4) and ng_ubt(4) drivers. The 3Com Bluetooth PC Card 3CRWB60-A is supported by the ng_bt3c(4) driver. Serial and UART based Bluetooth devices are supported via sio(4), ng_h4(4) and hcseriald(8). This section describes the use of the USB Bluetooth dongle.

30.4.2. Plugging in the Device

By default Bluetooth device drivers are available as kernel modules. Before attaching a device, you will need to load the driver into the kernel:

```
# kldload ng_ubt
```

If the Bluetooth device is present in the system during system startup, load the module from `/boot/loader.conf`:

```
ng_ubt_load="YES"
```

Plug in your USB dongle. The output similar to the following will appear on the console (or in syslog):

```
ubt0: vendor 0x0a12 product 0x0001, rev 1.10/5.25, addr 2
ubt0: Interface 0 endpoints: interrupt=0x81, bulk-in=0x82, bulk-out=0x2
ubt0: Interface 1 (alt.config 5) endpoints: isoc-in=0x83, isoc-out=0x3,
      wMaxPacketSize=49, nframes=6, buffer size=294
```

注意

The Bluetooth stack has to be started manually on FreeBSD 6.0, and on FreeBSD 5.X before 5.5. It is done automatically from devd(8) on FreeBSD 5.5, 6.1 and newer.

Copy `/usr/share/examples/netgraph/bluetooth/rc.bluetooth` into some convenient place, like `/etc/rc.bluetooth`. This script is used to start and stop the Bluetooth stack. It is a good idea to stop the stack before unplugging the device, but it is not (usually) fatal. When starting the stack, you will receive output similar to the following:

```
# /etc/rc.bluetooth start ubt0
BD_ADDR: 00:02:72:00:d4:1a
```

```
Features: 0xff 0xff 0xf 00 00 00 00 00
<3-Slot> <5-Slot> <Encryption> <Slot offset>
<Timing accuracy> <Switch> <Hold mode> <Sniff mode>
<Park mode> <RSSI> <Channel quality> <SCO link>
<HV2 packets> <HV3 packets> <u-law log> <A-law log> <CVSD>
<Paging scheme> <Power control> <Transparent SCO data>
Max. ACL packet size: 192 bytes
Number of ACL packets: 8
Max. SCO packet size: 64 bytes
Number of SCO packets: 8
```

30.4.3. Host Controller Interface (HCI)

Host Controller Interface (HCI) provides a command interface to the baseband controller and link manager, and access to hardware status and control registers. This interface provides a uniform method of accessing the Bluetooth baseband capabilities. HCI layer on the Host exchanges data and commands with the HCI firmware on the Bluetooth hardware. The Host Controller Transport Layer (i.e. physical bus) driver provides both HCI layers with the ability to exchange information with each other.

A single Netgraph node of type hci is created for a single Bluetooth device. The HCI node is normally connected to the Bluetooth device driver node (downstream) and the L2CAP node (upstream). All HCI operations must be performed on the HCI node and not on the device driver node. Default name for the HCI node is "devicehci". For more details refer to the ng_hci(4) manual page.

One of the most common tasks is discovery of Bluetooth devices in RF proximity. This operation is called inquiry. Inquiry and other HCI related operations are done with the hccontrol(8) utility. The example below shows how to find out which Bluetooth devices are in range. You should receive the list of devices in a few seconds. Note that a remote device will only answer the inquiry if it put into discoverable mode.

```
% hccontrol -n ubt0hci inquiry
Inquiry result, num_responses=1
Inquiry result #0
       BD_ADDR: 00:80:37:29:19:a4
       Page Scan Rep. Mode: 0x1
       Page Scan Period Mode: 00
       Page Scan Mode: 00
       Class: 52:02:04
       Clock offset: 0x78ef
Inquiry complete. Status: No error [00]
```

BD_ADDR is unique address of a Bluetooth device, similar to MAC addresses of a network card. This address is needed for further communication with a device. It is possible to assign human readable name to a BD_ADDR. The /etc/bluetooth/hosts file contains information regarding the known Bluetooth hosts. The following example shows how to obtain human readable name that was assigned to the remote device:

```
% hccontrol -n ubt0hci remote_name_request 00:80:37:29:19:a4
BD_ADDR: 00:80:37:29:19:a4
Name: Pav's T39
```

If you perform an inquiry on a remote Bluetooth device, it will find your computer as "your.host.name (ubt0)". The name assigned to the local device can be changed at any time.

The Bluetooth system provides a point-to-point connection (only two Bluetooth units involved), or a point-to-multipoint connection. In the point-to-multipoint connection the connection is shared among several Bluetooth devices. The following example shows how to obtain the list of active baseband connections for the local device:

```
% hccontrol -n ubt0hci read_connection_list
Remote BD_ADDR    Handle Type Mode Role Encrypt Pending Queue State
00:80:37:29:19:a4     41  ACL    0 MAST    NONE       0     0 OPEN
```

A connection handle is useful when termination of the baseband connection is required. Note, that it is normally not required to do it by hand. The stack will automatically terminate inactive baseband connections.

```
# hccontrol -n ubt0hci disconnect 41
Connection handle: 41
Reason: Connection terminated by local host [0x16]
```

Refer to `hccontrol help` for a complete listing of available HCI commands. Most of the HCI commands do not require superuser privileges.

30.4.4. Logical Link Control and Adaptation Protocol (L2CAP)

Logical Link Control and Adaptation Protocol (L2CAP) provides connection-oriented and connectionless data services to upper layer protocols with protocol multiplexing capability and segmentation and reassembly operation. L2CAP permits higher level protocols and applications to transmit and receive L2CAP data packets up to 64 kilobytes in length.

L2CAP is based around the concept of channels. Channel is a logical connection on top of baseband connection. Each channel is bound to a single protocol in a many-to-one fashion. Multiple channels can be bound to the same protocol, but a channel cannot be bound to multiple protocols. Each L2CAP packet received on a channel is directed to the appropriate higher level protocol. Multiple channels can share the same baseband connection.

A single Netgraph node of type l2cap is created for a single Bluetooth device. The L2CAP node is normally connected to the Bluetooth HCI node (downstream) and Bluetooth sockets nodes (upstream). Default name for the L2CAP node is "devicel2cap". For more details refer to the ng_l2cap(4) manual page.

A useful command is l2ping(8), which can be used to ping other devices. Some Bluetooth implementations might not return all of the data sent to them, so `0 bytes` in the following example is normal.

```
# l2ping -a 00:80:37:29:19:a4
0 bytes from 0:80:37:29:19:a4 seq_no=0 time=48.633 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=1 time=37.551 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=2 time=28.324 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=3 time=46.150 ms result=0
```

The l2control(8) utility is used to perform various operations on L2CAP nodes. This example shows how to obtain the list of logical connections (channels) and the list of baseband connections for the local device:

```
% l2control -a 00:02:72:00:d4:1a read_channel_list
L2CAP channels:
Remote BD_ADDR     SCID/ DCID   PSM  IMTU/ OMTU State
00:07:e0:00:0b:ca    66/   64     3   132/  672 OPEN
% l2control -a 00:02:72:00:d4:1a read_connection_list
L2CAP connections:
Remote BD_ADDR    Handle Flags Pending State
00:07:e0:00:0b:ca     41 O           0 OPEN
```

Another diagnostic tool is btsockstat(1). It does a job similar to as netstat(1) does, but for Bluetooth network-related data structures. The example below shows the same logical connection as l2control(8) above.

```
% btsockstat
Active L2CAP sockets
PCB      Recv-Q Send-Q Local address/PSM       Foreign address   CID   State
c2afe900      0      0 00:02:72:00:d4:1a/3     00:07:e0:00:0b:ca 66    OPEN
Active RFCOMM sessions
L2PCB    PCB      Flag MTU   Out-Q DLCs State
c2afe900 c2b53380 1    127   0     Yes  OPEN
Active RFCOMM sockets
PCB      Recv-Q Send-Q Local address     Foreign address   Chan DLCI State
c2e8bc80      0    250 00:02:72:00:d4:1a 00:07:e0:00:0b:ca 3    6    OPEN
```

30.4.5. RFCOMM Protocol

The RFCOMM protocol provides emulation of serial ports over the L2CAP protocol. The protocol is based on the ETSI standard TS 07.10. RFCOMM is a simple transport protocol, with additional provisions for emulating the 9 circuits of RS-232 (EIATIA-232-E) serial ports. The RFCOMM protocol supports up to 60 simultaneous connections (RFCOMM channels) between two Bluetooth devices.

For the purposes of RFCOMM, a complete communication path involves two applications running on different devices (the communication endpoints) with a communication segment between them. RFCOMM is intended to cover applications that make use of the serial ports of the devices in which they reside. The communication segment is a Bluetooth link from one device to another (direct connect).

RFCOMM is only concerned with the connection between the devices in the direct connect case, or between the device and a modem in the network case. RFCOMM can support other configurations, such as modules that communicate via Bluetooth wireless technology on one side and provide a wired interface on the other side.

In FreeBSD the RFCOMM protocol is implemented at the Bluetooth sockets layer.

30.4.6. Pairing of Devices

By default, Bluetooth communication is not authenticated, and any device can talk to any other device. A Bluetooth device (for example, cellular phone) may choose to require authentication to provide a particular service (for example, Dial-Up service). Bluetooth authentication is normally done with PIN codes. A PIN code is an ASCII string up to 16 characters in length. User is required to enter the same PIN code on both devices. Once user has entered the PIN code, both devices will generate a link key. After that the link key can be stored either in the devices themselves or in a persistent storage. Next time both devices will use previously generated link key. The described above procedure is called pairing. Note that if the link key is lost by any device then pairing must be repeated.

The hcsecd(8) daemon is responsible for handling of all Bluetooth authentication requests. The default configuration file is `/etc/bluetooth/hcsecd.conf` . An example section for a cellular phone with the PIN code arbitrarily set to "1234" is shown below:

```
device {
        bdaddr  00:80:37:29:19:a4;
        name    "Pav's T39";
        key     nokey;
        pin     "1234";
      }
```

There is no limitation on PIN codes (except length). Some devices (for example Bluetooth headsets) may have a fixed PIN code built in. The `-d` switch forces the hcsecd(8) daemon to stay in the foreground, so it is easy to see what is happening. Set the remote device to receive pairing and initiate the Bluetooth connection to the remote device. The remote device should say that pairing was accepted, and request the PIN code. Enter the same PIN code as you have in `hcsecd.conf` . Now your PC and the remote device are paired. Alternatively, you can initiate pairing on the remote device.

On FreeBSD 5.5, 6.1 and newer, the following line can be added to the `/etc/rc.conf` file to have hcsecd started automatically on system start:

```
hcsecd_enable="YES"
```

The following is a sample of the hcsecd daemon output:

```
hcsecd[16484]: Got Link_Key_Request event from 'ubt0hci', remote bdaddr 0:80:37:29:19:a4
hcsecd[16484]: Found matching entry, remote bdaddr 0:80:37:29:19:a4, name 'Pav's T39', ↺
link key doesn't exist
hcsecd[16484]: Sending Link_Key_Negative_Reply to 'ubt0hci' for remote bdaddr ↺
0:80:37:29:19:a4
hcsecd[16484]: Got PIN_Code_Request event from 'ubt0hci', remote bdaddr 0:80:37:29:19:a4
```

```
hcsecd[16484]: Found matching entry, remote bdaddr 0:80:37:29:19:a4, name 'Pav's T39', ↺
PIN code exists
hcsecd[16484]: Sending PIN_Code_Reply to 'ubt0hci' for remote bdaddr 0:80:37:29:19:a4
```

30.4.7. Service Discovery Protocol (SDP)

The Service Discovery Protocol (SDP) provides the means for client applications to discover the existence of services provided by server applications as well as the attributes of those services. The attributes of a service include the type or class of service offered and the mechanism or protocol information needed to utilize the service.

SDP involves communication between a SDP server and a SDP client. The server maintains a list of service records that describe the characteristics of services associated with the server. Each service record contains information about a single service. A client may retrieve information from a service record maintained by the SDP server by issuing a SDP request. If the client, or an application associated with the client, decides to use a service, it must open a separate connection to the service provider in order to utilize the service. SDP provides a mechanism for discovering services and their attributes, but it does not provide a mechanism for utilizing those services.

Normally, a SDP client searches for services based on some desired characteristics of the services. However, there are times when it is desirable to discover which types of services are described by an SDP server's service records without any a priori information about the services. This process of looking for any offered services is called browsing.

The Bluetooth SDP server sdpd(8) and command line client sdpcontrol(8) are included in the standard FreeBSD installation. The following example shows how to perform a SDP browse query.

```
% sdpcontrol -a 00:01:03:fc:6e:ec browse
Record Handle: 00000000
Service Class ID List:
        Service Discovery Server (0x1000)
Protocol Descriptor List:
        L2CAP (0x0100)
                Protocol specific parameter #1: u/int/uuid16 1
                Protocol specific parameter #2: u/int/uuid16 1

Record Handle: 0x00000001
Service Class ID List:
        Browse Group Descriptor (0x1001)

Record Handle: 0x00000002
Service Class ID List:
        LAN Access Using PPP (0x1102)
Protocol Descriptor List:
        L2CAP (0x0100)
        RFCOMM (0x0003)
                Protocol specific parameter #1: u/int8/bool 1
Bluetooth Profile Descriptor List:
        LAN Access Using PPP (0x1102) ver. 1.0
```

... and so on. Note that each service has a list of attributes (RFCOMM channel for example). Depending on the service you might need to make a note of some of the attributes. Some Bluetooth implementations do not support service browsing and may return an empty list. In this case it is possible to search for the specific service. The example below shows how to search for the OBEX Object Push (OPUSH) service:

```
% sdpcontrol -a 00:01:03:fc:6e:ec search OPUSH
```

Offering services on FreeBSD to Bluetooth clients is done with the sdpd(8) server. On FreeBSD 5.5, 6.1 and newer, the following line can be added to the `/etc/rc.conf` file:

```
sdpd_enable="YES"
```

Then the sdpd daemon can be started with:

```
# /etc/rc.d/sdpd start
```

On FreeBSD 6.0, and on FreeBSD 5.X before 5.5, sdpd is not integrated into the system startup scripts. It has to be started manually with:

```
# sdpd
```

The local server application that wants to provide Bluetooth service to the remote clients will register service with the local SDP daemon. The example of such application is rfcomm_pppd(8). Once started it will register Bluetooth LAN service with the local SDP daemon.

The list of services registered with the local SDP server can be obtained by issuing SDP browse query via local control channel:

```
# sdpcontrol -l browse
```

30.4.8. Dial-Up Networking (DUN) and Network Access with PPP (LAN) Profiles

The Dial-Up Networking (DUN) profile is mostly used with modems and cellular phones. The scenarios covered by this profile are the following:

- use of a cellular phone or modem by a computer as a wireless modem for connecting to a dial-up Internet access server, or using other dial-up services;
- use of a cellular phone or modem by a computer to receive data calls.

Network Access with PPP (LAN) profile can be used in the following situations:

- LAN access for a single Bluetooth device;
- LAN access for multiple Bluetooth devices;
- PC to PC (using PPP networking over serial cable emulation).

In FreeBSD both profiles are implemented with ppp(8) and rfcomm_pppd(8) - a wrapper that converts RFCOMM Bluetooth connection into something PPP can operate with. Before any profile can be used, a new PPP label in the `/etc/ppp/ppp.conf` must be created. Consult rfcomm_pppd(8) manual page for examples.

In the following example rfcomm_pppd(8) will be used to open RFCOMM connection to remote device with BD_ADDR 00:80:37:29:19:a4 on DUN RFCOMM channel. The actual RFCOMM channel number will be obtained from the remote device via SDP. It is possible to specify RFCOMM channel by hand, and in this case rfcomm_pppd(8) will not perform SDP query. Use sdpcontrol(8) to find out RFCOMM channel on the remote device.

```
# rfcomm_pppd -a 00:80:37:29:19:a4 -c -C dun -l rfcomm-dialup
```

In order to provide Network Access with PPP (LAN) service the sdpd(8) server must be running. A new entry for LAN clients must be created in the `/etc/ppp/ppp.conf` file. Consult rfcomm_pppd(8) manual page for examples. Finally, start RFCOMM PPP server on valid RFCOMM channel number. The RFCOMM PPP server will automatically register Bluetooth LAN service with the local SDP daemon. The example below shows how to start RFCOMM PPP server.

```
# rfcomm_pppd -s -C 7 -l rfcomm-server
```

30.4.9. OBEX Object Push (OPUSH) Profile

OBEX is a widely used protocol for simple file transfers between mobile devices. Its main use is in infrared communication, where it is used for generic file transfers between notebooks or PDAs, and for sending business cards or calendar entries between cellular phones and other devices with PIM applications.

The OBEX server and client are implemented as a third-party package obexapp, which is available as comms/obexapp port.

OBEX client is used to push and/or pull objects from the OBEX server. An object can, for example, be a business card or an appointment. The OBEX client can obtain RFCOMM channel number from the remote device via SDP. This can be done by specifying service name instead of RFCOMM channel number. Supported service names are: IrMC, FTRN and OPUSH. It is possible to specify RFCOMM channel as a number. Below is an example of an OBEX session, where device information object is pulled from the cellular phone, and a new object (business card) is pushed into the phone's directory.

```
% obexapp -a 00:80:37:29:19:a4 -C IrMC
obex> get telecom/devinfo.txt devinfo-t39.txt
Success, response: OK, Success (0x20)
obex> put new.vcf
Success, response: OK, Success (0x20)
obex> di
Success, response: OK, Success (0x20)
```

In order to provide OBEX Object Push service, sdpd(8) server must be running. A root folder, where all incoming objects will be stored, must be created. The default path to the root folder is `/var/spool/obex` . Finally, start OBEX server on valid RFCOMM channel number. The OBEX server will automatically register OBEX Object Push service with the local SDP daemon. The example below shows how to start OBEX server.

```
# obexapp -s -C 10
```

30.4.10. Serial Port Profile (SPP)

The Serial Port Profile (SPP) allows Bluetooth devices to perform RS232 (or similar) serial cable emulation. The scenario covered by this profile deals with legacy applications using Bluetooth as a cable replacement, through a virtual serial port abstraction.

The rfcomm_sppd(1) utility implements the Serial Port profile. A pseudo tty is used as a virtual serial port abstraction. The example below shows how to connect to a remote device Serial Port service. Note that you do not have to specify a RFCOMM channel - rfcomm_sppd(1) can obtain it from the remote device via SDP. If you would like to override this, specify a RFCOMM channel on the command line.

```
# rfcomm_sppd -a 00:07:E0:00:0B:CA -t /dev/ttyp6
rfcomm_sppd[94692]: Starting on /dev/ttyp6...
```

Once connected, the pseudo tty can be used as serial port:

```
# cu -l ttyp6
```

30.4.11. Troubleshooting

30.4.11.1. A remote device cannot connect

Some older Bluetooth devices do not support role switching. By default, when FreeBSD is accepting a new connection, it tries to perform a role switch and become master. Devices, which do not support this will not be able to connect. Note that role switching is performed when a new connection is being established, so it is not possible to ask the remote device if it does support role switching. There is a HCI option to disable role switching on the local side:

```
# hccontrol -n ubt0hci write_node_role_switch 0
```

30.4.11.2. Something is going wrong, can I see what exactly is happening?

Yes, you can. Use the third-party package hcidump, which is available as comms/hcidump port. The hcidump utility is similar to tcpdump(1). It can be used to display the content of the Bluetooth packets on the terminal and to dump the Bluetooth packets to a file.

30.5. Bridging

Written by Andrew Thompson.

30.5.1. Introduction

It is sometimes useful to divide one physical network (such as an Ethernet segment) into two separate network segments without having to create IP subnets and use a router to connect the segments together. A device that connects two networks together in this fashion is called a “bridge”. A FreeBSD system with two network interface cards can act as a bridge.

The bridge works by learning the MAC layer addresses (Ethernet addresses) of the devices on each of its network interfaces. It forwards traffic between two networks only when its source and destination are on different networks.

In many respects, a bridge is like an Ethernet switch with very few ports.

30.5.2. Situations Where Bridging Is Appropriate

There are many common situations in which a bridge is used today.

30.5.2.1. Connecting Networks

The basic operation of a bridge is to join two or more network segments together. There are many reasons to use a host based bridge over plain networking equipment such as cabling constraints, firewalling or connecting pseudo networks such as a Virtual Machine interface. A bridge can also connect a wireless interface running in hostap mode to a wired network and act as an access point.

30.5.2.2. Filtering/Traffic Shaping Firewall

A common situation is where firewall functionality is needed without routing or network address translation (NAT).

An example is a small company that is connected via DSL or ISDN to their ISP. They have a 13 globally-accessible IP addresses from their ISP and have 10 PCs on their network. In this situation, using a router-based firewall is difficult because of subnetting issues.

A bridge-based firewall can be configured and dropped into the path just downstream of their DSL/ISDN router without any IP numbering issues.

30.5.2.3. Network Tap

A bridge can join two network segments and be used to inspect all Ethernet frames that pass between them. This can either be from using bpf(4)/tcpdump(1) on the bridge interface or by sending a copy of all frames out an additional interface (span port).

30.5.2.4. Layer 2 VPN

Two Ethernet networks can be joined across an IP link by bridging the networks to an EtherIP tunnel or a tap(4) based solution such as OpenVPN.

30.5.2.5. Layer 2 Redundancy

A network can be connected together with multiple links and use the Spanning Tree Protocol to block redundant paths. For an Ethernet network to function properly only one active path can exist between two devices, Spanning Tree will detect loops and put the redundant links into a blocked state. Should one of the active links fail then the protocol will calculate a different tree and reenable one of the blocked paths to restore connectivity to all points in the network.

30.5.3. Kernel Configuration

This section covers if_bridge(4) bridge implementation, a netgraph bridging driver is also available, for more information see ng_bridge(4) manual page.

The bridge driver is a kernel module and will be automatically loaded by ifconfig(8) when creating a bridge interface. It is possible to compile the bridge in to the kernel by adding `device if_bridge` to your kernel configuration file.

Packet filtering can be used with any firewall package that hooks in via the pfil(9) framework. The firewall can be loaded as a module or compiled into the kernel.

The bridge can be used as a traffic shaper with altq(4) or dummynet(4).

30.5.4. Enabling the Bridge

The bridge is created using interface cloning. To create a bridge use ifconfig(8), if the bridge driver is not present in the kernel then it will be loaded automatically.

```
# ifconfig bridge create
bridge0
# ifconfig bridge0
bridge0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> metric 0 mtu 1500
        ether 96:3d:4b:f1:79:7a
        id 00:00:00:00:00:00 priority 32768 hellotime 2 fwddelay 15
        maxage 20 holdcnt 6 proto rstp maxaddr 100 timeout 1200
        root id 00:00:00:00:00:00 priority 0 ifcost 0 port 0
```

A bridge interface is created and is automatically assigned a randomly generated Ethernet address. The `maxaddr` and `timeout` parameters control how many MAC addresses the bridge will keep in its forwarding table and how many seconds before each entry is removed after it is last seen. The other parameters control how Spanning Tree operates.

Add the member network interfaces to the bridge. For the bridge to forward packets all member interfaces and the bridge need to be up:

```
# ifconfig bridge0 addm fxp0 addm fxp1 up
# ifconfig fxp0 up
# ifconfig fxp1 up
```

The bridge is now forwarding Ethernet frames between `fxp0` and `fxp1`. The equivalent configuration in `/etc/rc.conf` so the bridge is created at startup is:

```
cloned_interfaces="bridge0"
ifconfig_bridge0="addm fxp0 addm fxp1 up"
ifconfig_fxp0="up"
ifconfig_fxp1="up"
```

If the bridge host needs an IP address then the correct place to set this is on the bridge interface itself rather than one of the member interfaces. This can be set statically or via DHCP:

```
# ifconfig bridge0 inet 192.168.0.1/24
```

It is also possible to assign an IPv6 address to a bridge interface.

30.5.5. Firewalling

When packet filtering is enabled, bridged packets will pass through the filter inbound on the originating interface, on the bridge interface and outbound on the appropriate interfaces. Either stage can be disabled. When direction of the packet flow is important it is best to firewall on the member interfaces rather than the bridge itself.

The bridge has several configurable settings for passing non-IP and ARP packets, and layer2 firewalling with IPFW. See if_bridge(4) for more information.

30.5.6. Spanning Tree

The bridge driver implements the Rapid Spanning Tree Protocol (RSTP or 802.1w) with backwards compatibility with the legacy Spanning Tree Protocol (STP). Spanning Tree is used to detect and remove loops in a network topology. RSTP provides faster Spanning Tree convergence than legacy STP, the protocol will exchange information with neighbouring switches to quickly transition to forwarding without creating loops.

The following table shows the supported operating modes:

OS Version	STP Modes	Default Mode
FreeBSD 5.4——FreeBSD 6.2	STP	STP
FreeBSD 6.3+	RSTP or STP	STP
FreeBSD 7.0+	RSTP or STP	RSTP

Spanning Tree can be enabled on member interfaces using the `stp` command. For a bridge with `fxp0` and `fxp1` as the current interfaces, enable STP with the following:

```
# ifconfig bridge0 stp fxp0 stp fxp1
bridge0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        ether d6:cf:d5:a0:94:6d
        id 00:01:02:4b:d4:50 priority 32768 hellotime 2 fwddelay 15
        maxage 20 holdcnt 6 proto rstp maxaddr 100 timeout 1200
        root id 00:01:02:4b:d4:50 priority 32768 ifcost 0 port 0
        member: fxp0 flags=1c7<LEARNING,DISCOVER,STP,AUTOEDGE,PTP,AUTOPTP>
                port 3 priority 128 path cost 200000 proto rstp
                role designated state forwarding
        member: fxp1 flags=1c7<LEARNING,DISCOVER,STP,AUTOEDGE,PTP,AUTOPTP>
                port 4 priority 128 path cost 200000 proto rstp
                role designated state forwarding
```

This bridge has a spanning tree ID of `00:01:02:4b:d4:50` and a priority of `32768`. As the `root id` is the same it indicates that this is the root bridge for the tree.

Another bridge on the network also has spanning tree enabled:

```
bridge0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        ether 96:3d:4b:f1:79:7a
        id 00:13:d4:9a:06:7a priority 32768 hellotime 2 fwddelay 15
        maxage 20 holdcnt 6 proto rstp maxaddr 100 timeout 1200
        root id 00:01:02:4b:d4:50 priority 32768 ifcost 400000 port 4
        member: fxp0 flags=1c7<LEARNING,DISCOVER,STP,AUTOEDGE,PTP,AUTOPTP>
                port 4 priority 128 path cost 200000 proto rstp
                role root state forwarding
        member: fxp1 flags=1c7<LEARNING,DISCOVER,STP,AUTOEDGE,PTP,AUTOPTP>
                port 5 priority 128 path cost 200000 proto rstp
                role designated state forwarding
```

The line `root id 00:01:02:4b:d4:50 priority 32768 ifcost 400000 port 4` shows that the root bridge is `00:01:02:4b:d4:50` as above and has a path cost of `400000` from this bridge, the path to the root bridge is via `port 4` which is `fxp0`.

30.5.7. Advanced Bridging

30.5.7.1. Reconstruct Traffic Flows

The bridge supports monitor mode, where the packets are discarded after bpf(4) processing, and are not processed or forwarded further. This can be used to multiplex the input of two or more interfaces into a single bpf(4) stream.

This is useful for reconstructing the traffic for network taps that transmit the RX/TX signals out through two separate interfaces.

To read the input from four network interfaces as one stream:

```
# ifconfig bridge0 addm fxp0 addm fxp1 addm fxp2 addm fxp3 monitor up
# tcpdump -i bridge0
```

30.5.7.2. Span Ports

A copy of every Ethernet frame received by the bridge will be transmitted out a designated span port. The number of span ports configured on a bridge is unlimited, if an interface is designated as a span port then it may not also be used as a regular bridge port. This is most useful for snooping a bridged network passively on another host connected to one of the span ports of the bridge.

To send a copy of all frames out the interface named `fxp4`:

```
# ifconfig bridge0 span fxp4
```

30.5.7.3. Private Interfaces

A private interface does not forward any traffic to any other port that is also a private interface. The traffic is blocked unconditionally so no Ethernet frames will be forwarded, including ARP. If traffic needs to be selectively blocked then a firewall should be used instead.

30.5.7.4. Sticky Interfaces

If a bridge member interface is marked as sticky then dynamically learned address entries are treated at static once entered into the forwarding cache. Sticky entries are never aged out of the cache or replaced, even if the address is seen on a different interface. This gives the benefit of static address entries without the need to pre-populate the forwarding table, clients learnt on a particular segment of the bridge can not roam to another segment.

Another example of using sticky addresses would be to combine the bridge with VLANs to create a router where customer networks are isolated without wasting IP address space. Consider that `CustomerA` is on `vlan100` and `CustomerB` is on `vlan101`. The bridge has the address `192.168.0.1` and is also an internet router.

```
# ifconfig bridge0 addm vlan100 sticky vlan100 addm vlan101 sticky ↺
vlan101
# ifconfig bridge0 inet 192.168.0.1/24
```

Both clients see `192.168.0.1` as their default gateway and since the bridge cache is sticky they can not spoof the MAC address of the other customer to intercept their traffic.

Any communication between the VLANs can be blocked using private interfaces (or a firewall):

```
# ifconfig bridge0 private vlan100 private vlan101
```

The customers are completely isolated from each other, the full `/24` address range can be allocated without subnetting.

30.5.7.5. SNMP Monitoring

The bridge interface and STP parameters can be monitored via the SNMP daemon which is included in the FreeBSD base system. The exported bridge MIBs conform to the IETF standards so any SNMP client or monitoring package can be used to retrieve the data.

On the bridge machine uncomment the `begemotSnmpdModulePath."bridge" = "/usr/lib/snmp_bridge.so"` line from `/etc/snmp.config` and start the bsnmpd daemon. Other configuration such as community names and access lists may need to be modified. See bsnmpd(1) and snmp_bridge(3) for more information.

The following examples use the Net-SNMP software (net-mgmt/net-snmp) to query a bridge, the net-mgmt/bsnmptools port can also be used. From the SNMP client host add to `$HOME/.snmp/snmp.conf` the following lines to import the bridge MIB definitions in to Net-SNMP:

```
mibdirs +/usr/share/snmp/mibs
mibs +BRIDGE-MIB:RSTP-MIB:BEGEMOT-MIB:BEGEMOT-BRIDGE-MIB
```

To monitor a single bridge via the IETF BRIDGE-MIB (RFC4188) do

```
% snmpwalk -v 2c -c public bridge1.example.com mib-2.dot1dBridge
BRIDGE-MIB::dot1dBaseBridgeAddress.0 = STRING: 66:fb:9b:6e:5c:44
BRIDGE-MIB::dot1dBaseNumPorts.0 = INTEGER: 1 ports
BRIDGE-MIB::dot1dStpTimeSinceTopologyChange.0 = Timeticks: (189959) 0:31:39.59 centi-
seconds
BRIDGE-MIB::dot1dStpTopChanges.0 = Counter32: 2
BRIDGE-MIB::dot1dStpDesignatedRoot.0 = Hex-STRING: 80 00 00 01 02 4B D4 50
...
BRIDGE-MIB::dot1dStpPortState.3 = INTEGER: forwarding(5)
BRIDGE-MIB::dot1dStpPortEnable.3 = INTEGER: enabled(1)
BRIDGE-MIB::dot1dStpPortPathCost.3 = INTEGER: 200000
BRIDGE-MIB::dot1dStpPortDesignatedRoot.3 = Hex-STRING: 80 00 00 01 02 4B D4 50
BRIDGE-MIB::dot1dStpPortDesignatedCost.3 = INTEGER: 0
BRIDGE-MIB::dot1dStpPortDesignatedBridge.3 = Hex-STRING: 80 00 00 01 02 4B D4 50
BRIDGE-MIB::dot1dStpPortDesignatedPort.3 = Hex-STRING: 03 80
BRIDGE-MIB::dot1dStpPortForwardTransitions.3 = Counter32: 1
RSTP-MIB::dot1dStpVersion.0 = INTEGER: rstp(2)
```

The `dot1dStpTopChanges.0` value is two which means that the STP bridge topology has changed twice, a topology change means that one or more links in the network have changed or failed and a new tree has been calculated. The `dot1dStpTimeSinceTopologyChange.0` value will show when this happened.

To monitor multiple bridge interfaces one may use the private BEGEMOT-BRIDGE-MIB:

```
% snmpwalk -v 2c -c public bridge1.example.com
enterprises.fokus.begemot.begemotBridge
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseName."bridge0" = STRING: bridge0
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseName."bridge2" = STRING: bridge2
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseAddress."bridge0" = STRING: e:ce:3b:5a:9e:13
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseAddress."bridge2" = STRING: 12:5e:4d:74:d:fc
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseNumPorts."bridge0" = INTEGER: 1
BEGEMOT-BRIDGE-MIB::begemotBridgeBaseNumPorts."bridge2" = INTEGER: 1
...
BEGEMOT-BRIDGE-MIB::begemotBridgeStpTimeSinceTopologyChange."bridge0" = Timeticks: ↺
(116927) 0:19:29.27 centi-seconds
BEGEMOT-BRIDGE-MIB::begemotBridgeStpTimeSinceTopologyChange."bridge2" = Timeticks: ↺
(82773) 0:13:47.73 centi-seconds
BEGEMOT-BRIDGE-MIB::begemotBridgeStpTopChanges."bridge0" = Counter32: 1
BEGEMOT-BRIDGE-MIB::begemotBridgeStpTopChanges."bridge2" = Counter32: 1
BEGEMOT-BRIDGE-MIB::begemotBridgeStpDesignatedRoot."bridge0" = Hex-STRING: 80 00 00 40 ↺
95 30 5E 31
BEGEMOT-BRIDGE-MIB::begemotBridgeStpDesignatedRoot."bridge2" = Hex-STRING: 80 00 00 50 ↺
8B B8 C6 A9
```

To change the bridge interface being monitored via the `mib-2.dot1dBridge` subtree do:

```
% snmpset -v 2c -c private bridge1.example.com
BEGEMOT-BRIDGE-MIB::begemotBridgeDefaultBridgeIf.0 s bridge2
```

30.6. Link Aggregation and Failover

Written by Andrew Thompson.

30.6.1. Introduction

The lagg(4) interface allows aggregation of multiple network interfaces as one virtual interface for the purpose of providing fault-tolerance and high-speed links.

30.6.2. Operating Modes

failover
: Sends and receives traffic only through the master port. If the master port becomes unavailable, the next active port is used. The first interface added is the master port; any interfaces added after that are used as failover devices.

fec
: Supports Cisco EtherChannel. This is a static setup and does not negotiate aggregation with the peer or exchange frames to monitor the link, if the switch supports LACP then that should be used instead.

  Balances outgoing traffic across the active ports based on hashed protocol header information and accepts incoming traffic from any active port. The hash includes the Ethernet source and destination address, and, if available, the VLAN tag, and the IPv4/IPv6 source and destination address.

lacp
: Supports the IEEE 802.3ad Link Aggregation Control Protocol (LACP) and the Marker Protocol. LACP will negotiate a set of aggregable links with the peer in to one or more Link Aggregated Groups. Each LAG is composed of ports of the same speed, set to full-duplex operation. The traffic will be balanced across the ports in the LAG with the greatest total speed, in most cases there will only be one LAG which contains all ports. In the event of changes in physical connectivity, Link Aggregation will quickly converge to a new configuration.

  Balances outgoing traffic across the active ports based on hashed protocol header information and accepts incoming traffic from any active port. The hash includes the Ethernet source and destination address, and, if available, the VLAN tag, and the IPv4/IPv6 source and destination address.

loadbalance
: This is an alias of fec mode.

roundrobin
: Distributes outgoing traffic using a round-robin scheduler through all active ports and accepts incoming traffic from any active port. This mode will violate Ethernet frame ordering and should be used with caution.

30.6.3. Examples

範例 30.1. LACP aggregation with a Cisco switch

This example connects two interfaces on a FreeBSD machine to the switch as a single load balanced and fault tolerant link. More interfaces can be added to increase throughput and fault tolerance. Since frame ordering is mandatory on Ethernet links then any traffic between two stations always flows over the same physical link limiting the maximum speed to that of one interface. The transmit algorithm attempts to use as much information as it can to distinguish different traffic flows and balance across the available interfaces.

On the Cisco switch add the interfaces to the channel group.

```
interface FastEthernet0/1
 channel-group 1 mode active
 channel-protocol lacp
!
interface FastEthernet0/2
```

```
 channel-group 1 mode active
 channel-protocol lacp
!
```

On the FreeBSD machine create the lagg interface.

```
# ifconfig lagg0 create
# ifconfig lagg0 up laggproto lacp laggport fxp0 laggport fxp1
```

View the interface status from ifconfig; ports marked as ACTIVE are part of the active aggregation group that has been negotiated with the remote switch and traffic will be transmitted and received. Use the verbose output of ifconfig(8) to view the LAG identifiers.

```
lagg0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        options=8<VLAN_MTU>
        ether 00:05:5d:71:8d:b8
        media: Ethernet autoselect
        status: active
        laggproto lacp
        laggport: fxp1 flags=1c<ACTIVE,COLLECTING,DISTRIBUTING>
        laggport: fxp0 flags=1c<ACTIVE,COLLECTING,DISTRIBUTING>
```

The switch will show which ports are active. For more detail use **`show lacp neighbor detail`** .

```
switch# show lacp neighbor
Flags:  S - Device is requesting Slow LACPDUs
        F - Device is requesting Fast LACPDUs
        A - Device is in Active mode       P - Device is in Passive mode

Channel group 1 neighbors

Partner's information:

                  LACP port                        Oper    Port     Port
Port      Flags   Priority  Dev ID         Age     Key     Number   State
Fa0/1     SA      32768     0005.5d71.8db8  29s    0x146   0x3      0x3D
Fa0/2     SA      32768     0005.5d71.8db8  29s    0x146   0x4      0x3D
```

範例 30.2. Failover mode

Failover mode can be used to switch over to another interface if the link is lost on the master.

```
# ifconfig lagg0 create
# ifconfig lagg0 up laggproto failover laggport fxp0 laggport fxp1
```

```
lagg0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> metric 0 mtu 1500
        options=8<VLAN_MTU>
        ether 00:05:5d:71:8d:b8
        media: Ethernet autoselect
        status: active
        laggproto failover
        laggport: fxp1 flags=0<>
        laggport: fxp0 flags=5<MASTER,ACTIVE>
```

Traffic will be transmitted and received on `fxp0`. If the link is lost on `fxp0` then `fxp1` will become the active link. If the link is restored on the master interface then it will once again become the active link.

30.7. Diskless Operation

Updated by Jean-François Dockès.
Reorganized and enhanced by Alex Dupre.

A FreeBSD machine can boot over the network and operate without a local disk, using file systems mounted from an NFS server. No system modification is necessary, beyond standard configuration files. Such a system is relatively easy to set up because all the necessary elements are readily available:

- There are at least two possible methods to load the kernel over the network:
  - PXE: The Intel® Preboot eXecution Environment system is a form of smart boot ROM built into some networking cards or motherboards. See pxeboot(8) for more details.
  - The Etherboot port (net/etherboot) produces ROM-able code to boot kernels over the network. The code can be either burnt into a boot PROM on a network card, or loaded from a local floppy (or hard) disk drive, or from a running MS-DOS® system. Many network cards are supported.
- A sample script (`/usr/share/examples/diskless/clone_root`) eases the creation and maintenance of the workstation's root file system on the server. The script will probably require a little customization but it will get you started very quickly.
- Standard system startup files exist in `/etc` to detect and support a diskless system startup.
- Swapping, if needed, can be done either to an NFS file or to a local disk.

There are many ways to set up diskless workstations. Many elements are involved, and most can be customized to suit local taste. The following will describe variations on the setup of a complete system, emphasizing simplicity and compatibility with the standard FreeBSD startup scripts. The system described has the following characteristics:

- The diskless workstations use a shared read-only `/` file system, and a shared read-only `/usr`.

  The root file system is a copy of a standard FreeBSD root (typically the server's), with some configuration files overridden by ones specific to diskless operation or, possibly, to the workstation they belong to.

  The parts of the root which have to be writable are overlaid with md(4) file systems. Any changes will be lost when the system reboots.
- The kernel is transferred and loaded either with Etherboot or PXE as some situations may mandate the use of either method.

注意

As described, this system is insecure. It should live in a protected area of a network, and be untrusted by other hosts.

All the information in this section has been tested using FreeBSD 5.2.1-RELEASE.

30.7.1. Background Information

Setting up diskless workstations is both relatively straightforward and prone to errors. These are sometimes difficult to diagnose for a number of reasons. For example:

- Compile time options may determine different behaviors at runtime.

- Error messages are often cryptic or totally absent.

In this context, having some knowledge of the background mechanisms involved is very useful to solve the problems that may arise.

Several operations need to be performed for a successful bootstrap:

- The machine needs to obtain initial parameters such as its IP address, executable filename, server name, root path. This is done using the DHCP or BOOTP protocols. DHCP is a compatible extension of BOOTP, and uses the same port numbers and basic packet format.

  It is possible to configure a system to use only BOOTP. The bootpd(8) server program is included in the base FreeBSD system.

  However, DHCP has a number of advantages over BOOTP (nicer configuration files, possibility of using PXE, plus many others not directly related to diskless operation), and we will describe mainly a DHCP configuration, with equivalent examples using bootpd(8) when possible. The sample configuration will use the ISC DHCP software package (release 3.0.1.r12 was installed on the test server).

- The machine needs to transfer one or several programs to local memory. Either TFTP or NFS are used. The choice between TFTP and NFS is a compile time option in several places. A common source of error is to specify filenames for the wrong protocol: TFTP typically transfers all files from a single directory on the server, and would expect filenames relative to this directory. NFS needs absolute file paths.

- The possible intermediate bootstrap programs and the kernel need to be initialized and executed. There are several important variations in this area:

  - PXE will load pxeboot(8), which is a modified version of the FreeBSD third stage loader. The loader(8) will obtain most parameters necessary to system startup, and leave them in the kernel environment before transferring control. It is possible to use a `GENERIC` kernel in this case.

  - Etherboot, will directly load the kernel, with less preparation. You will need to build a kernel with specific options.

  PXE and Etherboot work equally well; however, because kernels normally let the loader(8) do more work for them, PXE is the preferred method.

  If your BIOS and network cards support PXE, you should probably use it.

- Finally, the machine needs to access its file systems. NFS is used in all cases.

See also diskless(8) manual page.

30.7.2. Setup Instructions

30.7.2.1. Configuration Using ISC DHCP

The ISC DHCP server can answer both BOOTP and DHCP requests.

ISC DHCP 3.0 is not part of the base system. You will first need to install the net/isc-dhcp3-server port or the corresponding package.

Once ISC DHCP is installed, it needs a configuration file to run (normally named `/usr/local/etc/dhcpd.conf`). Here follows a commented example, where host `margaux` uses Etherboot and host `corbieres` uses PXE:

```
default-lease-time 600;
max-lease-time 7200;
```

```
authoritative;

option domain-name "example.com";
option domain-name-servers 192.168.4.1;
option routers 192.168.4.1;

subnet 192.168.4.0 netmask 255.255.255.0 {
  use-host-decl-names on; ❶
  option subnet-mask 255.255.255.0;
  option broadcast-address 192.168.4.255;

  host margaux {
    hardware ethernet 01:23:45:67:89:ab;
    fixed-address margaux.example.com;
    next-server 192.168.4.4; ❷
    filename "/data/misc/kernel.diskless"; ❸
    option root-path "192.168.4.4:/data/misc/diskless"; ❹
  }
  host corbieres {
    hardware ethernet 00:02:b3:27:62:df;
    fixed-address corbieres.example.com;
    next-server 192.168.4.4;
    filename "pxeboot";
    option root-path "192.168.4.4:/data/misc/diskless";
  }
}
```

❶ This option tells dhcpd to send the value in the `host` declarations as the hostname for the diskless host. An alternate way would be to add an `option host-name margaux` inside the `host` declarations.

❷ The `next-server` directive designates the TFTP or NFS server to use for loading loader or kernel file (the default is to use the same host as the DHCP server).

❸ The `filename` directive defines the file that Etherboot or PXE will load for the next execution step. It must be specified according to the transfer method used. Etherboot can be compiled to use NFS or TFTP. The FreeBSD port configures NFS by default. PXE uses TFTP, which is why a relative filename is used here (this may depend on the TFTP server configuration, but would be fairly typical). Also, PXE loads `pxeboot`, not the kernel. There are other interesting possibilities, like loading `pxeboot` from a FreeBSD CD-ROM `/boot` directory (as pxeboot(8) can load a `GENERIC` kernel, this makes it possible to use PXE to boot from a remote CD-ROM).

❹ The `root-path` option defines the path to the root file system, in usual NFS notation. When using PXE, it is possible to leave off the host's IP as long as you do not enable the kernel option BOOTP. The NFS server will then be the same as the TFTP one.

30.7.2.2. Configuration Using BOOTP

Here follows an equivalent bootpd configuration (reduced to one client). This would be found in `/etc/bootptab`.

Please note that Etherboot must be compiled with the non-default option `NO_DHCP_SUPPORT` in order to use BOOTP, and that PXE needs DHCP. The only obvious advantage of bootpd is that it exists in the base system.

```
.def100:\
  :hn:ht=1:sa=192.168.4.4:vm=rfc1048:\
  :sm=255.255.255.0:\
  :ds=192.168.4.1:\
  :gw=192.168.4.1:\
  :hd="/tftpboot":\
  :bf="/kernel.diskless":\
  :rp="192.168.4.4:/data/misc/diskless":

margaux:ha=0123456789ab:tc=.def100
```

30.7.2.3. Preparing a Boot Program with Etherboot

Etherboot's Web site contains extensive documentation mainly intended for Linux systems, but nonetheless containing useful information. The following will just outline how you would use Etherboot on a FreeBSD system.

You must first install the net/etherboot package or port.

You can change the Etherboot configuration (i.e. to use TFTP instead of NFS) by editing the `Config` file in the Etherboot source directory.

For our setup, we shall use a boot floppy. For other methods (PROM, or MS-DOS® program), please refer to the Etherboot documentation.

To make a boot floppy, insert a floppy in the drive on the machine where you installed Etherboot, then change your current directory to the `src` directory in the Etherboot tree and type:

```
# gmake bin32/devicetype.fd0
```

`devicetype` depends on the type of the Ethernet card in the diskless workstation. Refer to the `NIC` file in the same directory to determine the right *`devicetype`*.

30.7.2.4. Booting with PXE

By default, the pxeboot(8) loader loads the kernel via NFS. It can be compiled to use TFTP instead by specifying the `LOADER_TFTP_SUPPORT` option in `/etc/make.conf`. See the comments in `/usr/share/examples/etc/make.conf` for instructions.

There are two other `make.conf` options which may be useful for setting up a serial console diskless machine: `BOOT_PXELDR_PROBE_KEYBOARD`, and `BOOT_PXELDR_ALWAYS_SERIAL`.

To use PXE when the machine starts, you will usually need to select the `Boot from network` option in your BIOS setup, or type a function key during the PC initialization.

30.7.2.5. Configuring the TFTP and NFS Servers

If you are using PXE or Etherboot configured to use TFTP, you need to enable tftpd on the file server:

1. Create a directory from which tftpd will serve the files, e.g. `/tftpboot`.
2. Add this line to your `/etc/inetd.conf`:

   ```
   tftp dgram udp wait root /usr/libexec/tftpd tftpd -l -s /tftpboot
   ```

   注意

   It appears that at least some PXE versions want the TCP version of TFTP. In this case, add a second line, replacing `dgram udp` with `stream tcp`.

3. Tell inetd to reread its configuration file. The `inetd_enable="YES"` must be in the `/etc/rc.conf` file for this command to execute correctly:

   ```
   # /etc/rc.d/inetd restart
   ```

You can place the `tftpboot` directory anywhere on the server. Make sure that the location is set in both `inetd.conf` and `dhcpd.conf`.

In all cases, you also need to enable NFS and export the appropriate file system on the NFS server.

1. Add this to `/etc/rc.conf`:

   ```
   nfs_server_enable="YES"
   ```

2. Export the file system where the diskless root directory is located by adding the following to `/etc/exports` (adjust the volume mount point and replace *`margaux corbieres`* with the names of the diskless workstations):

   ```
   /data/misc -alldirs -ro margaux corbieres
   ```

3. Tell mountd to reread its configuration file. If you actually needed to enable NFS in `/etc/rc.conf` at the first step, you probably want to reboot instead.

   ```
   # /etc/rc.d/mountd restart
   ```

30.7.2.6. Building a Diskless Kernel

If using Etherboot, you need to create a kernel configuration file for the diskless client with the following options (in addition to the usual ones):

```
options     BOOTP          # Use BOOTP to obtain IP address/hostname
options     BOOTP_NFSROOT  # NFS mount root file system using BOOTP info
```

You may also want to use `BOOTP_NFSV3`, `BOOT_COMPAT` and `BOOTP_WIRED_TO` (refer to `NOTES`).

These option names are historical and slightly misleading as they actually enable indifferent use of DHCP and BOOTP inside the kernel (it is also possible to force strict BOOTP or DHCP use).

Build the kernel (see 章 8, 設定 FreeBSD Kernel), and copy it to the place specified in `dhcpd.conf`.

注意

When using PXE, building a kernel with the above options is not strictly necessary (though suggested). Enabling them will cause more DHCP requests to be issued during kernel startup, with a small risk of inconsistency between the new values and those retrieved by pxeboot(8) in some special cases. The advantage of using them is that the host name will be set as a side effect. Otherwise you will need to set the host name by another method, for example in a client-specific `rc.conf` file.

注意

In order to be loadable with Etherboot, a kernel needs to have the device hints compiled in. You would typically set the following option in the configuration file (see the `NOTES` configuration comments file):

```
hints  "GENERIC.hints"
```

30.7.2.7. Preparing the Root Filesystem

You need to create a root file system for the diskless workstations, in the location listed as `root-path` in `dhcpd.conf`.

30.7.2.7.1. Using `make world` to populate root

This method is quick and will install a complete virgin system (not only the root file system) into `DESTDIR`. All you have to do is simply execute the following script:

```
#!/bin/sh
export DESTDIR=/data/misc/diskless
mkdir -p ${DESTDIR}
cd /usr/src; make buildworld && make buildkernel
cd /usr/src/etc; make distribution
```

Once done, you may need to customize your `/etc/rc.conf` and `/etc/fstab` placed into `DESTDIR` according to your needs.

30.7.2.8. Configuring Swap

If needed, a swap file located on the server can be accessed via NFS.

30.7.2.8.1. NFS Swap

The kernel does not support enabling NFS swap at boot time. Swap must be enabled by the startup scripts, by mounting a writable file system and creating and enabling a swap file. To create a swap file of appropriate size, you can do like this:

```
# dd if=/dev/zero of=/path/to/swapfile bs=1k count=1 oseek=100000
```

To enable it you have to add the following line to your `rc.conf`:

```
swapfile=/path/to/swapfile
```

30.7.2.9. Miscellaneous Issues

30.7.2.9.1. Running with a Read-only `/usr`

If the diskless workstation is configured to run X, you will have to adjust the XDM configuration file, which puts the error log on `/usr` by default.

30.7.2.9.2. Using a Non-FreeBSD Server

When the server for the root file system is not running FreeBSD, you will have to create the root file system on a FreeBSD machine, then copy it to its destination, using `tar` or `cpio`.

In this situation, there are sometimes problems with the special files in `/dev`, due to differing major/minor integer sizes. A solution to this problem is to export a directory from the non-FreeBSD server, mount this directory onto a FreeBSD machine, and use devfs(5) to allocate device nodes transparently for the user.

30.8. ISDN

A good resource for information on ISDN technology and hardware is Dan Kegel's ISDN Page.

A quick simple road map to ISDN follows:

- If you live in Europe you might want to investigate the ISDN card section.

- If you are planning to use ISDN primarily to connect to the Internet with an Internet Provider on a dial-up non-dedicated basis, you might look into Terminal Adapters. This will give you the most flexibility, with the fewest problems, if you change providers.
- If you are connecting two LANs together, or connecting to the Internet with a dedicated ISDN connection, you might consider the stand alone router/bridge option.

Cost is a significant factor in determining what solution you will choose. The following options are listed from least expensive to most expensive.

30.8.1. ISDN Cards

Contributed by Hellmuth Michaelis.

FreeBSD's ISDN implementation supports only the DSS1/Q.931 (or Euro-ISDN) standard using passive cards. Some active cards are supported where the firmware also supports other signaling protocols; this also includes the first supported Primary Rate (PRI) ISDN card.

The isdn4bsd software allows you to connect to other ISDN routers using either IP over raw HDLC or by using synchronous PPP: either by using kernel PPP with `isppp`, a modified sppp(4) driver, or by using userland ppp(8). By using userland ppp(8), channel bonding of two or more ISDN B-channels is possible. A telephone answering machine application is also available as well as many utilities such as a software 300 Baud modem.

Some growing number of PC ISDN cards are supported under FreeBSD and the reports show that it is successfully used all over Europe and in many other parts of the world.

The passive ISDN cards supported are mostly the ones with the Infineon (formerly Siemens) ISAC/HSCX/IPAC ISDN chipsets, but also ISDN cards with chips from Cologne Chip (ISA bus only), PCI cards with Winbond W6692 chips, some cards with the Tiger300/320/ISAC chipset combinations and some vendor specific chipset based cards such as the AVM Fritz!Card PCI V.1.0 and the AVM Fritz!Card PnP.

Currently the active supported ISDN cards are the AVM B1 (ISA and PCI) BRI cards and the AVM T1 PCI PRI cards.

For documentation on isdn4bsd, have a look at `/usr/share/examples/isdn/` directory on your FreeBSD system or at the homepage of isdn4bsd which also has pointers to hints, erratas and much more documentation such as the isdn4bsd handbook.

In case you are interested in adding support for a different ISDN protocol, a currently unsupported ISDN PC card or otherwise enhancing isdn4bsd, please get in touch with Hellmuth Michaelis.

For questions regarding the installation, configuration and troubleshooting isdn4bsd, a freebsd-isdn mailing list is available.

30.8.2. ISDN Terminal Adapters

Terminal adapters (TA), are to ISDN what modems are to regular phone lines.

Most TA's use the standard Hayes modem AT command set, and can be used as a drop in replacement for a modem.

A TA will operate basically the same as a modem except connection and throughput speeds will be much faster than your old modem. You will need to configure PPP exactly the same as for a modem setup. Make sure you set your serial speed as high as possible.

The main advantage of using a TA to connect to an Internet Provider is that you can do Dynamic PPP. As IP address space becomes more and more scarce, most providers are not willing to provide you with a static IP anymore. Most stand-alone routers are not able to accommodate dynamic IP allocation.

TA's completely rely on the PPP daemon that you are running for their features and stability of connection. This allows you to upgrade easily from using a modem to ISDN on a FreeBSD machine, if you already have PPP set up. However, at the same time any problems you experienced with the PPP program and are going to persist.

If you want maximum stability, use the kernel PPP option, not the userland PPP.

The following TA's are known to work with FreeBSD:

- Motorola BitSurfer and Bitsurfer Pro
- Adtran

Most other TA's will probably work as well, TA vendors try to make sure their product can accept most of the standard modem AT command set.

The real problem with external TA's is that, like modems, you need a good serial card in your computer.

You should read the FreeBSD Serial Hardware tutorial for a detailed understanding of serial devices, and the differences between asynchronous and synchronous serial ports.

A TA running off a standard PC serial port (asynchronous) limits you to 115.2 Kbs, even though you have a 128 Kbs connection. To fully utilize the 128 Kbs that ISDN is capable of, you must move the TA to a synchronous serial card.

Do not be fooled into buying an internal TA and thinking you have avoided the synchronous/asynchronous issue. Internal TA's simply have a standard PC serial port chip built into them. All this will do is save you having to buy another serial cable and find another empty electrical socket.

A synchronous card with a TA is at least as fast as a stand-alone router, and with a simple 386 FreeBSD box driving it, probably more flexible.

The choice of synchronous card/TA v.s. stand-alone router is largely a religious issue. There has been some discussion of this in the mailing lists. We suggest you search the archives for the complete discussion.

30.8.3. Stand-alone ISDN Bridges/Routers

ISDN bridges or routers are not at all specific to FreeBSD or any other operating system. For a more complete description of routing and bridging technology, please refer to a networking reference book.

In the context of this section, the terms router and bridge will be used interchangeably.

As the cost of low end ISDN routers/bridges comes down, it will likely become a more and more popular choice. An ISDN router is a small box that plugs directly into your local Ethernet network, and manages its own connection to the other bridge/router. It has built in software to communicate via PPP and other popular protocols.

A router will allow you much faster throughput than a standard TA, since it will be using a full synchronous ISDN connection.

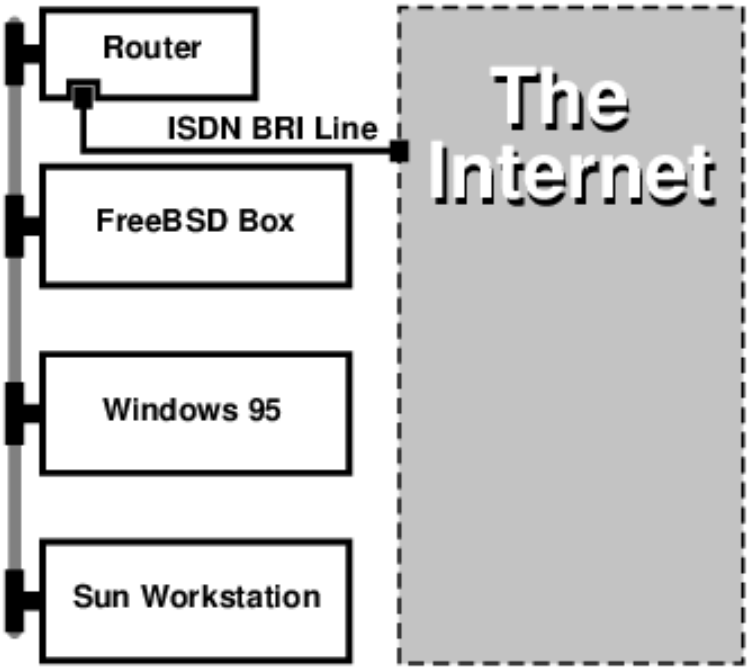
The main problem with ISDN routers and bridges is that interoperability between manufacturers can still be a problem. If you are planning to connect to an Internet provider, you should discuss your needs with them.

If you are planning to connect two LAN segments together, such as your home LAN to the office LAN, this is the simplest lowest maintenance solution. Since you are buying the equipment for both sides of the connection you can be assured that the link will work.

For example to connect a home computer or branch office network to a head office network the following setup could be used:

範例 30.3. Branch Office or Home Network

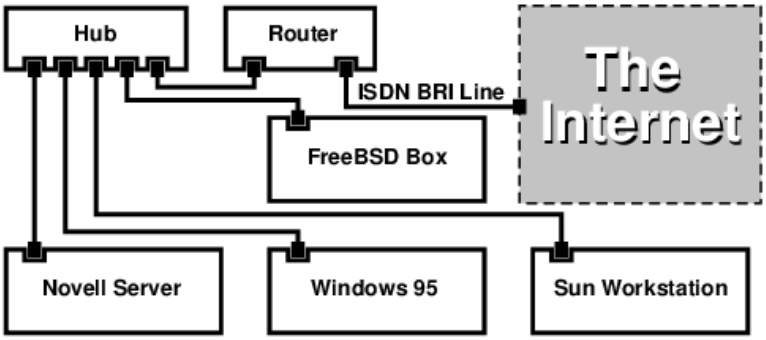
Network uses a bus based topology with 10 base 2 Ethernet (“thinnet”). Connect router to network cable with AUI/10BT transceiver, if necessary.



If your home/branch office is only one computer you can use a twisted pair crossover cable to connect to the stand-alone router directly.

範例 30.4. Head Office or Other LAN

Network uses a star topology with 10 base T Ethernet (“Twisted Pair”).



One large advantage of most routers/bridges is that they allow you to have 2 separate independent PPP connections to 2 separate sites at the same time. This is not supported on most TA's, except for specific (usually expensive) models that have two serial ports. Do not confuse this with channel bonding, MPP, etc.

This can be a very useful feature if, for example, you have an dedicated ISDN connection at your office and would like to tap into it, but do not want to get another ISDN line at work. A router at the office location can manage a dedicated

B channel connection (64 Kbps) to the Internet and use the other B channel for a separate data connection. The second B channel can be used for dial-in, dial-out or dynamically bonding (MPP, etc.) with the first B channel for more bandwidth.

An Ethernet bridge will also allow you to transmit more than just IP traffic. You can also send IPX/SPX or whatever other protocols you use.

30.9. Network Address Translation

Contributed by Chern Lee.

30.9.1. Overview

FreeBSD's Network Address Translation daemon, commonly known as natd(8) is a daemon that accepts incoming raw IP packets, changes the source to the local machine and re-injects these packets back into the outgoing IP packet stream. natd(8) does this by changing the source IP address and port such that when data is received back, it is able to determine the original location of the data and forward it back to its original requester.

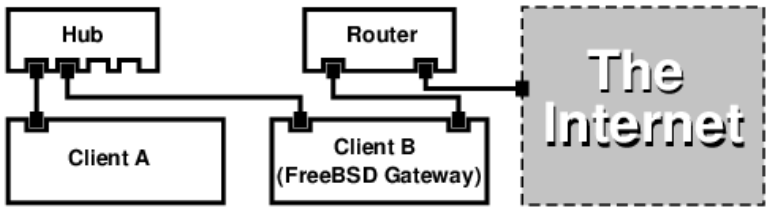
The most common use of NAT is to perform what is commonly known as Internet Connection Sharing.

30.9.2. Setup

Due to the diminishing IP space in IPv4, and the increased number of users on high-speed consumer lines such as cable or DSL, people are increasingly in need of an Internet Connection Sharing solution. The ability to connect several computers online through one connection and IP address makes natd(8) a reasonable choice.

Most commonly, a user has a machine connected to a cable or DSL line with one IP address and wishes to use this one connected computer to provide Internet access to several more over a LAN.

To do this, the FreeBSD machine on the Internet must act as a gateway. This gateway machine must have two NICs ——one for connecting to the Internet router, the other connecting to a LAN. All the machines on the LAN are connected through a hub or switch.



A setup like this is commonly used to share an Internet connection. One of the LAN machines is connected to the Internet. The rest of the machines access the Internet through that “gateway” machine.

30.9.3. Configuration

The following options must be in the kernel configuration file:

```
options IPFIREWALL
options IPDIVERT
```

Additionally, at choice, the following may also be suitable:

```
options IPFIREWALL_DEFAULT_TO_ACCEPT
options IPFIREWALL_VERBOSE
```

The following must be in `/etc/rc.conf` :

```
gateway_enable="YES" ❶
firewall_enable="YES" ❷
firewall_type="OPEN" ❸
natd_enable="YES"
natd_interface="fxp0" ❹
natd_flags="" ❺
```

❶ Sets up the machine to act as a gateway. Running `sysctl net.inet.ip.forwarding=1` would have the same effect.
❷ Enables the firewall rules in `/etc/rc.firewall` at boot.
❸ This specifies a predefined firewall ruleset that allows anything in. See `/etc/rc.firewall` for additional types.
❹ Indicates which interface to forward packets through (the interface connected to the Internet).
❺ Any additional configuration options passed to natd(8) on boot.

Having the previous options defined in `/etc/rc.conf` would run `natd -interface fxp0` at boot. This can also be run manually.

注意

It is also possible to use a configuration file for natd(8) when there are too many options to pass. In this case, the configuration file must be defined by adding the following line to `/etc/rc.conf` :

```
natd_flags="-f /etc/natd.conf"
```

The `/etc/natd.conf` file will contain a list of configuration options, one per line. For example the next section case would use the following file:

```
redirect_port tcp 192.168.0.2:6667 6667
redirect_port tcp 192.168.0.3:80 80
```

For more information about the configuration file, consult the natd(8) manual page about the `-f` option.

Each machine and interface behind the LAN should be assigned IP address numbers in the private network space as defined by RFC 1918 and have a default gateway of the natd machine's internal IP address.

For example, client A and B behind the LAN have IP addresses of `192.168.0.2` and `192.168.0.3` , while the natd machine's LAN interface has an IP address of `192.168.0.1` . Client A and B's default gateway must be set to that of the natd machine, `192.168.0.1` . The natd machine's external, or Internet interface does not require any special modification for natd(8) to work.

30.9.4. Port Redirection

The drawback with natd(8) is that the LAN clients are not accessible from the Internet. Clients on the LAN can make outgoing connections to the world but cannot receive incoming ones. This presents a problem if trying to

run Internet services on one of the LAN client machines. A simple way around this is to redirect selected Internet ports on the natd machine to a LAN client.

For example, an IRC server runs on client A, and a web server runs on client B. For this to work properly, connections received on ports 6667 (IRC) and 80 (web) must be redirected to the respective machines.

The `-redirect_port` must be passed to natd(8) with the proper options. The syntax is as follows:

```
     -redirect_port proto targetIP:targetPORT[-targetPORT]
                    [aliasIP:]aliasPORT[-aliasPORT]
                    [remoteIP[:remotePORT[-remotePORT]]]
```

In the above example, the argument should be:

```
    -redirect_port tcp 192.168.0.2:6667 6667
    -redirect_port tcp 192.168.0.3:80 80
```

This will redirect the proper tcp ports to the LAN client machines.

The `-redirect_port` argument can be used to indicate port ranges over individual ports. For example, *`tcp 192.168.0.2:2000-3000 2000-3000`* would redirect all connections received on ports 2000 to 3000 to ports 2000 to 3000 on client A.

These options can be used when directly running natd(8), placed within the `natd_flags=""` option in `/etc/rc.conf`, or passed via a configuration file.

For further configuration options, consult natd(8)

30.9.5. Address Redirection

Address redirection is useful if several IP addresses are available, yet they must be on one machine. With this, natd(8) can assign each LAN client its own external IP address. natd(8) then rewrites outgoing packets from the LAN clients with the proper external IP address and redirects all traffic incoming on that particular IP address back to the specific LAN client. This is also known as static NAT. For example, the IP addresses `128.1.1.1`, `128.1.1.2`, and `128.1.1.3` belong to the natd gateway machine. `128.1.1.1` can be used as the natd gateway machine's external IP address, while `128.1.1.2` and `128.1.1.3` are forwarded back to LAN clients A and B.

The `-redirect_address` syntax is as follows:

```
-redirect_address localIP publicIP
```

localIP	The internal IP address of the LAN client.
publicIP	The external IP address corresponding to the LAN client.

In the example, this argument would read:

```
-redirect_address 192.168.0.2 128.1.1.2
-redirect_address 192.168.0.3 128.1.1.3
```

Like `-redirect_port`, these arguments are also placed within the `natd_flags=""` option of `/etc/rc.conf`, or passed via a configuration file. With address redirection, there is no need for port redirection since all data received on a particular IP address is redirected.

The external IP addresses on the natd machine must be active and aliased to the external interface. Look at rc.conf(5) to do so.

30.10. Parallel Line IP (PLIP)

PLIP lets us run TCP/IP between parallel ports. It is useful on machines without network cards, or to install on laptops. In this section, we will discuss:

- Creating a parallel (laplink) cable.
- Connecting two computers with PLIP.

30.10.1. Creating a Parallel Cable

You can purchase a parallel cable at most computer supply stores. If you cannot do that, or you just want to know how it is done, the following table shows how to make one out of a normal parallel printer cable.

表格 30.1. Wiring a Parallel Cable for Networking

A-name	A-End	B-End	Descr.	Post/Bit
DATA0 -ERROR	2 15	15 2	Data	0/0x01 1/0x08
DATA1 +SLCT	3 13	13 3	Data	0/0x02 1/0x10
DATA2 +PE	4 12	12 4	Data	0/0x04 1/0x20
DATA3 -ACK	5 10	10 5	Strobe	0/0x08 1/0x40
DATA4 BUSY	6 11	11 6	Data	0/0x10 1/0x80
GND	18-25	18-25	GND	-

30.10.2. Setting Up PLIP

First, you have to get a laplink cable. Then, confirm that both computers have a kernel with lpt(4) driver support:

```
# grep lp /var/run/dmesg.boot
lpt0: <Printer> on ppbus0
lpt0: Interrupt-driven port
```

The parallel port must be an interrupt driven port, you should have lines similar to the following in your in the `/boot/device.hints` file:

```
hint.ppc.0.at="isa"
hint.ppc.0.irq="7"
```

Then check if the kernel configuration file has a `device plip` line or if the `plip.ko` kernel module is loaded. In both cases the parallel networking interface should appear when you use the ifconfig(8) command to display it:

```
# ifconfig plip0
plip0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
```

Plug the laplink cable into the parallel interface on both computers.

Configure the network interface parameters on both sites as `root`. For example, if you want to connect the host `host1` with another machine `host2`:

```
                host1 <-----> host2
IP Address    10.0.0.1      10.0.0.2
```

Configure the interface on `host1` by doing:

```
# ifconfig plip0 10.0.0.1 10.0.0.2
```

Configure the interface on `host2` by doing:

```
# ifconfig plip0 10.0.0.2 10.0.0.1
```

You now should have a working connection. Please read the manual pages lp(4) and lpt(4) for more details.

You should also add both hosts to `/etc/hosts` :

```
127.0.0.1               localhost.my.domain localhost
10.0.0.1                host1.my.domain host1
10.0.0.2                host2.my.domain
```

To confirm the connection works, go to each host and ping the other. For example, on `host1`:

```
# ifconfig plip0
plip0: flags=8851<UP,POINTOPOINT,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 10.0.0.1 --> 10.0.0.2 netmask 0xff000000
# netstat -r
Routing tables

Internet:
Destination        Gateway          Flags     Refs     Use      Netif Expire
host2              host1            UH          0       0      plip0
# ping -c 4 host2
PING host2 (10.0.0.2): 56 data bytes
64 bytes from 10.0.0.2: icmp_seq=0 ttl=255 time=2.774 ms
64 bytes from 10.0.0.2: icmp_seq=1 ttl=255 time=2.530 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=255 time=2.556 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=255 time=2.714 ms

--- host2 ping statistics ---
4 packets transmitted, 4 packets received, 0% packet loss
round-trip min/avg/max/stddev = 2.530/2.643/2.774/0.103 ms
```

30.11. IPv6

Originally Written by Aaron Kaplan.
Restructured and Added by Tom Rhodes.
Extended by Brad Davis.

IPv6 (also known as IPng "IP next generation") is the new version of the well known IP protocol (also known as IPv4). Like the other current *BSD systems, FreeBSD includes the KAME IPv6 reference implementation. So your FreeBSD system comes with all you will need to experiment with IPv6. This section focuses on getting IPv6 configured and running.

In the early 1990s, people became aware of the rapidly diminishing address space of IPv4. Given the expansion rate of the Internet there were two major concerns:

- Running out of addresses. Today this is not so much of a concern anymore since RFC1918 private address space (`10.0.0.0/8` , `172.16.0.0/12` , and `192.168.0.0/16`) and Network Address Translation (NAT) are being employed.
- Router table entries were getting too large. This is still a concern today.

IPv6 deals with these and many other issues:

- 128 bit address space. In other words theoretically there are 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses available. This means there are approximately 6.67 * 10^27 IPv6 addresses per square meter on our planet.

- Routers will only store network aggregation addresses in their routing tables thus reducing the average space of a routing table to 8192 entries.

There are also lots of other useful features of IPv6 such as:

- Address autoconfiguration (RFC2462)
- Anycast addresses ("one-out-of many")
- Mandatory multicast addresses
- IPsec (IP security)
- Simplified header structure
- Mobile IP
- IPv6-to-IPv4 transition mechanisms

For more information see:

- IPv6 overview at playground.sun.com
- KAME.net

30.11.1. Background on IPv6 Addresses

There are different types of IPv6 addresses: Unicast, Anycast and Multicast.

Unicast addresses are the well known addresses. A packet sent to a unicast address arrives exactly at the interface belonging to the address.

Anycast addresses are syntactically indistinguishable from unicast addresses but they address a group of interfaces. The packet destined for an anycast address will arrive at the nearest (in router metric) interface. Anycast addresses may only be used by routers.

Multicast addresses identify a group of interfaces. A packet destined for a multicast address will arrive at all interfaces belonging to the multicast group.

注意

The IPv4 broadcast address (usually `xxx.xxx.xxx.255`) is expressed by multicast addresses in IPv6.

表格 30.2. Reserved IPv6 addresses

IPv6 address	Prefixlength (Bits)	Description	Notes
`::`	128 bits	unspecified	cf. `0.0.0.0` in IPv4
`::1`	128 bits	loopback address	cf. `127.0.0.1` in IPv4
`::00:xx:xx:xx:xx`	96 bits	embedded IPv4	The lower 32 bits are the IPv4 address. Also called "IPv4 compatible IPv6 address"
`::ff:xx:xx:xx:xx`	96 bits	IPv4 mapped IPv6 address	The lower 32 bits are the IPv4 address. For hosts which do not support IPv6.

IPv6 address	Prefixlength (Bits)	Description	Notes
`fe80::` - `feb::`	10 bits	link-local	cf. loopback address in IPv4
`fec0::` - `fef::`	10 bits	site-local	
`ff::`	8 bits	multicast	
`001` (base 2)	3 bits	global unicast	All global unicast addresses are assigned from this pool. The first 3 bits are "001".

30.11.2. Reading IPv6 Addresses

The canonical form is represented as: `x:x:x:x:x:x:x:x` , each "x" being a 16 Bit hex value. For example `FEBC:A574:382B:23C1:AA49:4592:4EFE:9982`

Often an address will have long substrings of all zeros therefore one such substring per address can be abbreviated by "::". Also up to three leading "0"s per hexquad can be omitted. For example `fe80::1` corresponds to the canonical form `fe80:0000:0000:0000:0000:0000:0000:0001` .

A third form is to write the last 32 Bit part in the well known (decimal) IPv4 style with dots "." as separators. For example `2002::10.0.0.1` corresponds to the (hexadecimal) canonical representation `2002:0000:0000:0000:0000:0000:0a00:0001` which in turn is equivalent to writing `2002::a00:1` .

By now the reader should be able to understand the following:

```
# ifconfig
```

```
rl0: flags=8943<UP,BROADCAST,RUNNING,PROMISC,SIMPLEX,MULTICAST> mtu 1500
        inet 10.0.0.10 netmask 0xffffff00 broadcast 10.0.0.255
        inet6 fe80::200:21ff:fe03:8e1%rl0 prefixlen 64 scopeid 0x1
        ether 00:00:21:03:08:e1
        media: Ethernet autoselect (100baseTX )
        status: active
```

`fe80::200:21ff:fe03:8e1%rl0` is an auto configured link-local address. It is generated from the MAC address as part of the auto configuration.

For further information on the structure of IPv6 addresses see RFC3513.

30.11.3. Getting Connected

Currently there are four ways to connect to other IPv6 hosts and networks:

- Getting an IPv6 network from your upstream provider. Talk to your Internet provider for instructions.
- Tunnel via 6-to-4 (RFC3068)
- Use the net/freenet6 port if you are on a dial-up connection.

30.11.4. DNS in the IPv6 World

There used to be two types of DNS records for IPv6. The IETF has declared A6 records obsolete. AAAA records are the standard now.

Using AAAA records is straightforward. Assign your hostname to the new IPv6 address you just received by adding:

```
MYHOSTNAME            AAAA     MYIPv6ADDR
```

To your primary zone DNS file. In case you do not serve your own DNS zones ask your DNS provider. Current versions of bind (version 8.3 and 9) and dns/djbdns (with the IPv6 patch) support AAAA records.

30.11.5. Applying the needed changes to /etc/rc.conf

30.11.5.1. IPv6 Client Settings

These settings will help you configure a machine that will be on your LAN and act as a client, not a router. To have rtsol(8) autoconfigure your interface on boot all you need to add is:

```
ipv6_enable="YES"
```

To statically assign an IP address such as `2001:471:1f11:251:290:27ff:fee0:2093`, to your `fxp0` interface, add:

```
ipv6_ifconfig_fxp0="2001:471:1f11:251:290:27ff:fee0:2093"
```

To assign a default router of `2001:471:1f11:251::1` add the following to `/etc/rc.conf`:

```
ipv6_defaultrouter="2001:471:1f11:251::1"
```

30.11.5.2. IPv6 Router/Gateway Settings

This will help you take the directions that your tunnel provider has given you and convert it into settings that will persist through reboots. To restore your tunnel on startup use something like the following in `/etc/rc.conf`:

List the Generic Tunneling interfaces that will be configured, for example `gif0`:

```
gif_interfaces="gif0"
```

To configure the interface with a local endpoint of *MY_IPv4_ADDR* to a remote endpoint of *REMOTE_IPv4_ADDR*:

```
gifconfig_gif0="MY_IPv4_ADDR REMOTE_IPv4_ADDR "
```

To apply the IPv6 address you have been assigned for use as your IPv6 tunnel endpoint, add:

```
ipv6_ifconfig_gif0="MY_ASSIGNED_IPv6_TUNNEL_ENDPOINT_ADDR "
```

Then all you have to do is set the default route for IPv6. This is the other side of the IPv6 tunnel:

```
ipv6_defaultrouter="MY_IPv6_REMOTE_TUNNEL_ENDPOINT_ADDR "
```

30.11.5.3. IPv6 Tunnel Settings

If the server is to route IPv6 between the rest of your network and the world, the following `/etc/rc.conf` setting will also be needed:

```
ipv6_gateway_enable="YES"
```

30.11.6. Router Advertisement and Host Auto Configuration

This section will help you setup rtadvd(8) to advertise the IPv6 default route.

To enable rtadvd(8) you will need the following in your `/etc/rc.conf`:

```
rtadvd_enable="YES"
```

It is important that you specify the interface on which to do IPv6 router solicitation. For example to tell rtadvd(8) to use `fxp0`:

```
rtadvd_interfaces="fxp0"
```

Now we must create the configuration file, `/etc/rtadvd.conf` . Here is an example:

```
fxp0:\
 :addrs#1:addr="2001:471:1f11:246::":prefixlen#64:tc=ether:
```

Replace `fxp0` with the interface you are going to be using.

Next, replace `2001:471:1f11:246::` with the prefix of your allocation.

If you are dedicated a `/64` subnet you will not need to change anything else. Otherwise, you will need to change the `prefixlen#` to the correct value.

30.12. Asynchronous Transfer Mode (ATM)

Contributed by Harti Brandt.

30.12.1. Configuring classical IP over ATM (PVCs)

Classical IP over ATM (CLIP) is the simplest method to use Asynchronous Transfer Mode (ATM) with IP. It can be used with switched connections (SVCs) and with permanent connections (PVCs). This section describes how to set up a network based on PVCs.

30.12.1.1. Fully meshed configurations

The first method to set up a CLIP with PVCs is to connect each machine to each other machine in the network via a dedicated PVC. While this is simple to configure it tends to become impractical for a larger number of machines. The example supposes that we have four machines in the network, each connected to the ATM network with an ATM adapter card. The first step is the planning of the IP addresses and the ATM connections between the machines. We use the following:

Host	IP Address
hostA	192.168.173.1
hostB	192.168.173.2
hostC	192.168.173.3
hostD	192.168.173.4

To build a fully meshed net we need one ATM connection between each pair of machines:

Machines	VPI.VCI couple
hostA - hostB	0.100
hostA - hostC	0.101
hostA - hostD	0.102
hostB - hostC	0.103
hostB - hostD	0.104
hostC - hostD	0.105

The VPI and VCI values at each end of the connection may of course differ, but for simplicity we assume that they are the same. Next we need to configure the ATM interfaces on each host:

```
hostA# ifconfig hatm0 192.168.173.1 up
hostB# ifconfig hatm0 192.168.173.2 up
hostC# ifconfig hatm0 192.168.173.3 up
```

```
hostD# ifconfig hatm0 192.168.173.4 up
```

assuming that the ATM interface is `hatm0` on all hosts. Now the PVCs need to be configured on `hostA` (we assume that they are already configured on the ATM switches, you need to consult the manual for the switch on how to do this).

```
hostA# atmconfig natm add 192.168.173.2 hatm0 0 100 llc/snap ubr
hostA# atmconfig natm add 192.168.173.3 hatm0 0 101 llc/snap ubr
hostA# atmconfig natm add 192.168.173.4 hatm0 0 102 llc/snap ubr

hostB# atmconfig natm add 192.168.173.1 hatm0 0 100 llc/snap ubr
hostB# atmconfig natm add 192.168.173.3 hatm0 0 103 llc/snap ubr
hostB# atmconfig natm add 192.168.173.4 hatm0 0 104 llc/snap ubr

hostC# atmconfig natm add 192.168.173.1 hatm0 0 101 llc/snap ubr
hostC# atmconfig natm add 192.168.173.2 hatm0 0 103 llc/snap ubr
hostC# atmconfig natm add 192.168.173.4 hatm0 0 105 llc/snap ubr

hostD# atmconfig natm add 192.168.173.1 hatm0 0 102 llc/snap ubr
hostD# atmconfig natm add 192.168.173.2 hatm0 0 104 llc/snap ubr
hostD# atmconfig natm add 192.168.173.3 hatm0 0 105 llc/snap ubr
```

Of course other traffic contracts than UBR can be used given the ATM adapter supports those. In this case the name of the traffic contract is followed by the parameters of the traffic. Help for the atmconfig(8) tool can be obtained with:

```
# atmconfig help natm add
```

or in the atmconfig(8) manual page.

The same configuration can also be done via `/etc/rc.conf` . For `hostA` this would look like:

```
network_interfaces="lo0 hatm0"
ifconfig_hatm0="inet 192.168.173.1 up"
natm_static_routes="hostB hostC hostD"
route_hostB="192.168.173.2 hatm0 0 100 llc/snap ubr"
route_hostC="192.168.173.3 hatm0 0 101 llc/snap ubr"
route_hostD="192.168.173.4 hatm0 0 102 llc/snap ubr"
```

The current state of all CLIP routes can be obtained with:

```
hostA# atmconfig natm show
```

30.13. Common Access Redundancy Protocol (CARP)

Contributed by Tom Rhodes.

The Common Access Redundancy Protocol, or CARP allows multiple hosts to share the same IP address. In some configurations, this may be used for availability or load balancing. Hosts may use separate IP addresses as well, as in the example provided here.

To enable support for CARP, the FreeBSD kernel must be rebuilt with the following option:

```
device carp
```

CARP functionality should now be available and may be tuned via several `sysctl` OIDs. Devices themselves may be loaded via the `ifconfig` command:

```
# ifconfig carp0 create
```

In a real environment, these interfaces will need unique identification numbers known as a VHID. This VHID or Virtual Host Identification will be used to distinguish the host on the network.

30.13.1. Using CARP For Server Availability (CARP)

One use of CARP, as noted above, is for server availability. This example will provide failover support for three hosts, all with unique IP addresses and providing the same web content. These machines will act in conjunction with a Round Robin DNS configuration. The failover machine will have two additional CARP interfaces, one for each of the content server's IPs. When a failure occurs, the failover server should pick up the failed machine's IP address. This means the failure should go completely unnoticed to the user. The failover server requires identical content and services as the other content servers it is expected to pick up load for.

The two machines should be configured identically other than their issued hostnames and VHIDs. This example calls these machines `hosta.example.org` and `hostb.example.org` respectively. First, the required lines for a CARP configuration have to be added to `rc.conf`. For `hosta.example.org`, the `rc.conf` file should contain the following lines:

```
hostname="hosta.example.org"
ifconfig_fxp0="inet 192.168.1.3 netmask 255.255.255.0"
cloned_interfaces="carp0"
ifconfig_carp0="vhid 1 pass testpast 192.168.1.50/24"
```

On `hostb.example.org` the following lines should be in `rc.conf`:

```
hostname="hostb.example.org"
ifconfig_fxp0="inet 192.168.1.4 netmask 255.255.255.0"
cloned_interfaces="carp0"
ifconfig_carp0="vhid 2 pass testpass 192.168.1.51/24"
```

注意

It is very important that the passwords, specified by the `pass` option to `ifconfig`, are identical. The `carp` devices will only listen to and accept advertisements from machines with the correct password. The VHID must also be different for each machine.

The third machine, `provider.example.org`, should be prepared so that it may handle failover from either host. This machine will require two `carp` devices, one to handle each host. The appropriate `rc.conf` configuration lines will be similar to the following:

```
hostname="provider.example.org"
ifconfig_fxp0="inet 192.168.1.5 netmask 255.255.255.0"
cloned_interfaces="carp0 carp1"
ifconfig_carp0="vhid 1 advskew 100 pass testpass 192.168.1.50/24"
ifconfig_carp1="vhid 2 advskew 100 pass testpass 192.168.1.51/24"
```

Having the two `carp` devices will allow `provider.example.org` to notice and pick up the IP address of either machine should it stop responding.

注意

The default FreeBSD kernel may have preemption enabled. If so, `provider.example.org` may not relinquish the IP address back to the original content server. In this case, an administrator may “nudge” the interface. The following command should be issued on `provider.example.org`:

```
# ifconfig carp0 down && ifconfig carp0 up
```

This should be done on the `carp` interface which corresponds to the correct host.

At this point, CARP should be completely enabled and available for testing. For testing, either networking has to be restarted or the machines need to be rebooted.

More information is always available in the carp(4) manual page.

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附錄 A. 取得 FreeBSD 的方式

A.1. CD 及 DVD 合集

FreeBSD CD 及 DVD 合集 可以從這些網路零售商取得：

- FreeBSD Mall, Inc.
  2420 Sand Creek Rd C-1 #347
  Brentwood, CA
  94513
  USA
  Phone: +1 925 240-6652
  Fax: +1 925 674-0821
  Email: <info@freebsdmall.com >
  WWW: http://www.freebsdmall.com/

- Getlinux
  78 Rue de la Croix Rochopt
  Épinay-sous-Sénart
  91860
  France
  Email: <contact@getlinux.fr >
  WWW: http://www.getlinux.fr/

- Dr. Hinner EDV
  Kochelseestr. 11
  D-81371 München
  Germany
  Phone: (0177) 428 419 0
  Email: <infow@hinner.de >
  WWW: http://www.hinner.de/linux/freebsd.html

- Linux Center
  Galernaya Street, 55
  Saint-Petersburg
  190000
  Russia
  Phone: +7-812-309-06-86
  Email: <info@linuxcenter.ru >
  WWW: http://linuxcenter.ru/shop/freebsd

A.2. FTP 站

The official sources for FreeBSD are available via anonymous FTP from a worldwide set of mirror sites. The site `ftp://ftp.FreeBSD.org/pub/FreeBSD/` is well connected and allows a large number of connections to it, but you are probably better off finding a “closer” mirror site (especially if you decide to set up some sort of mirror site).

Additionally, FreeBSD is available via anonymous FTP from the following mirror sites. If you choose to obtain FreeBSD via anonymous FTP, please try to use a site near you. The mirror sites listed as "Primary Mirror Sites" typically have the entire FreeBSD archive (all the currently available versions for each of the architectures) but you will probably have faster download times from a site that is in your country or region. The regional sites carry the most recent versions for the most popular architecture(s) but might not carry the entire FreeBSD archive. All sites provide access via anonymous FTP but some sites also provide access via other methods. The access methods available for each site are provided in parentheses after the hostname.

Central Servers, Primary Mirror Sites, Armenia, Australia, Austria, Brazil, Canada, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Ireland, Japan, Korea, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Russia, Saudi Arabia, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Ukraine, United Kingdom, USA.

(as of UTC)

Central Servers

- ftp://ftp.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp.FreeBSD.org/pub/FreeBSD/ / http://ftp.FreeBSD.org/pub/FreeBSD/)

Primary Mirror Sites

In case of problems, please contact the hostmaster <mirror-admin@FreeBSD.org> for this domain.

- ftp://ftp1.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp3.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp4.FreeBSD.org/pub/FreeBSD/ / http://ftp4.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp5.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp6.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp7.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp10.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp10.FreeBSD.org/pub/FreeBSD/ / http://ftp10.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp11.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp13.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp14.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp14.FreeBSD.org/pub/FreeBSD/)

Armenia

In case of problems, please contact the hostmaster <hostmaster@am.FreeBSD.org> for this domain.

- ftp://ftp1.am.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp1.am.FreeBSD.org/pub/FreeBSD/ / rsync)

Australia

In case of problems, please contact the hostmaster <hostmaster@au.FreeBSD.org> for this domain.

- ftp://ftp.au.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.au.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp3.au.FreeBSD.org/pub/FreeBSD/ (ftp)

Austria
In case of problems, please contact the hostmaster <hostmaster@at.FreeBSD.org> for this domain.

- ftp://ftp.at.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp.at.FreeBSD.org/pub/FreeBSD/ / http://ftp.at.FreeBSD.org/pub/FreeBSD/)

Brazil
In case of problems, please contact the hostmaster <hostmaster@br.FreeBSD.org> for this domain.

- ftp://ftp2.br.FreeBSD.org/FreeBSD/ (ftp / http://ftp2.br.FreeBSD.org/)
- ftp://ftp3.br.FreeBSD.org/pub/FreeBSD/ (ftp / rsync)
- ftp://ftp4.br.FreeBSD.org/pub/FreeBSD/ (ftp)

Canada
In case of problems, please contact the hostmaster <hostmaster@ca.FreeBSD.org> for this domain.

- ftp://ftp.ca.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.ca.FreeBSD.org/pub/FreeBSD/ (ftp)

China
In case of problems, please contact the hostmaster <hostmaster@cn.FreeBSD.org> for this domain.

- ftp://ftp.cn.FreeBSD.org/pub/FreeBSD/ (ftp)

Czech Republic
In case of problems, please contact the hostmaster <hostmaster@cz.FreeBSD.org> for this domain.

- ftp://ftp.cz.FreeBSD.org/pub/FreeBSD/ (ftp / ftp://ftp.cz.FreeBSD.org/pub/FreeBSD/ / http://ftp.cz.FreeBSD.org/pub/FreeBSD/ / http://ftp.cz.FreeBSD.org/pub/FreeBSD/ / rsync / rsyncv6)
- ftp://ftp2.cz.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp2.cz.FreeBSD.org/pub/FreeBSD/)

Denmark
In case of problems, please contact the hostmaster <hostmaster@dk.FreeBSD.org> for this domain.

- ftp://ftp.dk.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp.dk.FreeBSD.org/pub/FreeBSD/ / http://ftp.dk.FreeBSD.org/pub/FreeBSD/)

Estonia
In case of problems, please contact the hostmaster <hostmaster@ee.FreeBSD.org> for this domain.

- ftp://ftp.ee.FreeBSD.org/pub/FreeBSD/ (ftp)

Finland
In case of problems, please contact the hostmaster <hostmaster@fi.FreeBSD.org> for this domain.

- ftp://ftp.fi.FreeBSD.org/pub/FreeBSD/ (ftp)

France
In case of problems, please contact the hostmaster <hostmaster@fr.FreeBSD.org> for this domain.

- ftp://ftp.fr.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp1.fr.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp1.fr.FreeBSD.org/pub/FreeBSD/ / rsync)
- ftp://ftp3.fr.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp5.fr.FreeBSD.org/pub/FreeBSD/ (ftp)

- ftp://ftp6.fr.FreeBSD.org/pub/FreeBSD/ (ftp / rsync)
- ftp://ftp7.fr.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp8.fr.FreeBSD.org/pub/FreeBSD/ (ftp)

Germany
In case of problems, please contact the hostmaster <de-bsd-hubs@de.FreeBSD.org> for this domain.

- ftp://ftp.de.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp1.de.FreeBSD.org/freebsd/ (ftp / http://www1.de.FreeBSD.org/freebsd/ / rsync://rsync3.de.FreeBSD.org/freebsd/)
- ftp://ftp2.de.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp2.de.FreeBSD.org/pub/FreeBSD/ / rsync)
- ftp://ftp4.de.FreeBSD.org/FreeBSD/ (ftp / http://ftp4.de.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp5.de.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp7.de.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp7.de.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp8.de.FreeBSD.org/pub/FreeBSD/ (ftp)

Greece
In case of problems, please contact the hostmaster <hostmaster@gr.FreeBSD.org> for this domain.

- ftp://ftp.gr.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.gr.FreeBSD.org/pub/FreeBSD/ (ftp)

Hong Kong

- ftp://ftp.hk.FreeBSD.org/pub/FreeBSD/ (ftp)

Ireland
In case of problems, please contact the hostmaster <hostmaster@ie.FreeBSD.org> for this domain.

- ftp://ftp3.ie.FreeBSD.org/pub/FreeBSD/ (ftp / rsync)

Japan
In case of problems, please contact the hostmaster <hostmaster@jp.FreeBSD.org> for this domain.

- ftp://ftp.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp3.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp5.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp6.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp7.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp8.jp.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp9.jp.FreeBSD.org/pub/FreeBSD/ (ftp)

Korea
In case of problems, please contact the hostmaster <hostmaster@kr.FreeBSD.org> for this domain.

- ftp://ftp.kr.FreeBSD.org/pub/FreeBSD/ (ftp / rsync)
- ftp://ftp2.kr.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp2.kr.FreeBSD.org/pub/FreeBSD/)

Latvia
In case of problems, please contact the hostmaster <hostmaster@lv.FreeBSD.org> for this domain.

- ftp://ftp.lv.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.lv.FreeBSD.org/pub/FreeBSD/)

Lithuania
In case of problems, please contact the hostmaster <hostmaster@lt.FreeBSD.org> for this domain.

- ftp://ftp.lt.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.lt.FreeBSD.org/pub/FreeBSD/)

Netherlands
In case of problems, please contact the hostmaster <hostmaster@nl.FreeBSD.org> for this domain.

- ftp://ftp.nl.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.nl.FreeBSD.org/os/FreeBSD/ / rsync)
- ftp://ftp2.nl.FreeBSD.org/pub/FreeBSD/ (ftp)

New Zealand

- ftp://ftp.nz.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.nz.FreeBSD.org/pub/FreeBSD/)

Norway
In case of problems, please contact the hostmaster <hostmaster@no.FreeBSD.org> for this domain.

- ftp://ftp.no.FreeBSD.org/pub/FreeBSD/ (ftp / rsync)

Poland
In case of problems, please contact the hostmaster <hostmaster@pl.FreeBSD.org> for this domain.

- ftp://ftp.pl.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp2.pl.FreeBSD.org

Russia
In case of problems, please contact the hostmaster <hostmaster@ru.FreeBSD.org> for this domain.

- ftp://ftp.ru.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.ru.FreeBSD.org/FreeBSD/ / rsync)
- ftp://ftp2.ru.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp2.ru.FreeBSD.org/pub/FreeBSD/ / rsync)
- ftp://ftp4.ru.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp5.ru.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp5.ru.FreeBSD.org/pub/FreeBSD/ / rsync)
- ftp://ftp6.ru.FreeBSD.org/pub/FreeBSD/ (ftp)

Saudi Arabia
In case of problems, please contact the hostmaster <ftpadmin@isu.net.sa> for this domain.

- ftp://ftp.isu.net.sa/pub/ftp.freebsd.org/ (ftp)

Slovenia
In case of problems, please contact the hostmaster <hostmaster@si.FreeBSD.org> for this domain.

- ftp://ftp.si.FreeBSD.org/pub/FreeBSD/ (ftp)

South Africa
In case of problems, please contact the hostmaster <hostmaster@za.FreeBSD.org> for this domain.

- ftp://ftp.za.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.za.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.za.FreeBSD.org/pub/FreeBSD/ (ftp)

Spain
In case of problems, please contact the hostmaster <hostmaster@es.FreeBSD.org> for this domain.

- ftp://ftp.es.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.es.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp3.es.FreeBSD.org/pub/FreeBSD/ (ftp)

Sweden
In case of problems, please contact the hostmaster <hostmaster@se.FreeBSD.org> for this domain.

- ftp://ftp.se.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.se.FreeBSD.org/pub/FreeBSD/ (ftp / rsync://ftp2.se.FreeBSD.org/)
- ftp://ftp3.se.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.se.FreeBSD.org/pub/FreeBSD/ (ftp / ftp://ftp4.se.FreeBSD.org/pub/FreeBSD/ / http://ftp4.se.FreeBSD.org/pub/FreeBSD/ / http://ftp4.se.FreeBSD.org/pub/FreeBSD/ / rsync://ftp4.se.FreeBSD.org/pub/FreeBSD/ / rsync://ftp4.se.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp6.se.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp6.se.FreeBSD.org/pub/FreeBSD/)

Switzerland
In case of problems, please contact the hostmaster <hostmaster@ch.FreeBSD.org> for this domain.

- ftp://ftp.ch.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.ch.FreeBSD.org/pub/FreeBSD/)

Taiwan
In case of problems, please contact the hostmaster <hostmaster@tw.FreeBSD.org> for this domain.

- ftp://ftp.tw.FreeBSD.org/pub/FreeBSD/ (ftp / ftp://ftp.tw.FreeBSD.org/pub/FreeBSD/ / rsync / rsyncv6)
- ftp://ftp2.tw.FreeBSD.org/pub/FreeBSD/ (ftp / ftp://ftp2.tw.FreeBSD.org/pub/FreeBSD/ / http://ftp2.tw.FreeBSD.org/pub/FreeBSD/ / http://ftp2.tw.FreeBSD.org/pub/FreeBSD/ / rsync / rsyncv6)
- ftp://ftp4.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp5.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp6.tw.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp6.tw.FreeBSD.org/ / rsync)
- ftp://ftp7.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp8.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp11.tw.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp11.tw.FreeBSD.org/FreeBSD/)
- ftp://ftp12.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp13.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp14.tw.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp15.tw.FreeBSD.org/pub/FreeBSD/ (ftp)

Ukraine

- ftp://ftp.ua.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp.ua.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp6.ua.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp6.ua.FreeBSD.org/pub/FreeBSD / rsync://ftp6.ua.FreeBSD.org/FreeBSD/)
- ftp://ftp7.ua.FreeBSD.org/pub/FreeBSD/ (ftp)

United Kingdom
In case of problems, please contact the hostmaster <hostmaster@uk.FreeBSD.org> for this domain.

- ftp://ftp.uk.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.uk.FreeBSD.org/pub/FreeBSD/ (ftp / rsync://ftp2.uk.FreeBSD.org/ftp.freebsd.org/pub/FreeBSD/)
- ftp://ftp3.uk.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.uk.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp5.uk.FreeBSD.org/pub/FreeBSD/ (ftp)

USA
In case of problems, please contact the hostmaster <hostmaster@us.FreeBSD.org> for this domain.

- ftp://ftp1.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp2.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp3.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp4.us.FreeBSD.org/pub/FreeBSD/ (ftp / ftpv6 / http://ftp4.us.FreeBSD.org/pub/FreeBSD/ / http://ftp4.us.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp5.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp6.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp8.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp10.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp11.us.FreeBSD.org/pub/FreeBSD/ (ftp)
- ftp://ftp13.us.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp13.us.FreeBSD.org/pub/FreeBSD/ / rsync)
- ftp://ftp14.us.FreeBSD.org/pub/FreeBSD/ (ftp / http://ftp14.us.FreeBSD.org/pub/FreeBSD/)
- ftp://ftp15.us.FreeBSD.org/pub/FreeBSD/ (ftp)

A.3. Using CTM

CTM is a method for keeping a remote directory tree in sync with a central one. It is built into FreeBSD and can be used to synchronize a system with FreeBSD's source repositories. It supports synchronization of an entire repository or just a specified set of branches.

CTM is specifically designed for use on lousy or non-existent TCP/IP connections and provides the ability for changes to be automatically sent by email. It requires the user to obtain up to three deltas per day for the most

active branches. Update sizes are always kept as small as possible and are typically less than 5K. About one in very ten updates is 10-50K in size, and there will occasionally be an update larger than 100K+.

When using CTM to track FreeBSD development, refer to the caveats related to working directly from the development sources rather than a pre-packaged release. These are discussed in Tracking a Development Branch.

Little documentation exists on the process of creating deltas or using CTM for other purposes. Contact the ctm-users mailing list for answers to questions on using CTM.

A.3.1. Getting Deltas

The "deltas" used by CTM can be obtained either through anonymous FTP or email.

FTP deltas can be obtained from the following mirror sites. When using anonymous FTP to obtain CTM deltas, select a mirror that is geographically nearby. In case of problems, contact the ctm-users mailing list.

California, Bay Area, official source

- `ftp://ftp.FreeBSD.org/pub/FreeBSD/development/CTM/`
- `ftp://ftp.FreeBSD.org/pub/FreeBSD/CTM/`

South Africa, backup server for old deltas

- `ftp://ftp.za.FreeBSD.org/pub/FreeBSD/CTM/`

Taiwan/R.O.C.

- `ftp://ctm.tw.FreeBSD.org/pub/FreeBSD/development/CTM/`
- `ftp://ctm2.tw.FreeBSD.org/pub/FreeBSD/development/CTM/`
- `ftp://ctm3.tw.FreeBSD.org/pub/FreeBSD/development/CTM/`

To instead receive deltas through email, subscribe to one of the `ctm-src` distribution lists available from `http://lists.freebsd.org/mailman/listinfo` . For example, ctm-src-cur supports the head development branch and ctm-src-9 supports the 9.X release branch.

As CTM updates arrive through email, use `ctm_rmail` to unpack and apply them. This command can be run directly from an entry in `/etc/aliases` in order to automate this process. Refer to ctm_rmail(1) for more details.

注意

Regardless of the method which is used to get deltas, CTM users should subscribe to the ctm-announce mailing list as this is the only mechanism by which CTM announcements are posted.

A.3.2. CTM Usage

Before CTM deltas can be used for the first time, a starting point must be produced.

One method is to apply a "starter" delta to an empty directory. A starter delta can be recognized by the `XEmpty` in its name, such as `src-cur.3210XEmpty.gz` . The designation following the `X` corresponds to the origin of the initial "seed", where `Empty` is an empty directory. As a rule, a base transition from `Empty` is produced every 100 deltas. Be aware that starter deltas are large and 70 to 80 Megabytes of `gzip`'d data is common for the `XEmpty` deltas.

Another method is to copy or extract an initial source from a RELEASE media as this can save a significant transfer of data from the Internet.

Once a base delta has been created, apply all deltas with higher numbers. To apply the deltas:

```
# cd /directory/to/store/the/stuff
# ctm -v -v /directory/which/stores/the/deltas/src-xxx.*
```

Multiple deltas can be applied with a single command as they will be processed one at a time and any deltas that are already applied will be ignored. CTM understands `gzip` compressed deltas, which saves disk space.

To verify a delta without applying it, include `-c` in the command line. CTM will not actually modify the local tree but will instead verify the integrity of the delta to see if it would apply cleanly. Refer to ctm(1) for more information about available options and an overview of the process CTM uses when applying deltas.

To keep the local source tree up-to-date, every time a new delta becomes available, apply it through CTM.

Once applied, it is recommended to not delete the deltas if it is a burden to download them again. This way, a local copy is available in case it is needed for future disaster recovery.

A.3.3. Keeping Local Changes

Developers often experiment with and change files in their local source tree. CTM supports local modifications in a limited way: before checking for the presence of a file, it first looks for a file with the same name and a `.ctm` extension. If this file exists, CTM will operate on it instead of the original filename.

This behavior provides a simple way to maintain local changes. Before modifying a file, make a copy with a `.ctm` suffix. Make any changes to the original filename, knowing that CTM will only apply updates to the file with the `.ctm` suffix.

A.3.4. Other CTM Options

Finding Out Exactly What Would Be Touched by an Update
: To determine the list of changes that CTM will make to the local source repository, use `-l`. This option is useful for creating logs of the changes or when performing pre- or post-processing on any of the modified files.

Making Backups Before Updating
: To backup all of the files that would be changed by a CTM update, specify `-B` *`backup-file`*. This option tells CTM to backup all files touched by the applied CTM delta to `backup-file`.

Restricting the Files Touched by an Update
: To restrict the scope of a given CTM update, or to extract just a few files from a sequence of deltas, filtering regular expressions can be specified using `-e`, which specifies which files to process, or `-x`, which specifies which files to ignore.

  For example, to extract an up-to-date copy of `lib/libc/Makefile` from a collection of saved CTM deltas:

  ```
  # cd /directory/to/extract/to/
  # ctm -e '^lib/libc/Makefile' /directory/which/stores/the/deltas/src-
  xxx.*
  ```

  For every file specified in a CTM delta, `-e` and `-x` are applied in the order given on the command line. A file is processed by CTM only if it is marked as eligible after all `-e` and `-x` options are applied.

A.4. Using Subversion

A.4.1. Introduction

As of July 2012, FreeBSD uses Subversion as the primary version control system for storing all of FreeBSD's source code, documentation, and the Ports Collection.

注意

Subversion is generally a developer tool. Most users should use `freebsd-update` (節 23.2, “FreeBSD Update”) to update the FreeBSD base system, and `portsnap` (節 4.5, “使用 Ports 管理機制”) to update the FreeBSD Ports Collection.

This chapter demonstrates how to install Subversion on a FreeBSD system and then use it to create a local copy of a FreeBSD repository. It includes a list of the available FreeBSD Subversion mirrors and resources to additional information on how to use Subversion.

A.4.2. Installation

Subversion must be installed before it can be used to check out the contents of any of the repositories. If a copy of the ports tree is already present, one can install Subversion like this:

```
# cd /usr/ports/devel/subversion
# make install clean
```

If the ports tree is not available, Subversion can be installed as a package:

```
# pkg install devel/subversion
```

A.4.3. Running Subversion

The `svn` command is used to fetch a clean copy of the sources into a local directory. The files in this directory are called a local working copy.

警告

Move or delete the local directory before using **checkout**.

Checkout over an existing non-`svn` directory can cause conflicts between the existing files and those brought in from the repository.

Subversion uses URLs to designate a repository, taking the form of *`protocol://hostname/path`*. Mirrors may support different protocols as specified below. The first component of the path is the FreeBSD repository to access. There are three different repositories, `base` for the FreeBSD base system source code, `ports` for the Ports Collection, and `doc` for documentation. For example, the URL `svn://svn0.us-east.FreeBSD.org/ports/head/` specifies the main branch of the ports repository on the `svn0.us-east.FreeBSD.org` mirror, using the `svn` protocol.

A checkout from a given repository is performed with a command like this:

```
# svn checkout svn-mirror/repository/branch lwcdir
```

where:

- *`svn-mirror`* is a URL for one of the Subversion mirror sites.

- *repository* is one of the Project repositories, i.e., base, ports, or doc.
- *branch* depends on the repository used. ports and doc are mostly updated in the head branch, while base maintains the latest version of -CURRENT under head and the respective latest versions of the -STABLE branches under stable/8 (for 8.*x*), stable/9 (9.*x*) and stable/10 (10.*x*).
- *lwcdir* is the target directory where the contents of the specified branch should be placed. This is usually /usr/ports for ports, /usr/src for base, and /usr/doc for doc.

This example checks out the Ports Collection from the western US repository using the HTTPS protocol, placing the local working copy in /usr/ports . If /usr/ports is already present but was not created by svn, remember to rename or delete it before the checkout.

```
# svn checkout https://svn0.us-west.FreeBSD.org /ports/head /usr/ports
```

Because the initial checkout has to download the full branch of the remote repository, it can take a while. Please be patient.

After the initial checkout, the local working copy can be updated by running:

```
# svn update lwcdir
```

To update /usr/ports created in the example above, use:

```
# svn update /usr/ports
```

The update is much quicker than a checkout, only transferring files that have changed.

An alternate way of updating the local working copy after checkout is provided by the Makefile in the /usr/ports, /usr/src , and /usr/doc directories. Set SVN_UPDATE and use the update target. For example, to update /usr/src :

```
# cd /usr/src
# make update SVN_UPDATE=yes
```

A.4.4. Subversion Mirror Sites

All mirrors carry all repositories.

The master FreeBSD Subversion server, svn.FreeBSD.org , is publicly accessible, read-only. That may change in the future, so users are encouraged to use one of the official mirrors. To view the FreeBSD Subversion repositories through a browser, use http://svnweb.FreeBSD.org/.

注意

The FreeBSD Subversion mirror network is still in its early days, and will likely change. Do not count on this list of mirrors being static. In particular, the SSL certificates of the servers will likely change at some point.

Name	Protoc	Location	SSL Fingerprint
svn0.us-west.FreeBSD.org	svn, http, https	USA, California	SHA1 1C:BD:85:95:11:9F:EB:75:A5:4B:C8:A3:FE:08:E4:02:73:06:1E:61
svn0.us-east.FreeBSD.org	svn, http,	USA, New Jersey	SHA1 1C:BD:85:95:11:9F:EB:75:A5:4B:C8:A3:FE:08:E4:02:73:06:1E:61

Name	Protoc	Location	SSL Fingerprint
	https, rsync		
svn0.eu.FreeBSD.org	svn, http, https, rsync	Europe, UK	SHA1 39:B0:53:35:CE:60:C7:BB:00:54:96:96:71:10:94:BB:CE:1C:07:A7
svn0.ru.FreeBSD.org	svn, http, https, rsync	Russia, Moscow	SHA1 F6:44:AA:B9:03:89:0E:3E:8C:4D:4D:14:F0:27:E6:C7:C1:8B:17:C5

HTTPS is the preferred protocol, providing protection against another computer pretending to be the FreeBSD mirror (commonly known as a "man in the middle" attack) or otherwise trying to send bad content to the end user.

On the first connection to an HTTPS mirror, the user will be asked to verify the server fingerprint:

```
Error validating server certificate for 'https://svn0.us-west.freebsd.org:443':
 - The certificate is not issued by a trusted authority. Use the
   fingerprint to validate the certificate manually!
 - The certificate hostname does not match.
Certificate information:
 - Hostname: svnmir.ysv.FreeBSD.org
 - Valid: from Jul 29 22:01:21 2013 GMT until Dec 13 22:01:21 2040 GMT
 - Issuer: clusteradm, FreeBSD.org, (null), CA, US (clusteradm@FreeBSD.org)
 - Fingerprint: 1C:BD:85:95:11:9F:EB:75:A5:4B:C8:A3:FE:08:E4:02:73:06:1E:61
(R)eject, accept (t)emporarily or accept (p)ermanently?
```

Compare the fingerprint shown to those listed in the table above. If the fingerprint matches, the server security certificate can be accepted temporarily or permanently. A temporary certificate will expire after a single session with the server, and the verification step will be repeated on the next connection. Accepting the certificate permanently will store the authentication credentials in `~/.subversion/auth/` and the user will not be asked to verify the fingerprint again until the certificate expires.

If `https` cannot be used due to firewall or other problems, `svn` is the next choice, with slightly faster transfers. When neither can be used, use `http`.

A.4.5. For More Information

For other information about using Subversion, please see the "Subversion Book", titled Version Control with Subversion, or the Subversion Documentation.

A.5. Using rsync

The following sites make FreeBSD available through the rsync protocol. The rsync utility works in much the same way as the rcp(1) command, but has more options and uses the rsync remote-update protocol which transfers only the differences between two sets of files, thus greatly speeding up the synchronization over the network. This is most useful if you are a mirror site for the FreeBSD FTP server, or the CVS repository. The rsync suite is available for many operating systems, on FreeBSD, see the net/rsync port or use the package.

Czech Republic
: rsync://ftp.cz.FreeBSD.org/

  Available collections:

  - ftp: A partial mirror of the FreeBSD FTP server.

- FreeBSD: A full mirror of the FreeBSD FTP server.

Netherlands
rsync://ftp.nl.FreeBSD.org/

Available collections:

- FreeBSD: A full mirror of the FreeBSD FTP server.

Russia
rsync://ftp.mtu.ru/

Available collections:

- FreeBSD: A full mirror of the FreeBSD FTP server.
- FreeBSD-Archive: The mirror of FreeBSD Archive FTP server.

Sweden
rsync://ftp4.se.freebsd.org/

Available collections:

- FreeBSD: A full mirror of the FreeBSD FTP server.

Taiwan
rsync://ftp.tw.FreeBSD.org/

rsync://ftp2.tw.FreeBSD.org/

rsync://ftp6.tw.FreeBSD.org/

Available collections:

- FreeBSD: A full mirror of the FreeBSD FTP server.

United Kingdom
rsync://rsync.mirrorservice.org/

Available collections:

- ftp.freebsd.org: A full mirror of the FreeBSD FTP server.

United States of America
rsync://ftp-master.FreeBSD.org/

This server may only be used by FreeBSD primary mirror sites.

Available collections:

- FreeBSD: The master archive of the FreeBSD FTP server.
- acl: The FreeBSD master ACL list.

rsync://ftp13.FreeBSD.org/

Available collections:

- FreeBSD: A full mirror of the FreeBSD FTP server.

附錄 B. 參考文獻

雖然線上說明(manual pages)有提供 FreeBSD 各個特定部分明確的說明， 但它們卻難免有「小學而大遺」之憾，像是如何讓整個系統運作順暢。 因此， 身邊有 UNIX® 系統管理的好書以及好的使用手冊是不可或缺的。

B.1. FreeBSD 相關的書籍、雜誌

非英語的書籍、雜誌：

- FreeBSD 入門與應用(光碟豪華版)（繁體中文）， 博碩文化 ，1997。 ISBN 9-578-39435-7
- FreeBSD 技術內幕 (FreeBSD Unleashed 簡體中譯版)， 機械工業出版社 。 ISBN 7-111-10201-0
- FreeBSD 使用大全第一版（簡體中文）， 機械工業出版社。 ISBN 7-111-07482-3
- FreeBSD 使用大全第二版（簡體中文）， 機械工業出版社。 ISBN 7-111-10286-X
- FreeBSD Handbook 第二版（簡體中譯版）， 人民郵電出版社 。 ISBN 7-115-10541-3
- FreeBSD 3.x Internet 高級服務器的架設與管理（簡體中文）， 清華大學出版社 。 ISBN 7-900625-66-6
- FreeBSD & Windows 集成組網實務（簡體中文）， 中國鐵道出版社 。 ISBN 7-113-03845-X
- FreeBSD 網站架設實務（簡體中文），中國鐵道出版社 。 ISBN 7-113-03423-3
- FreeBSD for PC 98'ers（日文），SHUWA SystemCo, LTD 。 ISBN 4-87966-468-5 C3055 定價 2900 日圓。
- FreeBSD（日文），CUTT。 ISBN 4-906391-22-2 C3055 定價 2400 日圓。
- Complete Introduction to FreeBSD（日文），Shoeisha Co., Ltd。 ISBN 4-88135-473-6 定價 3600 日圓。
- Personal UNIX Starter Kit FreeBSD（日文）， ASCII。 ISBN 4-7561-1733-3 定價 3000 日圓。
- FreeBSD Handbook（日文譯版）， ASCII。 ISBN 4-7561-1580-2 定價 3800 日圓。
- FreeBSD mit Methode（德文），Computer und Literatur Verlag/Vertrieb Hanser，1998。 ISBN 3-932311-31-0
- FreeBSD 4 - Installieren, Konfigurieren, Administrieren（德文），Computer und Literatur Verlag，2001。 ISBN 3-932311-88-4
- FreeBSD 5 - Installieren, Konfigurieren, Administrieren（德文），Computer und Literatur Verlag，2003。 ISBN 3-936546-06-1
- FreeBSD de Luxe（德文）， Verlag Modere Industrie， 2003。 ISBN 3-8266-1343-0
- FreeBSD Install and Utilization Manual（日文），Mainichi Communications Inc. ，1998。 ISBN 4-8399-0112-0
- Onno W Purbo, Dodi Maryanto, Syahrial Hubbany, Widjil Widodo Building Internet Server with FreeBSD（印尼文），Elex Media Komputindo。
- FreeBSD 完全探索 (Absolute BSD: The Ultimate Guide to FreeBSD 繁體中文譯版)，上奇，2003。 ISBN 986-7944-92-5
- FreeBSD 6.0架設管理與應用（繁體中文），博碩，2006。ISBN 9-575-27878-X

英文的書籍、雜誌：

- Absolute BSD: The Ultimate Guide to FreeBSD， No Starch Press，2002。 ISBN: 1886411743
- The Complete FreeBSD， O'Reilly，2003。 ISBN: 0596005164
- The FreeBSD Corporate Networker's Guide， Addison-Wesley，2000。 ISBN: 0201704811
- FreeBSD: An Open-Source Operating System for Your Personal Computer，The Bit Tree Press，2001。 ISBN: 0971204500
- Teach Yourself FreeBSD in 24 Hours， Sams，2002。 ISBN: 0672324245
- FreeBSD 6 Unleashed， Sams，2006。 ISBN: 0672328755
- FreeBSD: The Complete Reference， McGrawHill，2003。 ISBN: 0072224096

B.2. 使用說明手冊

- Computer Systems Research Group, UC Berkeley. 4.4BSD User's Reference Manual. O'Reilly & Associates, Inc., 1994. ISBN 1-56592-075-9
- Computer Systems Research Group, UC Berkeley. 4.4BSD User's Supplementary Documents. O'Reilly & Associates, Inc., 1994. ISBN 1-56592-076-7
- UNIX in a Nutshell. O'Reilly & Associates, Inc., 1990. ISBN 093717520X
- Mui, Linda. What You Need To Know When You Can't Find Your UNIX System Administrator. O'Reilly & Associates, Inc., 1995. ISBN 1-56592-104-6
- Ohio State University 有撰寫 UNIX 介紹的課程，並提供 HTML 或 PostScript 兩種格式供人瀏覽。

  UNIX 介紹的義大利文翻譯版 ，同時本文件也是 FreeBSD Italian Documentation Project 之一。
- Jpman Project, Japan FreeBSD Users Group. FreeBSD User's Reference Manual（日文翻譯）。 Mainichi Communications Inc., 1998. ISBN4-8399-0088-4 P3800E.
- Edinburgh University 為 UNIX 新手所撰寫的 Online Guide 指引說明。

B.3. 系統管理指南

- Albitz, Paul and Liu, Cricket. DNS and BIND, 4th Ed. O'Reilly & Associates, Inc., 2001. ISBN 1-59600-158-4
- Computer Systems Research Group, UC Berkeley. 4.4BSD System Manager's Manual. O'Reilly & Associates, Inc., 1994. ISBN 1-56592-080-5
- Costales, Brian, et al. Sendmail, 2nd Ed. O'Reilly & Associates, Inc., 1997. ISBN 1-56592-222-0
- Frisch, Æleen. Essential System Administration, 2nd Ed. O'Reilly & Associates, Inc., 1995. ISBN 1-56592-127-5
- Hunt, Craig. TCP/IP Network Administration, 2nd Ed. O'Reilly & Associates, Inc., 1997. ISBN 1-56592-322-7
- Nemeth, Evi. UNIX System Administration Handbook. 3rd Ed. Prentice Hall, 2000. ISBN 0-13-020601-6
- Stern, Hal Managing NFS and NIS O'Reilly & Associates, Inc., 1991. ISBN 0-937175-75-7
- Jpman Project, Japan FreeBSD Users Group. FreeBSD System Administrator's Manual（日文翻譯）。 Mainichi Communications Inc., 1998. ISBN4-8399-0109-0 P3300E.
- Dreyfus, Emmanuel. Cahiers de l'Admin: BSD 2nd Ed.（法文）, Eyrolles, 2004. ISBN 2-212-11463-X

B.4. 程式設計師指南

- Asente, Paul, Converse, Diana, and Swick, Ralph. X Window System Toolkit. Digital Press, 1998. ISBN 1-55558-178-1
- Computer Systems Research Group, UC Berkeley. 4.4BSD Programmer's Reference Manual. O'Reilly & Associates, Inc., 1994. ISBN 1-56592-078-3
- Computer Systems Research Group, UC Berkeley. 4.4BSD Programmer's Supplementary Documents. O'Reilly & Associates, Inc., 1994. ISBN 1-56592-079-1
- Harbison, Samuel P. and Steele, Guy L. Jr. C: A Reference Manual. 4th ed. Prentice Hall, 1995. ISBN 0-13-326224-3
- Kernighan, Brian and Dennis M. Ritchie. The C Programming Language. 2nd Ed. PTR Prentice Hall, 1988. ISBN 0-13-110362-8
- Lehey, Greg. Porting UNIX Software. O'Reilly & Associates, Inc., 1995. ISBN 1-56592-126-7
- Plauger, P. J. The Standard C Library. Prentice Hall, 1992. ISBN 0-13-131509-9
- Spinellis, Diomidis. Code Reading: The Open Source Perspective. Addison-Wesley, 2003. ISBN 0-201-79940-5
- Spinellis, Diomidis. Code Quality: The Open Source Perspective. Addison-Wesley, 2006. ISBN 0-321-16607-8
- Stevens, W. Richard and Stephen A. Rago. Advanced Programming in the UNIX Environment. 2nd Ed. Reading, Mass. : Addison-Wesley, 2005. ISBN 0-201-43307-9
- Stevens, W. Richard. UNIX Network Programming. 2nd Ed, PTR Prentice Hall, 1998. ISBN 0-13-490012-X
- Wells, Bill. “Writing Serial Drivers for UNIX”. Dr. Dobb's Journal. 19(15), December 1994. pp68-71, 97-99.

B.5. 深入作業系統

- Andleigh, Prabhat K. UNIX System Architecture. Prentice-Hall, Inc., 1990. ISBN 0-13-949843-5
- Jolitz, William. “Porting UNIX to the 386”. Dr. Dobb's Journal. January 1991-July 1992.
- Leffler, Samuel J., Marshall Kirk McKusick, Michael J Karels and John Quarterman The Design and Implementation of the 4.3BSD UNIX Operating System. Reading, Mass. : Addison-Wesley, 1989. ISBN 0-201-06196-1
- Leffler, Samuel J., Marshall Kirk McKusick, The Design and Implementation of the 4.3BSD UNIX Operating System: Answer Book. Reading, Mass. : Addison-Wesley, 1991. ISBN 0-201-54629-9
- McKusick, Marshall Kirk, Keith Bostic, Michael J Karels, and John Quarterman. The Design and Implementation of the 4.4BSD Operating System. Reading, Mass. : Addison-Wesley, 1996. ISBN 0-201-54979-4

  （本書第二章的 網路版 是 FreeBSD 文件計劃的一部份，以及第九章的部分可以在 這邊找到）
- Marshall Kirk McKusick, George V. Neville-Neil The Design and Implementation of the FreeBSD Operating System. Boston, Mass. : Addison-Wesley, 2004. ISBN 0-201-70245-2
- Stevens, W. Richard. TCP/IP Illustrated, Volume 1: The Protocols. Reading, Mass. : Addison-Wesley, 1996. ISBN 0-201-63346-9
- Schimmel, Curt. Unix Systems for Modern Architectures. Reading, Mass. : Addison-Wesley, 1994. ISBN 0-201-63338-8
- Stevens, W. Richard. TCP/IP Illustrated, Volume 3: TCP for Transactions, HTTP, NNTP and the UNIX Domain Protocols. Reading, Mass. : Addison-Wesley, 1996. ISBN 0-201-63495-3

- Vahalia, Uresh. UNIX Internals -- The New Frontiers. Prentice Hall, 1996. ISBN 0-13-101908-2
- Wright, Gary R. and W. Richard Stevens. TCP/IP Illustrated, Volume 2: The Implementation. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-63354-X

B.6. 資安領域的參考文獻

- Cheswick, William R. and Steven M. Bellovin. Firewalls and Internet Security: Repelling the Wily Hacker. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-63357-4
- Garfinkel, Simson and Gene Spafford. Practical UNIX & Internet Security. 2nd Ed. O'Reilly & Associates, Inc., 1996. ISBN 1-56592-148-8
- Garfinkel, Simson. PGP Pretty Good Privacy O'Reilly & Associates, Inc., 1995. ISBN 1-56592-098-8

B.7. 硬體方面的參考文獻

- Anderson, Don and Tom Shanley. Pentium Processor System Architecture. 2nd Ed. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-40992-5
- Ferraro, Richard F. Programmer's Guide to the EGA, VGA, and Super VGA Cards. 3rd ed. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-62490-7
- Intel Corporation 通常會以 PDF 格式在 developer web site 網站放他們的 CPU、晶片組、相關標準的規格書文件。
- Shanley, Tom. 80486 System Architecture. 3rd ed. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-40994-1
- Shanley, Tom. ISA System Architecture. 3rd ed. Reading, Mass. : Addison-Wesley, 1995. ISBN 0-201-40996-8
- Shanley, Tom. PCI System Architecture. 4th ed. Reading, Mass. : Addison-Wesley, 1999. ISBN 0-201-30974-2
- Van Gilluwe, Frank. The Undocumented PC, 2nd Ed. Reading, Mass: Addison-Wesley Pub. Co., 1996. ISBN 0-201-47950-8
- Messmer, Hans-Peter. The Indispensable PC Hardware Book, 4th Ed. Reading, Mass: Addison-Wesley Pub. Co., 2002. ISBN 0-201-59616-4

B.8. UNIX® 歷史淵源

- Lion, John Lion's Commentary on UNIX, 6th Ed. With Source Code. ITP Media Group, 1996. ISBN 1573980137
- Raymond, Eric S. The New Hacker's Dictionary, 3rd edition. MIT Press, 1996. ISBN 0-262-68092-0. Also known as the Jargon File
- Salus, Peter H. A quarter century of UNIX. Addison-Wesley Publishing Company, Inc., 1994. ISBN 0-201-54777-5
- Simon Garfinkel, Daniel Weise, Steven Strassmann. The UNIX-HATERS Handbook. IDG Books Worldwide, Inc., 1994. ISBN 1-56884-203-1. Out of print, but available online.
- Don Libes, Sandy Ressler Life with UNIX —— special edition. Prentice-Hall, Inc., 1989. ISBN 0-13-536657-7
- BSD 族譜： `http://www.FreeBSD.org/cgi/cvsweb.cgi/src/share/misc/bsd-family-tree` 或 FreeBSD 機器內的 `/usr/share/misc/bsd-family-tree` 。
- The BSD Release Announcements collection. 1997. `http://www.de.FreeBSD.org/de/ftp/releases/`

- Networked Computer Science Technical Reports Library. http://www.ncstrl.org/
- Old BSD releases from the Computer Systems Research group (CSRG). http://www.mckusick.com/csrg/: The 4CD set covers all BSD versions from 1BSD to 4.4BSD and 4.4BSD-Lite2 (but not 2.11BSD, unfortunately). The last disk also holds the final sources plus the SCCS files.

B.9. 雜誌、期刊

- The C/C++ Users Journal. R&D Publications Inc. ISSN 1075-2838
- Sys Admin —— The Journal for UNIX System Administrators Miller Freeman, Inc., ISSN 1061-2688
- freeX —— Das Magazin für Linux - BSD - UNIX（德文）Computer- und Literaturverlag GmbH, ISSN 1436-7033

附錄 C. 網際網路上的資源

進展飛快的 FreeBSD 使得現有的印刷、平面媒體跟不上它的最新進度！ 反而數位版本的資源，也許有時並不是最好，但通常是唯一一個跟上最新進展的方式。 正由於 FreeBSD 是來自於許多志工的努力，所以廣大的使用者群也通常扮演著“IT技術支援部門” 的角色。 只要善用電子郵件和 USENET 新聞群組就可以很快速地聯繫這些社群了。

以下簡介與 FreeBSD 社群搭上線的主要方式。 若你還知道其他這裡沒有列出的資源，請告知 FreeBSD documentation project 郵遞論壇，以便我們更新。

C.1. 郵遞論壇(Mailing Lists)

雖然，大部份的 FreeBSD 開發人員都有看 USENET 新聞群組， 我們也不能保證我們永遠可以及時得知您的問題。 尤其是，若您只在 `comp.unix.bsd.freebsd.*` 其中群組內發問的話。 建議您將問題發到適當的郵遞論壇(mailing list)上，不但可以同時讓 FreeBSD 開發者和其他看倌們知道，通常也可以得到一個較好的(最起碼會比較快)的回應。

本文後面介紹的是各式不同的郵遞論壇、討論規則(`charter`)。 在訂閱任何 list 之前，請先閱讀討論規則。 訂閱這些 list 的人們現在每天都會收到數百封 FreeBSD 相關信件。 而討論規則的制訂，則有助於提升彼此討論品質。 否則，這些討論 FreeBSD 的 list 終將陷入溝通不良，而失去其原本美意。

對於該在哪個 list 發問覺得很疑惑的時候，就來看看 《如何在 FreeBSD-questions mailing list 上得到正解》一文吧

在發表問題、回覆到 list 之前，請先讀過 FreeBSD Mailing Lists 常見問答集(FAQ) 一文以學會如何善用 mailing list ，才能避免像是經常重複的月經文、戰文之類的事情發生。

全部的 mailing lists 討論記錄都可以在 FreeBSD WWW主機 上找到。它提供了很棒的關鍵字搜尋功能，可讓您找到常用問答集(FAQ) 。而在 mailing lists 上發問之前，也請先搜尋是否已有解答。

C.1.1. List 一覽表

一般論壇： 以下的 list 都是一般性質，而且大家可以自由地參與， 我們也鼓勵大家訂閱：

List 名稱	目的
cvs-all	所有的 FreeBSD 提交(commit)記錄
freebsd-advocacy	FreeBSD 惡魔福音電台
freebsd-announce	公布重要事件、計劃里程碑
freebsd-arch	架構研發討論
freebsd-bugbusters	FreeBSD 問題回報(PR)資料庫的維護議題與工具
freebsd-bugs	Bug 回報
freebsd-chat	非技術交流的 FreeBSD 社群聊天區
freebsd-current	討論 FreeBSD-CURRENT 版本的 FreeBSD
freebsd-isp	FreeBSD 的 ISP 業者技術交流區
freebsd-jobs	FreeBSD 人力銀行
freebsd-questions	使用問題及技術支援
freebsd-security-notifications	安全漏洞通知
freebsd-stable	討論 FreeBSD-STABLE 版本的 FreeBSD

List 名稱	目的
freebsd-test	論壇新手發表區，這裡可以讓你小試身手

技術論壇： 以下 list 主是要以探討技術問題為主， 在加入訂閱及討論之前，請務必仔細閱讀每個 list 的版規(charter)， 因為它們的討論內容都有很嚴謹的限制。

List 名稱	目的
freebsd-acpi	ACPI 以及電力管理議題
freebsd-afs	移植 AFS 到 FreeBSD
freebsd-aic7xxx	研發 Adaptec® AIC 7xxx 的驅動程式
freebsd-alpha	移植 FreeBSD 到 Alpha 系統架構
freebsd-amd64	移植 FreeBSD 到 AMD64 系統架構
freebsd-apache	探討 Apache 相關的 ports 議題
freebsd-arm	移植 FreeBSD 到 ARM® CPU 架構
freebsd-atm	在 FreeBSD 上使用 ATM 網路
freebsd-bluetooth	在 FreeBSD 中使用藍芽(Bluetooth®)技術
freebsd-cluster	把 FreeBSD 在叢集架構環境(clustered environment)的運用
freebsd-database	討論各式資料庫在 FreeBSD 的研發、運用
freebsd-doc	撰寫 FreeBSD 相關文件
freebsd-drivers	撰寫 FreeBSD 用的驅動程式
freebsd-eclipse	FreeBSD 的 Eclipse IDE 工具愛用者交流
freebsd-emulation	在 FreeBSD 上模擬其他系統，如：Linux、MS-DOS®、Windows®
freebsd-firewire	FreeBSD 的 FireWire® (iLink, IEEE 1394) 方面技術交流
freebsd-fs	檔案系統的探討、研發
freebsd-geom	GEOM 議題的探討、研發
freebsd-gnome	移植 GNOME 及 GNOME 相關應用軟體
freebsd-hackers	一般技術議題的探討
freebsd-hardware	FreeBSD 上的各式硬體問題交流
freebsd-i18n	FreeBSD 的多語化(Internationalization)
freebsd-ia32	FreeBSD 在 IA-32 (Intel® x86) 平台上的使用探討
freebsd-ia64	移植 FreeBSD 到 Intel® 的未來 IA64 平台架構
freebsd-ipfw	對 ipfw(IP firewall) 的技術探討
freebsd-isdn	ISDN 研發
freebsd-java	Java™ 程式開發者以及移植 JDK™s 到 FreeBSD 上
freebsd-kde	移植 KDE 以及 KDE 相關應用程式
freebsd-lfs	移植 LFS 到 FreeBSD
freebsd-mips	移植 FreeBSD 到 MIPS®
freebsd-mobile	關於各類 mobile computing(比如：筆記型電腦)的研討
freebsd-mozilla	把 Mozilla 軟體移植到 FreeBSD
freebsd-multimedia	各式影音運用、軟體

List 名稱	目的
freebsd-new-bus	各式 bus 架構的技術探討
freebsd-net	網路運用探討與 TCP/IP source code
freebsd-performance	在高效能/負荷環境下的效能調校(tuning)議題
freebsd-perl	探討 Perl 相關 ports 的維護
freebsd-pf	pf(packet filter) 防火牆機制的探討
freebsd-platforms	討論著重於移植 port 到非 Intel® 架構平台的議題
freebsd-ports	關於 Ports Collection 的運用、探討
freebsd-ports-bugs	ports 相關的 bugs/PRs
freebsd-ppc	移植 FreeBSD 到 PowerPC® 系統架構
freebsd-proliant	FreeBSD 在 HP ProLiant 主機平台的使用交流
freebsd-python	Python 在 FreeBSD 上使用的各式議題。
freebsd-qa	QA(Quality Assurance)討論，通常會決定是否已經到達可以 release 的程度
freebsd-rc	`rc.d` 機制的討論、研發
freebsd-realtime	FreeBSD 上 realtime extensions 的研發
freebsd-scsi	SCSI 方面議題
freebsd-security	FreeBSD 安全漏洞議題
freebsd-small	在嵌入式硬體環境的應用、探討
freebsd-smp	CPU 對稱多工處理(SMP, [A]Symmetric Multiprocessing)的應用、研討
freebsd-sparc64	移植 FreeBSD 到 Sparc® 平台架構
freebsd-standards	FreeBSD 與 C99 及 POSIX®標準的相容議題
freebsd-threads	FreeBSD 上的 Threading 運用、探討
freebsd-testing	FreeBSD 的效能與穩定性測試
freebsd-tokenring	FreeBSD 的 Token Ring 支援的應用、探討
freebsd-usb	FreeBSD 的 USB 支援的應用、探討
freebsd-vuxml	VuXML 漏洞通報架構的探討
freebsd-x11	X11 在 FreeBSD 的運用

有訂閱限制的論壇： 以下的 lists 是針對一些特定要求的讀者而設， 而且並不適合當成是一般的公開討論區。 您最好先在某些技術討論區參與一段時間的討論後，再選擇訂閱這些有限制的論壇。 因為如此一來，您可以了解到在這些討論區發言所須的禮儀。

List 名稱	目的
freebsd-hubs	映射站台(mirror)的交流討論區
freebsd-user-groups	社群間的協調
freebsd-vendors	Vendors pre-release coordination
freebsd-www	www.FreeBSD.org 的管理維護

論壇的摘要版： 上述的各 lists 都有摘要版(`digest`)， 在訂閱 list 之後，就可以先以自己帳號登入，然後個人訂閱選項那邊改為摘要版即可。

CVS lists: 以下的 lists 是提供給想要看各個 tree 的提交(commit)紀錄， 請注意：他們是 唯讀(Read-Only) 性質的 list ，而且不能寄信給這。

List 名稱	Source 區域	本區簡介 (source for)
cvs-all	`/usr/(CVSROOT|doc|ports|projects|src)`	全部的變更記錄(包括各類 CVS commit)
cvs-doc	`/usr/(doc|www)`	doc 及 www trees 的所有變更紀錄
cvs-ports	`/usr/ports`	ports tree 的所有變更紀錄
cvs-projects	`/usr/projects`	projects tree 的所有變更紀錄
cvs-src	`/usr/src`	src tree 的所有變更紀錄

C.1.2. 要如何訂閱

要訂閱 list 的話，請以滑鼠按下上述 list 名稱， 或是到 http://lists.FreeBSD.org/mailman/listinfo 然後即可挑選有興趣的 list 來訂閱了， 該網頁會指示你如何進行訂閱的步驟。

To actually post to a given list you simply send mail to <*listname*@FreeBSD.org>. It will then be redistributed to mailing list members world-wide.

To unsubscribe yourself from a list, click on the URL found at the bottom of every email received from the list. It is also possible to send an email to <*listname*-unsubscribe@FreeBSD.org> to unsubscribe yourself.

Again, we would like to request that you keep discussion in the technical mailing lists on a technical track. If you are only interested in important announcements then it is suggested that you join the FreeBSD announcements 郵遞論壇, which is intended only for infrequent traffic.

C.1.3. List Charters

All FreeBSD mailing lists have certain basic rules which must be adhered to by anyone using them. Failure to comply with these guidelines will result in two (2) written warnings from the FreeBSD Postmaster <postmaster@FreeBSD.org>, after which, on a third offense, the poster will removed from all FreeBSD mailing lists and filtered from further posting to them. We regret that such rules and measures are necessary at all, but today's Internet is a pretty harsh environment, it would seem, and many fail to appreciate just how fragile some of its mechanisms are.

Rules of the road:

- The topic of any posting should adhere to the basic charter of the list it is posted to, e.g. if the list is about technical issues then your posting should contain technical discussion. Ongoing irrelevant chatter or flaming only detracts from the value of the mailing list for everyone on it and will not be tolerated. For free-form discussion on no particular topic, the FreeBSD chat 郵遞論壇 is freely available and should be used instead.

- No posting should be made to more than 2 mailing lists, and only to 2 when a clear and obvious need to post to both lists exists. For most lists, there is already a great deal of subscriber overlap and except for the most esoteric mixes (say "-stable & -scsi"), there really is no reason to post to more than one list at a time. If a message is sent to you in such a way that multiple mailing lists appear on the `Cc` line then the `Cc` line should also be trimmed before sending it out again. You are still responsible for your own cross-postings, no matter who the originator might have been.

- Personal attacks and profanity (in the context of an argument) are not allowed, and that includes users and developers alike. Gross breaches of netiquette, like excerpting or reposting private mail when permission to do so was not and would not be forthcoming, are frowned upon but not specifically enforced. However, there are also very few cases where such content would fit within the charter of a list and it would therefore probably rate a warning (or ban) on that basis alone.

- Advertising of non-FreeBSD related products or services is strictly prohibited and will result in an immediate ban if it is clear that the offender is advertising by spam.

Individual list charters:

freebsd-acpi
: ACPI and power management development

freebsd-afs
: Andrew File System

  This list is for discussion on porting and using AFS from CMU/Transarc

freebsd-announce
: Important events / milestones

  This is the mailing list for people interested only in occasional announcements of significant FreeBSD events. This includes announcements about snapshots and other releases. It contains announcements of new FreeBSD capabilities. It may contain calls for volunteers etc. This is a low volume, strictly moderated mailing list.

freebsd-arch
: Architecture and design discussions

  This list is for discussion of the FreeBSD architecture. Messages will mostly be kept strictly technical in nature. Examples of suitable topics are:

  - How to re-vamp the build system to have several customized builds running at the same time.
  - What needs to be fixed with VFS to make Heidemann layers work.
  - How do we change the device driver interface to be able to use the same drivers cleanly on many buses and architectures.
  - How to write a network driver.

freebsd-bluetooth
: Bluetooth® in FreeBSD

  This is the forum where FreeBSD's Bluetooth® users congregate. Design issues, implementation details, patches, bug reports, status reports, feature requests, and all matters related to Bluetooth® are fair game.

freebsd-bugbusters
: Coordination of the Problem Report handling effort

  The purpose of this list is to serve as a coordination and discussion forum for the Bugmeister, his Bugbusters, and any other parties who have a genuine interest in the PR database. This list is not for discussions about specific bugs, patches or PRs.

freebsd-bugs
: Bug reports

  This is the mailing list for reporting bugs in FreeBSD. Whenever possible, bugs should be submitted using the send-pr(1) command or the WEB interface to it.

freebsd-chat
: Non technical items related to the FreeBSD community

  This list contains the overflow from the other lists about non-technical, social information. It includes discussion about whether Jordan looks like a toon ferret or not, whether or not to type in capitals, who is drinking too much coffee, where the best beer is brewed, who is brewing beer in their basement, and so on. Occasional announcements of important events (such as upcoming parties, weddings, births, new jobs, etc) can be made to the technical lists, but the follow ups should be directed to this -chat list.

freebsd-core
: FreeBSD core team

This is an internal mailing list for use by the core members. Messages can be sent to it when a serious FreeBSD-related matter requires arbitration or high-level scrutiny.

freebsd-current
: Discussions about the use of FreeBSD-CURRENT

  This is the mailing list for users of FreeBSD-CURRENT. It includes warnings about new features coming out in -CURRENT that will affect the users, and instructions on steps that must be taken to remain -CURRENT. Anyone running "CURRENT" must subscribe to this list. This is a technical mailing list for which strictly technical content is expected.

freebsd-doc
: Documentation project

  This mailing list is for the discussion of issues and projects related to the creation of documentation for FreeBSD. The members of this mailing list are collectively referred to as "The FreeBSD Documentation Project". It is an open list; feel free to join and contribute!

freebsd-drivers
: Writing device drivers for FreeBSD

  This is a forum for technical discussions related to device drivers on FreeBSD. It is primarily a place for device driver writers to ask questions about how to write device drivers using the APIs in the FreeBSD kernel.

freebsd-eclipse
: FreeBSD users of Eclipse IDE, tools, rich client applications and ports.

  The intention of this list is to provide mutual support for everything to do with choosing, installing, using, developing and maintaining the Eclipse IDE, tools, rich client applications on the FreeBSD platform and assisting with the porting of Eclipse IDE and plugins to the FreeBSD environment.

  The intention is also to facilitate exchange of information between the Eclipse community and the FreeBSD community to the mutual benefit of both.

  Although this list is focused primarily on the needs of Eclipse users it will also provide a forum for those who would like to develop FreeBSD specific applications using the Eclipse framework.

freebsd-emulation
: Emulation of other systems such as Linux/MS-DOS®/Windows®

  This is a forum for technical discussions related to running programs written for other operating systems on FreeBSD.

freebsd-firewire
: FireWire® (iLink, IEEE 1394)

  This is a mailing list for discussion of the design and implementation of a FireWire® (aka IEEE 1394 aka iLink) subsystem for FreeBSD. Relevant topics specifically include the standards, bus devices and their protocols, adapter boards/cards/chips sets, and the architecture and implementation of code for their proper support.

freebsd-fs
: File systems

  Discussions concerning FreeBSD file systems. This is a technical mailing list for which strictly technical content is expected.

freebsd-geom
: GEOM

  Discussions specific to GEOM and related implementations. This is a technical mailing list for which strictly technical content is expected.

freebsd-gnome
: GNOME

  Discussions concerning The GNOME Desktop Environment for FreeBSD systems. This is a technical mailing list for which strictly technical content is expected.

freebsd-ipfw
: IP Firewall

  This is the forum for technical discussions concerning the redesign of the IP firewall code in FreeBSD. This is a technical mailing list for which strictly technical content is expected.

freebsd-ia64
: Porting FreeBSD to IA64

  This is a technical mailing list for individuals actively working on porting FreeBSD to the IA-64 platform from Intel®, to bring up problems or discuss alternative solutions. Individuals interested in following the technical discussion are also welcome.

freebsd-isdn
: ISDN Communications

  This is the mailing list for people discussing the development of ISDN support for FreeBSD.

freebsd-java
: Java™ Development

  This is the mailing list for people discussing the development of significant Java™ applications for FreeBSD and the porting and maintenance of JDK™s.

freebsd-jobs
: Jobs offered and sought

  This is a forum for posting employment notices and resumes specifically related to FreeBSD, e.g. if you are seeking FreeBSD-related employment or have a job involving FreeBSD to advertise then this is the right place. This is not a mailing list for general employment issues since adequate forums for that already exist elsewhere.

  Note that this list, like other `FreeBSD.org` mailing lists, is distributed worldwide. Thus, you need to be clear about location and the extent to which telecommuting or assistance with relocation is available.

  Email should use open formats only —— preferably plain text, but basic Portable Document Format (PDF), HTML, and a few others are acceptable to many readers. Closed formats such as Microsoft® Word (`.doc`) will be rejected by the mailing list server.

freebsd-kde
: KDE

  Discussions concerning KDE on FreeBSD systems. This is a technical mailing list for which strictly technical content is expected.

freebsd-hackers
: Technical discussions

  This is a forum for technical discussions related to FreeBSD. This is the primary technical mailing list. It is for individuals actively working on FreeBSD, to bring up problems or discuss alternative solutions. Individuals interested in following the technical discussion are also welcome. This is a technical mailing list for which strictly technical content is expected.

freebsd-hardware
: General discussion of FreeBSD hardware

General discussion about the types of hardware that FreeBSD runs on, various problems and suggestions concerning what to buy or avoid.

freebsd-hubs
Mirror sites

Announcements and discussion for people who run FreeBSD mirror sites.

freebsd-isp
Issues for Internet Service Providers

This mailing list is for discussing topics relevant to Internet Service Providers (ISPs) using FreeBSD. This is a technical mailing list for which strictly technical content is expected.

freebsd-performance
Discussions about tuning or speeding up FreeBSD

This mailing list exists to provide a place for hackers, administrators, and/or concerned parties to discuss performance related topics pertaining to FreeBSD. Acceptable topics includes talking about FreeBSD installations that are either under high load, are experiencing performance problems, or are pushing the limits of FreeBSD. Concerned parties that are willing to work toward improving the performance of FreeBSD are highly encouraged to subscribe to this list. This is a highly technical list ideally suited for experienced FreeBSD users, hackers, or administrators interested in keeping FreeBSD fast, robust, and scalable. This list is not a question-and-answer list that replaces reading through documentation, but it is a place to make contributions or inquire about unanswered performance related topics.

freebsd-pf
Discussion and questions about the packet filter firewall system

Discussion concerning the packet filter (pf) firewall system in terms of FreeBSD. Technical discussion and user questions are both welcome. This list is also a place to discuss the ALTQ QoS framework.

freebsd-platforms
Porting to Non Intel® platforms

Cross-platform FreeBSD issues, general discussion and proposals for non Intel® FreeBSD ports. This is a technical mailing list for which strictly technical content is expected.

freebsd-ports
Discussion of “ports”

Discussions concerning FreeBSD's “ports collection” (`/usr/ports`), ports infrastructure, and general ports coordination efforts. This is a technical mailing list for which strictly technical content is expected.

freebsd-ports-bugs
Discussion of “ports” bugs

Discussions concerning problem reports for FreeBSD's “ports collection” (`/usr/ports`), proposed ports, or modifications to ports. This is a technical mailing list for which strictly technical content is expected.

freebsd-proliant
Technical discussion of FreeBSD on HP ProLiant server platforms

This mailing list is to be used for the technical discussion of the usage of FreeBSD on HP ProLiant servers, including the discussion of ProLiant-specific drivers, management software, configuration tools, and BIOS updates. As such, this is the primary place to discuss the hpasmd, hpasmcli, and hpacucli modules.

freebsd-python
Python on FreeBSD

This is a list for discussions related to improving Python-support on FreeBSD. This is a technical mailing list. It is for individuals working on porting Python, its 3rd party modules and Zope stuff to FreeBSD. Individuals interested in following the technical discussion are also welcome.

freebsd-questions
User questions

This is the mailing list for questions about FreeBSD. You should not send "how to" questions to the technical lists unless you consider the question to be pretty technical.

freebsd-scsi
SCSI subsystem

This is the mailing list for people working on the SCSI subsystem for FreeBSD. This is a technical mailing list for which strictly technical content is expected.

freebsd-security
Security issues

FreeBSD computer security issues (DES, Kerberos, known security holes and fixes, etc). This is a technical mailing list for which strictly technical discussion is expected. Note that this is not a question-and-answer list, but that contributions (BOTH question AND answer) to the FAQ are welcome.

freebsd-security-notifications
Security Notifications

Notifications of FreeBSD security problems and fixes. This is not a discussion list. The discussion list is FreeBSD-security.

freebsd-small
Using FreeBSD in embedded applications

This list discusses topics related to unusually small and embedded FreeBSD installations. This is a technical mailing list for which strictly technical content is expected.

freebsd-stable
Discussions about the use of FreeBSD-STABLE

This is the mailing list for users of FreeBSD-STABLE. It includes warnings about new features coming out in -STABLE that will affect the users, and instructions on steps that must be taken to remain -STABLE. Anyone running "STABLE" should subscribe to this list. This is a technical mailing list for which strictly technical content is expected.

freebsd-standards
C99 & POSIX Conformance

This is a forum for technical discussions related to FreeBSD Conformance to the C99 and the POSIX standards.

freebsd-usb
Discussing FreeBSD support for USB

This is a mailing list for technical discussions related to FreeBSD support for USB.

freebsd-user-groups
User Group Coordination List

This is the mailing list for the coordinators from each of the local area Users Groups to discuss matters with each other and a designated individual from the Core Team. This mail list should be limited to meeting synopsis and coordination of projects that span User Groups.

freebsd-vendors
: Vendors

  Coordination discussions between The FreeBSD Project and Vendors of software and hardware for FreeBSD.

C.1.4. Filtering on the Mailing Lists

The FreeBSD mailing lists are filtered in multiple ways to avoid the distribution of spam, viruses, and other unwanted emails. The filtering actions described in this section do not include all those used to protect the mailing lists.

Only certain types of attachments are allowed on the mailing lists. All attachments with a MIME content type not found in the list below will be stripped before an email is distributed on the mailing lists.

- application/octet-stream
- application/pdf
- application/pgp-signature
- application/x-pkcs7-signature
- message/rfc822
- multipart/alternative
- multipart/related
- multipart/signed
- text/html
- text/plain
- text/x-diff
- text/x-patch

注意

Some of the mailing lists might allow attachments of other MIME content types, but the above list should be applicable for most of the mailing lists.

If an email contains both an HTML and a plain text version, the HTML version will be removed. If an email contains only an HTML version, it will be converted to plain text.

C.2. Usenet Newsgroups

In addition to two FreeBSD specific newsgroups, there are many others in which FreeBSD is discussed or are otherwise relevant to FreeBSD users. Keyword searchable archives are available for some of these newsgroups from courtesy of Warren Toomey <wkt@cs.adfa.edu.au >.

C.2.1. BSD Specific Newsgroups

- comp.unix.bsd.freebsd.announce

- comp.unix.bsd.freebsd.misc
- de.comp.os.unix.bsd (German)
- fr.comp.os.bsd (French)
- it.comp.os.freebsd (Italian)

C.2.2. Other UNIX® Newsgroups of Interest

- comp.unix
- comp.unix.questions
- comp.unix.admin
- comp.unix.programmer
- comp.unix.shell
- comp.unix.user-friendly
- comp.security.unix
- comp.sources.unix
- comp.unix.advocacy
- comp.unix.misc
- comp.bugs.4bsd
- comp.bugs.4bsd.ucb-fixes
- comp.unix.bsd

C.2.3. X Window System

- comp.windows.x.i386unix
- comp.windows.x
- comp.windows.x.apps
- comp.windows.x.announce
- comp.windows.x.intrinsics
- comp.windows.x.motif
- comp.windows.x.pex
- comp.emulators.ms-windows.wine

C.3. World Wide Web Servers

Central Servers, Armenia, Australia, Austria, Canada, Czech Republic, Denmark, Finland, France, Germany, Hong Kong, Ireland, Japan, Latvia, Lithuania, Netherlands, Norway, Russia, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, United Kingdom, USA.

(as of UTC)

- Central Servers
  - http://www.FreeBSD.org/
- Armenia
  - http://www1.am.FreeBSD.org/ (IPv6)
- Australia
  - http://www.au.FreeBSD.org/
  - http://www2.au.FreeBSD.org/
- Austria
  - http://www.at.FreeBSD.org/ (IPv6)
- Canada
  - http://www.ca.FreeBSD.org/
  - http://www2.ca.FreeBSD.org/
- Czech Republic
  - http://www.cz.FreeBSD.org/ (IPv6)
- Denmark
  - http://www.dk.FreeBSD.org/ (IPv6)
- Finland
  - http://www.fi.FreeBSD.org/
- France
  - http://www1.fr.FreeBSD.org/
- Germany
  - http://www.de.FreeBSD.org/
- Hong Kong
  - http://www.hk.FreeBSD.org/
- Ireland

- http://www.ie.FreeBSD.org/

- Japan
  - http://www.jp.FreeBSD.org/www.FreeBSD.org/ (IPv6)
- Latvia
  - http://www.lv.FreeBSD.org/
- Lithuania
  - http://www.lt.FreeBSD.org/
- Netherlands
  - http://www.nl.FreeBSD.org/
- Norway
  - http://www.no.FreeBSD.org/
- Russia
  - http://www.ru.FreeBSD.org/ (IPv6)
- Slovenia
  - http://www.si.FreeBSD.org/
- South Africa
  - http://www.za.FreeBSD.org/
- Spain
  - http://www.es.FreeBSD.org/
  - http://www2.es.FreeBSD.org/
- Sweden
  - http://www.se.FreeBSD.org/
- Switzerland
  - http://www.ch.FreeBSD.org/ (IPv6)
  - http://www2.ch.FreeBSD.org/ (IPv6)
-

Taiwan

- http://www.tw.FreeBSD.org/
- http://www2.tw.FreeBSD.org/
- http://www4.tw.FreeBSD.org/
- http://www5.tw.FreeBSD.org/ (IPv6)

- United Kingdom
  - http://www1.uk.FreeBSD.org/
  - http://www3.uk.FreeBSD.org/

- USA
  - http://www5.us.FreeBSD.org/ (IPv6)

C.4. Email Addresses

The following user groups provide FreeBSD related email addresses for their members. The listed administrator reserves the right to revoke the address if it is abused in any way.

Domain	Facilities	User Group	Administrator
ukug.uk.FreeBSD.org	Forwarding only	<freebsd-users@uk.FreeBSD.org>	Lee Johnston <lee@uk.FreeBSD.org>

C.5. Shell Accounts

The following user groups provide shell accounts for people who are actively supporting the FreeBSD project. The listed administrator reserves the right to cancel the account if it is abused in any way.

Host	Access	Facilities	Administrator
dogma.freebsd-uk.eu.org	Telnet/FTP/SSH	Email, Web space, Anonymous FTP	Lee Johnston <lee@uk.FreeBSD.org>

附錄 D. PGP Keys

In case you need to verify a signature or send encrypted email to one of the officers or developers a number of keys are provided here for your convenience. A complete keyring of FreeBSD.org users is available for download from http://www.FreeBSD.org/doc/pgpkeyring.txt.

D.1. Officers

D.1.1. Security Officer Team <security-officer@FreeBSD.org >

```
pub   rsa4096/ED67ECD65DCF6AE7 2013-09-24 [expires: 2018-01-01]
      Key fingerprint = 1CF7 FF6F ADF5 CA9F BE1B  8CB2 ED67 ECD6 5DCF 6AE7
uid                           FreeBSD Security Officer <security-officer@FreeBSD.org>
sub   rsa4096/B64357A343D9CBAE 2013-09-24 [expires: 2018-01-01]
```

```
-----BEGIN PGP PUBLIC KEY BLOCK-----

mQINBFJBjOYBEADuKnefrbTVFTZf9mITVx1lFAqwDHPRHZeWBr2Vq1B/Y1eKKsen
BKbK/O/CXaLuGFRn/6Ptvi9eLuWnho88qzaPU1Aa7BFRRiZlN+WrTmaDwdONJnJQ
p1LTPjqHmLVAkD7mFZe/H8Glxot62zEqY7LrEs+ZuxQ8oI51YKjhGaACvkrFMinO
09+TDey1fupVH1+yskVKQZo1zp//Hl/IrPbZKfGCxIGePQowZF7YLvl8DKPo4jI5
KO4tZ1kOPcPL2CqwhuCDy0fpUhrQZBswp6tsGx5mRJxDxfgePRBYDK4tMK+BSVsR
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D.1.2. Security Team Secretary <secteam-secretary@FreeBSD.org >

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      Key fingerprint = FA97 AA04 4DF9 0969 D5EF  4ADA 3CB2 EAFC C3D6 C666
uid                          FreeBSD Security Team Secretary <secteam-secretary@FreeBSD.↺
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D.1.3. Core Team Secretary <core-secretary@FreeBSD.org >

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pub   rsa4096/36A7C05FE1ECF9BB 2014-07-09 [expires: 2016-07-08]
      Key fingerprint = C07B F5E3 10AE 64BF 6120  B0F6 36A7 C05F E1EC F9BB
uid                           Core Secretary <core-secretary@freebsd.org>
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sub   rsa4096/7B5150C8D7CE5D02 2014-07-09 [expires: 2016-07-08]
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D.1.4. Ports Management Team Secretary <portmgr-secretary@FreeBSD.org >

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      Key fingerprint = FB37 45C8 6F15 E8ED AC81  32FC D829 4EC3 BBC4 D7D5
uid                          FreeBSD Ports Management Team Secretary <portmgr-
secretary@FreeBSD.org>
sub   2048R/5CC117965F65CFE7 2012-07-24
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-----END PGP PUBLIC KEY BLOCK-----
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D.2. Core Team Members

D.2.1. Gavin Atkinson <gavin@FreeBSD.org >

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pub   4096R/4DA114E5C4A2E57F 2013-09-25 [expires: 2018-09-24]
      Key fingerprint = A12B D878 2A5E A90F D37C  43BC 4DA1 14E5 C4A2 E57F
uid                          Gavin Atkinson (Work email) <gavin.atkinson@york.ac.uk>
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D.2.2. David Chisnall <theraven@FreeBSD.org >

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D.2.3. Baptiste Daroussin <bapt@FreeBSD.org >

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D.2.4. Ed Maste <emaste@FreeBSD.org >

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pub   rsa2048/5D9A9C3B43EEF099 2015-07-08 [expires: 2017-07-07]
      Key fingerprint = F7E1 F016 EF5B 923A 6134  8BC8 5D9A 9C3B 43EE F099
uid                           Ed Maste <emaste@freebsd.org>
sub   rsa2048/A294A95EA92D2D89 2015-07-08 [expires: 2017-07-07]
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D.2.5. George V. Neville-Neil <gnn@FreeBSD.org >

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pub   1024D/440A33D2 2002-09-17
      Key fingerprint = AF66 410F CC8D 1FC9 17DB  6225 61D8 76C1 440A 33D2
uid                  George V. Neville-Neil <gnn@freebsd.org>
uid                  George V. Neville-Neil <gnn@neville-neil.com>
sub   2048g/95A74F6E 2002-09-17
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D.2.6. Hiroki Sato <hrs@FreeBSD.org >

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pub   1024D/2793CF2D 2001-06-12
      Key fingerprint = BDB3 443F A5DD B3D0 A530  FFD7 4F2C D3D8 2793 CF2D
uid                  Hiroki Sato <hrs@allbsd.org>
uid                  Hiroki Sato <hrs@eos.ocn.ne.jp>
uid                  Hiroki Sato <hrs@ring.gr.jp>
uid                  Hiroki Sato <hrs@FreeBSD.org>
uid                  Hiroki Sato <hrs@jp.FreeBSD.org>
uid                  Hiroki Sato <hrs@vlsi.ee.noda.tus.ac.jp>
uid                  Hiroki Sato <hrs@jp.NetBSD.org>
uid                  Hiroki Sato <hrs@NetBSD.org>
uid                  Hiroki Sato <hrs@ec.ss.titech.ac.jp>
uid                  Hiroki Sato <hrs@ieee.org>
uid                  Hiroki Sato <hrs@acm.org>
uid                  Hiroki Sato <hrs@bsdconsulting.co.jp>
uid                  Hiroki Sato <hrs@bsdresearch.org>
uid                  Hiroki Sato <hrs@ec.ce.titech.ac.jp>
sub   1024g/8CD251FF 2001-06-12
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D.2.7. Gleb Smirnoff <glebius@FreeBSD.org >

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pub   2048D/6C7E5E82 2013-01-30 [expires: 2023-08-25]
      Key fingerprint = 6E06 7260 B83D CF2C A93C  566F 5185 0968 6C7E 5E82
uid                  Gleb Smirnoff <glebius@FreeBSD.org>
sub   2048g/11E89DCE 2013-01-30 [expires: 2023-08-25]
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D.2.8. Peter Wemm <peter@FreeBSD.org >

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pub   1024D/1512AE527277717F 2003-12-14
      Key fingerprint = 622B 2282 E92B 3BAB 57D1  A417 1512 AE52 7277 717F
uid                          Peter Wemm <peter@wemm.org>
uid                          Peter Wemm <peter@FreeBSD.ORG>
sub   1024g/2C5F53778B40D9D1 2003-12-14

pub   2048R/35D69709EC809E04 2014-05-08 [expires: 2024-05-05]
      Key fingerprint = 060A C0D1 5AFF BDF3 55B8  FA14 35D6 9709 EC80 9E04
uid                          Peter Wemm <peter@wemm.org>
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sub   2048R/B5D591B339B03C75 2014-05-08 [expires: 2024-05-05]
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D.3. Developers

D.3.1. Ariff Abdullah <ariff@FreeBSD.org >

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pub   1024D/C5304CDA 2005-10-01
      Key fingerprint = 5C7C 6BF4 8293 DE76 27D9  FD57 96BF 9D78 C530 4CDA
uid                  Ariff Abdullah <skywizard@MyBSD.org.my>
uid                  Ariff Abdullah <ariff@MyBSD.org.my>
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D.3.2. Thomas Abthorpe <tabthorpe@FreeBSD.org >

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uid                          Thomas Abthorpe (FreeBSD Committer) <tabthorpe@FreeBSD.org>
uid                          Thomas Abthorpe <tabthorpe@abthorpe.org>
uid                          Thomas Abthorpe <tabthorpe@goodking.ca>
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D.3.3. Eitan Adler <eadler@FreeBSD.org >

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D.3.4. Matthew Ahrens <mahrens@FreeBSD.org >

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      Key fingerprint = 998A 25DF CA35 CC0B 1C14  39F4 9A9E CAFE E896 EC4F
uid                          Matthew Ahrens <matt@mahrens.org>
uid                          Matthew Ahrens <matthew.ahrens@delphix.com>
uid                          Matthew Ahrens <mahrens@alumni.brown.edu>
uid                          Matthew Ahrens <mahrens@freebsd.org>
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sub   2048R/1137F565976A0587 2014-04-08 [expires: 2017-04-07]
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D.3.5. Shaun Amott <shaun@FreeBSD.org >

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uid                  Shaun Amott <shaun@inerd.com>
uid                  Shaun Amott <shaun@FreeBSD.org>
sub   2048g/26FA8703 2001-03-19
sub   2048R/7FFF5151 2005-11-06
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D.3.6. Henrik Brix Andersen <brix@FreeBSD.org >

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D.3.7. Matthias Andree <mandree@FreeBSD.org >

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pub   1024D/052E7D95 2003-08-28
      Key fingerprint = FDD0 0C43 6E33 07E1 0758  C6A8 BE61 8339 052E 7D95
uid                  Matthias Andree <mandree@freebsd.org>
uid                  Matthias Andree <matthias.andree@gmx.de>
sub   1536g/E65A83DA 2003-08-28
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D.3.8. Will Andrews <will@FreeBSD.org >

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pub  1024D/F81672C5 2000-05-22 Will Andrews (Key for official matters) <will@FreeBSD.org>
     Key fingerprint = 661F BBF7 9F5D 3D02 C862  5F6C 178E E274 F816 72C5
uid                            Will Andrews <will@physics.purdue.edu>
uid                            Will Andrews <will@puck.firepipe.net>
uid                            Will Andrews <will@c-60.org>
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D.3.9. Dimitry Andric <dim@FreeBSD.org >

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D.3.10. Eric Anholt <anholt@FreeBSD.org >

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D.3.11. Marcus von Appen <mva@FreeBSD.org >

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pub   1024D/B267A647 2009-02-14
      Key fingerprint = C7CC 1853 D8C5 E580 7795  B654 8BAF 3F12 B267 A647
uid                  Marcus von Appen <freebsd@sysfault.org>
uid                  Marcus von Appen <mva@freebsd.org>
sub   2048g/D34A3BAF 2009-02-14
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D.3.12. Marcelo Araujo <araujo@FreeBSD.org >

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pub   1024D/53E4CFA8 2007-04-27
      Key fingerprint = 9D6A 2339 925C 4F61 ED88  ED8B A2FC 4977 53E4 CFA8
uid                  Marcelo Araujo (Ports Committer) <araujo@FreeBSD.org>
sub   2048g/63CC012D 2007-04-27
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D.3.13. Mathieu Arnold <mat@FreeBSD.org >

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pub   4096R/0x3A4516F35183CE48 2013-09-23 [expires: 2018-09-22]
      Key fingerprint = 3AB6 9789 D2ED 1210 6440  BA5B 3A45 16F3 5183 CE48
uid                 [  full  -] Mathieu Arnold <mat@FreeBSD.org>
uid                 [  full  -] Mathieu Arnold <mat@mat.cc>
uid                 [  full  -] Mathieu Arnold <m@absolight.fr>
uid                 [  full  -] Mathieu Arnold <m@w2my.net>
sub   4096R/0xA99F9AA711E3DFC9 2013-09-23 [expires: 2018-09-22]
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D.3.14. Takuya ASADA <syuu@FreeBSD.org >

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pub   2048R/43788F78 2012-11-21
      Key fingerprint = 31CE 242E 6F4F F24F EEF4  D9BB 0890 2C5F 4378 8F78
uid                  Takuya ASADA <syuu@freebsd.org>
sub   2048R/A87B0906 2012-11-21
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.15. Satoshi Asami <asami@FreeBSD.org >

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pub  1024R/1E08D889 1997-07-23 Satoshi Asami <asami@cs.berkeley.edu>
     Key fingerprint = EB 3C 68 9E FB 6C EB 3F  DB 2E 0F 10 8F CE 79 CA
uid                           Satoshi Asami <asami@FreeBSD.ORG>
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.16. Gavin Atkinson <gavin@FreeBSD.org >

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pub   4096R/4DA114E5C4A2E57F 2013-09-25 [expires: 2018-09-24]
      Key fingerprint = A12B D878 2A5E A90F D37C  43BC 4DA1 14E5 C4A2 E57F
uid                          Gavin Atkinson (Work email) <gavin.atkinson@york.ac.uk>
uid                          Gavin Atkinson (Work email - deprecated) <ga9@york.ac.uk>
uid                          Gavin Atkinson (URY email) <gavin.atkinson@ury.york.ac.uk>
uid                          Gavin Atkinson (FreeBSD key) <gavin@FreeBSD.org>
sub   4096R/443BBD9486DFCC25 2013-09-25 [expires: 2018-09-24]
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D.3.17. Joseph S. Atkinson <jsa@FreeBSD.org >

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pub   2048R/21AA7B06 2010-07-14
      Key fingerprint = 5B38 63B0 9CCA 12BE 3919  9412 CC9D FC84 21AA 7B06
uid                  Joseph S. Atkinson <jsa@FreeBSD.org>
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sub   2048R/5601C3E3 2010-07-14
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D.3.18. Philippe Audeoud <jadawin@FreeBSD.org >

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pub   4096R/3D5DD05DE3EDC705 2014-05-27 [expires: 2016-05-26]
      Key fingerprint = C1CA C5C4 F29A 40BF 507A  D85B 3D5D D05D E3ED C705
uid                          Philippe Audeoud <jadawin@tuxaco.net>
uid                          Philippe Audeoud (Main ID) <philippe@tuxaco.net>
uid                          Philippe Audeoud (FreeBSD) <jadawin@FreeBSD.org>
sub   4096R/BC29A282B624266C 2014-05-27 [expires: 2016-05-26]
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D.3.19. Timur I. Bakeyev <timur@FreeBSD.org >

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D.3.20. John Baldwin <jhb@FreeBSD.org >

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D.3.21. Glen Barber <gjb@FreeBSD.org >

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D.3.22. Nick Barkas <snb@FreeBSD.org >

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D.3.23. Simon Barner <barner@FreeBSD.org >

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pub   1024D/EBADA82A 2000-11-10
      Key fingerprint = 67D1 3562 9A2F 3177 E46A  35ED 0A49 FEFD EBAD A82A
uid                  Simon Barner <barner@FreeBSD.org>
uid                  Simon Barner <barner@in.tum.de>
uid                  Simon Barner <barner@informatik.tu-muenchen.de>
uid                  Simon Barner <barner@gmx.de>
sub   2048g/F63052DE 2000-11-10
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D.3.24. Jan Beich <jbeich@FreeBSD.org >

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pub   2048R/E4C77883479DBDDB 2015-01-05 [expires: 2018-01-04]
      Key fingerprint = DB44 3674 C7D2 3578 6E14  92CE E4C7 7883 479D BDDB
uid                          Jan Beich <jbeich@FreeBSD.org>
uid                          Jan Beich <jbeich@vfemail.net>
sub   2048R/4E6607EF660A8DEC 2015-01-05 [expires: 2018-01-04]
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D.3.25. Artem Belevich <art@FreeBSD.org >

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pub   2048R/9ED4C836 2011-03-28
      Key fingerprint = 7400 D541 07ED 3DF3 3E97  F2D5 8BDF 101C 9ED4 C836
uid                  Artem Belevich <artemb@gmail.com>
uid                  Artem Belevich <art@freebsd.org>
sub   2048R/55B0E4EB 2011-03-28
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D.3.26. Anton Berezin <tobez@FreeBSD.org >

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pub  1024D/7A7BA3C0 2000-05-25 Anton Berezin <tobez@catpipe.net>
     Key fingerprint = CDD8 560C 174B D8E5 0323  83CE 22CA 584C 7A7B A3C0
uid                           Anton Berezin <tobez@tobez.org>
uid                           Anton Berezin <tobez@FreeBSD.org>
sub  1024g/ADC71E87 2000-05-25
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.27. Damien Bergamini <damien@FreeBSD.org >

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pub   2048R/D129F093 2005-03-02
      Key fingerprint = D3AB 28C3 1A4A E219 3145  54FE 220A 7486 D129 F093
uid                  Damien Bergamini <damien.bergamini@free.fr>
uid                  Damien Bergamini <damien@FreeBSD.org>
sub   2048R/9FBA73A4 2005-03-02
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D.3.28. Tim Bishop <tdb@FreeBSD.org >

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pub   rsa4096/6C226B37FDF38D55 2013-08-07 [expires: 2018-08-20]
      Key fingerprint = 4BD9 5F90 8A50 40E8 D26C  D681 6C22 6B37 FDF3 8D55
uid                           Tim Bishop <tim@bishnet.net>
uid                           Tim Bishop <T.D.Bishop@kent.ac.uk>
uid                           Tim Bishop <tdb@FreeBSD.org>
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sub   rsa4096/4F748D5A25CEA948 2013-08-07 [expires: 2018-08-20]
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D.3.29. Grzegorz Blach <gblach@FreeBSD.org >

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      Key fingerprint = 3177 46ED D8A4 1544 E2E2  4420 522D 7838 0880 9986
uid                           Grzegorz Blach <gblach@FreeBSD.org>
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D.3.30. Martin Blapp <mbr@FreeBSD.org >

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pub  1024D/D300551E 2001-12-20 Martin Blapp <mb@imp.ch>
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sub  1024g/998281C8 2001-12-20
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Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.31. Warren Block <wblock@FreeBSD.org >

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pub   2048R/BB37E0C846CB85CF 2014-03-13 [expires: 2017-03-12]
      Key fingerprint = EC53 662F FEFE D6F4 2DBA  B483 BB37 E0C8 46CB 85CF
uid                          Warren Block <wblock@FreeBSD.org>
uid                          Warren Block <wblock@wonkity.com>
sub   2048R/D79E292E145902B5 2014-03-13 [expires: 2017-03-12]
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D.3.32. Vitaly Bogdanov <bvs@FreeBSD.org >

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pub  1024D/B32017F7 2005-10-02 Vitaly Bogdanov <gad@gad.glazov.net>
     Key fingerprint = 402E B8E4 53CB 22FF BE62  AE35 A0BF B077 B320 17F7
uid                            Vitaly Bogdanov <bvs@freebsd.org>
sub  1024g/0E88C62E 2005-10-02
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D.3.33. Zbigniew Bodek <zbb@FreeBSD.org >

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pub   2048R/C32C9921 2013-09-04 [expires: 2018-09-03]
      Key fingerprint = B3EF DAFC C938 03EE 7B1B  5748 0EBE 8E50 C32C 9921
uid                  Zbigniew Bodek <zbb@FreeBSD.org>
sub   2048R/62B40108 2013-09-04 [expires: 2018-09-03]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.34. Roman Bogorodskiy <novel@FreeBSD.org >

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pub   2048R/08C2226A 2010-12-03
      Key fingerprint = 8BA4 DF2A D14F 99B6 37E0  0070 C96D 5FFE 08C2 226A
uid                  Roman Bogorodskiy <bogorodskiy@gmail.com>
uid                  Roman Bogorodskiy <novel@FreeBSD.org>
uid                  Roman Bogorodskiy <rbogorodskiy@apache.org>
uid                  Roman Bogorodskiy <rbogorodskiy@griddynamics.com>
sub   2048R/EC4ED237 2010-12-03
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.35. Renato Botelho <garga@FreeBSD.org >

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pub   4096R/9F625790 2012-11-28 [expires: 2017-11-27]
      Key fingerprint = E3DA 9B2A 6160 99CB 4B31  7641 F1F0 E7A1 9F62 5790
uid                  Renato Botelho (FreeBSD) <garga@FreeBSD.org>
uid                  Renato Botelho (Personal) <rbgarga@gmail.com>
uid                  Renato Botelho (FreeBSD) <garga.bsd@gmail.com>
sub   4096R/473CC82A 2012-11-28 [expires: 2017-11-27]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.36. Alexander Botero-Lowry <alexbl@FreeBSD.org >

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pub   1024D/12A95A7B 2006-09-13
      Key fingerprint = D0C3 47F8 AE87 C829 0613  3586 24DF F52B 12A9 5A7B
uid                  Alexander Botero-Lowry <alexbl@FreeBSD.org>
sub   2048g/CA287923 2006-09-13
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.37. Sofian Brabez <sbz@FreeBSD.org >

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pub   1024D/2487E57E 2011-03-15 [expires: 2016-03-14]
      Key fingerprint = 05BA DC7E F628 DE3F B241  BFBB 7363 51F4 2487 E57E
uid                  Sofian Brabez <sbrabez@gmail.com>
uid                  Sofian Brabez <sbz@FreeBSD.org>
uid                  Sofian Brabez <sbz@6dev.net>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.38. Edson Brandi <ebrandi@FreeBSD.org >

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pub   3072R/FFD3035B 2012-11-26 [expires: 2017-11-25]
      Key fingerprint = 443B 5363 564F 06C3 EA54  9482 209E 9B54 FFD3 035B
uid                  Edson Brandi <ebrandi@FreeBSD.org>
uid                  Edson Brandi <ebrandi@fugspbr.org>
uid                  Edson Brandi <ebrandi@ebrandi.eti.br>
uid                  Edson Brandi <edson.brandi@gmail.com>
uid                  Edson Brandi <ebrandi@primeirospassos.org>
uid                  Edson Brandi <ebrandi@gmail.com>
uid                  Edson Brandi <ebrandi@fug.com.br>
uid                  Edson Brandi <contato@edsonbrandi.com>
uid                  Edson Brandi (Born 1977-08-14 in S. S. DA GRAMA, SP - Brazil)
sub   3072R/A34B8175 2012-11-26 [expires: 2013-11-26]
sub   3072R/4EB0E0EA 2012-11-26 [expires: 2013-11-26]
sub   3072R/89917E73 2012-11-26 [expires: 2013-11-26]
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Comment: GPGTools - http://gpgtools.org
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.39. Hartmut Brandt <harti@FreeBSD.org >

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pub  1024D/5920099F 2003-01-29 Hartmut Brandt <brandt@fokus.fraunhofer.de>
     Key fingerprint = F60D 09A0 76B7 31EE 794B  BB91 082F 291D 5920 099F
uid                            Hartmut Brandt <harti@freebsd.org>
sub  1024g/21D30205 2003-01-29
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.40. Oliver Braun <obraun@FreeBSD.org >

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pub  1024D/EF25B1BA 2001-05-06 Oliver Braun <obraun@unsane.org>
     Key fingerprint = 6A3B 042A 732E 17E4 B6E7  3EAF C0B1 6B7D EF25 B1BA
uid                            Oliver Braun <obraun@obraun.net>
uid                            Oliver Braun <obraun@freebsd.org>
uid                            Oliver Braun <obraun@haskell.org>
sub  1024g/09D28582 2001-05-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.41. Max Brazhnikov <makc@FreeBSD.org >

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pub   1024D/ACB3CD12 2008-08-18
      Key fingerprint = 4BAA 200E 720A 0BD1 7BB0  9DFD FBD9 08C2 ACB3 CD12
uid                  Max Brazhnikov <makc@FreeBSD.org>
uid                  Max Brazhnikov <makc@issp.ac.ru>
sub   1024g/5FAA4088 2008-08-18
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.42. Jonathan M. Bresler <jmb@FreeBSD.org >

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pub  1024R/97E638DD 1996-06-05 Jonathan M. Bresler <jmb@Bresler.org>
     Key fingerprint = 31 57 41 56 06 C1 40 13  C5 1C E3 E5 DC 62 0E FB
uid                            Jonathan M. Bresler <jmb@FreeBSD.ORG>
uid                            Jonathan M. Bresler
uid                            Jonathan M. Bresler <Jonathan.Bresler@USi.net>
uid                            Jonathan M. Bresler <jmb@Frb.GOV>
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.43. Antoine Brodin <antoine@FreeBSD.org >

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pub   1024D/50CC2671 2008-02-03
      Key fingerprint = F3F7 72F0 9C4C 9E56 4BE9  44EA 1B80 31F3 50CC 2671
uid                  Antoine Brodin <antoine@FreeBSD.org>
sub   2048g/6F4AFBE5 2008-02-03
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D.3.44. Diane Bruce <db@FreeBSD.org >

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pub   2048R/8E9CAA7B 2012-05-16
      Key fingerprint = 8B08 E022 705D 0083 64C4  5E60 5148 0C74 8E9C AA7B
uid                  Diane Bruce <db@db.net>
uid                  Diane Bruce <db@FreeBSD.org>
sub   2048R/932E5985 2012-05-16
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D.3.45. Christian Brueffer <brueffer@FreeBSD.org >

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pub   4096R/A2E0582D3A67DC36 2013-09-23 [expires: 2018-10-23]
      Key fingerprint = 04D7 4375 648A B688 F821  57D2 A2E0 582D 3A67 DC36
uid                          Christian Brueffer <christian@brueffer.de>
uid                          Christian Brueffer <brueffer@FreeBSD.org>
uid                          Christian Brueffer <christian.brueffer@med.lu.se>
sub   4096R/78C8369847E16487 2013-09-23 [expires: 2018-10-23]
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D.3.46. Markus Brüffer <markus@FreeBSD.org >

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      Key fingerprint = 3F9B EBE8 F290 E5CC 1447  8760 D48D 1072 78F8 A8D4
uid                  Markus Brueffer <markus@brueffer.de>
uid                  Markus Brueffer <buff@hitnet.rwth-aachen.de>
uid                  Markus Brueffer <mbrueffer@mi.rwth-aachen.de>
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sub   4096g/B7E5C7B6 2002-10-21
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D.3.47. Sean Bruno <sbruno@FreeBSD.org >

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pub   2048R/1201EFCA1E727E64 2014-05-06 [expires: 2017-05-05]
      Key fingerprint = BAAD 4632 E712 1DE8 D209  97DD 1201 EFCA 1E72 7E64
uid                          Sean Bruno (FreeBSD Committer and Clusteradm) ↺
<sbruno@freebsd.org>
sub   2048R/E1703D6B0E4E4A20 2014-05-06 [expires: 2017-05-05]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.48. Ruslan Bukin <br@FreeBSD.org >

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pub   2048R/10F5E66E 2013-09-04
      Key fingerprint = 57DF DADB 15FE EF7A 14C9  1DF3 ABF4 AFEB 10F5 E66E
uid                  Ruslan Bukin <br@freebsd.org>
sub   2048R/A33057CA 2013-09-04
```

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mQENBFIm+QEBCADVjtwGKebX8ovnb5tNqb8zkiepjvBjJyZNvbazhIccNmn0ZWLi
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lK9dRmJIVtXUZHGesQfMHoBtFJR9MGDhKnvgsRpDwV4X4SCioSAAmceSyKTa8mac
BBkjmHVWpFczqYE2HWmVjCv9i4Wtn26R6XvFSE9PheP1l77GJTrIKY5XlB4JhtQW
OrxdtWxPhbNiHfqts7psIIOMDo/qMUvv3Qun/jUV/HFpZ4An5mw/E0vCWrLDTnRH
ByLqS7G1/Zg7tiMoNkNxyWqYDRuedsO2B0LbABEBAAG0HVJ1c2xhbiBCdWtpbiA8
YnJAZnJlZWJzZC5vcmc+iQE5BBMBAgAjBQJSJvkBAhsDBwsJCAcDAgEGFQgCCQoL
BBYCAwECHgECF4AACgkQq/Sv6xD15m6STwgAjzr0ThvhcsD6rFbGUMz1EMeFhlBQ
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Y7PqRGj9TajrViuVMVwIEI5ZnYiOW7G2UMWPOWOTt04Ici6i1TJE3a4lCDxb4KKH
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JvkBAQgA6fDUJPMXKqS+ntQzZULuurL6ju14lLkdNWI7apYubEvnfSPIA1nXfcPr
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IHDH2wSlQf9/4JSAu4JsvePwO7mFT1NhpDqe177qGovj0zgxixp7xz9ZBML8Jrax
7KMY+92j4sn8ErcQzwIesdyp3/4gz+H7EuqUrg4VwJTc/QZk4irevp20A0rexXNd
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=ysoS
-----END PGP PUBLIC KEY BLOCK-----
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D.3.49. Oleg Bulyzhin <oleg@FreeBSD.org >

```
pub   1024D/78CE105F 2004-02-06
      Key fingerprint = 98CC 3E66 26DE 50A8 DBC4  EB27 AF22 DCEF 78CE 105F
uid                  Oleg Bulyzhin <oleg@FreeBSD.org>
uid                  Oleg Bulyzhin <oleg@rinet.ru>
sub   1024g/F747C159 2004-02-06
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-----BEGIN PGP PUBLIC KEY BLOCK-----

mQGiBEAjnDYRBACecNDd39vZ9wnodFlATK+xvhlyX4M3FBEV34t9eVZtJz4916yb
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EcbuqLZTjYxxN5mxUYswtiNDmdWn+Ivmw46wTOl5Pu+B7W2KVl8mwwbAjwCgl9hA
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9Ag4tUWLkhxAqaqomesfI2yS4o+QGTJgQdGU3IUrOnMJD7Ascwj7304lYuqYcaqT
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vAyGNxEFpPQMVrSXHnFmK9AOcLcfssE24a3zw7So33asH2Ha9yYBrfKGrTCPZAsa
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CRCvItzveM4QX+tfAKCLk3zeTyzbbN6TqYpnqocno4H9kACePQaaDytLX+zk4plw
sywqPLv67SG5AQ0EQCOcNxAEAIUR6Uj/bLAu0/FSGDSCXfjuThVT1lh1rCLQkbBw
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E6lho11qPhjYXmFHk42VhtVlOcikZ/Azgqgycfql81H3bKWv6jA0el9SnX4yk5qf
tgZTAAMFA/9T7/ty76bNeP3/LcY9ZL9KYWB8v8pJ9jEt/RfBXB0GTuV/H+bzTjSc
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VFHBr+TxpUWBq4ZtI9K8YUbPD+s86irYn9fHlnj9qnYsod3ySvU0xYhJBBgRAgAJ
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V8DuSaXJtEgVE7Wp5CeArqtwUg==
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.50. Michael Bushkov <bushman@FreeBSD.org >

```
pub   1024D/F694C6E4 2007-03-11 [expires: 2008-03-10]
      Key fingerprint = 4278 4392 BF6B 2864 C48E  0FA9 7216 C73C F694 C6E4
uid                  Michael Bushkov <bushman@rsu.ru>
uid                  Michael Bushkov <bushman@freebsd.org>
sub   2048g/5A783997 2007-03-11 [expires: 2008-03-10]
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-----BEGIN PGP PUBLIC KEY BLOCK-----
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c2hrb3YgPGJ1c2htYW5AcnN1LnJ1PohmBBMRAgAmBQJF85xpAhsDBQkB4TOABgsJ
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.51. Adrian Chadd <adrian@FreeBSD.org >

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pub   rsa2048/7CA5E05D69F3D0F3 2015-04-25 [expires: 2018-04-24]
      Key fingerprint = B4E0 4958 1F1C 5DA4 1634  BA5B 7CA5 E05D 69F3 D0F3
uid                          Adrian Chadd <adrian@freebsd.org>
sub   rsa2048/2C3793946FA31D6C 2015-04-25 [expires: 2018-04-24]
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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YWRyaWFuQGZyZWVic2Qub3JnPokBPQQTAQgAJwUCVTrchgIbAwUJBaOagAULCQgH
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Yc0vo9Avh5c44ntvjbRej9682IYI55weLRNTNECaJtuXz9OFScyT1yPnN3Y1Pq0J
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.52. Julien Charbon <jch@FreeBSD.org >

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pub   2048R/A56543925EE9D871 2014-09-16 [expires: 2017-02-07]
      Key fingerprint = 4021 6646 A364 3729 C754  1058 A565 4392 5EE9 D871
uid                          Julien Charbon <jch@freebsd.org>
uid                          Julien Charbon <julien@jch.io>
sub   2048R/957EE70462461D7D 2014-09-16 [expires: 2017-02-07]
```

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-----BEGIN PGP PUBLIC KEY BLOCK-----

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7ebUrxkQ69cqUVOAkUrCdNbTO3d8pEQxHRcJu+AVBHKThA7Js8uo5UzYgJ/Z5Chg
4P7uR1W9ixSpVo81smbWFnyenMEHOj3T11MST9QmyAoLPz2hi6fnuJnHJHP09zGv
jmmvnOZLuAxEhYSEaNIdKJBrx0gciOaTxQ9LCnDtz82LTPgxWzrXCL76DCT9xJdf
cVQo3JERh55WCqr5xQ==
=lPHq
-----END PGP PUBLIC KEY BLOCK-----
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D.3.53. Jayachandran C. <jchandra@FreeBSD.org >

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pub   1024D/3316E465 2010-05-19
      Key fingerprint = 320B DB08 4FE3 BCFD 60AF  E4DB F486 015F 3316 E465
uid                  Jayachandran C. <jchandra@freebsd.org>
sub   2048g/1F7755F9 2010-05-19
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D.3.54. Jesus R. Camou <jcamou@FreeBSD.org >

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pub   1024D/C2161947 2005-03-01
      Key fingerprint = 274C B265 48EC 42AE A2CA  47D9 7D98 588A C216 1947
uid                  Jesus R. Camou <jcamou@FreeBSD.org>
sub   2048g/F8D2A8DF 2005-03-01
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D.3.55. Alonso Cárdenas Márquez <acm@FreeBSD.org >

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pub   rsa4096/82E1399C11E68208 2015-06-17 [caduca: 2018-06-16]
      Huella de clave = 9485 3AA6 4C32 6543 2C83  8201 82E1 399C 11E6 8208
uid                          Alonso Cardenas Marquez <acm@FreeBSD.org>
sub   rsa4096/8DAA3CCE41FD26B2 2015-06-17 [caduca: 2018-06-16]
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D.3.56. Pietro Cerutti <gahr@FreeBSD.org >

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pub   rsa4096/ADD0D38EA192089E 2013-09-23 [expires: 2018-09-22]
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      Key fingerprint = DA6D E106 A5B8 54B8 5DD8  6D49 ADD0 D38E A192 089E
uid                           Pietro Cerutti <gahr@gahr.ch>
uid                           Pietro Cerutti (The FreeBSD Project) <gahr@FreeBSD.org>
sub   rsa4096/3AC8004B408BA46A 2013-09-23 [expires: 2018-09-22]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.57. Dmitry Chagin <dchagin@FreeBSD.org >

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pub   1024D/738EFCED 2009-02-27
      Key fingerprint = 3F3F 8B87 CE09 9E10 3606  6ACA D2DD 936F 738E FCED
uid                  Dmitry Chagin <dchagin@freebsd.org>
uid                  Dmitry Chagin (dchagin key) <chagin.dmitry@gmail.com>
sub   2048g/6A3FDFF9 2009-02-27
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D.3.58. Hye-Shik Chang <perky@FreeBSD.org >

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pub  1024D/CFDB4BA4 1999-04-23 Hye-Shik Chang <perky@FreeBSD.org>
     Key fingerprint = 09D9 57D6 58BA 44DD CAEC  71CD 0D65 2C59 CFDB 4BA4
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uid                           Hye-Shik Chang <hyeshik@gmail.com>
sub  1024g/A94A8ED1 1999-04-23
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.59. Jonathan Chen <jon@FreeBSD.org >

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pub  1024D/2539468B 1999-10-11 Jonathan Chen <jon@spock.org>
     Key fingerprint = EE31 CDA1 A105 C8C9 5365  3DB5 C2FC 86AA 2539 468B
uid                            Jonathan Chen <jon@freebsd.org>
uid                            Jonathan Chen <chenj@rpi.edu>
uid                            Jonathan Chen <spock@acm.rpi.edu>
uid                            Jonathan Chen <jon@cs.rpi.edu>
sub  3072g/B81EF1DB 1999-10-11
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.60. Jonathan Anderson <jonathan@FreeBSD.org >

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      Key fingerprint = 563B 20C1 BFBF F638 610F  C584 B11B 3804 9C0E E010
uid                  Jonathan Anderson <jonathan.anderson@ieee.org>
uid                  Jonathan Anderson (MUN) <jonathan.anderson@mun.ca>
uid                  Jonathan Anderson (Cambridge) <jonathan.anderson@cl.cam.ac.uk>
uid                  Jonathan Anderson (FreeBSD) <jonathan@FreeBSD.org>
sub   2048R/2E0832D2 2014-03-07 [expires: 2024-03-04]
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D.3.61. 陳福康 <loader@FreeBSD.org > <loader@FreeBSD.org >

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pub   4096R/6BD4DDE6 2012-10-26
      Key fingerprint = A33E 88AB D358 DA49 59A6  B263 A9A2 599C 6BD4 DDE6
uid                  loader <loader@FreeBSD.org>
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sub   4096R/1036D26C 2012-10-26
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.62. 陳洛祁 <luoqi@FreeBSD.org > <luoqi@FreeBSD.org >

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pub  1024D/2926F3BE 2002-02-22 Luoqi Chen <luoqi@FreeBSD.org>
     Key fingerprint = B470 A815 5917 D9F4 37F3  CE2A 4D75 3BD1 2926 F3BE
uid                            Luoqi Chen <luoqi@bricore.com>
uid                            Luoqi Chen <lchen@onetta.com>
sub  1024g/5446EB72 2002-02-22
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.63. Andrey A. Chernov <ache@FreeBSD.org >

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pub   2048R/A51C92FD0C8DF6CA 2014-08-09
      Key fingerprint = 36A5 CEDA 5878 AAC1 4888  79FA A51C 92FD 0C8D F6CA
uid                           Andrey Chernov <ache@FreeBSD.org>
sub   2048R/85902C6618402312 2014-08-09
      Key fingerprint = C8F1 E3F5 999F E916 FD0E  AAE3 8590 2C66 1840 2312
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.64. Alexander V. Chernikov <melifaro@FreeBSD.org >

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pub   1024D/2675AB69 2008-02-17
      Key fingerprint = 00D2 E063 2FB0 2990 C602  50FD C1C2 7889 2675 AB69
uid                  Alexander V. Chernikov <melifaro@yandex-team.ru>
uid                  Alexander V. Chernikov <melifaro@ipfw.ru>
uid                  Alexander V. Chernikov <melifaro@freebsd.org>
sub   4096g/BC64F40C 2008-02-17
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.65. Sean Chittenden <seanc@FreeBSD.org >

```
pub  1024D/EE278A28 2004-02-08 Sean Chittenden <sean@chittenden.org>
     Key fingerprint = E41F F441 7E91 6CBA 1844  65CF B939 3C78 EE27 8A28
sub  2048g/55321853 2004-02-08
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.66. Junho CHOI <cjh@FreeBSD.org >

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pub  1024D/E60260F5 2002-10-14 CHOI Junho (Work) <cjh@wdb.co.kr>
     Key fingerprint = 1369 7374 A45F F41A F3C0  07E3 4A01 C020 E602 60F5
uid                          CHOI Junho (Personal) <cjh@kr.FreeBSD.org>
uid                          CHOI Junho (FreeBSD) <cjh@FreeBSD.org>
sub  1024g/04A4FDD8 2002-10-14
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Version: GnuPG v1.2.0 (FreeBSD)
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.67. David Christensen <davidch@FreeBSD.org >

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pub   4096R/6EF8EA544E261A57 2013-10-04 [expires: 2018-10-03]
      Key fingerprint = 6D3B 985F 2737 C936 F37D  93D6 6EF8 EA54 4E26 1A57
uid                          David Christensen (FreeBSD Committer Key) <davidch@freebsd.↺
org>
sub   4096R/6B5D5DE299525D80 2013-10-04 [expires: 2018-10-03]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.68. Jonathan Chu <milki@FreeBSD.org >

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pub   4096R/1DAACB3510D2041A 2013-12-16
      Key fingerprint = 9F11 FB1D 917F CD6A 479D  EA46 1DAA CB35 10D2 041A
uid                        Jonathan Chu (ports) <milki@FreeBSD.org>
sub   4096R/02DDC04CA046B32A 2013-12-16
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.69. Crist J. Clark <cjc@FreeBSD.org >

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pub  1024D/FE886AD3 2002-01-25 Crist J. Clark <cjclark@jhu.edu>
     Key fingerprint = F04E CCD7 3834 72C2 707F  0A8F 259F 8F4B FE88 6AD3
uid                            Crist J. Clark <cjclark@alum.mit.edu>
uid                            Crist J. Clark <cjc@freebsd.org>
sub  1024g/9B6BAB99 2002-01-25
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.70. Joe Marcus Clarke <marcus@FreeBSD.org >

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pub  1024D/FE14CF87 2002-03-04 Joe Marcus Clarke (FreeBSD committer address) ↺
<marcus@FreeBSD.org>
     Key fingerprint = CC89 6407 73CC 0286 28E4  AFB9 6F68 8F8A FE14 CF87
uid                            Joe Marcus Clarke <marcus@marcuscom.com>
sub  1024g/B9ACE4D2 2002-03-04
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.71. Nik Clayton <nik@FreeBSD.org >

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pub  1024D/2C37E375 2000-11-09 Nik Clayton <nik@freebsd.org>
     Key fingerprint = 15B8 3FFC DDB4 34B0 AA5F  94B7 93A8 0764 2C37 E375
uid                            Nik Clayton <nik@slashdot.org>
uid                            Nik Clayton <nik@crf-consulting.co.uk>
uid                            Nik Clayton <nik@ngo.org.uk>
uid                            Nik Clayton <nik@bsdi.com>
sub  1024g/769E298A 2000-11-09
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.72. Benjamin Close <benjsc@FreeBSD.org >

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pub   1024D/4842B5B4 2002-04-10
      Key fingerprint = F00D C83D 5F7E 5561 DF91  B74D E602 CAA3 4842 B5B4
uid                  Benjamin Simon Close <Benjamin.Close@clearchain.com>
uid                  Benjamin Simon Close <benjsc@FreeBSD.org>
uid                  Benjamin Simon Close <benjsc@clearchain.com>
sub   2048g/3FA8A57E 2002-04-10
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.73. Garrett Cooper <ngie@FreeBSD.org >

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pub   2048R/C66BE5053A4BBDDE 2014-07-30 [expires: 2015-07-30]
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      Key fingerprint = EB41 F9FC FB0F E8F4 3983  F6F8 C66B E505 3A4B BDDE
uid                          Garrett Cooper <yaneurabeya@gmail.com>
sub   2048R/8072A2EF5B1FADD0 2014-07-30 [expires: 2015-07-30]
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Comment: GPGTools - https://gpgtools.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.74. Tijl Coosemans <tijl@FreeBSD.org >

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pub   dsa2048/7E8092D820A0B62B 2010-07-13 [expires: 2017-09-15]
      Key fingerprint = 39AA F580 6B44 5161 9F86  ED49 7E80 92D8 20A0 B62B
uid                           Tijl Coosemans <tijl@coosemans.org>
uid                           Tijl Coosemans <tijl@freebsd.org>
sub   elg2048/8E9707DD7D71BA74 2010-07-13 [expires: 2017-09-15]
      Key fingerprint = E8E1 95A3 7750 DB71 8FA5  24F9 8E97 07DD 7D71 BA74
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D.3.75. Raphael Kubo da Costa <rakuco@FreeBSD.org >

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      Key fingerprint = 6911 54FE BA6E 6106 5789  7099 8DD0 7D21 18DC EED6
uid                          Raphael Kubo da Costa (Personal key) <rakuco@FreeBSD.org>
uid                          Raphael Kubo da Costa (Personal Gmail account.) ↺
<kubito@gmail.com>
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D.3.76. Alan L. Cox <alc@FreeBSD.org >

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pub   2048R/33E2893B 2013-06-15
      Key fingerprint = FC7C 93FD 2C2C ABA5 C1D1  3E74 8513 043C 33E2 893B
uid                  Alan Cox <alc@FreeBSD.org>
uid                  Alan Cox <alc@cs.rice.edu>
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sub   2048R/693757AA 2013-06-15
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D.3.77. Bruce Cran <brucec@FreeBSD.org >

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pub   2048R/6AF6F99E 2010-01-29
      Key fingerprint = 9A3C AE57 2706 B0E3 4B8A  8374 5787 A72B 6AF6 F99E
uid                  Bruce Cran <brucec@FreeBSD.org>
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D.3.78. Olivier Cochard-Labbé <olivier@FreeBSD.org >

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pub   rsa4096/89A5246DC4C57722 2016-02-15
      Key fingerprint = 18D2 A78C 6BBA 0A5B 3A1A  4C7C 89A5 246D C4C5 7722
uid                           Olivier Cochard <olivier@cochard.me>
uid                           Olivier Cochard-Labbé <olivier@FreeBSD.org>
sub   rsa4096/BC44032DC2707BE0 2016-02-15
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D.3.79. Frederic Culot <culot@FreeBSD.org >

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pub   1024D/34876C5B 2006-08-26
      Key fingerprint = 50EE CE94 E43E BA85 CB67  262B B739 1A26 3487 6C5B
uid                  Frederic Culot <culot@FreeBSD.org>
uid                  Frederic Culot <frederic@culot.org>
sub   2048g/F1EF901F 2006-08-26
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D.3.80. Aaron Dalton <aaron@FreeBSD.org >

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pub   1024D/8811D2A4 2006-06-21 [expires: 2011-06-20]
      Key fingerprint = 8DE0 3CBB 3692 992F 53EF  ACC7 BE56 0A4D 8811 D2A4
uid                  Aaron Dalton <aaron@freebsd.org>
sub   2048g/304EE8E5 2006-06-21 [expires: 2011-06-20]
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D.3.81. Baptiste Daroussin <bapt@FreeBSD.org >

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pub   rsa4096/63898BDCF1B73E5A 2015-12-03 [expires: 2025-12-06]
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      Key fingerprint = 80E4 E3DE CB92 DAEA C65D  5537 6389 8BDC F1B7 3E5A
uid                           Baptiste Daroussin <bapt@FreeBSD.org>
uid                           Baptiste Daroussin <bapt@etoilebsd.net>
sub   rsa4096/35BAFBEB24FF27FB 2015-12-03
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D.3.82. Ceri Davies <ceri@FreeBSD.org >

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D.3.83. Brad Davis <brd@FreeBSD.org >

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pub   1024D/ED0A754D 2005-05-14 [expires: 2020-05-10]
      Key fingerprint = 5DFD D1A6 BEEE A6D4 B3F5  4236 D362 3291 ED0A 754D
uid                  Brad Davis <brd@FreeBSD.org>
uid                  Brad Davis <so14k@so14k.com>
sub   2048g/1F29D404 2005-05-14 [expires: 2020-05-10]
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D.3.84. Eric Davis <edavis@FreeBSD.org >

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pub   2048R/F52DF060EC5583DD 2013-10-09
      Key fingerprint = F368 53A8 E3CB 7135 3140  2AE4 F52D F060 EC55 83DD
uid                          Eric Davis <edavis@insanum.com>
uid                          Eric Davis <edavis@FreeBSD.org>
uid                          Eric Davis <edavis@broadcom.com>
sub   2048R/156FF9FC786CB51C 2013-10-09
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D.3.85. Paweł Jakub Dawidek <pjd@FreeBSD.org >

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pub   rsa4096/0x954B852BB1285B75 2015-04-17 [expires: 2020-04-15]
      Key fingerprint = B1C5 F673 045B 6C7B AFFB  3A1D 954B 852B B128 5B75
uid                 [ultimate] Paweł Jakub Dawidek <pjd@FreeBSD.org>
uid                 [ultimate] Paweł Jakub Dawidek <pawel@dawidek.net>
uid                 [ultimate] Paweł Jakub Dawidek <p.dawidek@wheelsystems.com>
uid                 [ultimate] Paweł Jakub Dawidek <p.dawidek@mobter.com>
sub   rsa4096/0x8EABD55DE4D6A714 2015-04-17 [expires: 2020-04-15]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.86. Alexey Degtyarev <alexey@FreeBSD.org >

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pub   2048R/392CE63AA025BC4D 2013-11-08
      Key fingerprint = B347 13EF BDDA 45FE EEB1  9110 392C E63A A025 BC4D
uid                          Alexey Degtyarev <alexey@freebsd.org>
sub   2048R/6D5FB75FB723C378 2013-11-08
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.87. Brian S. Dean <bsd@FreeBSD.org >

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pub  1024D/723BDEE9 2002-01-23 Brian S. Dean <bsd@FreeBSD.org>
     Key fingerprint = EF49 7ABE 47ED 91B3 FC3D  7EA5 4D90 2FF7 723B DEE9
sub  1024g/4B02F876 2002-01-23
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.88. Carl Delsey <carl@FreeBSD.org >

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pub   4096R/FB3B5D38 2013-01-15
      Key fingerprint = F0E5 3849 C6C3 668B 68A3  BCC7 6031 E963 FB3B 5D38
uid                  Carl Delsey <carl@FreeBSD.org>
sub   4096R/256F29D3 2013-01-15
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.89. Vasil Dimov <vd@FreeBSD.org >

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pub   1024D/F6C1A420 2004-12-08
      Key fingerprint = B1D5 04C6 26CC 0D20 9525  14B8 170E 923F F6C1 A420
uid                  Vasil Dimov <vd@FreeBSD.org>
uid                  Vasil Dimov <vd@datamax.bg>
sub   4096g/A0148C94 2004-12-08
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.90. Roman Divacky <rdivacky@FreeBSD.org >

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pub   1024D/3DC2044C 2006-11-15
      Key fingerprint = 6B61 25CA 49BC AAC5 21A9  FA7A 2D51 23E8 3DC2 044C
uid                  Roman Divacky <rdivacky@freebsd.org>
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sub   2048g/39BDCE16 2006-11-15
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D.3.91. Alexey Dokuchaev <danfe@FreeBSD.org >

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pub  1024D/3C060B44 2004-08-23 Alexey Dokuchaev <danfe@FreeBSD.org>
     Key fingerprint = D970 08A4 922C 8D63 0C19  8D27 F421 76EE 3C06 0B44
sub  1024g/70BAE967 2004-08-23
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D.3.92. Dima Dorfman <dd@FreeBSD.org >

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pub   1024D/69FAE582 2001-09-04
      Key fingerprint = B340 8338 7DA3 4D61 7632  098E 0730 055B 69FA E582
uid                  Dima Dorfman <dima@trit.org>
uid                  Dima Dorfman <dima@unixfreak.org>
uid                  Dima Dorfman <dd@freebsd.org>
sub   2048g/65AF3B89 2003-08-19 [expires: 2005-08-18]
sub   2048g/8DB0CF2C 2005-05-29 [expires: 2007-05-29]
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D.3.93. Bryan Drewery <bdrewery@FreeBSD.org >

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pub   2048R/35D771BB6E4697CF 2013-10-24 [expires: 2018-10-23]
      Key fingerprint = F917 3CB2 C3AA EA7A 5C8A  1F09 35D7 71BB 6E46 97CF
uid                          Bryan Drewery <bdrewery@FreeBSD.org>
uid                          Bryan Drewery <bryan@shatow.net>
sub   2048R/FF5A7FF27D55A32D 2013-10-24 [expires: 2018-10-23]
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D.3.94. Garance A Drosehn <gad@FreeBSD.org >

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pub   4096R/CBBBB1AECCAC052F 2015-04-25 [expires: 2017-08-12]
      Key fingerprint = BF87 9EE6 2DBE 97B7 3039  1EF9 CBBB B1AE CCAC 052F
uid                          Garance Alistair Drosehn <drosehn@mac.com>
uid                          Garance Alistair Drosehn <drosehn@rpi.edu>
uid                          Garance Alistair Drosehn <gad@FreeBSD.org>
sub   4096R/77B88ECC2BF0AC18 2015-04-25 [expires: 2018-04-09]
      Key fingerprint = 844D BA81 AC32 A7E9 D63E  417E 77B8 8ECC 2BF0 AC18
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Comment: GPGTools - https://gpgtools.org

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D.3.95. Olivier Duchateau <olivierd@FreeBSD.org >

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pub   2048R/22431859 2012-05-28 [expires: 2017-05-27]
      Key fingerprint = C057 112A 4A27 B5F2 CD8F  6C9A FC5A 0167 2243 1859
uid                  Olivier Duchateau <duchateau.olivier@gmail.com>
sub   2048R/63A85BDF 2012-05-28 [expires: 2017-05-27]
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D.3.96. Bruno Ducrot <bruno@FreeBSD.org >

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pub   1024D/7F463187 2000-12-29
      Key fingerprint = 7B79 E1D6 F5A1 6614 792F  D906 899B 4D28 7F46 3187
uid                  Ducrot Bruno (Poup Master) <ducrot@poupinou.org>
sub   1024g/40282874 2000-12-29
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D.3.97. Alex Dupre <ale@FreeBSD.org >

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pub  1024D/CE5F554D 1999-06-27 Alex Dupre <sysadmin@alexdupre.com>
     Key fingerprint = DE23 02EA 5927 D5A9 D793  2BA2 8115 E9D8 CE5F 554D
uid                            Alex Dupre <ale@FreeBSD.org>
uid                            [jpeg image of size 5544]
uid                            Alex Dupre <ICQ:5431856>
sub  2048g/FD5E2D21 1999-06-27
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D.3.98. Rusmir Dusko <nemysis@FreeBSD.org >

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pub   4096R/4C93E3D2 2013-05-01
      Key fingerprint = 6FEB 14C6 26D4 7E3A 57DE  487F B6B9 B8F6 4C93 E3D2
uid                  nemysis <nemysis@FreeBSD.org>
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D.3.99. Peter Edwards <peadar@FreeBSD.org >

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pub  1024D/D80B4B3F 2004-03-01 Peter Edwards <peadar@FreeBSD.org>
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uid                            Peter Edwards <pmedwards@eircom.net>
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D.3.100. Daniel Eischen <deischen@FreeBSD.org >

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      Key fingerprint = 0039 2133 69CA 14D3 236A  E331 361A 68B2 7D15 560B
uid                  Daniel Eischen <deischen@FreeBSD.org>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.101. Josef El-Rayes <josef@FreeBSD.org >

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pub  2048R/A79DB53C 2004-01-04 Josef El-Rayes <josef@FreeBSD.org>
     Key fingerprint = 58EB F5B7 2AB9 37FE 33C8  716B 59C5 22D9 A79D B53C
uid                            Josef El-Rayes <josef@daemon.li>
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D.3.102. Lars Engels <lme@FreeBSD.org >

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pub   2048R/E54CB37D3A089D6D 2014-03-10 [expires: 2017-03-09]
      Key fingerprint = 8F40 017E 4DF5 3125 7AFE  5149 E54C B37D 3A08 9D6D
uid                          Lars Martin Engels <lars@bsd-geek.de>
uid                          Lars Martin Engels <lars.engels@0x20.net>
uid                          Lars Martin Engels <lars@0x20.net>
uid                          Lars Martin Engels <lme@FreeBSD.org>
sub   2048R/5AB391DB0BA67DBB 2014-03-10 [expires: 2017-03-09]
      Key fingerprint = C31C 8DAA 4A95 2507 F065  C42D 5AB3 91DB 0BA6 7DBB
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.103. Udo Erdelhoff <ue@FreeBSD.org >

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pub  1024R/E74FA871 1994-07-19 Udo Erdelhoff <uer@de.uu.net>
     Key fingerprint = 8C B1 80 CA 2C 52 73 81  FB A7 B4 03 C5 32 C8 67
uid                            Udo Erdelhoff <ue@nathan.ruhr.de>
uid                            Udo Erdelhoff <ue@freebsd.org>
uid                            Udo Erdelhoff <uerdelho@eu.uu.net>
uid                            Udo Erdelhoff <uerdelho@uu.net>
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.104. Ruslan Ermilov <ru@FreeBSD.org >

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pub  1024D/996E145E 2004-06-02 Ruslan Ermilov (FreeBSD) <ru@FreeBSD.org>
     Key fingerprint = 274E D201 71ED 11F6 9CCB  0194 A917 E9CC 996E 145E
uid                            Ruslan Ermilov (FreeBSD Ukraine) <ru@FreeBSD.org.ua>
uid                            Ruslan Ermilov (IPNet) <ru@ip.net.ua>
sub  1024g/557E3390 2004-06-02 [expires: 2007-06-02]
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D.3.105. Lukas Ertl <le@FreeBSD.org >

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pub  1024D/F10D06CB 2000-11-23 Lukas Ertl <le@FreeBSD.org>
     Key fingerprint = 20CD C5B3 3A1D 974E 065A  B524 5588 79A9 F10D 06CB
uid                            Lukas Ertl <a9404849@unet.univie.ac.at>
uid                            Lukas Ertl <l.ertl@univie.ac.at>
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sub  1024g/5960CE8E 2000-11-23
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Version: GnuPG v1.2.5 (FreeBSD)

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D.3.106. Stefan Eßer <se@FreeBSD.org >

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  Schl.-Fingerabdruck = A371 EA65 9C0B ECC8 2B71  5313 47EB B5EF 5AFD F544
uid                          Stefan Eßer (FreeBSD) <se@freebsd.org>
sub   2048R/ACCC7EFAB7B32CCA 2015-06-05 [verfällt: 2018-06-04]
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D.3.107. Brendan Fabeny <bf@FreeBSD.org >

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pub   4096R/0x4AE10A7E8F65FECF 2013-09-27 [expires: 2016-09-26]
      Key fingerprint = C5C3 8EB7 0DCD 2BA2 B8AB  6BBC 4AE1 0A7E 8F65 FECF
uid                 [ultimate] Brendan Fabeny <bf@FreeBSD.org>
sub   4096R/0x8B6BF0BED7B81E31 2013-09-27 [expires: 2016-09-26]
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D.3.108. Guido Falsi <madpilot@FreeBSD.org >

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pub   2048R/1AE6860E56CBD293 2012-04-12
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sub   4096R/CB95603DDCCDB1C8 2014-02-28
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D.3.109. 范榮恩 <rafan@FreeBSD.org > <rafan@FreeBSD.org >

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uid                  Rong-En Fan <rafan@infor.org>
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D.3.110. Dominic Fandrey <kami@FreeBSD.org >

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pub   2048R/6FF05D69A92A59DB 2014-09-18 [expires: 2017-09-17]
      Key fingerprint = 7D88 4610 FFBB BA86 F17B  C037 6FF0 5D69 A92A 59DB
uid                          Dominic Fandrey <kami@freebsd.org>
sub   2048R/B4EC9D5FBC909F27 2014-09-18 [expires: 2017-09-17]
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D.3.111. Stefan Farfeleder <stefanf@FreeBSD.org >

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pub  1024D/8BEFD15F 2004-03-14 Stefan Farfeleder <stefan@fafoe.narf.at>
     Key fingerprint = 4220 FE60 A4A1 A490 5213  27A6 319F 8B28 8BEF D15F
uid                            Stefan Farfeleder <stefanf@complang.tuwien.ac.at>
uid                            Stefan Farfeleder <stefanf@FreeBSD.org>
uid                            Stefan Farfeleder <stefanf@ten15.org>
sub  2048g/418753E9 2004-03-14 [expires: 2007-03-14]
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D.3.112. Babak Farrokhi <farrokhi@FreeBSD.org >

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pub   rsa4096/6B267AD85D632E9A 2015-07-25 [expires: 2020-07-28]
      Key fingerprint = F081 5F88 61BF 2DEA F261  E9C1 6B26 7AD8 5D63 2E9A
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uid                             Babak Farrokhi <babak@farrokhi.net>
uid                             Babak Farrokhi <farrokhi@imenpardis.com>
uid                             Babak Farrokhi <farrokhi@FreeBSD.org>
sub   rsa4096/1CB810DE7321676A 2015-07-25 [expires: 2020-07-23]
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D.3.113. Chris D. Faulhaber <jedgar@FreeBSD.org >

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pub  1024D/FE817A50 2000-12-20 Chris D. Faulhaber <jedgar@FreeBSD.org>
     Key fingerprint = A47D A838 9216 F921 A456  54FF 39B6 86E0 FE81 7A50
uid                            Chris D. Faulhaber <jedgar@fxp.org>
sub  2048g/93452698 2000-12-20
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Comment: For info see http://www.gnupg.org

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D.3.114. Mark Felder <feld@FreeBSD.org >

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      Key fingerprint = 7481 93E6 C417 1C8A 4B6B  2488 983B 6450 1F13 E252
uid                          Mark Felder <feld@FreeBSD.org>
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sub   2048R/80920C42C025EB78 2013-11-09 [expires: 2015-11-10]
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D.3.115. Brian F. Feldman <green@FreeBSD.org >

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pub  1024D/41C13DE3 2000-01-11 Brian Fundakowski Feldman <green@FreeBSD.org>
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     Key fingerprint = 6A32 733A 1BF6 E07B 5B8D  AE14 CC9D DCA2 41C1 3DE3
sub  1024g/A98B9FCC 2000-01-11 [expires: 2001-01-10]

pub  1024D/773905D6 2000-09-02 Brian Fundakowski Feldman <green@FreeBSD.org>
     Key fingerprint = FE23 7481 91EA 5E58 45EA  6A01 B552 B043 7739 05D6
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Comment: For info see http://www.gnupg.org

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D.3.116. Mário Sérgio Fujikawa Ferreira <lioux@FreeBSD.org >

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pub   4096R/B43B673FDAE448D1 2014-02-13 [expires: 2019-02-12]
      Key fingerprint = 0617 5DB3 8B1A C326 A542  3B3C B43B 673F DAE4 48D1
uid                          Mario Sergio Fujikawa Ferreira (lioux) <lioux@FreeBSD.org>
sub   4096R/D780173751E6FF87 2014-02-13 [expires: 2019-02-12]
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sub   3072D/BB0B0361BC87D308 2014-02-13 [expires: 2015-02-13]
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D.3.117. Matthew Fleming <mdf@FreeBSD.org >

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pub   2048R/A783DAA2 2012-11-22 [expires: 2016-11-22]
      Key fingerprint = 773F E069 BE98 CE96 4AC6  B8AB 1A1B 255E A783 DAA2
uid                  Matthew D Fleming <mdf356@gmail.com>
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sub   2048R/4015B7AA 2012-11-22 [expires: 2016-11-22]
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D.3.118. Tony Finch <fanf@FreeBSD.org >

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     Key fingerprint = 199C F25B 2679 6D04 63C5  2159 FFC0 F14C 84C7 1B6E
uid                           Tony Finch <fanf@FreeBSD.org>
uid                           Tony Finch <fanf@apache.org>
uid                           Tony Finch <fanf2@cam.ac.uk>
sub  2048g/FD101E8B 2002-05-03
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D.3.119. Marc Fonvieille <blackend@FreeBSD.org >

```
pub  1024D/4F8E74E8 2004-12-25 Marc Fonvieille <blackend@FreeBSD.org>
     Key fingerprint = 55D3 4883 4A04 828A A139  A5CF CD0F 51C0 4F8E 74E8
uid                            Marc Fonvieille <marc@blackend.org>
uid                            Marc Fonvieille <marc@freebsd-fr.org>
sub  1024g/37AD4E7D 2004-12-25
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D.3.120. Pete Fritchman <petef@FreeBSD.org >

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pub  1024D/74B91CFD 2001-01-30 Pete Fritchman <petef@FreeBSD.org>
     Key fingerprint = 9A9F 8A13 DB0D 7777 8D8E  1CB2 C5C9 A08F 74B9 1CFD
uid                            Pete Fritchman <petef@databits.net>
uid                            Pete Fritchman <petef@csh.rit.edu>
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sub  1024g/0C02AF0C 2001-01-30
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.121. Bernhard Fröhlich <decke@FreeBSD.org >

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pub   rsa2048/4DD88C3F9F3B8333 2015-05-05 [expires: 2018-05-04]
      Key fingerprint = 3924 2DE3 BD34 BB70 529C  03D2 4DD8 8C3F 9F3B 8333
uid                          Bernhard Froehlich <decke@bluelife.at>
uid                          Bernhard Froehlich <decke@FreeBSD.org>
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sub   rsa2048/623F4D906034D944 2015-05-05 [expires: 2018-05-04]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.122. Bill Fumerola <billf@FreeBSD.org >

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pub  1024D/7F868268 2000-12-07 Bill Fumerola (FreeBSD Developer) <billf@FreeBSD.org>
     Key fingerprint = 5B2D 908E 4C2B F253 DAEB  FC01 8436 B70B 7F86 8268
uid                            Bill Fumerola (Security Yahoo) <fumerola@yahoo-inc.com>
sub  1024g/43980DA9 2000-12-07
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.123. Stanislav Galabov <sgalabov@FreeBSD.org >

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pub   2048R/82A681748682CA20 2016-02-24 [expires: 2019-02-25]
      Key fingerprint = 66D5 DF41 FA7C F850 406C  B009 82A6 8174 8682 CA20
uid                          Stanislav Galabov <sgalabov@gmail.com>
uid                          Stanislav Galabov <sgalabov@FreeBSD.org>
sub   2048R/DC04B413C1F2C9EF 2016-02-24 [expires: 2020-02-24]
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D.3.124. Andriy Gapon <avg@FreeBSD.org >

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pub   4096R/0x380342A852615619 2013-09-23 [expires: 2017-09-22]
      Key fingerprint = 6414 0613 EC1E 5175 77F5  785B 3803 42A8 5261 5619
uid                  [ultimate] Andriy Gapon <avg@FreeBSD.org>
uid                  [ultimate] Andriy Gapon <andriy.gapon@hybridcluster.com>
uid                  [ultimate] Andriy Gapon <avg@icyb.net.ua>
sub   4096R/0xFFF3DA35E4129D34 2013-09-23 [expires: 2017-09-22]
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D.3.125. Beat Gätzi <beat@FreeBSD.org >

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pub   rsa2048/A583FB36B6453181 2015-02-16 [expires: 2018-02-15]
      Key fingerprint = EF7D 332F 4D4A F252 BF4C  09E1 A583 FB36 B645 3181
uid                           Beat Gaetzi <beat@FreeBSD.org>
sub   rsa2048/5D496E43DD25AFED 2015-02-16 [expires: 2018-02-15]
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D.3.126. Daniel Geržo <danger@FreeBSD.org >

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pub   4096R/7D81BFC724F0CF16 2015-10-05 [expires: 2020-10-03]
      Key fingerprint = 9523 41A8 77DD 42EE A950  06DB 7D81 BFC7 24F0 CF16
uid                          Daniel Gerzo <danger@rulez.sk>
uid                          Daniel Gerzo <dgerzo@gmail.com>
uid                          Daniel Gerzo <gerzo@syscare.sk>
uid                          Daniel Gerzo <danger@FreeBSD.org>
sub   4096R/777D8003C7546767 2015-10-05 [expires: 2020-10-03]
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D.3.127. Simon J. Gerraty <sjg@FreeBSD.org >

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uid                  Simon J. Gerraty <sjg@crufty.net>
uid                  Simon J. Gerraty <sjg@juniper.net>
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D.3.128. Justin T. Gibbs <gibbs@FreeBSD.org >

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uid                  Justin T. Gibbs <gibbs@FreeBSD.org>
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D.3.129. Pedro Giffuni <pfg@FreeBSD.org >

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uid                          Pedro Giffuni <pfg@FreeBSD.org>
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D.3.130. Palle Girgensohn <girgen@FreeBSD.org >

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uid                  Palle Girgensohn <girgen@pingpong.net>
uid                  [jpeg image of size 8260]
uid                  Palle Girgensohn <girgen@FreeBSD.org>
sub   2048R/6BC41243 2012-02-23 [expires: 2016-02-23]
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D.3.131. Philip M. Gollucci <pgollucci@FreeBSD.org >

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D.3.132. Mikolaj Golub <trociny@FreeBSD.org >

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pub   2048D/19D0B7C168EB30CD 2011-03-13
      Key fingerprint = F941 9360 203C C663 A4A3  8FDF 19D0 B7C1 68EB 30CD
uid                          Mikolaj Golub <trociny@freebsd.org>
sub   2048g/8E49E362CF53D752 2011-03-13
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D.3.133. Danilo Egêa Gondolfo <danilo@FreeBSD.org >

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pub   rsa4096/8586A54720E27246 2015-10-19 [expires: 2018-10-18]
      Key fingerprint = 691E 7D8F 6521 8237 8EB1  1173 8586 A547 20E2 7246
uid                           Danilo Egea Gondolfo <daniloegea@yahoo.com.br>
uid                           Danilo Egea Gondolfo <danilo@FreeBSD.org>
uid                           Danilo Egea Gondolfo <danilogondolfo@gmail.com>
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sub   rsa4096/C2F847657133F473 2015-10-19 [expires: 2018-10-18]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.134. Daichi GOTO <daichi@FreeBSD.org >

```
pub  1024D/09EBADD6 2002-09-25 Daichi GOTO <daichi@freebsd.org>
     Key fingerprint = 620A 9A34 57FB 5E93 0828  28C7 C360 C6ED 09EB ADD6
sub  1024g/F0B1F1CA 2002-09-25
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.2.0 (FreeBSD)

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.135. Marcus Alves Grando <mnag@FreeBSD.org >

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pub   1024D/CDCC273F 2005-09-15 [expires: 2010-09-14]
      Key fingerprint = 57F9 DEC1 5BBF 06DE 44A5  9A4A 8BEE 5F3A CDCC 273F
uid                  Marcus Alves Grando <marcus@sbh.eng.br>
uid                  Marcus Alves Grando <marcus@corp.grupos.com.br>
uid                  Marcus Alves Grando <mnag@FreeBSD.org>
sub   2048g/698AC00C 2005-09-15 [expires: 2010-09-14]
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.4.2 (FreeBSD)

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.136. Peter Grehan <grehan@FreeBSD.org >

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pub  1024D/EA45EA7D 2004-07-13 Peter Grehan <grehan@freebsd.org>
     Key fingerprint = 84AD 73DC 370E 15CA 7556  43C8 F5C8 4450 EA45 EA7D
sub  2048g/0E122D70 2004-07-13
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.137. Jamie Gritton <jamie@FreeBSD.org >

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pub   1024D/8832CB7F 2009-01-29
      Key fingerprint = 34F8 1E62 C7A5 7CB9 A91F  7864 8C5A F85E 8832 CB7F
uid                  James Gritton <jamie@FreeBSD.org>
sub   2048g/94E3594D 2009-01-29
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.138. Edwin Groothuis <edwin@FreeBSD.org >

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pub   2048R/C593B37A 2013-11-02 [expires: 2017-11-02]
      Key fingerprint = 7046 C56A A497 73C6 096C  3F50 11C4 8287 C593 B37A
uid                  Edwin Groothuis <edwin@freebsd.org>
sub   2048R/731E3D42 2013-11-02 [expires: 2017-11-02]
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Version: GnuPG/MacGPG2 v2.0.22 (Darwin)
Comment: GPGTools - https://gpgtools.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.139. William Grzybowski <wg@FreeBSD.org >

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pub   2048R/CFC460C5 2012-09-28
      Key fingerprint = FC40 5CD8 0879 7F50 0036  D924 D9F7 8B27 CFC4 60C5
uid                  William Grzybowski (FreeBSD) <wg@freebsd.org>
uid                  William Grzybowski <william88@gmail.com>
sub   2048R/05577997 2012-09-28
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D.3.140. Barbara Guida <bar@FreeBSD.org >

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pub   2048R/3DF5F750 2012-11-13
      Key fingerprint = D367 F6C8 2A5F 2921 70D2  B446 27DD 6FD6 3DF5 F750
uid                  Barbara Guida <bar@FreeBSD.org>
uid                  Barbara Guida <barbara.freebsd@gmail.com>
sub   2048R/1DF7506C 2012-11-13
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.141. Anish Gupta <anish@FreeBSD.org >

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pub   rsa2048/032E006E119E57D4 2016-02-21 [expires: 2019-02-20]
      Key fingerprint = B6BC 1DA5 54F7 1115 CF3B  350E 032E 006E 119E 57D4
uid                           Anish Gupta <anish@freebsd.org>
sub   rsa2048/668CCACEEDAAC016 2016-02-21 [expires: 2019-02-20]
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D.3.142. John-Mark Gurney <jmg@FreeBSD.org >

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pub   4096R/D5FF5A51C0AC3D65 2015-06-11 [expires: 2018-06-10]
      Key fingerprint = D87A 235F FB71 1F3F 55B7  ED9B D5FF 5A51 C0AC 3D65
uid                          John-Mark Gurney <jmg@jmgurney.com>
uid                          John-Mark Gurney <jmg@FreeBSD.org>
uid                          John-Mark Gurney <jmg@funkthat.com>
sub   4096R/A38A405AF6F5641B 2015-06-11 [expires: 2018-06-10]
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D.3.143. Mateusz Guzik <mjg@FreeBSD.org >

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pub   2048R/21489259 2012-06-03
      Key fingerprint = 3A9F 25FF ABF6 BB23 5C70  C61B 96D3 5178 2148 9259
uid                  Mateusz Guzik <mjg@freebsd.org>
sub   2048R/EA19FE8D 2012-06-03
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D.3.144. Jason E. Hale <jhale@FreeBSD.org >

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pub   3072D/8F2E5907 2012-09-07
      Key fingerprint = 009C 54BF 32D0 F373 8126  C8A1 D8DD 2CA4 8F2E 5907
uid                  Jason E. Hale <jhale@FreeBSD.org>
uid                  Jason E. Hale <bsdkaffee@gmail.com>
sub   4096g/7081A001 2012-09-07
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D.3.145. Jason A. Harmening <jah@FreeBSD.org >

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pub   rsa2048/BB9F8BF992841D1B 2015-03-09 [expires: 2018-03-08]
      Key fingerprint = D6F7 142D E415 8182 FFC5  E685 BB9F 8BF9 9284 1D1B
uid                           Jason A. Harmening <jah@FreeBSD.org>
uid                           Jason A. Harmening <jason.harmening@gmail.com>
sub   rsa2048/65B797684FD3EC2F 2015-03-09 [expires: 2018-03-08]
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=+qKo
-----END PGP PUBLIC KEY BLOCK-----
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D.3.146. Daniel Harris <dannyboy@FreeBSD.org >

```
pub  1024D/84D0D7E7 2001-01-15 Daniel Harris <dannyboy@worksforfood.com>
     Key fingerprint = 3C61 B8A1 3F09 D194 3259  7173 6C63 DA04 84D0 D7E7
uid                           Daniel Harris <dannyboy@freebsd.org>
uid                           Daniel Harris <dh@askdh.com>
uid                           Daniel Harris <dh@wordassault.com>
sub  1024g/9DF0231A 2001-01-15
```

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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.7 (FreeBSD)

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.147. Daniel Hartmeier <dhartmei@FreeBSD.org >

```
pub  1024R/6A3A7409 1994-08-15 Daniel Hartmeier <dhartmei@freebsd.org>
     Key fingerprint = 13 7E 9A F3 36 82 09 FE  FD 57 B8 5C 2B 81 7E 1F
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.148. Oliver Hauer <ohauer@FreeBSD.org >

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pub   2048R/5D008F1A 2010-07-26
      Key fingerprint = E9EE C9A5 EB4C BD29 74D7  9178 E56E 06B3 5D00 8F1A
uid                  olli hauer <ohauer@FreeBSD.org>
uid                  olli hauer <ohauer@gmx.de>
sub   2048R/5E25776E 2010-07-26
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.149. Emanuel Haupt <ehaupt@FreeBSD.org >

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pub   rsa2048/104E62C545316E89 2016-01-30 [expires: 2019-01-29]
      Key fingerprint = D9F1 1649 6964 99EA ADBF  D1C4 104E 62C5 4531 6E89
uid                           Emanuel Haupt <ehaupt@FreeBSD.org>
sub   rsa2048/AB8EF8AD753A7017 2016-01-30 [expires: 2019-01-29]
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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=MRc2
-----END PGP PUBLIC KEY BLOCK-----
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D.3.150. John Hay <jhay@FreeBSD.org >

```
pub  2048R/A9275B93 2000-05-10 John Hay <jhay@icomtek.csir.co.za>
     Key fingerprint = E7 95 F4 B9 D4 A7 49 6A  83 B9 77 49 28 9E 37 70
uid                          John Hay <jhay@mikom.csir.co.za>
uid                          Thawte Freemail Member <jhay@mikom.csir.co.za>
uid                          John Hay <jhay@csir.co.za>
uid                          John Hay <jhay@FreeBSD.ORG>
```

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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.151. Björn Heidotting <bhd@FreeBSD.org >

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pub   rsa2048/B93D05A194D5A763 2014-11-19 [expires: 2017-11-18]
      Key fingerprint = D87F 0EDC 4B51 40A4 AD94  621D B93D 05A1 94D5 A763
uid                          Björn Heidotting <b.heidotting@yahoo.com>
uid                          Björn Heidotting <bhd@FreeBSD.org>
sub   rsa2048/774BC281D252F376 2014-11-19 [expires: 2017-11-18]
      Key fingerprint = AAC8 C89E 7CF6 68E2 6CDC  396B 774B C281 D252 F376
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.152. Sheldon Hearn <sheldonh@FreeBSD.org >

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pub  1024D/74A06ACD 2002-06-20 Sheldon Hearn <sheldonh@starjuice.net>
     Key fingerprint = 01A3 EF91 9C5A 3633 4E01  8085 A462 57F1 74A0 6ACD
sub  1536g/C42F8AC8 2002-06-20
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.153. Mike Heffner <mikeh@FreeBSD.org >

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pub  1024D/CDECBF99 2001-02-02 Michael Heffner <mheffner@novacoxmail.com>
     Key fingerprint = AFAB CCEB 68C7 573F 5110  9285 1689 1942 CDEC BF99
uid                            Michael Heffner <mheffner@vt.edu>
uid                            Michael Heffner <mikeh@FreeBSD.org>
uid                            Michael Heffner <spock@techfour.net>
uid                            Michael Heffner (ACM sysadmin) <mheffner@acm.vt.edu>
sub  1024g/3FE83FB5 2001-02-02
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.154. Martin Heinen <mheinen@FreeBSD.org >

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pub  1024D/116C5C85 2002-06-17 Martin Heinen <mheinen@freebsd.org>
     Key fingerprint = C898 3FCD EEA0 17ED BEA9  564D E5A6 AFF2 116C 5C85
uid                            Martin Heinen <martin@sumuk.de>
sub  1024g/EA67506B 2002-06-17
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.155. Niels Heinen <niels@FreeBSD.org >

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pub  1024D/5FE39B80 2004-12-06 Niels Heinen <niels.heinen@ubizen.com>
     Key fingerprint = 75D8 4100 CF5B 3280 543F  930C 613E 71AA 5FE3 9B80
uid                            Niels Heinen <niels@defaced.be>
uid                            Niels Heinen <niels@heinen.ws>
uid                            Niels Heinen <niels@FreeBSD.org>
sub  2048g/057F4DA7 2004-12-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.156. Jaakko Heinonen <jh@FreeBSD.org >

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pub   2048R/F9A44D24949D44A4 2014-09-23 [expires: 2017-09-22]
      Key fingerprint = 2DFD B93A C98C A47A 6920  1FDB F9A4 4D24 949D 44A4
uid                          Jaakko Heinonen (FreeBSD) <jh@FreeBSD.org>
sub   2048R/724C087956D7D3CB 2014-09-23 [expires: 2017-09-22]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.157. Jason Helfman <jgh@FreeBSD.org >

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pub   2048R/4150D3DC 2011-12-18 [expires: 2021-12-15]
      Key fingerprint = 8E0D C457 9A0F C91C 23F3  0454 2059 9A63 4150 D3DC
uid                  Jason Helfman <jgh@FreeBSD.org>
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sub   2048R/695B1B92 2011-12-18 [expires: 2021-12-15]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.158. Guy Helmer <ghelmer@FreeBSD.org >

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pub   2048R/8F1CEBC4 2012-05-22
      Key fingerprint = 483E 9E6C C644 2520 C9FE  4E87 9989 CCAF 8F1C EBC4
uid                  Guy Helmer <guy.helmer@palisadesystems.com>
uid                  Guy Helmer <guy.helmer@gmail.com>
uid                  Guy Helmer <ghelmer@freebsd.org>
sub   2048R/2073E3F8 2012-05-22

pub  1024R/35F4ED2D 1997-01-26 Guy G. Helmer <ghelmer@freebsd.org>
     Key fingerprint = A2 59 4B 92 02 5B 9E B1  B9 4E 2E 03 29 D5 DC 3A
uid                           Guy G. Helmer <ghelmer@cs.iastate.edu>
uid                           Guy G. Helmer <ghelmer@palisadesys.com>
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Comment: GPGTools - http://gpgtools.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.159. Maxime Henrion <mux@FreeBSD.org >

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pub  1024D/881D4806 2003-01-09 Maxime Henrion <mux@FreeBSD.org>
     Key fingerprint = 81F1 BE2D 12F1 184A 77E4  ACD0 5563 7614 881D 4806
sub  2048g/D0B510C0 2003-01-09
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.160. Wen Heping <wen@FreeBSD.org >

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pub   2048R/A03F07DA 2012-12-10
      Key fingerprint = 0258 F2C7 C123 E627 9E14  B4BA 270F 30AA A03F 07DA
uid                  Wen Heping (wen) <wen@FreeBSD.org>
sub   2048R/CFC8D6A9 2012-12-10
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D.3.161. Dennis Herrmann <dhn@FreeBSD.org >

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pub   4096R/F7CDCAA1 2012-08-26
      Key fingerprint = 0587 E730 68A6 2646 A991  505D CD9B 3A87 F7CD CAA1
uid                  Dennis 'dhn' Herrmann (Everybody wants to go to heaven, but nobody ↺
wants to die) <dhn@FreeBSD.org>
sub   4096R/0A6D554F 2012-08-26
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D.3.162. Justin Hibbits <jhibbits@FreeBSD.org >

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pub   2048R/37BE2DB9 2011-12-01
      Key fingerprint = 8A12 7064 4F3D 339A 191D  AD52 30C7 858E 37BE 2DB9
uid                  Justin Hibbits <chmeeedalf@gmail.com>
uid                  Justin Hibbits <jhibbits@freebsd.org>
uid                  Justin Hibbits <jrh29@alumni.cwru.edu>
sub   2048R/A8DA156F 2011-12-01
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D.3.163. Peter Holm <pho@FreeBSD.org >

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pub   1024D/CF244E81 2008-11-17
      Key fingerprint = BE9B 32D8 89F1 F285 00E4  E4C5 EF3F B4B5 CF24 4E81
uid                  Peter Holm <pho@FreeBSD.org>
sub   2048g/E20A409F 2008-11-17
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D.3.164. Michael L. Hostbaek <mich@FreeBSD.org >

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pub  1024D/0F55F6BE 2001-08-07 Michael L. Hostbaek <mich@freebsdcluster.org>
     Key fingerprint = 4D62 9396 B19F 38D3 5C99  1663 7B0A 5212 0F55 F6BE
uid                            Michael L. Hostbaek <mich@freebsdcluster.dk>
uid                            Michael L. Hostbaek <mich@icommerce-france.com>
uid                            Micahel L. Hostbaek <mich@freebsd.dk>
uid                            Michael L. Hostbaek <mich@the-lab.org>
uid                            Michael L. Hostbaek <mich@freebsd.org>
sub  1024g/8BE4E30F 2001-08-07
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D.3.165. Po-Chuan Hsieh <sunpoet@FreeBSD.org >

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D.3.166. 許立文 <lwhsu@FreeBSD.org > <lwhsu@FreeBSD.org >

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      Key fingerprint = 107D 53F6 5215 335B 7094  3F84 6727 E77C 8862 B656
uid                          Li-Wen Hsu <lwhsu@lwhsu.org>
uid                          Li-Wen Hsu <lwhsu@FreeBSD.org>
sub   rsa4096/081CF599F48DDD68 2015-06-13 [expires: 2020-06-11]
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D.3.167. 胡庭豪 <foxfair@FreeBSD.org > <foxfair@FreeBSD.org >

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pub  1024D/4E9BCA59 2003-09-01 Foxfair Hu <foxfair@FreeBSD.org>
     Key fingerprint = 280C A846 CA1B CAC9 DDCF  F4CB D553 4BD5 4E9B CA59
uid                            Foxfair Hu <foxfair@drago.fomokka.net>
uid                            Howard Hu <howardhu@yahoo-inc.com>
sub  1024g/3356D8C1 2003-09-01
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D.3.168. Wei Hu <whu@FreeBSD.org >

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pub   rsa2048/E6001C673CCD08F7 2015-02-27
      Key fingerprint = 351D AC21 7E16 BC06 7CA0  7705 E600 1C67 3CCD 08F7
uid                         Wei Hu <whu@FreeBSD.org>
sub   rsa2048/0C7F6F103AAA0465 2015-02-27
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=jnKf
-----END PGP PUBLIC KEY BLOCK-----
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D.3.169. 黃青山 <chinsan@FreeBSD.org > <chinsan@FreeBSD.org >

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pub   1024D/350EECFA 2006-10-04
      Key fingerprint = 1C4D 0C9E 0E68 DB74 0688  CE43 D2A5 3F82 350E ECFA
uid                  Chin-San Huang (lab) <chinsan@chinsan2.twbbs.org>
uid                  Chin-San Huang (FreeBSD committer) <chinsan@FreeBSD.org>
uid                  Chin-San Huang (Gmail) <chinsan.tw@gmail.com>
sub   2048g/35F75A30 2006-10-04
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.170. Stephen Hurd <shurd@FreeBSD.org >

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pub   2048R/B3B5A1B498CE5CD0 2014-06-11 [expires: 2017-06-10]
      Key fingerprint = CA52 12EE 760A BCAA 0D5E  2974 B3B5 A1B4 98CE 5CD0
uid                          Stephen Hurd <shurd@FreeBSD.org>
sub   2048R/DA5C47503253C094 2014-06-11 [expires: 2017-06-10]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.171. Davide Italiano <davide@FreeBSD.org >

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pub   2048R/4CB47484 2012-01-17
      Key fingerprint = B5C9 77F5 1E67 D110 8D19  7587 EB95 EA82 4CB4 7484
uid                  Davide Italiano <davide@FreeBSD.org>
sub   2048R/91F7443D 2012-01-17
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.172. Jordan K. Hubbard <jkh@FreeBSD.org >

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pub  1024R/8E542D5D 1996-04-04 Jordan K. Hubbard <jkh@FreeBSD.org>
     Key fingerprint = 3C F2 27 7E 4A 6C 09 0A  4B C9 47 CD 4F 4D 0B 20
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.173. Konrad Jankowski <versus@FreeBSD.org >

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pub   1024D/A01C218A 2008-10-28
      Key fingerprint = A805 21DC 859F E941 D2EA  9986 2264 8E5D A01C 218A
uid                  Konrad Jankowski <versus@freebsd.org>
sub   2048g/56AE1959 2008-10-28
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D.3.174. Kurt Jaeger <pi@FreeBSD.org >

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pub   4096R/2A4392E050E8798D 2014-04-24 [expires: 2016-04-23]
      Key fingerprint = FD38 1F8F 1360 2A49 26D4  4CF3 2A43 92E0 50E8 798D
uid                         Kurt Jaeger <pi@FreeBSD.org>
sub   4096R/2FC3A793B283D724 2014-04-24 [expires: 2016-04-23]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.175. Weongyo Jeong <weongyo@FreeBSD.org >

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pub   1024D/22354D7A 2007-12-28
      Key fingerprint = 138E 7115 A86F AA40 B509  5883 B387 DCE9 2235 4D7A
uid                  Weongyo Jeong <weongyo.jeong@gmail.com>
uid                  Weongyo Jeong <weongyo@freebsd.org>
sub   2048g/9AE6DAEE 2007-12-28
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D.3.176. Peter Jeremy <peterj@FreeBSD.org >

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pub   4096R/1D9214A2699F8CB2 2014-03-11 [expires: 2016-03-10]
      Key fingerprint = D8CE A5F2 F7C8 78E0 0297  8B94 1D92 14A2 699F 8CB2
uid                          Peter Jeremy (preferred) <peter@rulingia.com>
uid                          Peter Jeremy <peter.jeremy@auug.org.au>
uid                          Peter Jeremy <peterj@freebsd.org>
uid                          Peter Jeremy <peterjeremy@acm.org>
uid                          [jpeg image of size 4183]
sub   4096R/E0E07EC247C92CA8 2014-03-11 [expires: 2016-03-10]
sub   4096R/16A597A0E4A20B34 2014-03-12 [expires: 2016-03-11]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.177. Tatuya JINMEI <jinmei@FreeBSD.org >

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pub   1024D/ABA82228 2002-08-15
      Key fingerprint = BB70 3050 EE39 BE00 48BB  A5F3 5892 F203 ABA8 2228
```

```
uid                  JINMEI Tatuya <jinmei@FreeBSD.org>
uid                  JINMEI Tatuya <jinmei@jinmei.org>
uid                  JINMEI Tatuya (the KAME project) <jinmei@isl.rdc.toshiba.co.jp>
sub   1024g/8B43CF66 2002-08-15
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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=ISn8
-----END PGP PUBLIC KEY BLOCK-----
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D.3.178. Michael Johnson <ahze@FreeBSD.org >

```
pub  1024D/3C046FD6 2004-10-29 Michael Johnson (FreeBSD key) <ahze@FreeBSD.org>
     Key fingerprint = 363C 6ABA ED24 C23B 5F0C  3AB4 9F8B AA7D 3C04 6FD6
uid                            Michael Johnson (pgp key) <ahze@ahze.net>
sub  2048g/FA334AE3 2004-10-29
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.179. Mark Johnston <markj@FreeBSD.org >

```
pub   rsa4096/D5F19F287539B0D9 2015-06-27 [expires: 2020-06-25]
      Key fingerprint = B35E AF99 18C4 36C8 1746  A8EB D5F1 9F28 7539 B0D9
uid                           Mark Johnston <markj@FreeBSD.org>
sub   rsa4096/A41F65E8198861C5 2015-06-27 [expires: 2020-06-25]
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.180. Trevor Johnson <trevor@FreeBSD.org >

```
pub  1024D/3A3EA137 2000-04-20 Trevor Johnson <trevor@jpj.net>
     Key fingerprint = 7ED1 5A92 76C1 FFCB E5E3  A998 F037 5A0B 3A3E A137
sub  1024g/46C24F1E 2000-04-20
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.181. Eric Joyner <erj@FreeBSD.org >

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pub   rsa4096/96F0C6FD61E05DE3 2015-01-28 [expires: 2018-01-27]
      Key fingerprint = C5FA EC74 96D2 C61B C548  FA37 96F0 C6FD 61E0 5DE3
uid                          Eric Joyner <eric.joyner@intel.com>
uid                          Eric Joyner <erj@freebsd.org>
uid                          Eric Joyner <ricera10@gmail.com>
uid                          Eric Joyner <erj@erj.cc>
uid                          [jpeg image of size 5419]
sub   rsa4096/D2427EB089BCF21B 2015-01-28 [expires: 2018-01-27]
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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D.3.182. Allan Jude <allanjude@FreeBSD.org >

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D.3.183. Tom Judge <tj@FreeBSD.org >

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pub   2048R/81E22216 2012-05-27 [expires: 2017-05-26]
      Key fingerprint = 8EF8 36C8 44A6 9576 6ADB  EB0E 4252 33DC 81E2 2216
uid                  Tom Judge <tom@tomjudge.com>
uid                  Tom Judge <tjudge@sourcefire.com>
uid                  Tom Judge <tj@freebsd.org>
sub   2048R/2CA4AA0D 2012-05-27 [expires: 2017-05-26]
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D.3.184. Alexander Kabaev <kan@FreeBSD.org >

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pub   rsa4096/0713229992792E7E 2015-06-05 [expires: 2018-06-05]
      Key fingerprint = C5F7 D995 99B6 41E1 3C51  5691 0713 2299 9279 2E7E
uid                          Alexander Kabaev <kan@freebsd.org>
uid                          Alexander Kabaev <kan@fb.com>
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sub   rsa4096/BB68B7A439D5FFAC 2015-06-05 [expires: 2025-06-02]
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D.3.185. Benjamin Kaduk <bjk@FreeBSD.org >

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D.3.186. Poul-Henning Kamp <phk@FreeBSD.org >

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      Key fingerprint = 4357 5923 B8E1 1D70 3C66  5540 8E5F 44BA 68E6 89C5
uid                          Poul-Henning Kamp <phk@FreeBSD.org>
uid                          Poul-Henning Kamp <phk@phk.freebsd.dk>
uid                          Poul-Henning Kamp <phk@ing.dk>
uid                          Poul-Henning Kamp <phk@varnish.org>
sub   4096R/1A605690A520ABD6 2013-09-28 [expires: 2018-09-27]
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D.3.187. Sergey Kandaurov <pluknet@FreeBSD.org >

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pub   2048R/10607419 2010-10-04
      Key fingerprint = 020B EC25 7E1F 8BC5 C42C  513B 3F4E 97BA 1060 7419
uid                  Sergey Kandaurov (freebsd) <pluknet@freebsd.org>
uid                  Sergey Kandaurov <pluknet@gmail.com>
sub   2048R/5711F73B 2010-10-04
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D.3.188. Coleman Kane <cokane@FreeBSD.org >

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pub   1024D/C5DAB797 2007-07-22
      Key fingerprint = FC09 F326 4318 E714 DE45  6CB0 70C4 B141 C5DA B797
uid                  Coleman Kane (Personal PGP Key) <cokane@cokane.org>
uid                  Coleman Kane (Personal PGP Key) <cokane@FreeBSD.org>
sub   2048g/5C680129 2007-07-22
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D.3.189. Takenori KATO <kato@FreeBSD.org >

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pub   4096R/3CF9ACE7 2012-10-02
      Key fingerprint = 5B72 AEF9 B2F9 069D 54FE  CF60 444F 91C8 3CF9 ACE7
uid                  KATO Takenori <kato@FreeBSD.org>
uid                  KATO Takenori <kato@nendai.nagoya-u.ac.jp>
sub   4096R/1C593356 2012-10-02
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.190. Josef Karthauser <joe@FreeBSD.org >

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pub  1024D/E6B15016 2000-10-19 Josef Karthauser <joe@FreeBSD.org>
     Key fingerprint = 7266 8EAF 82C2 D439 5642  AC26 5D52 1C8C E6B1 5016
uid                            Josef Karthauser <joe@tao.org.uk>
uid                            Josef Karthauser <joe@uk.FreeBSD.org>
uid                            [revoked] Josef Karthauser <josef@bsdi.com>
uid                            [revoked] Josef Karthauser <joe@pavilion.net>
sub  2048g/1178B692 2000-10-19
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.191. Vinod Kashyap <vkashyap@FreeBSD.org >

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pub  1024R/04FCCDD3 2004-02-19 Vinod Kashyap (gnupg key) <vkashyap@freebsd.org>
     Key fingerprint = 9B83 0B55 604F E491 B7D2  759D DF92 DAA0 04FC CDD3
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D.3.192. Patrick Kelsey <pkelsey@FreeBSD.org >

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pub   2048R/044ADF500A4B194E 2014-05-30 [expires: 2017-05-29]
      Key fingerprint = 4082 2A15 231C 09EC D86E  63C2 044A DF50 0A4B 194E
uid                          Patrick J Kelsey <pkelsey@freebsd.org>
uid                          Patrick J Kelsey <kelsey@ieee.org>
sub   2048R/CB7433052A5B26E5 2014-05-30 [expires: 2017-05-29]
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D.3.193. Kris Kennaway <kris@FreeBSD.org >

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pub  1024D/68E840A5 2000-01-14 Kris Kennaway <kris@citusc.usc.edu>
     Key fingerprint = E65D 0E7D 7E16 B212 1BD6  39EE 5ABC B405 68E8 40A5
uid                           Kris Kennaway <kris@FreeBSD.org>
uid                           Kris Kennaway <kris@obsecurity.org>
sub  2048g/03A41C45 2000-01-14 [expires: 2006-01-14]
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Comment: For info see http://www.gnupg.org

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D.3.194. Giorgos Keramidas <keramida@FreeBSD.org >

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pub   1024D/318603B6 2001-09-21
      Key fingerprint = C1EB 0653 DB8B A557 3829  00F9 D60F 941A 3186 03B6
uid                  Giorgos Keramidas <keramida@FreeBSD.org>
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uid                  Giorgos Keramidas <keramida@hellug.gr>
uid                  Giorgos Keramidas <keramida@linux.gr>
uid                  Giorgos Keramidas <gkeramidas@gmail.com>
sub   1024g/50FDBAD1 2001-09-21
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D.3.195. Max Khon <fjoe@FreeBSD.org >

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pub   1024D/6B87E212 2009-02-17
      Key fingerprint = 124D EC6C 6365 D41A 497A  9C3E FCF3 8708 6B87 E212
uid                  Max Khon <fjoe@FreeBSD.org>
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sub   2048g/CB71491D 2009-02-17
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D.3.196. Manolis Kiagias <manolis@FreeBSD.org >

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pub   1024D/6E0FB494 2006-08-22
      Key fingerprint = F820 5AAF 7112 2CDD 23D8  3BDF 67F3 311A 6E0F B494
uid                  Manolis Kiagias <manolis@FreeBSD.org>
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uid                  Manolis Kiagias (A.K.A. sonic, sonicy, sonic2000gr) <sonic@diktia.↺
dyndns.org>
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x4PX/wzHxscAoIHPNcR8OKoESON7vCoepxdHTQ9n
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.197. Jung-uk Kim <jkim@FreeBSD.org >

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pub   2048R/FCDBF146 2013-09-24 [expires: 2023-12-31]
      Key fingerprint = 9756 EA80 A691 CAA7 D65E  EFC2 7C9F 9626 FCDB F146
uid                  Jung-uk Kim <jkim@FreeBSD.org>
sub   2048R/501598FB 2013-09-24 [expires: 2023-12-31]
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CgkICwUWAgMBAAIeAQIXgAAKCRB8n5Ym/NvxRqyzB/wL7QtsIpeGfGIAZPMtgXMu
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=apmV
-----END PGP PUBLIC KEY BLOCK-----
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D.3.198. Zack Kirsch <zack@FreeBSD.org >

```
pub  1024D/1A725562 2010-11-05 Zack Kirsch <zack@freebsd.org>
     Key fingerprint = A8CC AA5E FB47 A386 E757  A2B8 BDD2 0684 1A72 5562
sub  1024g/6BFE2C06 2010-11-05
```

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-----BEGIN PGP PUBLIC KEY BLOCK-----

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Hr++4PFj0nr8I6r5HKMrfzcD/i5B4dhi25M/KlQsM2dh3r/z8KZ/79gmHKBJMrHg
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.199. Jakub Klama <jceel@FreeBSD.org >

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pub   2048R/2AAEA67D 2011-09-27
      Key fingerprint = 40D6 097A 174F 511B 80EB  F3A3 0946 4193 2AAE A67D
uid                  Jakub Klama <jceel@FreeBSD.org>
sub   2048R/5291BC4D 2011-09-27
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.200. Andreas Klemm <andreas@FreeBSD.org >

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pub  1024D/6C6F6CBA 2001-01-06 Andreas Klemm <andreas.klemm@eu.didata.com>
     Key fingerprint = F028 D51A 0D42 DD67 4109  19A3 777A 3E94 6C6F 6CBA
uid                            Andreas Klemm <andreas@klemm.gtn.com>
uid                            Andreas Klemm <andreas@FreeBSD.org>
uid                            Andreas Klemm <andreas@apsfilter.org>
sub  2048g/FE23F866 2001-01-06
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.201. Johann Kois <jkois@FreeBSD.org >

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pub  1024D/DD61C2D8 2004-06-27 Johann Kois <J.Kois@web.de>
     Key fingerprint = 8B70 03DB 3C45 E71D 0ED4  4825 FEB0 EBEF DD61 C2D8
uid                            Johann Kois <jkois@freebsd.org>
sub  1024g/568307CB 2004-06-27
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.202. Sergei Kolobov <sergei@FreeBSD.org >

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pub  1024D/3BA53401 2003-10-10 Sergei Kolobov <sergei@FreeBSD.org>
     Key fingerprint = A2F4 5F34 0586 CC9C 493A  347C 14EC 6E69 3BA5 3401
uid                            Sergei Kolobov <sergei@kolobov.com>
sub  2048g/F8243671 2003-10-10
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.203. Maxim Konovalov <maxim@FreeBSD.org >

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pub  1024D/2C172083 2002-05-21 Maxim Konovalov <maxim@FreeBSD.org>
     Key fingerprint = 6550 6C02 EFC2 50F1 B7A3  D694 ECF0 E90B 2C17 2083
uid                            Maxim Konovalov <maxim@macomnet.ru>
sub  1024g/F305DDCA 2002-05-21
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D.3.204. Taras Korenko <taras@FreeBSD.org >

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pub   1024D/8ACCC68B 2010-03-30
      Key fingerprint = 5128 2A8B 9BC1 A664 21E0  1E61 D838 54D3 8ACC C68B
uid                  Taras Korenko <taras@freebsd.org>
uid                  Taras Korenko <ds@ukrhub.net>
uid                  Taras Korenko <tarasishche@gmail.com>
sub   2048g/8D7CC0FA 2010-03-30 [expires: 2015-03-29]
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D.3.205. Joseph Koshy <jkoshy@FreeBSD.org >

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pub  1024D/D93798B6 2001-12-21 Joseph Koshy (FreeBSD) <jkoshy@freebsd.org>
     Key fingerprint = 0DE3 62F3 EF24 939F 62AA  2E3D ABB8 6ED3 D937 98B6
sub  1024g/43FD68E9 2001-12-21
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.206. Wojciech A. Koszek <wkoszek@FreeBSD.org >

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pub   1024D/C9F25145 2006-02-15
      Key fingerprint = 6E56 C571 9D33 D23E 9A61  8E50 623C AD62 C9F2 5145
uid                  Wojciech A. Koszek <dunstan@FreeBSD.czest.pl>
uid                  Wojciech A. Koszek <wkoszek@FreeBSD.org>
sub   4096g/3BBD20A5 2006-02-15
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D.3.207. Alex Kozlov <ak@FreeBSD.org >

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pub   2048R/0D1D29A0 2012-03-01 [expires: 2024-02-27]
      Key fingerprint = 7774 4FCF 6AC9 126B BD0E  DBF3 5EBF 4968 0D1D 29A0
uid                  Alex Kozlov <ak@freebsd.org>
sub   2048R/2DD82C65 2012-03-01 [expires: 2024-02-27]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.208. Svatopluk Kraus <skra@FreeBSD.org >

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pub   rsa2048/B00691EEA480A803 2015-10-26 [expires: 2018-10-25]
      Key fingerprint = 04ED 6504 A0EF 9890 8CD3  86C2 B006 91EE A480 A803
uid                           Svatopluk Kraus <skra@freebsd.org>
uid                           Svatopluk Kraus <onwahe@gmail.com>
sub   rsa2048/A5545C0A04691FFC 2015-10-26 [expires: 2018-10-25]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.209. Steven Kreuzer <skreuzer@FreeBSD.org >

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pub   rsa2048/F528158459D71EE7 2015-05-01 [expires: 2017-04-30]
      Key fingerprint = 1DB8 2B72 1C60 E59E 946A  FF7F F528 1584 59D7 1EE7
uid                          Steven Kreuzer <skreuzer@exit2shell.com>
uid                          Steven Kreuzer <skreuzer@freebsd.org>
uid                          Steven Kreuzer <steven@kreuzer.cx>
sub   rsa2048/540AD5219F26626F 2015-05-01
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.210. Gábor Kövesdán <gabor@FreeBSD.org >

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pub   1024D/2373A6B1 2006-12-05
      Key fingerprint = A42A 10D6 834B BEC0 26F0  29B1 902D D04F 2373 A6B1
uid                  Gabor Kovesdan <gabor@FreeBSD.org>
sub   2048g/92B0A104 2006-12-05
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.211. Ana Kukec <anchie@FreeBSD.org >

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pub   2048R/510D23BB 2010-04-18
      Key fingerprint = 0A9B 0ABB 0E1C B5A4 3408  398F 778A C3B4 510D 23BB
uid                  Ana Kukec <anchie@FreeBSD.org>
sub   2048R/699E4DDA 2010-04-18
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.212. Roman Kurakin <rik@FreeBSD.org >

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pub   1024D/C8550F4C 2005-12-16 [expires: 2008-12-15]
      Key fingerprint = 25BB 789A 6E07 E654 8E59  0FA9 42B1 937C C855 0F4C
uid                  Roman Kurakin <rik@FreeBSD.org>
sub   2048g/D15F2AB6 2005-12-16 [expires: 2008-12-15]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.213. Hideyuki KURASHINA <rushani@FreeBSD.org >

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pub  1024D/439ADC57 2002-03-22 Hideyuki KURASHINA <rushani@bl.mmtr.or.jp>
     Key fingerprint = A052 6F98 6146 6FE3 91E2  DA6B F2FA 2088 439A DC57
uid                           Hideyuki KURASHINA <rushani@FreeBSD.org>
uid                           Hideyuki KURASHINA <rushani@jp.FreeBSD.org>
sub  1024g/64764D16 2002-03-22
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D.3.214. Jun Kuriyama <kuriyama@FreeBSD.org >

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pub  1024D/FE3B59CD 1998-11-23 Jun Kuriyama <kuriyama@imgsrc.co.jp>
     Key fingerprint = 5219 55CE AC84 C296 3A3B  B076 EE3C 4DBB FE3B 59CD
uid                            Jun Kuriyama <kuriyama@FreeBSD.org>
uid                            Jun Kuriyama <kuriyama@jp.FreeBSD.org>
sub  2048g/1CF20D27 1998-11-23
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.215. Gleb Kurtsou <gleb@FreeBSD.org >

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pub   2048R/C2A8382F0952092D 2013-11-02 [expires: 2016-11-01]
      Key fingerprint = D1F6 F20B BB68 06AD D051  4BD5 C2A8 382F 0952 092D
uid                          Gleb Kurtsou <gleb@FreeBSD.org>
uid                          Gleb Kurtsou <gleb.kurtsou@gmail.com>
sub   2048R/E628ECBAC4622293 2013-11-02 [expires: 2016-11-01]
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D.3.216. René Ladan <rene@FreeBSD.org >

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pub   4096R/ADBBF8610A3789B7 2012-11-18 [expires: 2016-12-26]
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      Key fingerprint = 101A 716B 162B 00E5 5BED  EA05 ADBB F861 0A37 89B7
uid                           René Ladan <rene@freebsd.org>
sub   4096R/CB77BE03B67184C6 2012-11-18
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D.3.217. Julien Laffaye <jlaffaye@FreeBSD.org >

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pub   2048R/6AEBE420 2011-06-06
      Key fingerprint = 031A B449 B383 5C3B B618  E2F4 BAD0 0F0E 6AEB E420
uid                  Julien Laffaye <jlaffaye@FreeBSD.org>
sub   2048R/538B8D5B 2011-06-06
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D.3.218. Clement Laforet <clement@FreeBSD.org >

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pub  1024D/0723BA1D 2003-12-13 Clement Laforet (FreeBSD committer address) ↺
<clement@FreeBSD.org>
     Key fingerprint = 3638 4B14 8463 A67B DC7E  641C B118 5F8F 0723 BA1D
uid                            Clement Laforet <sheepkiller@cultdeadsheep.org>
uid                            Clement Laforet <clement.laforet@cotds.org>
sub  2048g/23D57658 2003-12-13
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D.3.219. Max Laier <mlaier@FreeBSD.org >

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pub   1024D/3EB6046D 2004-02-09
      Key fingerprint = 917E 7F25 E90F 77A4 F746  2E8D 5F2C 84A1 3EB6 046D
uid                  Max Laier <max@love2party.net>
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uid                  Max Laier <max.laier@ira.uka.de>
uid                  Max Laier <mlaier@freebsd.org>
uid                  Max Laier <max.laier@tm.uka.de>
sub   4096g/EDD08B9B 2005-06-28
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D.3.220. Dan Langille

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D.3.221. Erwin Lansing <erwin@FreeBSD.org >

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D.3.222. Ganael Laplanche <martymac@FreeBSD.org >

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D.3.223. Greg Larkin <glarkin@FreeBSD.org >

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.224. Frank J. Laszlo <laszlof@FreeBSD.org >

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pub   4096R/012360EC 2006-11-06 [expires: 2011-11-05]
      Key fingerprint = 3D93 21DB B5CC 1339 E4B4  1BC4 AD50 C17C 0123 60EC
uid                  Frank J. Laszlo <laszlof@FreeBSD.org>
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D.3.225. Dru Lavigne <dru@FreeBSD.org >

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pub   1024D/C6AA2E94 2013-01-22
      Key fingerprint = 6CC4 2180 F27C 29B6 5A9C  EC0D A454 DC05 C6AA 2E94
uid                  Dru Lavigne <dru@freebsd.org>
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sub   1024g/7FAC82EA 2013-01-22
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.226. Sam Lawrance <lawrance@FreeBSD.org >

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pub   1024D/32708C59 2003-08-14
      Key fingerprint = 1056 2A02 5247 64D4 538D  6975 8851 7134 3270 8C59
uid                  Sam Lawrance <lawrance@FreeBSD.org>
uid                  Sam Lawrance <boris@brooknet.com.au>
sub   2048g/0F9CCF92 2003-08-14
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D.3.227. Nate Lawson <njl@FreeBSD.org >

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pub   1024D/60E5AC11 2007-02-07
      Key fingerprint = 18E2 7E5A FD6A 199B B08B  E9FB 73C8 DB67 60E5 AC11
uid                  Nate Lawson <nate@root.org>
sub   2048g/CDBC7E1B 2007-02-07
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D.3.228. Jeremie Le Hen <jlh@FreeBSD.org >

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pub   2048D/8BF6CF92 2012-04-18
      Key fingerprint = 66C9 B361 16CA BFF6 5C07  DA0A 28DE 3702 8BF6 CF92
uid                  Jeremie Le Hen <jeremie@le-hen.org>
uid                  Jeremie Le Hen <jeremie@lehen.org>
uid                  Jeremie Le Hen <ttz@chchile.org>
uid                  Jeremie Le Hen <jlh@FreeBSD.org>
sub   2048g/045479A3 2012-04-18
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.229. 李彥明 <leeym@FreeBSD.org > <leeym@FreeBSD.org >

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pub   1024D/93FA8BD6 2007-05-21
      Key fingerprint = DEC4 6E7F 69C0 4AC3 21ED  EE65 6C0E 9257 93FA 8BD6
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uid                  Yen-Ming Lee <leeym@leeym.com>
sub   2048g/899A3931 2007-05-21
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D.3.230. Sam Leffler <sam@FreeBSD.org >

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pub   1024D/BD147743 2005-03-28
      Key fingerprint = F618 F2FC 176B D201 D91C  67C6 2E33 A957 BD14 7743
uid                  Samuel J. Leffler <sam@freebsd.org>
sub   2048g/8BA91D05 2005-03-28
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D.3.231. Jean-Yves Lefort <jylefort@FreeBSD.org >

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pub   1024D/A3B8006A 2002-09-07
      Key fingerprint = CC99 D1B0 8E44 293D 32F7  D92E CB30 FB51 A3B8 006A
uid                  Jean-Yves Lefort <jylefort@FreeBSD.org>
uid                  Jean-Yves Lefort <jylefort@brutele.be>
sub   4096g/C9271AFC 2002-09-07
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.232. Greg Lehey <grog@FreeBSD.org >

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pub   1024D/22E6F290507A4223 2000-12-10
      Key fingerprint = 9A1B 8202 BCCE B846 F92F  09AC 22E6 F290 507A 4223
uid                          Greg Lehey <grog@lemis.com>
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sub   2048g/61D280F939E8DAFD 2000-12-10
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D.3.233. Alexander Leidinger <netchild@FreeBSD.org >

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D.3.234. Andrey V. Elsukov <ae@FreeBSD.org >

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pub   2048R/10C8A17A 2010-05-29
      Key fingerprint = E659 1E1B 41DA 1516 F0C9  BC00 01C5 EA04 10C8 A17A
uid                  Andrey V. Elsukov <ae@freebsd.org>
uid                  Andrey V. Elsukov <bu7cher@yandex.ru>
sub   2048R/0F6D64C5 2010-05-29
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D.3.235. Dejan Lesjak <lesi@FreeBSD.org >

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pub  1024D/96C5221F 2004-08-18 Dejan Lesjak <lesi@FreeBSD.org>
     Key fingerprint = 2C5C 02EA 1060 1D6D 9982  38C0 1DA7 DBC4 96C5 221F
uid                          Dejan Lesjak <dejan.lesjak@ijs.si>
sub  1024g/E0A69278 2004-08-18
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D.3.236. Achim Leubner <achim@FreeBSD.org >

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pub   2048R/2E15B3C1 2013-01-22
      Key fingerprint = 2A48 0317 D477 2A07 2AD9  CF1C 7C1D 832E 2E15 B3C1
uid                  Achim Leubner <achim@freebsd.org>
sub   2048R/E275EF01 2013-01-22
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D.3.237. Chuck Lever <cel@FreeBSD.org >

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pub   1024D/8FFC2B87 2006-02-13
      Key fingerprint = 6872 923F 5012 F88B 394C  2F69 37B4 8171 8FFC 2B87
uid                  Charles E. Lever <cel@freebsd.org>
sub   2048g/9BCE0459 2006-02-13
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/KWhtyRy
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.238. Don “Truck” Lewis <truckman@FreeBSD.org >

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pub   2048R/B082B167EC3362D8 2014-02-20 [expires: 2017-02-19]
      Key fingerprint = 7016 6C9F 3B88 E5E9 E7C7  E056 B082 B167 EC33 62D8
uid                          Don "Truck" Lewis <truckman@FreeBSD.org>
sub   2048R/76F1C2A82FEBF95E 2014-02-20 [expires: 2017-02-19]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.239. Greg Lewis <glewis@FreeBSD.org >

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pub  1024D/1BB6D9E0 2002-03-05 Greg Lewis (FreeBSD) <glewis@FreeBSD.org>
     Key fingerprint = 2410 DA6D 5A3C D801 65FE  C8DB DEEA 9923 1BB6 D9E0
uid                            Greg Lewis <glewis@eyesbeyond.com>
sub  2048g/45E67D60 2002-03-05
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.240. Qing Li <qingli@FreeBSD.org >

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pub   2048R/A3CA4C13 2013-06-12 [expires: 2017-06-12]
      Key fingerprint = E37B CB18 35D1 F01B 7D7B  1000 0EAF 4BEA A3CA 4C13
uid                  Qing Li <qingli@freebsd.org>
sub   2048R/EF3A9370 2013-06-12 [expires: 2017-06-12]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.241. 李鑫 <delphij@FreeBSD.org > <delphij@FreeBSD.org >

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pub   4096R/95B6181B2D33E9EC 2013-10-03 [expires: 2018-10-02]
      Key fingerprint = 0E1A 6039 BFD2 1F02 DD1B  BFF5 95B6 181B 2D33 E9EC
uid                          Xin Li <d@delphij.net>
uid                          Xin Li <delphij@FreeBSD.org>
uid                          Xin Li <delphij@delphij.net>
sub   4096R/7D0C88F036C2299B 2013-10-03 [expires: 2018-10-02]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.242. 梁泰華 <avatar@FreeBSD.org > <avatar@FreeBSD.org >

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pub  1024R/F4013AB1 1998-05-13 Tai-hwa Liang <avatar@FreeBSD.org>
     Key fingerprint = 5B 05 1D 37 7F 35 31 4E  5D 38 BD 07 10 32 B9 D0
uid                            Tai-hwa Liang <avatar@mmlab.cse.yzu.edu.tw>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.243. 廖英傑 <ijliao@FreeBSD.org > <ijliao@FreeBSD.org >

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pub  1024D/11C02382 2001-01-09 Ying-Chieh Liao <ijliao@CCCA.NCTU.edu.tw>
     Key fingerprint = 4E98 55CC 2866 7A90 EFD7  9DA5 ACC6 0165 11C0 2382
uid                            Ying-Chieh Liao <ijliao@FreeBSD.org>
uid                            Ying-Chieh Liao <ijliao@csie.nctu.edu.tw>
uid                            Ying-Chieh Liao <ijliao@dragon2.net>
uid                            Ying-Chieh Liao <ijliao@tw.FreeBSD.org>
sub  4096g/C1E16E89 2001-01-09
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.244. Kurt Lidl <lidl@FreeBSD.org >

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pub   rsa2048/9808DFE7C2CA3ABA 2015-10-22 [expires: 2018-10-21]
      Key fingerprint = 4A2D 4BC0 9C8D 6D58 4B96  96E9 9808 DFE7 C2CA 3ABA
uid                           Kurt Lidl <lidl@FreeBSD.Org>
uid                           Kurt Lidl <lidl@pix.net>
sub   rsa2048/A53F68D4F0D10479 2015-10-22 [expires: 2018-10-21]
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D.3.245. Ulf Lilleengen <lulf@FreeBSD.org >

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uid                  Ulf Lilleengen <ulf.lilleengen@gmail.com>
uid                  Ulf Lilleengen <lulf@pvv.ntnu.no>
uid                  Ulf Lilleengen <lulf@stud.ntnu.no>
uid                  Ulf Lilleengen <lulf@FreeBSD.org>
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sub   2048g/B5409122 2009-08-19 [expires: 2014-08-18]
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D.3.246. 林東毅 <clive@FreeBSD.org > <clive@FreeBSD.org >

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pub  1024D/A008C03E 2001-07-30 Clive Lin <clive@tongi.org>
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uid                          Clive Lin <clive@CirX.ORG>
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sub  1024g/03C2DC87 2001-07-30 [expires: 2005-08-25]
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D.3.247. Po-Chien Lin <pclin@FreeBSD.org >

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pub   4096R/865C427F 2013-02-05
      Key fingerprint = CF3B AB13 4C94 6388 B047  B599 8B28 1692 865C 427F
uid                  Po-Chien Lin <pclin@FreeBSD.org>
uid                  Po-Chien Lin <linpc@cs.nctu.edu.tw>
sub   4096R/F31280BA 2013-02-05
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.248. Yi-Jheng Lin <yzlin@FreeBSD.org >

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pub   2048R/A34C6A8A 2009-07-20
      Key fingerprint = 7E3A E981 BB7C 5D73 9534  ED39 0222 04D3 A34C 6A8A
uid                  Yi-Jheng Lin (FreeBSD) <yzlin@FreeBSD.org>
sub   2048R/B4D776FE 2009-07-20
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D.3.249. Mark Linimon <linimon@FreeBSD.org >

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pub   1024D/84C83473 2003-10-09
      Key fingerprint = 8D43 1B55 D127 0BFC 842E  1C96 803C 5A34 84C8 3473
uid                  Mark Linimon <linimon@FreeBSD.org>
uid                  Mark Linimon <linimon@lonesome.com>
sub   1024g/24BFF840 2003-10-09
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D.3.250. Tilman Keskinöz <arved@FreeBSD.org >

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pub   4096R/6774D2A3 2013-09-24 [expires: 2018-09-23]
      Key fingerprint = 4E07 0A2C F66B B844 7E9B  A25B 6CBE B6EB 6774 D2A3
uid                  Tilman Keskinöz <arved@FreeBSD.org>
uid                  Tilman Keskinöz <arved@arved.at>
sub   4096R/8CD560FB 2013-09-24 [expires: 2018-09-23]
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D.3.251. 劉棟 <dryice@FreeBSD.org > <dryice@FreeBSD.org >

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=QMqP
-----END PGP PUBLIC KEY BLOCK-----
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D.3.252. 劉彤 <nemoliu@FreeBSD.org > <nemoliu@FreeBSD.org >

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pub   1024D/ECC7C907 2007-07-10
      Key fingerprint = B62E 3109 896B B283 E2FA  60FE A1BA F92E ECC7 C907
uid                  Tong LIU <nemoliu@FreeBSD.org>
sub   4096g/B6D7B15D 2007-07-10
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.253. Zachary Loafman <zml@FreeBSD.org >

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pub   1024D/4D65492D 2009-05-26
      Key fingerprint = E513 4AE9 5D6D 8BF9 1CD3  4389 4860 D79B 4D65 492D
uid                  Zachary Loafman <zml@FreeBSD.org>
sub   2048g/1AD659F0 2009-05-26
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D.3.254. Juergen Lock <nox@FreeBSD.org >

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pub   1024D/1B6BFBFD 2006-12-22
      Key fingerprint = 33A7 7FAE 51AF 00BC F0D3  ECCE FAFD 34C1 1B6B FBFD
uid                  Juergen Lock <nox@FreeBSD.org>
sub   2048g/251229D1 2006-12-22
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D.3.255. Remko Lodder <remko@FreeBSD.org >

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pub   4096R/3F774079 2012-11-11 [expires: 2016-11-11]
      Key fingerprint = 7EE4 C4AF DCA3 E0B4 479B  A344 7135 8ED6 3F77 4079
uid                  Remko Lodder <remko@FreeBSD.org>
sub   4096R/59F38CB0 2012-11-11 [expires: 2016-11-11]
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D.3.256. Alexander Logvinov <avl@FreeBSD.org >

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uid                  Alexander Logvinov <alexander@logvinov.com>
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uid                  Alexander Logvinov <ports@logvinov.com>
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D.3.257. Isabell Long <issyl0@FreeBSD.org >

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D.3.258. Scott Long <scottl@FreeBSD.org >

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pub  1024D/017C5EBF 2003-01-18 Scott A. Long (This is my official FreeBSD key) ↺
<scottl@freebsd.org>
     Key fingerprint = 34EA BD06 44F7 F8C3 22BC  B52C 1D3A F6D1 017C 5EBF
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D.3.259. Jonathan T. Looney <jtl@FreeBSD.org >

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pub   4096R/F8C879462E5477E3 2015-04-09 [expires: 2017-06-30]
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D.3.260. Wojciech Macek <wma@FreeBSD.org >

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pub   rsa2048/BA2FD88965AA1A7F 2016-01-20 [expires: 2019-01-19]
      Key fingerprint = 09F2 3360 D512 C987 B4D8  1AE8 BA2F D889 65AA 1A7F
uid                          Wojciech Macek <wma@FreeBSD.org>
sub   rsa2048/F074ACB7E5B3B33A 2016-01-20 [expires: 2019-01-19]
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D.3.261. Rick Macklem <rmacklem@FreeBSD.org >

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pub   1024D/7FB9C5F1 2009-04-05
      Key fingerprint = B9EA 767A F6F3 3786 E0C7  434A 05C6 70D6 7FB9 C5F1
uid                  Rick Macklem <rmacklem@freebsd.org>
sub   1024g/D0B20E8A 2009-04-05
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D.3.262. 馬源浩 <bmah@FreeBSD.org > <bmah@FreeBSD.org >

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pub   2048R/4984910A8CAAEE8A 2014-01-17 [expires: 2017-01-16]
      Key fingerprint = F85A 3820 4369 F71A 34D4  4E83 4984 910A 8CAA EE8A
uid                          Bruce A. Mah <bmah@kitchenlab.org>
uid                          Bruce A. Mah <bmah@es.net>
uid                          Bruce A. Mah <bmah@acm.org>
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sub   2048R/3FE58165F851A044 2014-01-17 [expires: 2017-01-16]
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D.3.263. Ruslan Makhmatkhanov <rm@FreeBSD.org >

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pub   2048R/F60D756F 2011-11-10
      Key fingerprint = 9D18 8A88 304C B78B 8003  0379 4574 0BAF F60D 756F
uid                  Ruslan Makhmatkhanov <rm@FreeBSD.org>
sub   2048R/B658C269 2011-11-10
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D.3.264. Mike Makonnen <mtm@FreeBSD.org >

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pub  1024D/7CD41F55 2004-02-06 Michael Telahun Makonnen <mtm@FreeBSD.Org>
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uid                          Michael Telahun Makonnen <mtm@tmsa-inc.com>
uid                          Mike Makonnen <mtm@identd.net>
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sub  2048g/E7DC936B 2004-02-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.265. David Malone <dwmalone@FreeBSD.org >

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pub   4096R/214C82C2361FD728 2013-08-07
      Key fingerprint = 7759 C5C6 F872 7269 4A8A  FEFF 214C 82C2 361F D728
uid                          David Malone <dwmalone@maths.tcd.ie>
uid                          David Malone <David.Malone@nuim.ie>
uid                          David Malone <dwmalone@FreeBSD.org>
uid                          David Malone <dwmalone@dwmalone.net>
uid                          [jpeg image of size 9564]
sub   4096R/770F33478DF59E7B 2013-08-07
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D.3.266. Dmitry Marakasov <amdmi3@FreeBSD.org >

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pub   1024D/F9D2F77D 2008-06-15 [expires: 2010-06-15]
      Key fingerprint = 55B5 0596 FF1E 8D84 5F56  9510 D35A 80DD F9D2 F77D
uid                  Dmitry Marakasov <amdmi3@amdmi3.ru>
uid                  Dmitry Marakasov <amdmi3@FreeBSD.org>
sub   2048g/2042CDD8 2008-06-15
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D.3.267. John Marino <marino@FreeBSD.org >

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pub   2048R/A0AE6229 2011-07-19
      Key fingerprint = EE48 4F90 C861 3A5F E39E  AB9E 33CF 4190 A0AE 6229
uid                  John Marino (DragonFly) <draco@marino.st>
uid                  John R. Marino <john.secure@marino.st>
uid                  John Marino (NetBSD) <marino@netbsd.org>
sub   2048R/71D9FB68 2011-07-19
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D.3.268. Koop Mast <kwm@FreeBSD.org >

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pub   4096R/BF4E2D5B3B9D8847 2014-01-31 [expires: 2016-01-31]
      Key fingerprint = F986 EDE2 B3EC 4098 7820  E1D7 BF4E 2D5B 3B9D 8847
uid                          Koop Mast <kwm@FreeBSD.org>
uid                          Koop Mast <kwm@rainbow-runner.nl>
sub   4096R/19C3701D1BE7F671 2014-01-31 [expires: 2016-01-31]
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D.3.269. Ed Maste <emaste@FreeBSD.org >

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pub   rsa2048/5D9A9C3B43EEF099 2015-07-08 [expires: 2017-07-07]
      Key fingerprint = F7E1 F016 EF5B 923A 6134  8BC8 5D9A 9C3B 43EE F099
uid                          Ed Maste <emaste@freebsd.org>
sub   rsa2048/A294A95EA92D2D89 2015-07-08 [expires: 2017-07-07]
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D.3.270. Cherry G. Mathew <cherry@FreeBSD.org >

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pub   2048R/2D066FE1 2007-05-22
      Key fingerprint = FBF1 89FF 81BB E1C7 6C1B  378D 3438 20E9 2D06 6FE1
uid                  Cherry G. Mathew (FreeBSD email) <cherry@FreeBSD.org>
uid                  "Cherry G. Mathew" (NetBSD email) <cherry@NetBSD.org>
sub   2048R/7B2C4166 2007-05-22
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D.3.271. Makoto Matsushita <matusita@FreeBSD.org >

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pub   1024D/20544576 1999-04-18
      Key fingerprint = 71B6 13BF B262 2DD8 2B7C  6CD0 EB2D 4147 2054 4576
uid                  Makoto Matsushita <matusita@matatabi.or.jp>
uid                  Makoto Matsushita <matusita@FreeBSD.org>
uid                  Makoto Matsushita <matusita@jp.FreeBSD.ORG>
uid                  Makoto Matsushita <matusita@ist.osaka-u.ac.jp>
sub   1024g/F1F3C94D 1999-04-18
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D.3.272. Martin Matuska <mm@FreeBSD.org >

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pub   1024D/4261B0D1 2007-02-05
      Key fingerprint = 17C4 3F32 B3DE 3ED7 E84E  5592 A76B 8B03 4261 B0D1
uid                  Martin Matuska <martin@matuska.org>
uid                  Martin Matuska <mm@FreeBSD.org>
uid                  Martin Matuska <martin.matuska@wu-wien.ac.at>
sub   2048g/3AC9A5A6 2007-02-05
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D.3.273. Sergey Matveychuk <sem@FreeBSD.org >

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pub   1024D/B71F605D 1999-10-13
      Key fingerprint = 4704 F374 DB28 BEC6 51C8  1322 4DC9 4BD8 B71F 605D
uid                  Sergey Matveychuk <sem@FreeBSD.org>
uid                  Sergey Matveychuk <sem@ciam.ru>
uid                  Sergey Matveychuk <sem@core.inec.ru>
sub   2048g/DEAF9D91 1999-10-13
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D.3.274. Stephen McConnell <slm@FreeBSD.org >

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pub   2048R/E523D98C5DCEE9D0 2014-05-13 [expires: 2017-05-12]
      Key fingerprint = E5A6 6376 9B87 C35A B41E  1F7B E523 D98C 5DCE E9D0
uid                          Stephen McConnell <slm@FreeBSD.org>
sub   2048R/0A1BC20E46082DDE 2014-05-13 [expires: 2017-05-12]
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D.3.275. Stephen McKay <mckay@FreeBSD.org >

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pub   4096R/552482D45824C996 2015-04-26 [expires: 2018-04-25]
      Key fingerprint = DF52 7F13 0B49 9790 BFF3  6A17 5524 82D4 5824 C996
uid                          Stephen McKay <mckay@FreeBSD.org>
sub   4096R/3DBD459E455FF5B3 2015-04-26 [expires: 2018-04-25]
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D.3.276. Kirk McKusick <mckusick@FreeBSD.org >

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      Key fingerprint = 56A8 62BC E973 24B7 E787  3F75 CAB8 3758 086F 2431
uid                           Marshall Kirk McKusick <mckusick@freebsd.org>
uid                           Marshall Kirk McKusick <mckusick@mckusick.com>
sub   rsa2048/DD2D6C768B07C96A 2015-10-23
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D.3.277. Tom McLaughlin <tmclaugh@FreeBSD.org >

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      Key fingerprint = 7692 B222 8D23 CF94 1993  0138 E339 E225 E2F7 B3D8
uid                  Tom McLaughlin (Personal email address) <tmclaugh@sdf.lonestar.org>
uid                  Tom McLaughlin (Work email address) <tmclaughlin@meditech.com>
uid                  Tom McLaughlin (FreeBSD email address) <tmclaugh@FreeBSD.org>
sub   2048g/16838F62 2005-05-24
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D.3.278. Jared McNeill <jmcneill@FreeBSD.org >

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pub   rsa2048/4D7493AA16CF40D0 2016-02-24 [expires: 2019-02-23]
      Key fingerprint = 81ED 5420 3DF8 B48D 035D  8334 4D74 93AA 16CF 40D0
uid                           Jared McNeill (FreeBSD) <jmcneill@FreeBSD.org>
uid                           Jared McNeill <jmcneill@invisible.ca>
sub   rsa2048/0E6943EE9C65C7F0 2016-02-24 [expires: 2019-02-23]
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D.3.279. Johannes Meixner <xmj@FreeBSD.org >

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pub   2048R/FC9E29371B1B0D0B 2014-04-09 [expires: 2017-04-08]
      Key fingerprint = 224E D70A A3AE 3EF1 23B0  CA88 FC9E 2937 1B1B 0D0B
uid                          Johannes Jost Meixner <xmj@chaot.net>
uid                          Johannes Jost Meixner <xmj@FreeBSD.org>
sub   2048R/A9F0E3193C0C8867 2014-04-09 [expires: 2017-04-08]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.280. Jean Milanez Melo <jmelo@FreeBSD.org >

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pub   1024D/AA5114BF 2006-03-03
      Key fingerprint = 826D C2AA 6CF2 E29A EBE7  4776 D38A AB83 AA51 14BF
uid                  Jean Milanez Melo <jmelo@FreeBSD.org>
uid                  Jean Milanez Melo <jmelo@freebsdbrasil.com.br>
sub   4096g/E9E1CBD9 2006-03-03
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D.3.281. Michal Meloun <mmel@FreeBSD.org >

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pub   rsa2048/691EB26B5EC5AAAA 2015-10-26 [expires: 2018-10-31]
      Key fingerprint = 00DD 4A10 4B80 9FE0 2983  8D77 691E B26B 5EC5 AAAA
uid                           Michal Meloun <mmel@freebsd.org>
uid                           Michal Meloun <meloun@miracle.cz>
uid                           Michal Meloun <melounmichal@gmail.com>
sub   rsa2048/62E61A1BD4E386E2 2015-10-26 [expires: 2018-10-31]
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=d015
-----END PGP PUBLIC KEY BLOCK-----
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D.3.282. Julio Merino <jmmv@FreeBSD.org >

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pub   1024D/B889BD5041AD5625 2004-01-01
      Key fingerprint = 6D6F 53EB C86C AB33 17B5  331D B889 BD50 41AD 5625
uid                          Julio Merino <jmmv@julipedia.org>
uid                          Julio M. Merino Vidal <jmmv84@gmail.com>
uid                          Julio M. Merino Vidal <jmmv@NetBSD.org>
uid                          Julio Merino <jmmv@NetBSD.org>
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uid                          Julio Merino <julio@meroh.net>
uid                          Julio Merino <jmmv@FreeBSD.org>
sub   2048g/91A5E9E695283F9C 2004-01-01
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D.3.283. Kashyap D. Desai <kadesai@FreeBSD.org >

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      Key fingerprint = A14D 4FB6 333F D61A D202  C547 B58E 09A5 C6E4 A571
uid                          Kashyap D Desai <kashyap.desai@avagotech.com>
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D.3.284. Kenneth D. Merry <ken@FreeBSD.org >

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pub  1024D/54C745B5 2000-05-15 Kenneth D. Merry <ken@FreeBSD.org>
     Key fingerprint = D25E EBC5 F17A 9E52 84B4  BF14 9248 F0DA 54C7 45B5
uid                            Kenneth D. Merry <ken@kdm.org>
sub  2048g/89D0F797 2000-05-15

pub  1024R/2FA0A505 1995-10-30 Kenneth D. Merry <ken@plutotech.com>
     Key fingerprint = FD FA 85 85 95 C4 8E E8  98 1A CA 18 56 F0 00 1F
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Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.285. Mark Murray <markm@FreeBSD.org >

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pub   1024D/FB57D793 2000-01-20
      Key fingerprint = 3FB6 3D12 0CF0 611F 0441  CD18 CD0B 8A35 FB57 D793
uid                  Mark R V Murray <mark@grondar.org>
uid                  Mark R V Murray <mark@grondar.za>
uid                  Mark R V Murray <markm@uunet.co.za>
uid                  Mark R V Murray <markm@freebsd.org>
sub   2048g/EB82BBFC 2000-01-20
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Version: GnuPG/MacGPG2 v2.0
Comment: GPGTools - http://gpgtools.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.286. Dirk Meyer <dinoex@FreeBSD.org >

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pub  1024R/331CDA5D 1995-06-04 Dirk Meyer <dinoex@FreeBSD.org>
     Key fingerprint = 44 16 EC 0A D3 3A 4F 28  8A 8A 47 93 F1 CF 2F 12
uid                            Dirk Meyer <dirk.meyer@dinoex.sub.org>
uid                            Dirk Meyer <dirk.meyer@guug.de>
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.287. Yoshiro Sanpei MIHIRA <sanpei@FreeBSD.org >

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pub  1024R/391C5D69 1996-11-21 sanpei@SEAPLE.ICC.NE.JP
     Key fingerprint = EC 04 30 24 B0 6C 1E 63  5F 5D 25 59 3E 83 64 51
uid                            MIHIRA Yoshiro <sanpei@sanpei.org>
uid                            Yoshiro MIHIRA <sanpei@FreeBSD.org>
uid                            MIHIRA Yoshiro <sanpei@yy.cs.keio.ac.jp>
uid                            MIHIRA Yoshiro <sanpei@cc.keio.ac.jp>
uid                            MIHIRA Yoshiro <sanpei@educ.cc.keio.ac.jp>
uid                            MIHIRA Yoshiro <sanpei@st.keio.ac.jp>
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.288. Robert Millan <rmh@FreeBSD.org >

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pub   4096R/DEA2C38E 2009-08-14
      Key fingerprint = A537 F029 AAAE 0E9C 39A7  C22C BB9D 98D9 DEA2 C38E
uid                  Robert Millan <rmh@debian.org>
uid                  Robert Millan <rmh@freebsd.org>
uid                  Robert Millan <rmh@gnu.org>
sub   4096R/65A0A9CE 2009-08-14
sub   4096R/41F37946 2009-08-14
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Version: GnuPG v1.4.10 (GNU/kFreeBSD)

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D.3.289. Michael Moll <mmoll@FreeBSD.org >

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      Key fingerprint = 5048 2980 9458 0FF4 AE39  1B16 749B 7C68 AFB1 16C7
uid                          Michael Moll <kvedulv@kvedulv.de>
uid                          Michael Moll <mmoll@FreeBSD.org>
uid                          Michael Moll <mmoll@mmoll.at>
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D.3.290. Christoph Moench-Tegeder <cmt@FreeBSD.org >

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D.3.291. Stephen Montgomery-Smith <stephen@FreeBSD.org >

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pub   2048R/9A92D807 2011-06-14
      Key fingerprint = 2B61 D82E 168E F08B 6E08  712E 2DF1 2BD1 9A92 D807
uid                  Stephen Montgomery-Smith <stephen@freebsd.org>
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D.3.292. Marcel Moolenaar <marcel@FreeBSD.org >

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pub   4096R/875AF2DF1FD2D8E3 2012-11-17
      Key fingerprint = 745F 456E AE8D 07DB 07C0  998B 875A F2DF 1FD2 D8E3
uid                          Marcel Moolenaar <marcel@xcllnt.net>
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D.3.293. Kris Moore <kmoore@FreeBSD.org >

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pub   1024D/6294612C 2009-05-26
      Key fingerprint = 8B70 9876 346F 1F97 5687  6950 4C92 D789 6294 612C
uid                  Kris Moore <kmoore@freebsd.org>
sub   2048g/A7FFE8FB 2009-05-26
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D.3.294. Dmitry Morozovsky <marck@FreeBSD.org >

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pub   4096R/0650BCC042473949 2013-11-25 [expires: 2016-11-24]
      Key fingerprint = 6BF3 EE15 5E2D 46F5 0B57  3A81 0650 BCC0 4247 3949
uid                         Dmitry Morozovsky <marck@rinet.ru>
uid                         Dmitry Morozovsky <marck@FreeBSD.org>
sub   4096R/948FF5948B7DAAA4 2013-11-25 [expires: 2016-11-24]
sub   4096R/65AA79C860E297A8 2013-11-25 [expires: 2016-11-24]
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pub   1024D/85D450456B691B03 2001-07-20
      Key fingerprint = 39AC E336 F03D C0F8 5305  B725 85D4 5045 6B69 1B03
uid                          Dmitry Morozovsky <marck@rinet.ru>
uid                          Dmitry Morozovsky <marck@FreeBSD.org>
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D.3.295. Alexander Motin <mav@FreeBSD.org >

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pub   2048R/8318C3955BAB227F 2014-07-02 [годен до: 2017-07-01]
Отпечаток ключа = E98C F3C4 E69C C3CD 0E57  9D55 8318 C395 5BAB 227F
uid                          Alexander Motin <mav@FreeBSD.org>
uid                          Alexander Motin <mav@ixsystems.com>
uid                          Alexander Motin <mav@mavhome.dp.ua>
uid                          Alexander Motin <mavbsd@gmail.com>
sub   2048R/0644E1A545DBCC15 2014-07-02 [годен до: 2017-07-01]
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D.3.296. Felippe de Meirelles Motta <lippe@FreeBSD.org >

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pub   1024D/F2CF7DAE 2008-09-02 [expires: 2010-09-02]
      Key fingerprint = 0532 A900 286D DAFD 099D  394D 231B AF20 F2CF 7DAE
uid                  Felippe de Meirelles Motta (FreeBSD Ports Committer) ↺
<lippe@FreeBSD.org>
sub   2048g/38E8EEF3 2008-09-02 [expires: 2010-09-02]
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D.3.297. Rich Murphey <rich@FreeBSD.org >

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pub  1024R/583443A9 1995-03-31 Rich Murphey <rich@lamprey.utmb.edu>
     Key fingerprint = AF A0 60 C4 84 D6 0C 73  D1 EF C0 E9 9D 21 DB E4
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.298. Akinori MUSHA <knu@FreeBSD.org >

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pub  1024D/9FD9E1EE 2000-03-21 Akinori MUSHA <knu@and.or.jp>
     Key fingerprint = 081D 099C 1705 861D 4B70  B04A 920B EFC7 9FD9 E1EE
uid                            Akinori MUSHA <knu@FreeBSD.org>
uid                            Akinori MUSHA <knu@idaemons.org>
uid                            Akinori MUSHA <knu@ruby-lang.org>
sub  1024g/71BA9D45 2000-03-21
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.299. Thomas Möstl <tmm@FreeBSD.org >

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pub  1024D/419C776C 2000-11-28 Thomas Moestl <tmm@FreeBSD.org>
     Key fingerprint = 1C97 A604 2BD0 E492 51D0  9C0F 1FE6 4F1D 419C 776C
uid                            Thomas Moestl <tmoestl@gmx.net>
uid                            Thomas Moestl <t.moestl@tu-bs.de>
sub  2048g/ECE63CE6 2000-11-28
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.300. Masafumi NAKANE <max@FreeBSD.org >

```
pub  1024D/CE356B59 2000-02-19 Masafumi NAKANE <max@wide.ad.jp>
     Key fingerprint = EB40 BCAB 4CE5 0764 9942  378C 9596 159E CE35 6B59
uid                          Masafumi NAKANE <max@FreeBSD.org>
uid                          Masafumi NAKANE <max@accessibility.org>
uid                          Masafumi NAKANE <kd5pdi@qsl.net>
sub  1024g/FA9BD48B 2000-02-19
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.2.2 (FreeBSD)

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.301. Maho Nakata <maho@FreeBSD.org >

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pub   1024D/F28B4069 2009-02-09
      Key fingerprint = 3FE4 99A9 6F41 8161 4F5F  240C 8615 A60C F28B 4069
uid                  Maho NAKATA (NAKATA's FreeBSD.org alias) <maho@FreeBSD.org>
sub   2048g/6B49098E 2009-02-09
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-----BEGIN PGP PUBLIC KEY BLOCK-----

mQGiBEmPtPkRBADEcSQQGME+Df6I9jnjUBNMxvX8aMAH0+SKJEn0xTZvu9WLQmJv
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.302. Yoichi NAKAYAMA <yoichi@FreeBSD.org >

```
pub  1024D/E0788E46 2000-12-28 Yoichi NAKAYAMA <yoichi@assist.media.nagoya-u.ac.jp>
     Key fingerprint = 1550 2662 46B3 096C 0460  BC03 800D 0C8A E078 8E46
uid                            Yoichi NAKAYAMA <yoichi@eken.phys.nagoya-u.ac.jp>
uid                            Yoichi NAKAYAMA <yoichi@FreeBSD.org>
sub  1024g/B987A394 2000-12-28
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (GNU/Linux)
Comment: KUHASIKU WA http://www.gnupg.org/ WO GORANKUDASAI

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.303. Edward Tomasz Napierała <trasz@FreeBSD.org >

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pub   1024D/8E53F00E 2007-04-13
      Key fingerprint = DD8F 91B0 12D9 6237 42D9  DBE1 AFC8 CDE9 8E53 F00E
uid                  Edward Tomasz Napierala <trasz@FreeBSD.org>
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sub   2048g/7C1F5D67 2007-04-13
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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D.3.304. Neel Natu <neel@FreeBSD.org >

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pub   2048R/8E023181B17DA72B 2014-09-25 [expires: 2017-09-24]
      Key fingerprint = 1251 B214 E559 D763 A12C  96F4 8E02 3181 B17D A72B
uid                          Neel Natu <neel@freebsd.org>
sub   2048R/1F906913DB152E10 2014-09-25 [expires: 2017-09-24]
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D.3.305. David Naylor <dbn@FreeBSD.org >

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pub   rsa4096/35C84A0DEC1D97CD 2014-03-06 [SC] [expires: 2019-03-05]
      Key fingerprint = A372 D3E1 D587 2D99 A5FF  F243 35C8 4A0D EC1D 97CD
uid                           David Naylor (FreeBSD) <dbn@FreeBSD.org>
uid                           David Naylor (Private) <naylor.b.david@gmail.com>
sub   rsa4096/AD63FA8DD6B2DA55 2014-03-06 [S] [expires: 2017-03-13]
      Key fingerprint = 948E C511 A27F 0302 E799  B53A AD63 FA8D D6B2 DA55
sub   rsa4096/88D62359F19D95D0 2014-03-06 [E] [expires: 2017-03-13]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.306. Alexander Nedotsukov <bland@FreeBSD.org >

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pub  1024D/D004116C 2003-08-14 Alexander Nedotsukov <bland@FreeBSD.org>
     Key fingerprint = 35E2 5020 55FC 2071 4ADD  1A4A 86B6 8A5D D004 116C
sub  1024g/1CCA8D46 2003-08-14
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=bcPN
-----END PGP PUBLIC KEY BLOCK-----
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D.3.307. George V. Neville-Neil <gnn@FreeBSD.org >

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pub   1024D/440A33D2 2002-09-17
      Key fingerprint = AF66 410F CC8D 1FC9 17DB  6225 61D8 76C1 440A 33D2
uid                  George V. Neville-Neil <gnn@freebsd.org>
uid                  George V. Neville-Neil <gnn@neville-neil.com>
sub   2048g/95A74F6E 2002-09-17
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.308. Simon L. B. Nielsen <simon@FreeBSD.org >

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pub   1024D/FF7490AB 2007-01-14
      Key fingerprint = 4E92 BA8D E45E 85E2 0380  B264 049C 7480 FF74 90AB
uid                  Simon L. Nielsen <simon@FreeBSD.org>
uid                  Simon L. Nielsen <simon@nitro.dk>
sub   2048g/E3F5A76E 2007-01-14
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.309. Robert Noland <rnoland@FreeBSD.org >

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pub   1024D/8A9F44E3 2007-07-24
      Key fingerprint = 107A 0C87 E9D0 E581 677B  2A28 3384 EB43 8A9F 44E3
uid                  Robert C. Noland III <rnoland@FreeBSD.org>
uid                  Robert C. Noland III (Personal Key) <rnoland@2hip.net>
sub   2048g/76C3CF00 2007-07-24
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-----BEGIN PGP PUBLIC KEY BLOCK-----

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.310. Anders Nordby <anders@FreeBSD.org >

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pub  1024D/00835956 2000-08-13 Anders Nordby <anders@fix.no>
     Key fingerprint = 1E0F C53C D8DF 6A8F EAAD  19C5 D12A BC9F 0083 5956
uid                            Anders Nordby <anders@FreeBSD.org>
sub  2048g/4B160901 2000-08-13
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.311. Michael Nottebrock <lofi@FreeBSD.org >

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pub  1024D/6B2974B0 2002-06-06 Michael Nottebrock <michaelnottebrock@gmx.net>
     Key fingerprint = 1079 3C72 0726 F300 B8EC  60F9 5E17 3AF1 6B29 74B0
uid                            Michael Nottebrock <lofi@freebsd.org>
uid                            Michael Nottebrock <lofi@tigress.com>
uid                            Michael Nottebrock <lofi@lofi.dyndns.org>
uid                            Michael Nottebrock <michaelnottebrock@web.de>
uid                            Michael Nottebrock <michaelnottebrock@meitner.wh.uni-
dortmund.de>
sub  1024g/EF652E04 2002-06-06 [expires: 2004-06-15]
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D.3.312. David O'Brien <obrien@FreeBSD.org >

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pub  1024R/34F9F9D5 1995-04-23 David E. O'Brien <defunct - obrien@Sea.Legent.com>
     Key fingerprint = B7 4D 3E E9 11 39 5F A3  90 76 5D 69 58 D9 98 7A
uid                            David E. O'Brien <obrien@NUXI.com>
uid                            deobrien@ucdavis.edu
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pub  1024D/7F9A9BA2 1998-06-10 "David E. O'Brien" <obrien@cs.ucdavis.edu>
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D.3.313. Jimmy Olgeni <olgeni@FreeBSD.org >

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pub   4096R/FCDB3E82F778D8D7 2013-11-10 [expires: 2017-04-25]
      Key fingerprint = EE37 B427 91C5 7707 EC54  064A FCDB 3E82 F778 D8D7
uid                          Jimmy Olgeni <olgeni@FreeBSD.org>
sub   4096R/4B2EC123F42A1D2C 2013-11-10 [expires: 2017-04-25]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.314. Phil Shafer <phil@FreeBSD.org >

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pub   rsa2048/199B04AAB9FC8BC1 2015-12-30 [expires: 2018-12-29]
      Key fingerprint = C481 6D81 839D FABB 6E51  368E 199B 04AA B9FC 8BC1
uid   Phil Shafer <phil@freebsd.org>
uid   Phil Shafer <phil@juniper.net>
sub   rsa2048/393DFA173468E663 2015-12-30 [expires: 2018-12-29]
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D.3.315. Philip Paeps <philip@FreeBSD.org >

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pub   rsa2048/31AEB9B5FDBBCB0E 2015-06-14 [expires: 2018-06-13]
      Key fingerprint = 2CD1 92C2 6EE7 B7D1 F552  6619 31AE B9B5 FDBB CB0E
uid                           Philip Paeps <philip@trouble.is>
uid                           Philip Paeps <philip@fosdem.org>
uid                           Philip Paeps <philip@freebsd.org>
uid                           Philip Paeps <philip@nixsys.be>
sub   rsa2048/7C62BC4776C9F29E 2015-06-14 [expires: 2016-06-13]
sub   rsa2048/935DB8343AF25C94 2015-06-14 [expires: 2016-06-13]
sub   rsa2048/CFF632544136DF54 2015-06-14 [expires: 2016-06-13]

pub   rsa4096/BB5E2C462A0FA8B0 2013-12-19 [expires: 2016-01-01]
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      Key fingerprint = 73C5 0671 B4B6 7E19 1BAD  F87A BB5E 2C46 2A0F A8B0
uid                          Philip Paeps <philip@trouble.is>
uid                          Philip Paeps <philip@paeps.cx>
uid                          Philip Paeps <philip@nixsys.be>
uid                          Philip Paeps <philip@fosdem.org>
uid                          Philip Paeps <philip@freebsd.org>
sub   rsa4096/5E0637B4BCF333B4 2013-12-19 [expires: 2016-01-01]
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D.3.316. Josh Paetzel <jpaetzel@FreeBSD.org >

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pub   2048D/F6F63F01 2012-09-21
      Key fingerprint = 1D8D 506E B58C BD10 DC8C  97E1 D6AD 8621 F6F6 3F01
uid                  Josh Paetzel <josh@tcbug.org>
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sub   2048R/F32EF801 2012-09-21
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.317. Gábor Páli <pgj@FreeBSD.org >

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pub   4096R/6D7E445C 2013-06-14 [expires: 2018-06-13]
      Key fingerprint = 7AD5 76BA AF2D 14B9 6D45  440B C013 309D 6D7E 445C
uid                  Páli Gábor János (Primary identity) <pali.gabor@gmail.com>
uid                  Páli Gábor János (Eötvös Loránd University) <pgj@inf.elte.hu>
uid                  Gabor Pali (FreeBSD committer) <pgj@FreeBSD.org>
uid                  Páli Gábor János (Magyar BSD Egyesület) <pgj@bsd.hu>
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D.3.318. Hiren Panchasara <hiren@FreeBSD.org >

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pub   2048R/8B9250E1563EDFE5 2014-05-13 [expires: 2017-05-12]
      Key fingerprint = A4E2 0FA1 D878 8F3F 17E6  6F02 8B92 50E1 563E DFE5
uid                          hiren panchasara <hiren@freebsd.org>
sub   2048R/EAF1BEDEBEEA242B 2014-05-13 [expires: 2017-05-12]
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D.3.319. Hiten Pandya <hmp@FreeBSD.org >

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pub  1024D/938CACA8 2004-02-13 Hiten Pandya (FreeBSD) <hmp@FreeBSD.org>
     Key fingerprint = 84EB C75E C75A 50ED 304E  E446 D974 7842 938C ACA8
uid                            Hiten Pandya <hmp@backplane.com>
sub  2048g/783874B5 2004-02-13
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D.3.320. Dima Panov <fluffy@FreeBSD.org >

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pub   1024D/93E3B018 2006-11-08
      Key fingerprint = C73E 2B72 1FFD 61BD E206  1234 A626 76ED 93E3 B018
uid                  Dima Panov (FreeBSD.ORG Committer) <fluffy@FreeBSD.ORG>
uid                  Dima Panov (at home) <Fluffy@Fluffy.Khv.RU>
uid                  Dima Panov (at home) <fluffy.khv@gmail.com>
sub   2048g/89047419 2006-11-08

pub   4096R/D5398F29 2009-08-09
      Key fingerprint = 2D30 2CCB 9984 130C 6F87  BAFC FB8B A09D D539 8F29
uid                  Dima Panov (FreeBSD.ORG Committer) <fluffy@FreeBSD.ORG>
uid                  Dima Panov (at Home) <fluffy@Fluffy.Khv.RU>
uid                  Dima Panov (at GMail) <fluffy.khv@gmail.com>
sub   4096R/915A7785 2009-08-09
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D.3.321. Andrew Pantyukhin <sat@FreeBSD.org >

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pub   1024D/6F38A569 2006-05-06
      Key fingerprint = 4E94 994A C2EF CB86 C144  3B04 3381 67C0 6F38 A569
uid                  Andrew Pantyukhin <infofarmer@gubkin.ru>
uid                  Andrew Pantyukhin <sat@FreeBSD.org>
uid                  Andrew Pantyukhin <infofarmer@gmail.com>
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sub   2048g/5BD4D469 2006-05-06
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D.3.322. Navdeep Parhar <np@FreeBSD.org >

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pub   1024D/ACAB8812 2009-06-08
      Key fingerprint = C897 7AFB AFC0 4DA9 7B76  D991 CAB2 2B93 ACAB 8812
uid                  Navdeep Parhar <np@FreeBSD.org>
sub   2048g/AB61D2DC 2009-06-08
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D.3.323. Roger Pau Monné <royger@FreeBSD.org >

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uid                          Roger Pau Monné <roger.pau@citrix.com>
uid                          Roger Pau Monné <royger@NetBSD.org>
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uid                          Roger Pau Monne (NetBSD) <roger.pau@citrix.com>
sub   2048R/6927D92634ED085B 2012-07-10
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D.3.324. Rui Paulo <rpaulo@FreeBSD.org >

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pub   4096R/39CB4153 2010-02-03
      Key fingerprint = ABE8 8465 DE8F F04D E9C8  3FF6 AF89 B2E6 39CB 4153
uid                  Rui Paulo <rpaulo@FreeBSD.org>
uid                  Rui Paulo <rpaulo@gmail.com>
sub   4096R/F87D2F34 2010-02-03
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D.3.325. Jean-Sébastien Pédron <dumbbell@FreeBSD.org >

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pub   4096R/D938F9C86816981C 2014-01-14 [expires: 2017-01-16]
      Key fingerprint = D72F 4B84 7098 9244 20E6  2B93 D938 F9C8 6816 981C
uid                          Jean-Sébastien Pédron <jean-sebastien.pedron@dumbbell.fr>
uid                          Jean-Sébastien Pédron <dumbbell@FreeBSD.org>
sub   4096R/A185D28321B02B03 2014-01-14 [expires: 2017-01-16]
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      Key fingerprint = FDC4 0948 8453 5198 3EA1  5F56 A185 D283 21B0 2B03
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D.3.326. Mark Peek <mp@FreeBSD.org >

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D.3.327. Peter Pentchev <roam@FreeBSD.org >

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      Key fingerprint = FDBA FD79 C26F 3C51 C95E  DF9E ED18 B68D 1619 4553
uid                  Peter Pentchev <roam@ringlet.net>
uid                  Peter Pentchev <roam@cnsys.bg>
uid                  Peter Pentchev <roam@sbnd.net>
uid                  Peter Pentchev <roam@online.bg>
uid                  Peter Pentchev <roam@orbitel.bg>
uid                  Peter Pentchev <roam@FreeBSD.org>
uid                  Peter Pentchev <roam@techlab.office1.bg>
uid                  Peter Pentchev <roam@hoster.bg>
uid                  Peter Pentchev <roam@space.bg>
sub   1024g/7074473C 2002-02-01

pub   4096R/2527DF13 2009-10-16
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uid                  Peter Pentchev <roam@ringlet.net>
uid                  Peter Pentchev <roamer@users.sourceforge.net>
uid                  Peter Pentchev <roam@cpan.org>
uid                  Peter Pentchev <roam@cnsys.bg>
uid                  Peter Pentchev <roam@sbnd.net>
uid                  Peter Pentchev <roam@online.bg>
uid                  Peter Pentchev <roam@orbitel.bg>
uid                  Peter Pentchev <roam@FreeBSD.org>
uid                  Peter Pentchev <roam@techlab.office1.bg>
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uid                  Peter Pentchev <roam@hoster.bg>
uid                  Peter Pentchev <roam@space.bg>
uid                  Peter Pentchev <roam-guest@alioth.debian.org>
uid                  Peter Pentchev <ppentchev@alumni.princeton.edu>
sub   4096R/D0B337AA 2009-10-16
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D.3.328. Denis Peplin <den@FreeBSD.org >

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D.3.329. Christian S.J. Peron <csjp@FreeBSD.org >

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      Key fingerprint = 74AA 6040 89A7 936E D970  DDC0 CC71 6954 033F A33C
uid                  Christian S.J. Peron <csjp@FreeBSD.ORG>
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D.3.330. Gerald Pfeifer <gerald@FreeBSD.org >

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      Key fingerprint = B215 C163 3BCA 0477 615F  1B35 A5B3 A004 745C 015A
uid                          Gerald Pfeifer <gerald@pfeifer.com>
uid                          Gerald Pfeifer <gp@suse.com>
uid                          Gerald Pfeifer <gp@novell.com>
uid                          Gerald Pfeifer <gerald@FreeBSD.org>
sub   1536g/00EAD7F3F0156927 1999-11-09
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D.3.331. Giuseppe Pilichi <jacula@FreeBSD.org >

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.332. John Polstra <jdp@FreeBSD.org >

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pub  1024R/BFBCF449 1997-02-14 John D. Polstra <jdp@polstra.com>
     Key fingerprint = 54 3A 90 59 6B A4 9D 61  BF 1D 03 09 35 8D F6 0D
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Comment: For info see http://www.gnupg.org

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D.3.333. Kirill Ponomarew <krion@FreeBSD.org >

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uid                  Kirill Ponomarew <krion@voodoo.bawue.com>
uid                  Kirill Ponomarew <krion@guug.de>
uid                  Kirill Ponomarew <krion@FreeBSD.org>
sub   1024D/05AC7CA0 2006-01-30 [expires: 2008-01-30]
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D.3.334. Stephane E. Potvin <sepotvin@FreeBSD.org >

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pub   1024D/3097FE7B 2002-08-06
      Key fingerprint = 6B56 62FA ADE1 6F46 BB62  8B1C 99D3 97B5 3097 FE7B
uid                  Stephane E. Potvin <sepotvin@videotron.ca>
uid                  Stephane E. Potvin <stephane.potvin@telcobridges.com>
uid                  Stephane E. Potvin <stephane_potvin@telcobridges.com>
uid                  Stephane E. Potvin <sepotvin@FreeBSD.org>
sub   2048g/0C427BC9 2002-08-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.335. Mark Pulford <markp@FreeBSD.org >

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pub  1024D/182C368F 2000-05-10 Mark Pulford <markp@FreeBSD.org>
     Key fingerprint = 58C9 C9BF C758 D8D4 7022  8EF5 559F 7F7B 182C 368F
uid                            Mark Pulford <mark@kyne.com.au>
sub  2048g/380573E8 2000-05-10
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.336. Alejandro Pulver <alepulver@FreeBSD.org >

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pub   1024D/945C3F61 2005-11-13
      Key fingerprint = 085F E8A2 4896 4B19 42A4  4179 895D 3912 945C 3F61
uid                  Alejandro Pulver (Ale's GPG key pair) <alepulver@FreeBSD.org>
uid                  Alejandro Pulver (Ale's GPG key pair) <alejandro@varnet.biz>
sub   2048g/6890C6CA 2005-11-13
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D.3.337. Kristof Provost <kp@FreeBSD.org >

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pub   rsa2048/6FC4DC71FB5E4A46 2015-03-23 [expires: 2018-03-22]
      Key fingerprint = 86FB A6CE 751B B4CC 9A0E  5172 6FC4 DC71 FB5E 4A46
uid                           Kristof Provost <kp@freebsd.org>
sub   rsa2048/7287BC16FB5B8FA1 2015-03-23 [expires: 2018-03-22]
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D.3.338. Thomas Quinot <thomas@FreeBSD.org >

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      Key fingerprint = 6048 5466 BE2C 284C C140  FFE9 9495 D5E1 0F2C 905E
uid                          Thomas Quinot <thomas@quinot.org>
uid                          Thomas Quinot <thomas@cuivre.fr.eu.org>
uid                          Thomas Quinot (FreeBSD) <thomas@freebsd.org>
sub   4096R/DF8E0B5C7CC62EF2 2014-05-14 [expires: 2016-05-13]
sub   4096R/4FC12CCCCDF5176B 2014-05-14 [expires: 2016-05-13]
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D.3.339. Herve Quiroz <hq@FreeBSD.org >

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pub  1024D/85AC8A80 2004-07-22 Herve Quiroz <hq@FreeBSD.org>
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D.3.340. Doug Rabson <dfr@FreeBSD.org >

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      Key fingerprint = 9083 9CD0 6235 A655 70E2  A65A D841 102E 0B75 3B2F
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uid                          Doug Rabson <dfr@freebsd.org>
sub   2048R/FCC3E849854E03FC 2015-04-25 [expires: 2018-04-24]
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D.3.341. Muhammad Moinur Rahman <bofh@FreeBSD.org >

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D.3.342. Lars Balker Rasmussen <lbr@FreeBSD.org >

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D.3.343. Chris Rees <crees@FreeBSD.org >

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      Key fingerprint = 8C57 BE3B D320 5FFC C4C3  C0B0 900F 45A6 1E12 E96A
uid                          Chris Rees <crees@physics.org>
uid                          Chris Rees <crees@FreeBSD.org>
sub   2048R/A703CC3500749D52 2015-03-08 [expires: 2018-03-07]
sub   2048R/D589B12E85B13424 2015-03-08 [expires: 2018-03-07]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.344. Jim Rees <rees@FreeBSD.org >

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pub   512/B623C791 1995/02/21 Jim Rees <rees@umich.edu>
          Key fingerprint =  02 5F 1B 15 B4 6E F1 3E  F1 C5 E0 1D EA CC 17 88
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Version: GnuPG v1.0.7 (OpenBSD)

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D.3.345. Michael Reifenberger <mr@FreeBSD.org >

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  Schl.-Fingerabdruck = 8695 9903 4744 6EF8 E18D  177C 335E 9D48 E27A 80A0
uid                          Michael Reifenberger <mr@freebsd.org>
uid                          Michael Reifenberger <mike@reifenberger.com>
sub   4096R/898AF56CFE7CD649 2013-11-04 [verfällt: 2018-11-03]
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D.3.346. Benedict Reuschling <bcr@FreeBSD.org >

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pub   rsa4096/733FB585F27758FE 2015-05-22 [expires: 2018-05-21]
      Key fingerprint = 99B8 FF96 65FF 8980 3F58  DB55 733F B585 F277 58FE
uid                           Benedict Reuschling <bcr@FreeBSD.org>
sub   rsa4096/C04F357C5C6E5363 2015-05-22 [expires: 2018-05-21]
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D.3.347. Tom Rhodes <trhodes@FreeBSD.org >

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pub   1024D/FB7D88E1 2008-05-07
      Key fingerprint = 8279 3100 2DF2 F00E 7FDD  AC2C 5776 23AB FB7D 88E1
uid                  Tom Rhodes (trhodes) <trhodes@FreeBSD.org>
sub   4096g/7B0CD79F 2008-05-07
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D.3.348. Benno Rice <benno@FreeBSD.org >

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pub   4096R/B8DAD01271A4B35E 2013-11-23 [expires: 2017-11-23]
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      Key fingerprint = 01FE FD73 9E5B 6F14 5FCB  47F5 B8DA D012 71A4 B35E
uid                          Benno Rice <benno@jeamland.net>
uid                          Benno Rice <benno@FreeBSD.org>
sub   4096R/9AE831D60E72927F 2013-11-23 [expires: 2017-11-23]
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Comment: GPGTools - http://gpgtools.org

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D.3.349. Beech Rintoul <beech@FreeBSD.org >

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pub   2048D/68DFAE1F 2013-02-26
      Key fingerprint = D58B 3E9D B0E3 E081 EC6F  69D9 CDA3 51DD 68DF AE1F
uid                  Beech Rintoul <beech@freebsd.org>
sub   2048g/960F45D9 2013-02-26
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D.3.350. Matteo Riondato <matteo@FreeBSD.org >

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      Key fingerprint = F0F3 1B43 035D 65B1 08E9  4D66 D8CA 78A5 1EC5 6BEC
uid                  Matteo Riondato (Rionda) <matteo@FreeBSD.ORG>
uid                  Matteo Riondato (Rionda) <rionda@riondabsd.net>
uid                  Matteo Riondato (Rionda) <rionda@gufi.org>
uid                  Matteo Riondato (Rionda) <matteo@riondato.com>
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uid                  Matteo Riondato (Rionda) <rionda@FreeSBIE.ORG>
uid                  Matteo Riondato (Rionda) <rionda@autistici.org>
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sub   2048g/87C44A55 2008-09-23 [expires: 2009-09-23]
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D.3.351. Ollivier Robert <roberto@FreeBSD.org >

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D.3.352. Craig Rodrigues <rodrigc@FreeBSD.org >

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D.3.353. Bartek Rutkowski <robak@FreeBSD.org >

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pub   4096R/280E1199 2013-06-17 [expires: 2017-06-17]
      Key fingerprint = D292 1363 AE61 D2BE 1740  9ED2 D99F C356 280E 1199
uid                  Bartek Rutkowski <robak@freebsd.org>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.354. Guido van Rooij <guido@FreeBSD.org >

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pub  1024R/599F323D 1996-05-18 Guido van Rooij <guido@gvr.org>
     Key fingerprint = 16 79 09 F3 C0 E4 28 A7  32 62 FA F6 60 31 C0 ED
uid                            Guido van Rooij <guido@gvr.win.tue.nl>

pub  1024D/A95102C1 2000-10-25 Guido van Rooij <guido@madison-gurkha.nl>
     Key fingerprint = 5B3E 51B7 0E7A D170 0574  1E51 2471 117F A951 02C1
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sub  1024g/A5F20553 2000-10-25
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Comment: For info see http://www.gnupg.org

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D.3.355. Eygene Ryabinkin <rea@FreeBSD.org >

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pub   3072D/8152ECFB 2010-10-27
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      Key fingerprint = 82FE 06BC D497 C0DE 49EC  4FF0 16AF 9EAE 8152 ECFB
uid                  Eygene Ryabinkin <rea-fbsd@codelabs.ru>
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uid                  Eygene Ryabinkin <rea@codelabs.ru>
sub   3072g/5FC03749 2010-10-27
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D.3.356. Aleksandr Rybalko <ray@FreeBSD.org >

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pub   2048R/4B7B7A4E 2011-05-24
      Key fingerprint = BB9F D01D 7327 0B33 B2F5  6C72 EC49 E6ED 4B7B 7A4E
uid                  Aleksandr Rybalko (Aleksandr Rybalko FreeBSD project ↺
identification) <ray@freebsd.org>
sub   2048R/99F9F9EF 2011-05-24
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D.3.357. Andrew Rybchenko <arybchik@FreeBSD.org >

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pub   2048R/BB509584A3F4AEE6 2014-12-26 [expires: 2017-12-25]
      Key fingerprint = C2E0 7B36 3A25 75E5 75EB  FF79 BB50 9584 A3F4 AEE6
uid                          Andrew Rybchenko <arybchenko@solarflare.com>
uid                          Andrew Rybchenko <arybchik@FreeBSD.org>
uid                          Andrew Rybchenko <Andrew.Rybchenko@oktetlabs.ru>
uid                          Andrew Rybchenko <arybchik@gmail.com>
sub   2048R/BB28B694A902C314 2014-12-26 [expires: 2017-12-25]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.358. Niklas Saers <niklas@FreeBSD.org >

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pub  1024D/C822A476 2004-03-09 Niklas Saers <niklas@saers.com>
     Key fingerprint = C41E F734 AF0E 3D21 7499  9EB1 9A31 2E7E C822 A476
sub  1024g/81E2FF36 2004-03-09
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D.3.359. Boris Samorodov <bsam@FreeBSD.org >

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pub   4096R/960E20B03A3F6D28 2013-11-22 [expires: 2018-11-21]
      Key fingerprint = 8848 3672 3C1B C02B EA0B  5674 960E 20B0 3A3F 6D28
uid                          Boris Samorodov <bsam@FreeBSD.org>
uid                          Boris Samorodov <bsam@passap.ru>
sub   4096R/41BFAE676CF00B2D 2013-11-22 [expires: 2018-11-21]
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D.3.360. Mark Santcroos <marks@FreeBSD.org >

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pub   1024D/DBE7EB8E 2005-03-08
      Key fingerprint = C0F0 44F3 3F15 520F 6E32  186B BE0A BA42 DBE7 EB8E
uid                  Mark Santcroos <marks@ripe.net>
uid                  Mark Santcroos <mark@santcroos.net>
uid                  Mark Santcroos <marks@freebsd.org>
sub   2048g/FFF80F85 2005-03-08
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D.3.361. Alonso Schaich <alonso@FreeBSD.org >

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pub   2048R/FF8F6B6D0AACFC67 2014-08-27 [expires: 2017-08-26]
      Key fingerprint = FED5 7BC8 DEB9 94D9 B52C  0A35 FF8F 6B6D 0AAC FC67
uid                          Alonso Schaich <alonso@freebsd.org>
sub   2048R/34F58C3CB680DE68 2014-08-27 [expires: 2017-08-26]
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=dkSO
-----END PGP PUBLIC KEY BLOCK-----
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D.3.362. Bernhard Schmidt <bschmidt@FreeBSD.org >

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pub   1024D/5F754FBC 2009-06-15
      Key fingerprint = 6B87 C8A9 6BA5 6B18 11CF  8C38 A1B7 0731 5F75 4FBC
uid                  Bernhard Schmidt <bschmidt@FreeBSD.org>
uid                  Bernhard Schmidt <bschmidt@techwires.net>
sub   1024g/1945DC1D 2009-06-15
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.363. Wolfram Schneider <wosch@FreeBSD.org >

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Type Bits/KeyID    Date       User ID
pub  1024/2B7181AD 1997/08/09 Wolfram Schneider <wosch@FreeBSD.org>
            Key fingerprint = CA 16 91 D9 75 33 F1 07  1B F0 B4 9F 3E 95 B6 09
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D.3.364. Ed Schouten <ed@FreeBSD.org >

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pub   2048R/A407DC0D9F74246B 2016-03-03 [expires: 2021-03-02]
      Key fingerprint = F8CB 2A43 4CCA AEE7 F0BF  64A7 A407 DC0D 9F74 246B
uid                          Ed Schouten (FreeBSD, https://freebsd.org/) <ed@freebsd.org>
uid                          Ed Schouten (Nuxi, https://nuxi.nl/) <ed@nuxi.nl>
sub   2048R/66C17FAB03333635 2016-03-03 [expires: 2021-03-02]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.365. Cy Schubert <cy@FreeBSD.org >

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pub   1024D/CC81BA38D8BFCD8E 2000-01-08
      Key fingerprint = 8F40 99AC E9E3 7AB7 CB26  AF0C CC81 BA38 D8BF CD8E
uid                          Cy Schubert <Cy.Schubert@komquats.com>
uid                          Cy Schubert <cy@komquats.com>
uid                          Cy Schubert <cy@FreeBSD.org>
uid                          Cy Schubert <Cy.Schubert@cschubert.com>
uid                          Cy Schubert <cy@cschubert.com>
uid                          Cy Schubert <Cy.Schubert@vibsd.org>
uid                          Cy Schubert <cy@vibsd.org>
uid                          Cy Schubert <Cy.Schubert@vibsd.net>
uid                          Cy Schubert <cy@vibsd.net>
sub   3072g/F1FECA6C86D691BA 2000-01-08
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.366. David Schultz <das@FreeBSD.org >

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pub  1024D/BE848B57 2001-07-19 David Schultz <das@FreeBSD.ORG>
     Key fingerprint = 0C12 797B A9CB 19D9 FDAF  2A39 2D76 A2DB BE84 8B57
uid  David Schultz <dschultz@uclink.Berkeley.EDU>
uid  David Schultz <das@FreeBSD.ORG>
sub  2048g/69206E8E 2001-07-19
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D.3.367. Michael Scheidell <scheidell@FreeBSD.org >

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pub   2048R/34622C1D 2011-11-16
      Key fingerprint = 0A0C 9ECA 18EC 47AC C715  2187 91B9 F9FE 3462 2C1D
uid                  Michael Scheidell <scheidell@freebsd.org>
sub   2048R/8F241971 2011-11-16
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D.3.368. Jens Schweikhardt <schweikh@FreeBSD.org >

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pub  1024D/0FF231FD 2002-01-27 Jens Schweikhardt <schweikh@FreeBSD.org>
     Key fingerprint = 3F35 E705 F02F 35A1 A23E  330E 16FE EA33 0FF2 31FD
uid                           Jens Schweikhardt <schweikh@schweikhardt.net>
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sub  1024g/6E93CACC 2002-01-27 [expires: 2005-01-26]
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.369. Matthew Seaman <matthew@FreeBSD.org >

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uid                           Matthew Seaman <m.seaman@infracaninophile.co.uk>
uid                           Matthew Seaman <matthew.seaman@adestra.com>
uid                           Matthew Seaman <matthew@freebsd.org>
sub   rsa4096/5D0DFEAF7BFB01B4 2013-09-29 [expires: 2018-04-23]
sub   rsa4096/BB23AF518E1A4013 2013-10-06 [expires: 2018-04-23]
sub   rsa4096/E527EC985DBEA0A8 2013-10-06 [expires: 2018-04-23]
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D.3.370. Thomas-Martin Seck <tmseck@FreeBSD.org >

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pub   1024D/DF46EE05 2000-11-22
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      Key fingerprint = A38F AE66 6B11 6EB9 5D1A  B67D 2444 2FE1 DF46 EE05
uid                  Thomas-Martin Seck (Privat 2) <tmseck@netcologne.de>
uid                  Thomas-Martin Seck (Privat) <tmseck@web.de>
uid                  Thomas-Martin Seck (FreeBSD) <tmseck@FreeBSD.org>
sub   2048g/3DC33B0F 2000-11-22
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D.3.371. Stanislav Sedov <stas@FreeBSD.org >

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pub   2048R/5617EAFB 2013-09-15 [expires: 2018-09-14]
      Key fingerprint = 4C01 9D03 543E C623 3FF7  0D34 6D8E 4C9F 5617 EAFB
uid                  Stanislav Sedov <stas@FreeBSD.org>
uid                  Stanislav Sedov <stas@deglitch.com>
sub   2048R/55012891 2013-09-15 [expires: 2018-09-14]
sub   2048R/8E60582E 2013-09-15 [expires: 2018-09-14]
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D.3.372. Johan van Selst <johans@FreeBSD.org >

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pub   4096R/D3AE8D3A 2009-09-01
      Key fingerprint = 31C8 D089 DDB6 96C6 F3C1  29C0 A9C8 6C8D D3AE 8D3A
uid                  Johan van Selst
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uid                  Johan van Selst <johans@gletsjer.net>
uid                  Johan van Selst <johans@stack.nl>
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sub   2048R/B002E38C 2009-09-01
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D.3.373. Lev Serebryakov <lev@FreeBSD.org >

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.374. Bakul Shah <bakul@FreeBSD.org >

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pub   1024D/86AEE4CB 2006-04-20
      Key fingerprint = 0389 26E8 381C 6980 AEC0  10A5 E540 A157 86AE E4CB
uid                  Bakul Shah <bakul@freebsd.org>
sub   2048g/5C3DCC24 2006-04-20
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D.3.375. Gregory Neil Shapiro <gshapiro@FreeBSD.org >

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pub  1024R/4FBE2ADD 2000-10-13 Gregory Neil Shapiro <gshapiro@gshapiro.net>
     Key fingerprint = 56 D5 FF A7 A6 54 A6 B5  59 10 00 B9 5F 5F 20 09
uid                          Gregory Neil Shapiro <gshapiro@FreeBSD.org>
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pub  1024D/F76A9BF5 2001-11-14 Gregory Neil Shapiro <gshapiro@FreeBSD.org>
     Key fingerprint = 3B5E DAF1 4B04 97BA EE20  F841 21F9 C5BC F76A 9BF5
uid                            Gregory Neil Shapiro <gshapiro@gshapiro.net>
sub  2048g/935657DC 2001-11-14

pub  1024D/FCE56561 2000-10-14 Gregory Neil Shapiro <gshapiro@FreeBSD.org>
     Key fingerprint = 42C4 A87A FD85 C34F E77F  5EA1 88E1 7B1D FCE5 6561
uid                            Gregory Neil Shapiro <gshapiro@gshapiro.net>
sub  1024g/285DC8A0 2000-10-14 [expires: 2001-10-14]
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.376. Arun Sharma <arun@FreeBSD.org >

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D.3.377. Wesley Shields <wxs@FreeBSD.org >

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pub   1024D/17F0AA37 2007-12-27
      Key fingerprint = 96D1 2E6B F61C 2F3D 83EF  8F0B BE54 310C 17F0 AA37
uid                  Wesley Shields <wxs@FreeBSD.org>
uid                  Wesley Shields <wxs@atarininja.org>
sub   2048g/2EDA1BB8 2007-12-27
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D.3.378. Norikatsu Shigemura <nork@FreeBSD.org >

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pub   1024D/7104EA4E 2005-02-14
      Key fingerprint = 9580 60A3 B58A 0864 79CB  779A 6FAE 229B 7104 EA4E
uid                  Norikatsu Shigemura <nork@cityfujisawa.ne.jp>
uid                  Norikatsu Shigemura <nork@ninth-nine.com>
uid                  Norikatsu Shigemura <nork@FreeBSD.org>
sub   4096g/EF56997E 2005-02-14
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.379. Shteryana Shopova <syrinx@FreeBSD.org >

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pub   4096R/35047F7A 2013-09-24 [expires: 2018-09-23]
uid                  Shteryana Sotirova Shopova <syrinx@FreeBSD.org>
uid                  Shteryana Sotirova Shopova <shteryana@FreeBSD.org>
uid                  Shteryana Sotirova Shopova <shteryana@gmail.com>
sub   4096R/E509C37A 2013-09-24 [expires: 2018-09-23]
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D.3.380. 徐三泰 <vanilla@FreeBSD.org > <vanilla@FreeBSD.org >

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pub  1024D/ACE75853 2001-11-20 Vanilla I. Shu <vanilla@FreeBSD.org>
     Key fingerprint = 290F 9DB8 42A3 6257 5D9A  5585 B25A 909E ACE7 5853
sub  1024g/CE695D0E 2001-11-20
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Comment: For info see http://www.gnupg.org

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D.3.381. Ashish SHUKLA <ashish@FreeBSD.org >

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.382. Bruce M. Simpson <bms@FreeBSD.org >

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pub  1024D/860DB53B 2003-08-06 Bruce M Simpson <bms@freebsd.org>
     Key fingerprint = 0D5F 1571 44DF 51B7 8B12  041E B9E5 2901 860D B53B
sub  2048g/A2A32D8B 2003-08-06 [expires: 2006-08-05]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.383. Dmitry Sivachenko <demon@FreeBSD.org >

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pub  1024D/13D5DF80 2002-03-18 Dmitry Sivachenko <mitya@cavia.pp.ru>
     Key fingerprint = 72A9 12C9 BB02 46D4 4B13  E5FE 1194 9963 13D5 DF80
uid                            Dmitry S. Sivachenko <demon@FreeBSD.org>
sub  1024g/060F6DBD 2002-03-18
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.384. Jesper Skriver <jesper@FreeBSD.org >

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pub  1024D/F9561C31 2001-03-09 Jesper Skriver <jesper@FreeBSD.org>
     Key fingerprint = 6B88 9CE8 66E9 E631 C9C5  5EB4 22AB F0EC F956 1C31
uid                            Jesper Skriver <jesper@skriver.dk>
uid                            Jesper Skriver <jesper@wheel.dk>
sub  1024g/777C378C 2001-03-09
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.385. Ville Skyttä <scop@FreeBSD.org >

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pub  1024D/BCD241CB 2002-04-07 Ville Skyttä <ville.skytta@iki.fi>
     Key fingerprint = 4E0D EBAB 3106 F1FA 3FA9  B875 D98C D635 BCD2 41CB
uid                            Ville Skyttä <ville.skytta@xemacs.org>
uid                            Ville Skyttä <scop@FreeBSD.org>
sub  2048g/9426F4D1 2002-04-07
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Version: GnuPG v1.0.7 (GNU/Linux)

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D.3.386. Andrey Slusar <anray@FreeBSD.org >

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      Key fingerprint = DE70 C24B 55A0 4A06 68A1  D425 3C59 9A9B AE7B 5418
uid                  Andrey Slusar <anray@ext.by>
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D.3.387. Florian Smeets <flo@FreeBSD.org >

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      Key fingerprint = A701 0320 3BCA B44A 98FE  C844 E705 3DF9 FF86 F076
uid                           Florian Smeets <flo@smeets.xyz>
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D.3.388. Gleb Smirnoff <glebius@FreeBSD.org >

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      Key fingerprint = 6E06 7260 B83D CF2C A93C  566F 5185 0968 6C7E 5E82
uid                  Gleb Smirnoff <glebius@FreeBSD.org>
sub   2048g/11E89DCE 2013-01-30 [expires: 2023-08-25]
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D.3.389. Ken Smith <kensmith@FreeBSD.org >

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pub  1024D/29AEA7F6 2003-12-02 Ken Smith <kensmith@cse.buffalo.edu>
     Key fingerprint = 4AB7 D302 0753 8215 31E7  F1AD FC6D 7855 29AE A7F6
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uid                            Ken Smith <kensmith@freebsd.org>
sub  1024g/0D509C6C 2003-12-02
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D.3.390. Ben Smithurst <ben@FreeBSD.org >

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pub  1024D/2CEF442C 2001-07-11 Ben Smithurst <ben@LSRfm.com>
     Key fingerprint = 355D 0FFF B83A 90A9 D648  E409 6CFC C9FB 2CEF 442C
uid                            Ben Smithurst <ben@vinosystems.com>
uid                            Ben Smithurst <ben@smithurst.org>
uid                            Ben Smithurst <ben@FreeBSD.org>
uid                            Ben Smithurst <csxbcs@comp.leeds.ac.uk>
uid                            Ben Smithurst <ben@scientia.demon.co.uk>
sub  1024g/347071FF 2001-07-11
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.391. Dag-Erling C. Smørgrav <des@FreeBSD.org >

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D.3.392. Maxim Sobolev <sobomax@FreeBSD.org >

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pub  1024D/888205AF 2001-11-21 Maxim Sobolev <sobomax@FreeBSD.org>
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uid                            Maxim Sobolev <sobomax@mail.ru>
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pub  1024D/468EE6D8 2003-03-21 Maxim Sobolev <sobomax@portaone.com>
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D.3.393. Alan Somers <asomers@FreeBSD.org >

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      Key fingerprint = 9CD4 C982 738F 8B90 25E8  E6B3 5F74 63BC DA05 FCE8
uid                  Alan Somers <asomers@freebsd.org>
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sub   4096R/4E121B3E 2013-04-25 [expires: 2018-04-24]
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D.3.394. Brian Somers <brian@FreeBSD.org >

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pub  1024R/666A7421 1997-04-30 Brian Somers <brian@freebsd-services.com>
     Key fingerprint = 2D 91 BD C2 94 2C 46 8F  8F 09 C4 FC AD 12 3B 21
uid                            Brian Somers <brian@awfulhak.org>
uid                            Brian Somers <brian@FreeBSD.org>
uid                            Brian Somers <brian@OpenBSD.org>
uid                            Brian Somers <brian@uk.FreeBSD.org>
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.395. Stacey Son <sson@FreeBSD.org >

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pub   1024D/CE8319F3 2008-07-08
      Key fingerprint = 64C7 8D92 C1DF B940 1171  5ED3 186A 758A CE83 19F3
uid                  Stacey Son <sson@FreeBSD.org>
uid                  Stacey Son <stacey@son.org>
uid                  Stacey Son <sson@byu.net>
uid                  Stacey Son <sson@secure.net>
uid                  Stacey Son <sson@dev-random.com>
sub   2048g/0F724E52 2008-07-08
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.396. Nicolas Souchu <nsouch@FreeBSD.org >

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pub  1024D/C744F18B 2002-02-13 Nicholas Souchu <nsouch@freebsd.org>
     Key fingerprint = 992A 144F AC0F 40BA 55AE  DE6D 752D 0A6C C744 F18B
sub  1024g/90BD3231 2002-02-13
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: Pour information voir http://www.gnupg.org
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D.3.397. Suleiman Souhlal <ssouhlal@FreeBSD.org >

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pub  1024D/2EA50469 2004-07-24 Suleiman Souhlal <ssouhlal@FreeBSD.org>
     Key fingerprint = DACF 89DB 54C7 DA1D 37AF  9A94 EB55 E272 2EA5 0469
sub  2048g/0CDCC535 2004-07-24
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D.3.398. Luiz Otavio O Souza <loos@FreeBSD.org >

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pub   2048R/39165690 2013-07-03
      Key fingerprint = ABC9 71D9 016E 8D4A 936D  D748 6252 872F 3916 5690
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uid                  Luiz Otavio O Souza <loos.br@gmail.com>
uid                  Luiz Otavio O Souza <loos@freebsd.org>
sub   2048R/9D089395 2013-07-03
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.399. Bernard Spil <brnrd@FreeBSD.org >

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pub   4096R/EBF0A7E52E622158 2015-03-06 [expires: 2019-03-06]
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uid                          Bernard Spil <spil@keybase.io>
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D.3.400. Ulrich Spörlein <uqs@FreeBSD.org >

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D.3.401. Rink Springer <rink@FreeBSD.org >

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uid                  Rink Springer <rink@il.fontys.nl>
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D.3.402. Vsevolod Stakhov <vsevolod@FreeBSD.org >

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D.3.403. Ryan Steinmetz <zi@FreeBSD.org >

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      Key fingerprint = 9079 51A3 34EF 0CD4 F228  EDC6 1EF8 BA6B D028 46D7
uid                          Ryan Steinmetz <zi@zi0r.com>
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sub   2048R/A8A08AA9D827E5F8 2014-02-03 [expires: 2019-02-02]
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D.3.404. Lawrence Stewart <lstewart@FreeBSD.org >

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      Key fingerprint = 8FB2 E9A3 39EA 78A1 5E1D  B8A2 9A50 BCFC F40D 9B09
uid                          Lawrence A. Stewart <lstewart@freebsd.org>
uid                          Lawrence A. Stewart <lawrencestewart@gmail.com>
uid                          Lawrence A. Stewart <lstewart@netflix.com>
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D.3.405. Randall R. Stewart <rrs@FreeBSD.org >

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pub   2048R/71D3BF532B7BEF39 2015-04-27 [expires: 2018-04-26]
      Key fingerprint = 835D A1ED 279B E300 175A  5BAA 71D3 BF53 2B7B EF39
uid                          Randall Stewart <rrs@freebsd.org>
sub   2048R/1C2A8AA80F55CAEB 2015-04-27 [expires: 2018-04-26]
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D.3.406. Murray Stokely <murray@FreeBSD.org >

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pub  1024D/0E451F7D 2001-02-12 Murray Stokely <murray@freebsd.org>
     Key fingerprint = E2CA 411D DD44 53FD BB4B  3CB5 B4D7 10A2 0E45 1F7D
sub  1024g/965A770C 2001-02-12
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Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.407. Volker Stolz <vs@FreeBSD.org >

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pub  1024R/3FD1B6B5 1998-06-16 Volker Stolz <vs@freebsd.org>
     Key fingerprint = 69 6F BD A0 2E FE 19 66  CF B9 68 6E 41 7D F9 B9
uid                            Volker Stolz <stolz@i2.informatik.rwth-aachen.de> (LSK)
uid                            Volker Stolz <vs@foldr.org>
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D.3.408. Ryan Stone <rstone@FreeBSD.org >

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pub   1024D/3141B73A 2010-04-13
      Key fingerprint = 4A6D DC04 DDC5 0822 2687  A086 FD3F 16CB 3141 B73A
uid                  Ryan Stone (FreeBSD) <rstone@freebsd.org>
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D.3.409. Søren Straarup <xride@FreeBSD.org >

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pub   1024D/E683AD40 2006-09-28
      Key fingerprint = 8A0E 7E57 144B BC25 24A9  EC1A 0DBC 3408 E683 AD40
uid                  Soeren Straarup <xride@xride.dk>
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sub   2048g/2B18B3B8 2006-09-28
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D.3.410. Marius Strobl <marius@FreeBSD.org >

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uid                          Marius Strobl <marius@FreeBSD.org>
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D.3.411. Carlo Strub <cs@FreeBSD.org >

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      Key fingerprint = 7ECD 92F7 DAB0 D983 34A0  CCD0 3B8A D451 AC3C 43C1
uid                          Carlo Strub <cs@carlostrub.ch>
uid                          Carlo Strub <cs@FreeBSD.org>
sub   4096R/4E5530E5F9B075A5 2014-03-12 [expires: 2015-03-12]
sub   4096R/3685ABB2A694F014 2014-03-12 [expires: 2015-03-12]
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D.3.412. 宋政隆 <clsung@FreeBSD.org > <clsung@FreeBSD.org >

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pub  1024D/956E8BC1 2003-09-12 Cheng-Lung Sung <clsung@FreeBSD.org>
     Key fingerprint = E0BC 57F9 F44B 46C6 DB53  8462 F807 89F3 956E 8BC1
uid                            Cheng-Lung Sung (Software Engineer) <clsung@dragon2.net>
uid                            Cheng-Lung Sung (Alumnus of CSIE, NCTU, Taiwan) ↺
<clsung@sungsung.csie.nctu.edu.tw>
uid                            Cheng-Lung Sung (AlanSung) <clsung@tiger2.net>
uid                            Cheng-Lung Sung (FreeBSD@Taiwan) <clsung@freebsd.csie.↺
nctu.edu.tw>
uid                            Cheng-Lung Sung (Ph.D. Student of NTU.EECS) ↺
<d92921016@ntu.edu.tw>
uid                            Cheng-Lung Sung (FreeBSD Freshman) <clsung@tw.freebsd.org>
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sub  1024g/1FB800C2 2003-09-12
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D.3.413. Gregory Sutter <gsutter@FreeBSD.org >

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pub  1024D/845DFEDD 2000-10-10 Gregory S. Sutter <gsutter@zer0.org>
     Key fingerprint = D161 E4EA 4BFA 2427 F3F9  5B1F 2015 31D5 845D FEDD
uid                            Gregory S. Sutter <gsutter@freebsd.org>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.414. Koichi Suzuki <metal@FreeBSD.org >

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pub  1024D/AE562682 2004-05-23 SUZUKI Koichi <metal@FreeBSD.org>
     Key fingerprint = 92B9 A202 B5AB 8CB6 89FC  6DD1 5737 C702 AE56 2682
sub  4096g/730E604B 2004-05-23
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D.3.415. Ryusuke SUZUKI <ryusuke@FreeBSD.org >

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pub   1024D/63D29724 2009-12-18
      Key fingerprint = B108 7109 2E62 BECB 0F78  FE65 1B9A D1BE 63D2 9724
uid                  Ryusuke SUZUKI <ryusuke@FreeBSD.org>
uid                  Ryusuke SUZUKI <ryusuke@jp.FreeBSD.org>
sub   1024g/5E4DD044 2009-12-18
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D.3.416. Gary W. Swearingen <garys@FreeBSD.org >

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pub   1024D/FAA48AD5 2005-08-22 [expires: 2007-08-22]
      Key fingerprint = 8292 CC3E 81B5 E54F E3DD  F987 FA52 E643 FAA4 8AD5
uid                  Gary W. Swearingen <garys@freebsd.org>
sub   2048g/E34C3CA0 2005-08-22 [expires: 2007-08-22]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.417. Yoshihiro Takahashi <nyan@FreeBSD.org >

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pub   4096R/6624859E 2012-11-18
      Key fingerprint = 1CA5 445E 7ABD BC21 AEC0  7B89 47D7 4EFF 6624 859E
uid                  Yoshihiro TAKAHASHI <nyan@furiru.org>
uid                  Yoshihiro TAKAHASHI <nyan@FreeBSD.org>
uid                  Yoshihiro TAKAHASHI <nyan@jp.FreeBSD.org>
sub   4096R/362726EA 2012-11-18
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D.3.418. Sahil Tandon <sahil@FreeBSD.org >

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pub   2048R/C016D977 2010-04-08
      Key fingerprint = 6AD2 BA99 8E3A 8DA6 DFC1  53CF DBD0 6001 C016 D977
uid                  Sahil Tandon <sahil@tandon.net>
uid                  Sahil Tandon <sahil@FreeBSD.org>
sub   2048R/F7776FBC 2010-04-08
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D.3.419. TAKATSU Tomonari <tota@FreeBSD.org >

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pub   1024D/67F58F29 2009-05-17
      Key fingerprint = 6940 B575 FC4A FA26 C094  279A 4B9B 6326 67F5 8F29
uid                  TAKATSU Tomonari <tota@FreeBSD.org>
sub   2048g/18B112CD 2009-05-17
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D.3.420. Romain Tartière <romain@FreeBSD.org >

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pub   3072R/5112336F 2010-04-09
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      Key fingerprint = 8234 9A78 E7C0 B807 0B59  80FF BA4D 1D95 5112 336F
uid                  Romain Tartière <romain@blogreen.org>
uid                  Romain Tartière (FreeBSD) <romain@FreeBSD.org>
sub   3072R/C1B2B656 2010-04-09
sub   3072R/8F8125F4 2010-04-09
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.421. Sylvio Cesar Teixeira <sylvio@FreeBSD.org >

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pub   2048R/AA7395A1 2009-10-28
      Key fingerprint = B319 6AAF 0016 4308 6D93  E652 3C5F 21A2 AA73 95A1
uid                  Sylvio Cesar Teixeira (My key) <sylvio@FreeBSD.org>
sub   2048R/F758F556 2009-10-28
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D.3.422. Devin Teske <dteske@FreeBSD.org >

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pub   2048R/0xAACC9F947D9E9AB9 2013-11-01 [expires: 2014-11-01]
      Key fingerprint = E052 3882 1097 ABB9 A537 ED2F AACC 9F94 7D9E 9AB92
uid                 [ultimate] Devin Teske (FreeBSD Committer) <dteske@FreeBSD.org>
sub   2048R/0xB29F871CBC396837 2013-11-01 [expires: 2014-11-01]
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D.3.423. Ion-Mihai Tetcu <itetcu@FreeBSD.org >

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pub   4096R/29597D20 2013-05-02
      Key fingerprint = AB6F 39B6 605D E6B7 0D54  ED3D BCA2 129A 2959 7D20
uid                  Ion-Mihai Tetcu (FreeBSD Committer key) <itetcu@FreeBSD.org>
sub   4096R/EC9E17E3 2013-05-02
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.424. Mikhail Teterin <mi@FreeBSD.org >

```
pub  1024R/3FC71479 1995-09-08 Mikhail Teterin <mi@aldan.star89.galstar.com>
     Key fingerprint = 5F 15 EA 78 A5 40 6A 0F  14 D7 D9 EA 6E 2B DA A4
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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.425. Gordon Tetlow <gordon@FreeBSD.org >

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pub  1024D/357D65FB 2002-05-14 Gordon Tetlow <gordont@gnf.org>
     Key fingerprint = 34EF AD12 10AF 560E C3AE  CE55 46ED ADF4 357D 65FB
uid                            Gordon Tetlow <gordon@FreeBSD.org>
sub  1024g/243694AB 2002-05-14
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Version: GnuPG v1.0.7 (FreeBSD)

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D.3.426. Lars Thegler <lth@FreeBSD.org >

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pub  1024D/56B0CA08 2004-05-31 Lars Thegler <lth@FreeBSD.org>
     Key fingerprint = ABAE F98C EA78 1C8D 6FDD  CB27 1CA9 5A63 56B0 CA08
uid                            Lars Thegler <lars@thegler.dk>
sub  1024g/E8C58EF3 2004-05-31
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D.3.427. Jase Thew <jase@FreeBSD.org >

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uid                  [ultimate] Jase Thew <jase@FreeBSD.org>
uid                  [ultimate] Jase Thew <freebsd@beardz.net>
uid                  [ultimate] Jase Thew <jase.thew@googlemail.com>
sub   4096R/0x727970D29B509783 2013-09-24 [expires: 2018-09-23]
sub   4096R/0xD4E65C8BFF1C3829 2013-09-24 [expires: 2018-09-23]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.428. David Thiel <lx@FreeBSD.org >

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pub   1024D/A887A9B4 2006-11-30 [expires: 2011-11-29]
      Key fingerprint = F08F 6A12 738F C9DF 51AC  8C62 1E30 7CBE A887 A9B4
uid                  David Thiel <lx@FreeBSD.org>
sub   2048g/B9BD92C5 2006-11-30 [expires: 2011-11-29]
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D.3.429. Fabien Thomas <fabient@FreeBSD.org >

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pub   1024D/07745930 2009-03-16
      Key fingerprint = D8AC EFA2 2FBD 7788 9628  4E8D 3F35 3B88 0774 5930
uid                  Fabien Thomas <fabient@FreeBSD.org>
sub   2048g/BC173395 2009-03-16
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D.3.430. Thierry Thomas <thierry@FreeBSD.org >

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pub   4096R/F1C516B3C8359753 2013-09-23 [expires: 2018-09-22]
      Key fingerprint = E536 BE85 3853 99D0 0B6F  AA76 F1C5 16B3 C835 9753
uid                  [ultimate] Thierry Thomas <thierry@pompo.net>
uid                  [ultimate] Thierry Thomas <thierry@FreeBSD.org>
uid                  [ultimate] [jpeg image of size 1968]
sub   4096R/32B32808E6B52F4F 2013-09-23 [expires: 2018-09-22]
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D.3.431. Andrew Thompson <thompsa@FreeBSD.org >

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pub   1024D/BC6B839B 2005-05-05
      Key fingerprint = DE74 3F49 B97C A170 C8F1  8423 CAB6 9D57 BC6B 839B
uid                  Andrew Thompson <thompsa@freebsd.org>
uid                  Andrew Thompson <andy@fud.org.nz>
sub   2048g/92E370FB 2005-05-05
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D.3.432. Florent Thoumie <flz@FreeBSD.org >

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pub   1024D/5147DCF4 2004-12-04
      Key fingerprint = D203 AF5F F31A 63E2 BFD5  742B 3311 246D 5147 DCF4
uid                  Florent Thoumie (FreeBSD committer address) <flz@FreeBSD.org>
uid                  Florent Thoumie (flz) <florent@thoumie.net>
uid                  Florent Thoumie (flz) <flz@xbsd.org>
uid                  [jpeg image of size 1796]
sub   2048g/15D930B9 2004-12-04
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D.3.433. Jilles Tjoelker <jilles@FreeBSD.org >

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D.3.434. Ganbold Tsagaankhuu <ganbold@FreeBSD.org >

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pub   4096R/8617408EEAAC693A 2013-10-05 [expires: 2018-10-04]
      Key fingerprint = EB31 9B1E D3EA 4D95 A96E  7103 8617 408E EAAC 693A
uid                          Ganbold Tsagaankhuu <ganbold@freebsd.org>
uid                          Ganbold Tsagaankhuu <ganbold@gmail.com>
sub   4096R/A7E14611600EF443 2013-10-05 [expires: 2018-10-04]
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D.3.435. Michael Tuexen <tuexen@FreeBSD.org >

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pub   1024D/04EEDABE 2009-06-08
      Key fingerprint = 493A CCB8 60E6 5510 A01D  360E 8497 B854 04EE DABE
uid                  Michael Tuexen <tuexen@FreeBSD.org>
sub   2048g/F653AA03 2009-06-08
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D.3.436. Andrew Turner <andrew@FreeBSD.org >

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pub   2048R/31B31614 2010-07-01
      Key fingerprint = 08AC 2C57 F14F FDD1 2232  B5CD AA16 EFB8 31B3 1614
uid                  Andrew Turner <andrew@freebsd.org>
uid                  Andrew Turner <andrew@fubar.geek.nz>
sub   2048R/9ACBF138 2010-07-01
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Ob3EgYwIsqLQVY3y1UkeZri1QOqLHA92IRK+fZDnnjwHv+MWaARKACCVDbCSM2X6
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Xh6u6n09DNBw6vrdAmRQVxmb999tKyYbp4oYdpr03KXO/I+gzAiSoY2QwZ+NB6b1
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.437. Oleksandr Tymoshenko <gonzo@FreeBSD.org >

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pub   2048R/E84FC1018C87C180 2014-01-08 [expires: 2017-01-07]
      Key fingerprint = 4FE9 153B 126D A491 294D  012F E84F C101 8C87 C180
uid                          Oleksandr Tymoshenko (FreeBSD) <gonzo@freebsd.org>
sub   2048R/D6BE683DAEC52F52 2014-01-08 [expires: 2017-01-07]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.438. Hajimu UMEMOTO <ume@FreeBSD.org >

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pub   1024D/BF9071FE 2005-03-17
      Key fingerprint = 1F00 0B9E 2164 70FC 6DC5  BF5F 04E9 F086 BF90 71FE
uid                  Hajimu UMEMOTO <ume@mahoroba.org>
uid                  Hajimu UMEMOTO <ume@FreeBSD.org>
uid                  Hajimu UMEMOTO <ume@jp.FreeBSD.org>
sub   2048g/748DB3B0 2005-03-17
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.439. Jason Unovitch <junovitch@FreeBSD.org >

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pub   rsa2048/6FD49C30161CAA6E 2015-07-27 [expires: 2018-07-26]
      Key fingerprint = 45DF 5459 93BB E377 93CA  CDEE 6FD4 9C30 161C AA6E
uid                          Jason Unovitch <jason.unovitch@gmail.com>
uid                          Jason Unovitch <junovitch@FreeBSD.org>
sub   rsa2048/74E32D39F55621C5 2015-07-27 [expires: 2018-07-26]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.440. Stephan Uphoff <ups@FreeBSD.org >

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pub  2048R/D684B04A 2004-10-06 Stephan Uphoff <ups@freebsd.org>
     Key fingerprint = B5D2 04AE CA8F 7055 7474  3C85 F908 7F55 D684 B04A
uid                            Stephan Uphoff <ups@tree.com>
sub  2048R/A15F921B 2004-10-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.441. Eric van Gyzen <vangyzen@FreeBSD.org >

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pub   rsa2048/AFC12A13EC20DAB8 2015-01-28 [expires: 2018-01-27]
      Key fingerprint = 3E70 4F4A 0D13 41E8 BCE4  D73D AFC1 2A13 EC20 DAB8
uid                          Eric van Gyzen <vangyzen@FreeBSD.org>
uid                          Eric van Gyzen <eric@vangyzen.net>
sub   rsa2048/AEDFC8E4E2244266 2015-01-28 [expires: 2018-01-27]
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D.3.442. Bryan Venteicher <bryanv@FreeBSD.org >

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pub   4096R/E97DB7DB 2012-11-05
      Key fingerprint = 0F8F 11EF F4D2 EDCA ECEA  CB16 744C BF25 E97D B7DB
uid                  Bryan Venteicher (DITC) <bryanv@daemoninthecloset.org>
uid                  Bryan Venteicher (FreeBSD) <bryanv@freebsd.org>
sub   4096R/2EBC1A46 2012-11-05
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.443. Jacques Vidrine <nectar@FreeBSD.org >

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pub  2048R/33C1627B 2001-07-05 Jacques A. Vidrine <nectar@celabo.org>
     Key fingerprint = CB CE 7D A0 6E 01 DC 61  E5 91 0A BE 79 17 D3 82
uid                            Jacques A. Vidrine <jvidrine@verio.net>
uid                            Jacques A. Vidrine <n@nectar.com>
uid                            Jacques A. Vidrine <jacques@vidrine.cc>
uid                            Jacques A. Vidrine <nectar@FreeBSD.org>
uid                            Jacques A. Vidrine <n@nectar.cc>

pub  1024D/1606DB95 2001-07-05 Jacques A. Vidrine <nectar@celabo.org>
     Key fingerprint = 46BC EA5B F70A CC81 5332  0832 8C32 8CFF 1606 DB95
uid                            Jacques A. Vidrine <jvidrine@verio.net>
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.444. Alberto Villa <avilla@FreeBSD.org >

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pub   1024R/44350A8B 2010-01-24
      Key fingerprint = F740 CE4E EDDD DA9B 4A1B  1445 DF18 82EA 4435 0A8B
uid                  Alberto Villa <avilla@FreeBSD.org>
sub   1024R/F7C8254C 2010-01-24
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D.3.445. Nicola Vitale <nivit@FreeBSD.org >

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pub   1024D/F11699E5 2006-12-05
      Key fingerprint = 2C17 C591 2C6D 82BD F3DB  F1BF 8FC9 6763 F116 99E5
uid                  Nicola Vitale (Public key for nivit@FreeBSD.org) <nivit@FreeBSD.org>
sub   2048g/4C90805D 2006-12-05
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D.3.446. Ivan Voras <ivoras@FreeBSD.org >

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pub   1024D/FD08D5063DFF1D2C 2012-04-22
      Key fingerprint = 6141 82D7 8304 0002 EEB3  48E5 FD08 D506 3DFF 1D2C
uid                          Ivan Voras <ivoras@fer.hr>
uid                          Ivan Voras <ivoras@freebsd.org>
uid                          Ivan Voras <ivoras@pirati.hr>
uid                          Ivan Voras <ivoras@gmail.com>
uid                          [jpeg image of size 3697]
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sub   4096g/88C9ED7026B75D25 2012-04-22
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Version: GnuPG v2.0.22 (FreeBSD)

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D.3.447. Andriy Voskoboinyk <avos@FreeBSD.org >

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pub   rsa2048/558F4F536DC10B47 2015-10-19 [expires: 2018-10-18]
      Key fingerprint = 4056 7E58 FA1D D59F F3EA  CC83 558F 4F53 6DC1 0B47
uid                           Andriy Voskoboinyk <avos@freebsd.org>
sub   rsa2048/515B99612E8604AF 2015-10-19 [expires: 2018-10-18]
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D.3.448. Stefan Walter <stefan@FreeBSD.org >

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pub   3072R/12B9E0B3 2003-03-06
      Key fingerprint = 85D8 6A49 22C7 6CD9 B011  5D6A 5691 111B 12B9 E0B3
uid                  Stefan Walter <stefan@freebsd.org>
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sub   3072R/6D35457A 2003-03-06
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.449. 王楷 <kaiw@FreeBSD.org > <kaiw@FreeBSD.org >

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pub   1024D/AEB910EB 2006-09-27
      Key fingerprint = 3534 10A3 F143 B760 EF3E  BEDF 8509 6A06 AEB9 10EB
uid                  Kai Wang <kaiw@FreeBSD.org>
uid                  Kai Wang <kaiw@student.chalmers.se>
uid                  Kai Wang <kaiwang27@gmail.com>
uid                  Kai Wang <kaiw27@gmail.com>
sub   2048g/1D5AA4DD 2006-09-27
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.450. Adam Weinberger <adamw@FreeBSD.org >

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pub   2048R/1CCD0A5830E59D2B 2014-02-03 [expires: 2017-02-02]
      Key fingerprint = F95F 60DB 115C EA59 2FED  E1FB 1CCD 0A58 30E5 9D2B
uid                          Adam Weinberger <adamw@FreeBSD.org>
uid                          Adam Weinberger <adamw@adamw.org>
sub   2048R/92C1C8A42BDE2CCE 2014-02-03 [expires: 2017-02-02]
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D.3.451. Christian Weisgerber <naddy@FreeBSD.org >

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pub   rsa2048/73490227F70EEEA0 2015-05-03
      Key fingerprint = A264 04D3 05A4 189F D662  AF67 7349 0227 F70E EEA0
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uid                          Christian Weisgerber <naddy@mips.inka.de>
uid                          Christian Weisgerber <naddy@FreeBSD.org>
uid                          Christian Weisgerber <naddy@openbsd.org>
sub   rsa2048/1005F0A965D82467 2015-05-03
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.452. Peter Wemm <peter@FreeBSD.org >

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pub   1024D/1512AE527277717F 2003-12-14
      Key fingerprint = 622B 2282 E92B 3BAB 57D1  A417 1512 AE52 7277 717F
uid                          Peter Wemm <peter@wemm.org>
uid                          Peter Wemm <peter@FreeBSD.ORG>
sub   1024g/2C5F53778B40D9D1 2003-12-14

pub   2048R/35D69709EC809E04 2014-05-08 [expires: 2024-05-05]
      Key fingerprint = 060A C0D1 5AFF BDF3 55B8  FA14 35D6 9709 EC80 9E04
uid                          Peter Wemm <peter@wemm.org>
uid                          Peter Wemm <peter@FreeBSD.org>
sub   2048R/B5D591B339B03C75 2014-05-08 [expires: 2024-05-05]
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.453. Nathan Whitehorn <nwhitehorn@FreeBSD.org >

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pub   1024D/FC118258 2008-07-03
      Key fingerprint = A399 BEA0 8D2B 63B3 47B5  056D 8513 5B96 FC11 8258
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uid                  Nathan Whitehorn <nwhitehorn@freebsd.org>
uid                  Nathan Whitehorn <nwhitehorn@icecube.wisc.edu>
uid                  Nathan Whitehorn <nwhitehorn@physics.wisc.edu>
uid                  Nathan Whitehorn <whitehorn@wisc.edu>
sub   2048g/EDB55363 2008-07-03
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.454. Martin Wilke <miwi@FreeBSD.org >

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pub   1024D/B1E6FCE9 2009-01-31
      Key fingerprint = C022 7D60 F598 8188 2635  0F6E 74B2 4884 B1E6 FCE9
uid                  Martin Wilke <miwi@FreeBSD.org>
sub   4096g/096DA69D 2009-01-31
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-----END PGP PUBLIC KEY BLOCK-----
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D.3.455. Nate Williams <nate@FreeBSD.org >

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pub  1024D/C2AC6BA4 2002-01-28 Nate Williams (FreeBSD) <nate@FreeBSD.org>
     Key fingerprint = 8EE8 5E72 8A94 51FA EA68  E001 FFF9 8AA9 C2AC 6BA4
sub  1024g/03EE46D2 2002-01-28
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Version: GnuPG v1.0.6 (FreeBSD)
Comment: For info see http://www.gnupg.org

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D.3.456. Steve Wills <swills@FreeBSD.org >

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      Key fingerprint = 98FA 414A 5C2A 0EF9 CFD0  AD0D F5CF 62B3 207B 1BA1
uid                          Steve Wills <swills@FreeBSD.org>
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D.3.457. Thomas Wintergerst <twinterg@FreeBSD.org >

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uid                  Thomas Wintergerst <twinterg@gmx.de>
uid                  Thomas Wintergerst <twinterg@freebsd.org>
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uid                  Thomas Wintergerst <thomas.wintergerst@nord-com.net>
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D.3.458. Garrett Wollman <wollman@FreeBSD.org >

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pub  1024D/0B92FAEA 2000-01-20 Garrett Wollman <wollman@FreeBSD.org>
     Key fingerprint = 4627 19AF 4649 31BF DE2E  3C66 3ECF 741B 0B92 FAEA
sub  1024g/90D5EBC2 2000-01-20
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Comment: For info see http://www.gnupg.org

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-----END PGP PUBLIC KEY BLOCK-----
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D.3.459. Jörg Wunsch <joerg@FreeBSD.org >

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pub  1024D/69A85873 2001-12-11 Joerg Wunsch <j@uriah.heep.sax.de>
     Key fingerprint = 5E84 F980 C3CA FD4B B584  1070 F48C A81B 69A8 5873
pub  1024D/69A85873 2001-12-11 Joerg Wunsch <j@uriah.heep.sax.de>
uid                            Joerg Wunsch <joerg_wunsch@interface-systems.de>
uid                            Joerg Wunsch <joerg@FreeBSD.org>
uid                            Joerg Wunsch <j@ida.interface-business.de>
sub  1024g/21DC9924 2001-12-11
```

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-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.2.6 (FreeBSD)

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D.3.460. 徐逸鋒 <davidxu@FreeBSD.org > <davidxu@FreeBSD.org >

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pub   1024D/48F2BDAB 2006-07-13 [expires: 2009-07-12]
      Key fingerprint = 7182 434F 8809 A4AF 9AE8  F1B5 12F6 3390 48F2 BDAB
uid                  David Xu <davidxu@freebsd.org>
sub   4096g/ED7DB38A 2006-07-13 [expires: 2009-07-12]
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D.3.461. Maksim Yevmenkin <emax@FreeBSD.org >

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pub  1024D/F050D2DD 2003-10-01 Maksim Yevmenkin <m_evmenkin@yahoo.com>
     Key fingerprint = 8F3F D359 E318 5641 8C81  34AD 791D 53F5 F050 D2DD
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Version: GnuPG v1.2.2 (FreeBSD)

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D.3.462. Mariusz Zaborski <oshogbo@FreeBSD.org >

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pub   rsa4096/DFC2841AE2C6C564 2015-12-03 [expires: 2020-12-01]
      Key fingerprint = 903D 71D3 1909 5D55 58D4  6C1F DFC2 841A E2C6 C564
uid                           Mariusz Zaborski <oshogbo@FreeBSD.org>
uid                           Mariusz Zaborski <oshogbo@vexillium.org>
uid                           Mariusz Zaborski <m.zaborski@wheelsystems.com>
sub   rsa4096/35735C07BCDD5FC7 2015-12-03 [expires: 2020-12-01]
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D.3.463. Thomas Zander <riggs@FreeBSD.org >

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uid                          Thomas Zander <riggs@FreeBSD.org>
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D.3.464. Bjoern A. Zeeb <bz@FreeBSD.org >

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uid                  Bjoern A. Zeeb <bz@zabbadoz.net>
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D.3.465. Niclas Zeising <zeising@FreeBSD.org >

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D.3.466. Alexey Zelkin <phantom@FreeBSD.org >

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D.3.467. 喬彥(王民) <sephe@FreeBSD.org > <sephe@FreeBSD.org >

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D.3.468. Andrey Zonov <zont@FreeBSD.org >

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-----END PGP PUBLIC KEY BLOCK-----
```

FreeBSD Glossary

This glossary contains terms and acronyms used within the FreeBSD community and documentation.

A

ACL	参見 Access Control List.
ACPI	参見 Advanced Configuration and Power Interface.
AMD	参見 Automatic Mount Daemon.
AML	参見 ACPI Machine Language.
API	参見 Application Programming Interface.
APIC	参見 Advanced Programmable Interrupt Controller.
APM	参見 Advanced Power Management.
APOP	参見 Authenticated Post Office Protocol.
ASL	参見 ACPI Source Language.
ATA	参見 Advanced Technology Attachment.
ATM	参見 Asynchronous Transfer Mode.
ACPI Machine Language	Pseudocode, interpreted by a virtual machine within an ACPI-compliant operating system, providing a layer between the underlying hardware and the documented interface presented to the OS.
ACPI Source Language	The programming language AML is written in.
Access Control List	
Advanced Configuration and Power Interface	A specification which provides an abstraction of the interface the hardware presents to the operating system, so that the operating system should need to know nothing about the underlying hardware to make the most of it. ACPI evolves and supercedes the functionality provided previously by APM, PNPBIOS and other technologies, and provides facilities for controlling power consumption, machine suspension, device enabling and disabling, etc.
Application Programming Interface	A set of procedures, protocols and tools that specify the canonical interaction of one or more program parts; how, when and why they do work together, and what data they share or operate on.
Advanced Power Management	
Advanced Programmable Interrupt Controller	
Advanced Technology Attachment	
Asynchronous Transfer Mode	
Authenticated Post Office Protocol	

Automatic Mount Daemon
: A daemon that automatically mounts a filesystem when a file or directory within that filesystem is accessed.

B

BIND
: 參見 Berkeley Internet Name Domain.

BIOS
: 參見 Basic Input/Output System.

BSD
: 參見 Berkeley Software Distribution.

Basic Input/Output System
: The definition of BIOS depends a bit on the context. Some people refer to it as the ROM chip with a basic set of routines to provide an interface between software and hardware. Others refer to it as the set of routines contained in the chip that help in bootstrapping the system. Some might also refer to it as the screen used to configure the boostrapping process. The BIOS is PC-specific but other systems have something similar.

Berkeley Internet Name Domain
: An implementation of the DNS protocols.

Berkeley Software Distribution
: 這是由 U.C. Berkeley 的 Computer Systems Research Group(CSRG) 選來當作他們所改良、修改過的 AT&T's 32V UNIX® 名稱。FreeBSD 則是由 CSRG 的這個心血衍生出來。

Bikeshed Building
: A phenomenon whereby many people will give an opinion on an uncomplicated topic, whilst a complex topic receives little or no discussion. See the FAQ for the origin of the term.

C

CD
: 參見 Carrier Detect.

CHAP
: 參見 Challenge Handshake Authentication Protocol.

CLIP
: 參見 Classical IP over ATM.

COFF
: 參見 Common Object File Format.

CPU
: 參見 Central Processing Unit.

CTS
: 參見 Clear To Send.

CVS
: 參見 Concurrent Versions System.

Carrier Detect
: An RS232C signal indicating that a carrier has been detected.

Central Processing Unit
: Also known as the processor. This is the brain of the computer where all calculations take place. There are a number of different architectures with different instruction sets. Among the more well-known are the Intel-x86 and derivatives, Sun SPARC, PowerPC, and Alpha.

Challenge Handshake Authentication Protocol

Classical IP over ATM

Clear To Send
: An RS232C signal giving the remote system permission to send data.

Common Object File Format

Concurrent Versions System

D

DAC — 参見 Discretionary Access Control.

DDB — 参見 Debugger.

DES — 参見 Data Encryption Standard.

DHCP — 参見 Dynamic Host Configuration Protocol.

DNS — 参見 Domain Name System.

DSDT — 参見 Differentiated System Description Table.

DSR — 参見 Data Set Ready.

DTR — 参見 Data Terminal Ready.

DVMRP — 参見 Distance-Vector Multicast Routing Protocol.

Discretionary Access Control

Data Encryption Standard

Data Set Ready

Data Terminal Ready

Debugger

Differentiated System Description Table

Distance-Vector Multicast Routing Protocol

Domain Name System — The system that converts humanly readable hostnames (i.e., mail.example.net) to Internet addresses and vice versa.

Dynamic Host Configuration Protocol — A protocol that dynamically assigns IP addresses to a computer (host) when it requests one from the server. The address assignment is called a “lease”.

E

ECOFF — 参見 Extended COFF.

ELF — 参見 Executable and Linking Format.

ESP — 参見 Encapsulated Security Payload.

Encapsulated Security Payload

Executable and Linking Format

Extended COFF

F

FADT — 参見 Fixed ACPI Description Table.

FAT — 参見 File Allocation Table.

FAT16 参見 File Allocation Table (16-bit).

FTP 参見 File Transfer Protocol.

File Allocation Table

File Allocation Table (16-bit)

File Transfer Protocol A member of the family of high-level protocols implemented on top of TCP which can be used to transfer files over a TCP/IP network.

Fixed ACPI Description Table

G

GUI 参見 Graphical User Interface.

Giant The name of a mutual exclusion mechanism (a `sleep mutex`) that protects a large set of kernel resources. Although a simple locking mechanism was adequate in the days where a machine might have only a few dozen processes, one networking card, and certainly only one processor, in current times it is an unacceptable performance bottleneck. FreeBSD developers are actively working to replace it with locks that protect individual resources, which will allow a much greater degree of parallelism for both single-processor and multi-processor machines.

Graphical User Interface A system where the user and computer interact with graphics.

H

HTML 参見 HyperText Markup Language.

HUP 参見 HangUp.

HangUp

HyperText Markup Language The markup language used to create web pages.

I

I/O 参見 Input/Output.

IASL 参見 Intel's ASL compiler.

IMAP 参見 Internet Message Access Protocol.

IP 参見 Internet Protocol.

IPFW 参見 IP Firewall.

IPP 参見 Internet Printing Protocol.

IPv4 参見 IP Version 4.

IPv6 参見 IP Version 6.

ISP 参見 Internet Service Provider.

IP Firewall

IP Version 4
: The IP protocol version 4, which uses 32 bits for addressing. This version is still the most widely used, but it is slowly being replaced with IPv6.
另参見 IP Version 6.

IP Version 6
: The new IP protocol. Invented because the address space in IPv4 is running out. Uses 128 bits for addressing.

Input/Output

Intel's ASL compiler
: Intel's compiler for converting ASL into AML.

Internet Message Access Protocol

Internet Printing Protocol

Internet Protocol
: The packet transmitting protocol that is the basic protocol on the Internet. Originally developed at the U.S. Department of Defense and an extremly important part of the TCP/IP stack. Without the Internet Protocol, the Internet would not have become what it is today. For more information, see RFC 791.

Internet Service Provider
: A company that provides access to the Internet.

K

KAME
: Japanese for "turtle", the term KAME is used in computing circles to refer to the KAME Project, who work on an implementation of IPv6.

KDC
: 參見 Key Distribution Center.

KLD
: 參見 Kernel ld(1).

KSE
: 參見 Kernel Scheduler Entities.

KVA
: 參見 Kernel Virtual Address.

Kbps
: 參見 Kilo Bits Per Second.

Kernel ld(1)

Kernel Scheduler Entities
: A kernel-supported threading system. See the project home page for further details.

Kernel Virtual Address

Key Distribution Center

Kilo Bits Per Second
: Used to measure bandwith (how much data can pass a given point at a specified amount of time). Alternates to the Kilo prefix include Mega, Giga, Tera, and so forth.

L

LAN
: 參見 Local Area Network.

LOR
: 參見 Lock Order Reversal.

LPD
: 參見 Line Printer Daemon.

Line Printer Daemon

Local Area Network

A network used on a local area, e.g. office, home, or so forth.

Lock Order Reversal

The FreeBSD kernel uses a number of resource locks to arbitrate contention for those resources. A run-time lock diagnostic system found in FreeBSD-CURRENT kernels (but removed for releases), called witness(4), detects the potential for deadlocks due to locking errors. (witness(4) is actually slightly conservative, so it is possible to get false positives.) A true positive report indicates that "if you were unlucky, a deadlock would have happened here".

True positive LORs tend to get fixed quickly, so check http://lists.FreeBSD.org/mailman/listinfo/freebsd-current and the LORs Seen page before posting to the mailing lists.

M

MAC

參見 Mandatory Access Control.

MADT

參見 Multiple APIC Description Table.

MFC

參見 Merge From Current.

MFP4

參見 Merge From Perforce.

MFS

參見 Merge From Stable.

MIT

參見 Massachusetts Institute of Technology.

MLS

參見 Multi-Level Security.

MOTD

參見 Message Of The Day.

MTA

參見 Mail Transfer Agent.

MUA

參見 Mail User Agent.

Mail Transfer Agent

An application used to transfer email. An MTA has traditionally been part of the BSD base system. Today Sendmail is included in the base system, but there are many other MTAs, such as postfix, qmail and Exim.

Mail User Agent

An application used by users to display and write email.

Mandatory Access Control

Massachusetts Institute of Technology

Merge From Current

MFC 是一個縮寫，它代表了 "Merged From -CURRENT" ，這字眼會在 CVS logs 中常見， 以表示這是從 -CURRENT 中整合進其他分支(通常是 -STABLE)的 patch 或功能。

Merge From Perforce

To merge functionality or a patch from the Perforce repository to the -CURRENT branch.
另參見 Perforce.

Merge From Stable

In the normal course of FreeBSD development, a change will be committed to the -CURRENT branch for testing before being merged to -STABLE. On rare occasions, a change will go into -STABLE first and then be merged to -CURRENT.

This term is also used when a patch is merged from -STABLE to a security branch.

	另参見 Merge From Current.
Message Of The Day	A message, usually shown on login, often used to distribute information to users of the system.
Multi-Level Security	
Multiple APIC Description Table	

N

NAT	參見 Network Address Translation.
NDISulator	參見 Project Evil.
NFS	參見 Network File System.
NTFS	參見 New Technology File System.
NTP	參見 Network Time Protocol.
Network Address Translation	
Network File System	
New Technology File System	A filesystem developed by Microsoft and available in its “New Technology” operating systems, such as Windows® 2000, Windows NT® and Windows® XP.
Network Time Protocol	

O

OBE	參見 Overtaken By Events.
ODMR	參見 On-Demand Mail Relay.
OS	參見 Operating System.
On-Demand Mail Relay	
Operating System	A set of programs, libraries and tools that provide access to the hardware resources of a computer. Operating systems range today from simplistic designs that support only one program running at a time, accessing only one device to fully multi-user, multi-tasking and multi-process systems that can serve thousands of users simultaneously, each of them running dozens of different applications.
Overtaken By Events	Indicates a suggested change (such as a Problem Report or a feature request) which is no longer relevant or applicable due to such things as later changes to FreeBSD, changes in networking standards, the affected hardware having since become obsolete, and so forth.

P

p4	參見 Perforce.
PAE	參見 Physical Address Extensions.
PAM	參見 Pluggable Authentication Modules.

PAP — 参見 Password Authentication Protocol.

PC — 参見 Personal Computer.

PCNSFD — 参見 Personal Computer Network File System Daemon.

PDF — 参見 Portable Document Format.

PID — 参見 Process ID.

POLA — 参見 Principle Of Least Astonishment.

POP — 参見 Post Office Protocol.

POP3 — 参見 Post Office Protocol Version 3.

PPD — 参見 PostScript Printer Description.

PPP — 参見 Point-to-Point Protocol.

PPPoA — 参見 PPP over ATM.

PPPoE — 参見 PPP over Ethernet.

PPP over ATM

PPP over Ethernet

PR — 参見 Problem Report.

PXE — 参見 Preboot eXecution Environment.

Password Authentication Protocol

Perforce — A source code control product made by Perforce Software which is more advanced than CVS. Although not open source, it use is free of charge to open-source projects such as FreeBSD.

Some FreeBSD developers use a Perforce repository as a staging area for code that is considered too experimental for the -CURRENT branch.

Personal Computer

Personal Computer Network File System Daemon

Physical Address Extensions — A method of enabling access to up to 64 GB of RAM on systems which only physically have a 32-bit wide address space (and would therefore be limited to 4 GB without PAE).

Pluggable Authentication Modules

Point-to-Point Protocol

Pointy Hat — A mythical piece of headgear, much like a `dunce cap`, awarded to any FreeBSD committer who breaks the build, makes revision numbers go backwards, or creates any other kind of havoc in the source base. Any committer worth his or her salt will soon accumulate a large collection. The usage is (almost always?) humorous.

Portable Document Format

Post Office Protocol

Post Office Protocol Version 3

PostScript Printer Description

Preboot eXecution Environment

Principle Of Least Astonishment
在 FreeBSD 的發展過程中，任何的改變幅度，都不該讓使用者習慣感到不適。 舉例來說：若任意調動 `/etc/defaults/rc.conf` 中的系統啓動順序， 就是違背 POLA 原則的精神。任何開發人員，都該在做出重大改變前， 先三思是否會與 POLA 原則有所違背。

Problem Report
A description of some kind of problem that has been found in either the FreeBSD source or documentation. See Writing FreeBSD Problem Reports.

Process ID
A number, unique to a particular process on a system, which identifies it and allows actions to be taken against it.

Project Evil
The working title for the NDISulator, written by Bill Paul, who named it referring to how awful it is (from a philosophical standpoint) to need to have something like this in the first place. The NDISulator is a special compatibility module to allow Microsoft Windows™ NDIS miniport network drivers to be used with FreeBSD/i386. This is usually the only way to use cards where the driver is closed-source. See `src/sys/compat/ndis/subr_ndis.c` .

R

RA
參見 Router Advertisement.

RAID
參見 Redundant Array of Inexpensive Disks.

RAM
參見 Random Access Memory.

RD
參見 Received Data.

RFC
參見 Request For Comments.

RISC
參見 Reduced Instruction Set Computer.

RPC
參見 Remote Procedure Call.

RS232C
參見 Recommended Standard 232C.

RTS
參見 Request To Send.

Random Access Memory

Received Data

Recommended Standard 232C
A standard for communications between serial devices.

Reduced Instruction Set Computer

Redundant Array of Inexpensive Disks

Remote Procedure Call

repocopy
參見 Repository Copy.

Repository Copy

repocopy(“repository copy” 的縮寫）就是直接從 CVS repository 中複製檔案。

若不用 repocopy 的方式，那麼若要在 repository 內複製、移動檔案的話， committer 就必須執行 `cvs add` 來把檔案放到新位置， 並且還要執行 `cvs rm` 來刪除舊檔。

剛剛講的這種方式的缺點在於，該檔的之前相關紀錄（比如在 CVS logs 中的相關項目）並不會隨之而複製到新地方去。 而 FreeBSD 計劃中認為這些歷史記錄都是相當有用的， 所以會經常採用 repository copy 的方式。 這也就是為何 repository 管理員會直接在 repository 內複製檔案的方式， 而非採取 cvs(1) 程式來進行 `cvs add`、`cvs rm`之類的動作。

Request For Comments

A set of documents defining Internet standards, protocols, and so forth. See www.rfc-editor.org.

Also used as a general term when someone has a suggested change and wants feedback.

Request To Send

Router Advertisement

S

SCI

參見 System Control Interrupt.

SCSI

參見 Small Computer System Interface.

SG

參見 Signal Ground.

SMB

參見 Server Message Block.

SMP

參見 Symmetric MultiProcessor.

SMTP

參見 Simple Mail Transfer Protocol.

SMTP AUTH

參見 SMTP Authentication.

SSH

參見 Secure Shell.

STR

參見 Suspend To RAM.

SMTP Authentication

Server Message Block

Signal Ground

An RS232 pin or wire that is the ground reference for the signal.

Simple Mail Transfer Protocol

Secure Shell

Small Computer System Interface

Suspend To RAM

Symmetric MultiProcessor

System Control Interrupt

T

TCP
参見 Transmission Control Protocol.

TCP/IP
参見 Transmission Control Protocol/Internet Protocol.

TD
参見 Transmitted Data.

TFTP
参見 Trivial FTP.

TGT
参見 Ticket-Granting Ticket.

TSC
参見 Time Stamp Counter.

Ticket-Granting Ticket

Time Stamp Counter
A profiling counter internal to modern Pentium® processors that counts core frequency clock ticks.

Transmission Control Protocol
A protocol that sits on top of (e.g.) the IP protocol and guarantees that packets are delivered in a reliable, ordered, fashion.

Transmission Control Protocol/Internet Protocol
The term for the combination of the TCP protocol running over the IP protocol. Much of the Internet runs over TCP/IP.

Transmitted Data

Trivial FTP

U

UDP
参見 User Datagram Protocol.

UFS1
参見 Unix File System Version 1.

UFS2
参見 Unix File System Version 2.

UID
参見 User ID.

URL
参見 Uniform Resource Locator.

USB
参見 Universal Serial Bus.

Uniform Resource Locator

Unix File System Version 1

Unix File System Version 2

Universal Serial Bus

User ID
A unique number assigned to each user of a computer, by which the resources and permissions assigned to that user can be identified.

User Datagram Protocol

V

VPN
参見 Virtual Private Network.

Virtual Private Network

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版本記錄

本手冊是由數以百計 “The FreeBSD 文件計劃” 的志願工作者所合作而成。 這些文字是由依據 DocBook DTD 規範的XML所寫， 並由XSLT將XML轉換成其他不同格式。 要是沒有 Donald Knuth 的 TeX 排版語言， Leslie Lamport 的 LaTeX, 或 Sebastian Rahtz 的 JadeTeX 巨集套件的重要貢獻， 本文件的印刷版本將無以完成。