The NetBSD Guide

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The NetBSD Developers

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by The NetBSD Developers

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Table of Contents

List of Tables

Purpose of this guide

This guide describes the installation and the configuration of the NetBSD operating system as well as the setup and administration of some of its subsystems. It primarily addresses people coming from other Unix-like operating systems, and aims to be a useful guide in the face of the many small problems one encounters when using a new tool.

This guide is not a Unix tutorial: basic knowledge of some concepts and tools is assumed. You should know, for example, what a file and a directory are, and how to use an editor. There are plenty of books explaining basic Unix and operating system concepts, and you should consult one if you need more background information. It is better to choose a general book and avoid titles like "Learning Unix-XYZ, version 1.2.3.4 in 10 days", but this is a matter of personal taste.

Much work is still required to finish this introduction to NetBSD: some chapters are not finished (some are not even started) and some subjects need more testing. Corrections and additions are most certainly welcome.

This guide is currently maintained by the NetBSD www team (<`www@NetBSD.org`>). Corrections and suggestions should be sent to that address. See also Appendix B.

I. About NetBSD

Chapter 1

What is NetBSD?

NetBSD is a free, fast, secure, and highly portable Unix-like Open Source operating system. It is available for many platforms, from 64-bit x86 servers and PC desktop systems to embedded ARM- and MIPS- based devices. Its clean design and advanced features make it excellent in both production and research environments, and it is user-supported with complete source. Many applications are easily available through pkgsrc, the NetBSD Packages Collection.

1.1 The story of NetBSD

The first version of NetBSD (0.8) dates back to 1993 and springs from the 4.3BSD Lite operating system, a version of Unix developed at the University of California, Berkeley (BSD = Berkeley Software Distribution), and from the 386BSD system, the first BSD port to the Intel 386 CPU. In the following years, modifications from the 4.4BSD Lite release (the last release from the Berkeley group) were integrated into the system. The BSD branch of Unix has had a great importance and influence on the history of Unix-like operating systems, to which it has contributed many tools, ideas and improvements which are now standard: the vi editor, the C shell, job control, the Berkeley Fast File System, reliable signals, support for virtual memory and TCP/IP, just to name a few. This tradition of research and development survives today in the BSD systems and, in particular, in NetBSD.

1.2 NetBSD features

NetBSD operates on a vast range of hardware platforms and is very portable. The full source to the NetBSD kernel and userland is available for all the supported platforms; please see the details on the official site of the NetBSD Project (http://www.NetBSD.org/).

The basic features of NetBSD are:

- Code quality and correctness
- Portability to a wide range of hardware
- Secure defaults
- Adherence to industry standards
- Research and innovation

These characteristics also bring indirect advantages. For example, if you work on just one platform you could think that you're not interested in portability. But portability is tied to code quality; without a well-written and well-organized code base it would be impossible to support a large number of platforms. And code quality is the base of any good and solid software system, though surprisingly few people seem to understand it.

One of the key characteristics of NetBSD is that its developers are not satisfied with partial implementations. Some systems seem to have the philosophy of “If it works, it’s right”. In that light, NetBSD’s philosophy could be described as “It doesn’t work unless it’s right”. Think about how many overgrown programs are collapsing under their own weight and “features” and you’ll understand why NetBSD tries to avoid this situation at all costs.

1.3 Supported platforms

NetBSD supports many platforms, including the popular i386 and amd64, ARM, SPARC, Alpha, Amiga, Atari, and m68k- and PowerPC-based Apple Macintosh machines. Technical details for all of them can be found on the NetBSD site (http://www.NetBSD.org/ports/).

1.4 NetBSD’s target users

The NetBSD site states that: “The NetBSD Project provides a freely available and redistributable system that professionals, hobbyists, and researchers can use in whatever manner they wish”. It is also an ideal system if you want to learn Unix, mainly because of its adherence to standards (one of the project goals) and because it works equally well on the latest PC hardware as well as on hardware which is considered obsolete by many other operating systems. To learn and use Unix you don’t need to buy expensive hardware; you can use that old PC or Mac in your attic. It is important to note that although NetBSD runs on old hardware, modern hardware is well supported and care has been taken to ensure that supporting old machines does not inhibit performance on modern hardware. In addition, if you need a Unix system which runs consistently on a variety of platforms, NetBSD is probably your best choice.

1.5 Applications for NetBSD

Aside from the standard Unix productivity tools, editors, formatters, C/C++ compilers and debuggers, and so on, that are included with the base system, there is a huge collection of packages (currently over 20,000) that can be installed as binary packages or built from pkgsrc, including popular cross-platform software such as Firefox, PostgreSQL, Python, and Xfce.

1.6 How to get NetBSD

NetBSD is an Open Source operating system, and as such it is freely available for download from cdn.NetBSD.org (http://cdn.NetBSD.org) and other mirrors (http://www.NetBSD.org/mirrors/).

II. System installation and related issues

Chapter 2

Installing NetBSD: Preliminary considerations and preparations

2.1 Preliminary considerations

2.1.1 Dual booting

It is possible to install NetBSD together with other operating systems on one hard disk.

If there is already an operating system on the hard disk, think about how you can free some space for NetBSD; if NetBSD will share the disk with other operating systems you will probably need to create a new partition (which you will do with sysinst). Oftentimes this will not be possible unless you resize an existing partition.

Unfortunately, it is not possible to resize an existing partition with sysinst, but there are some commercial products (like Partition Magic) and some free tools (GNU Parted, FIPS, pfdisk) available for this.

You can also install NetBSD on a separate hard disk.

> **Advice:** Unless you are comfortable with setting up a partitioning scheme for two or more operating systems, and unless you understand the risk of data loss if you should make a mistake, it is recommended that you give NetBSD its own hard disk. This removes the risk of damage to the existing operating system.

2.1.2 NetBSD on emulation and virtualization

It is possible to install and run NetBSD on top of other operating systems without having to worry about partitioning. Emulators or virtualization environments provide a quick and secure way to try out NetBSD. The host operating system remains unchanged, and the risk of damaging important data is minimized.

Information about NetBSD as a Xen host and guest system is available on the NetBSD/xen web page (http://www.NetBSD.org/ports/xen/).

The NetBSD on emulated hardware (http://www.NetBSD.org/ports/emulators.html) web page provides detailed information about various emulators and the supported NetBSD platforms. It should also be noted that NetBSD runs as a VMware guest.

2.2 Install preparations

2.2.1 The INSTALL document

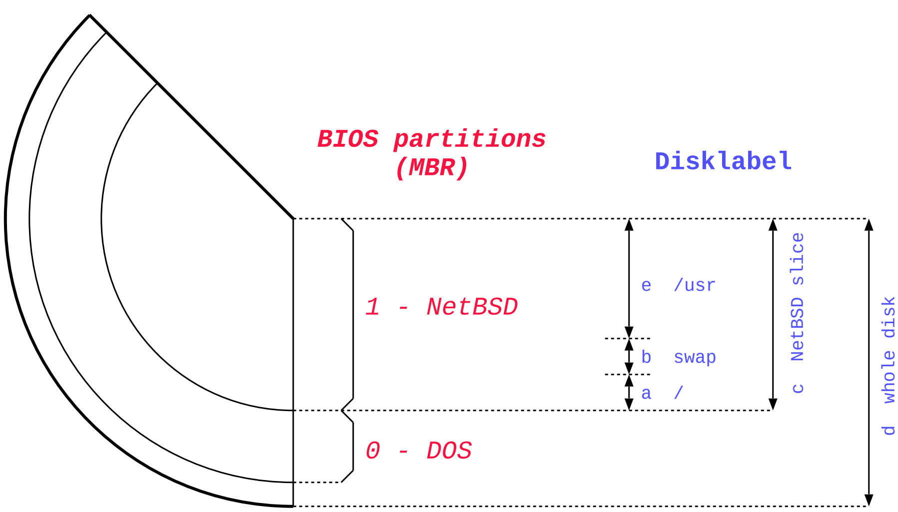
The first thing to do before installing NetBSD is to read the release information and installation notes in one of the `INSTALL` files: this is the official description of the installation procedure, with platform-specific information and important details. It is available in HTML, PostScript, plain text, and an enhanced text format to be used with more. These files can be found in the root directory of the NetBSD release (on the install CD or on the FTP server). For example, the amd64 install instructions are available at ftp.NetBSD.org/pub/NetBSD/NetBSD-9.3/amd64/INSTALL.html (//ftp.NetBSD.org/pub/NetBSD/NetBSD-9.3/amd64/INSTALL.html)

2.2.2 Partitions

The terminology used by NetBSD for partitioning is different from the typical DOS/Windows terminology; in fact, there are two partitioning schemes involved when running NetBSD on a typical PC. NetBSD installs in one of the four primary BIOS partitions (the partitions defined in the hard disk partition table).

Within a BIOS partition (also called *slice*) NetBSD defines its BSD partitions using a *disklabel*. These partitions can be seen only by NetBSD and are identified by lowercase letters (starting with “a”). For example, wd0a refers to the “a” partition of the first IDE disk (wd0) and sd0a refers to the “a” partition of the first SCSI disk. In Figure 2-1 there are two primary BIOS partitions, one used by DOS and the other by NetBSD. NetBSD describes the disk layout through the disklabel.

Figure 2-1. Partitions



Note: The meaning of partitions “c” and “d” is typical of the amd64 port. On most other ports, “c” represents the whole disk.

Note: If NetBSD shares the hard disk with another operating system (like in the previous example) you will want to install a *boot manager*, i.e., a program which lets you choose which OS to start at boot time. sysinst can do this for you and will ask if you want to install one. Unless you have specific reasons not to, you should let sysinst perform this step.

2.2.3 Hard disk space requirements

The exact amount of space required for a given NetBSD installation varies depending on the platform being used and which distribution sets are selected. Generally speaking, if you have a few GB of free space on your hard drive, you will have enough space for a full installation of the base system.

2.2.4 Network settings

If you plan to fetch distribution sets over the network (not necessary if you downloaded a full-size install ISO) and do not use DHCP, write down your basic network settings. You will need:

- Your IP address (example: 192.168.1.7)
- the netmask (example: 255.255.255.0)
- the IP address of your default gateway (example: 192.168.1.1)
- the IP address of the DNS server you use (example: 145.253.2.75)

2.2.5 Backup your data and operating systems!

Before you begin the installation, make sure that you have a reliable backup of any operating systems and data on the used hard disk. Mistakes in partitioning your hard disk can lead to data loss. Existing operating systems may become unbootable. "Reliable backup" means that the backup and restore procedure is tested and works flawlessly!

2.2.6 Preparing the installation media

The NetBSD installation system consists of two parts. The first part is the installation kernel. This kernel contains the NetBSD install program sysinst and it is booted from the install media (e.g, CD/DVD, USB drive, memory card, etc.). The sysinst program will prepare the disk: it separates the disk space into partitions, makes the disk bootable and creates the necessary file systems.

The second part of the install system is made up of the binary distribution sets: the files of the NetBSD operating system. The installer needs to have access to the distribution sets. sysinst will usually fetch these files from the install media you booted from, but it can also fetch them via FTP, NFS, or a local filesystem.

The NetBSD Project provides complete install media (https://cdn.NetBSD.org/pub/NetBSD/NetBSD-9.3/images/) for every supported hardware architecture. This is usually in the form of bootable CD images (`.iso` files).

2.2.6.1 Booting the install system from USB

To use a bootable USB install image (on amd64, i386), download the `img.gz` file for your hardware architecture, decompress and copy the image to a USB. For example on a Unix-like system you may use:

```
# gunzip NetBSD-9.3-amd64-install.img.gz
# dd if=NetBSD-9.3-amd64-install.img of=/dev/your-usb bs=2m
```

Examples of `your-usb` are `/dev/rsd0d` (NetBSD), `/dev/sda` (Linux).

Caution

Selecting the wrong device in **dd** may destroy your current system. Double-check it isn't mounted and is your USB stick. It should appear at the bottom of **dmesg** on connect, for example, if you see:

```
sd0 at scsibus0 target 0 lun 0: [...], disk removable
```

on NetBSD, you will want to select `/dev/rsd0d`.

2.2.6.2 Booting the install system from CD

To use a bootable NetBSD install CD, download the `iso` file for your hardware architecture and burn it to a CD or DVD. You will need to handle this step alone, as burning programs vary widely. Ensure that your computer is set up to boot from CD-ROM before hard drives, insert the disc, and reboot the computer.

2.3 Checklist

This is the checklist about the things that should be clear and on-hand now:

- Available disk space
- Bootable medium with the install system
- CD/DVD or server with the distribution sets
- Your network information (only if you will be fetching distribution sets via the network and do not use DHCP)
- A working backup
- A copy of the INSTALL document

Chapter 3
Example installation

3.1 Introduction

This chapter will guide you through the installation process. The concepts presented here apply to all installation methods. The only difference is in the way the distribution sets are fetched by the installer. Some details of the installation differ depending on the NetBSD release. The examples from this chapter were created with NetBSD 8.0.

> **Note:** The following install screens are just examples. Do not simply copy them, as your hardware and configuration details may be different!

3.2 The installation process

The installation process is divided logically into two parts. In the first part, you create a partition for NetBSD and write the disklabel for that partition. In the second part, you decide which distribution sets (subsets of the operating system) you want to install and then extract the files into the newly created partition(s).

3.3 Keyboard layout

The NetBSD install program sysinst allows you to change the keyboard layout during the installation. If for some reason this does not work for you, you can use the map in the following table.

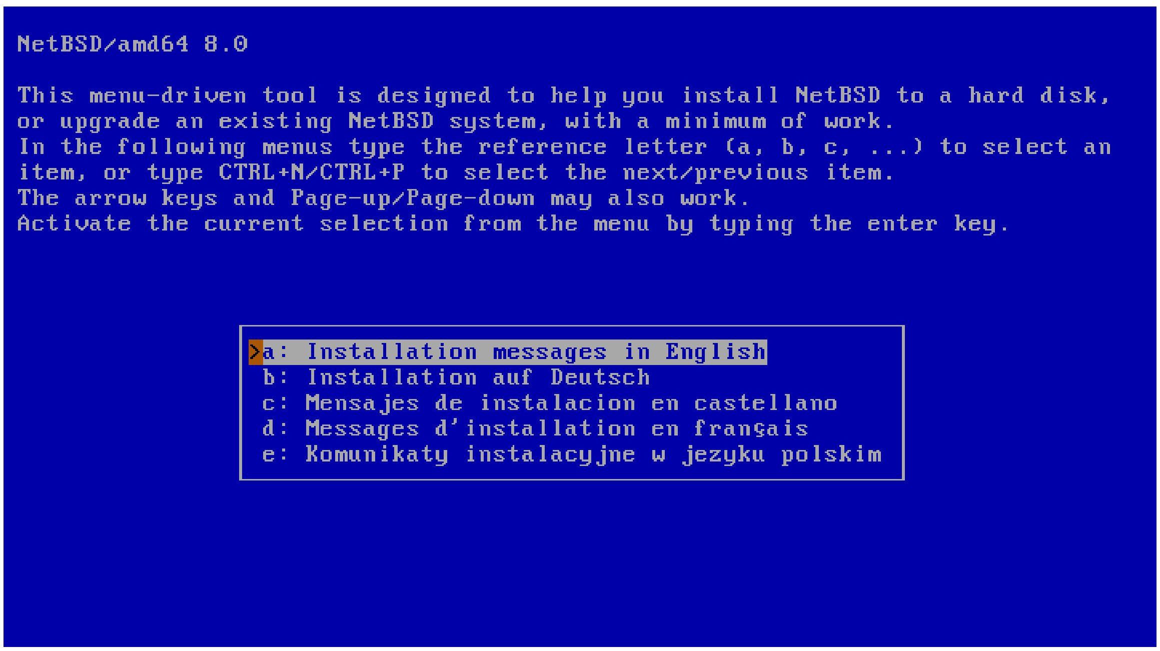
US	IT	DE	FR
-	’	ß	)
/	-	-	!
=	ì	’	-
:	ç	Ö	M
;	ò	ö	m
#	£	§	3
"	°	Ä	%
*	(	(	8
(	)	)	9
)	=	=	0

US	IT	DE	FR
’	à	ä	ù
‘	\	^	@
\	ù	#	‘

3.4 Starting the installation

To start the installation of NetBSD, insert your chosen boot medium (CD/DVD, USB drive, floppy, etc.) and reboot the computer. The kernel on the installation medium will be booted and it will start displaying a lot of messages on the screen about hardware being detected.

Figure 3-1. Selecting the language

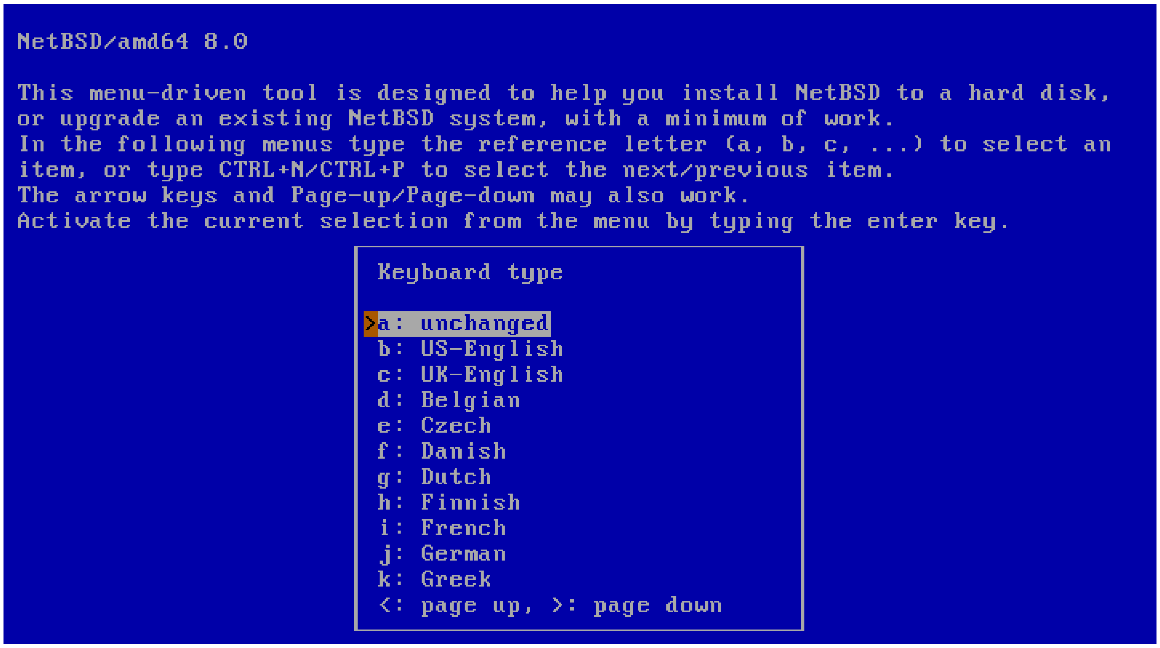


When the kernel has booted, you will find yourself in the NetBSD installation program, sysinst, shown in Figure 3-1. From here on, you should follow the instructions displayed on the screen, using the `INSTALL` document as a companion reference. You will find the INSTALL document in various formats in the root directory of the NetBSD release. The sysinst screens all have more or less the same layout: the upper part of the screen shows a short description of the current operation or a short help message, and the rest of the screen is made up of interactive menus and prompts. To make a choice, use the cursor keys, the “Ctrl+N” (next) and “Ctrl+P” (previous) keys, or press one of the letters displayed left of each choice. Confirm your choice by pressing the Return (also known as “Enter”) key.

Start by selecting the language you prefer to use for the installation process.

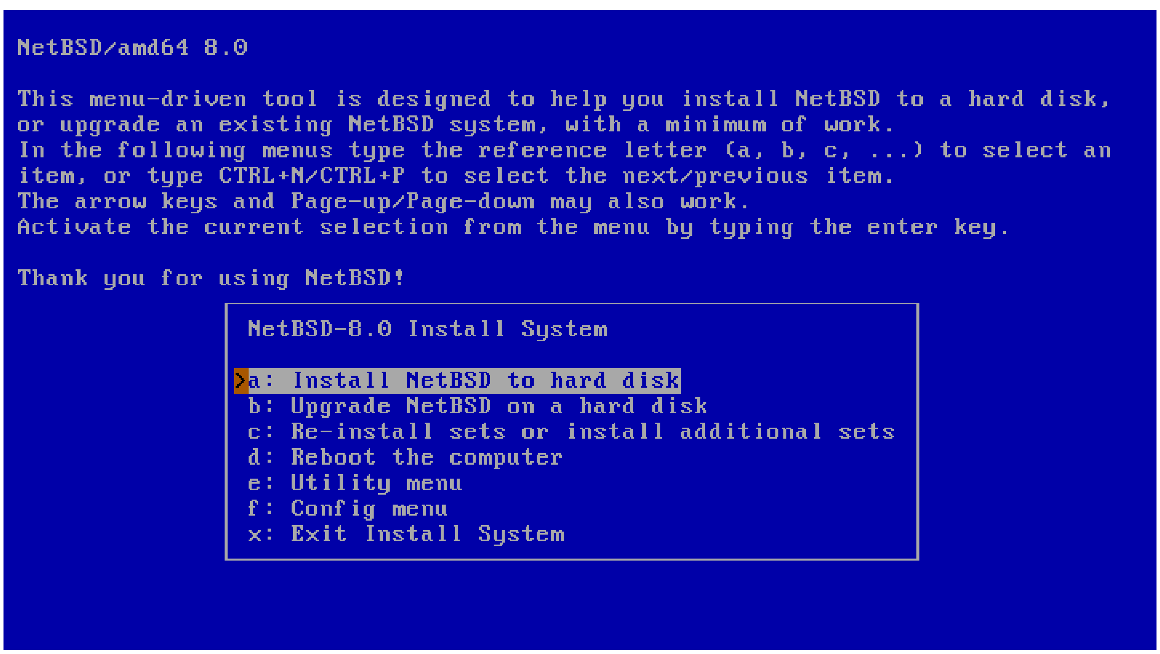
The next screen Figure 3-2 will allow you to select a suitable keyboard type.

Figure 3-2. Selecting a keyboard type



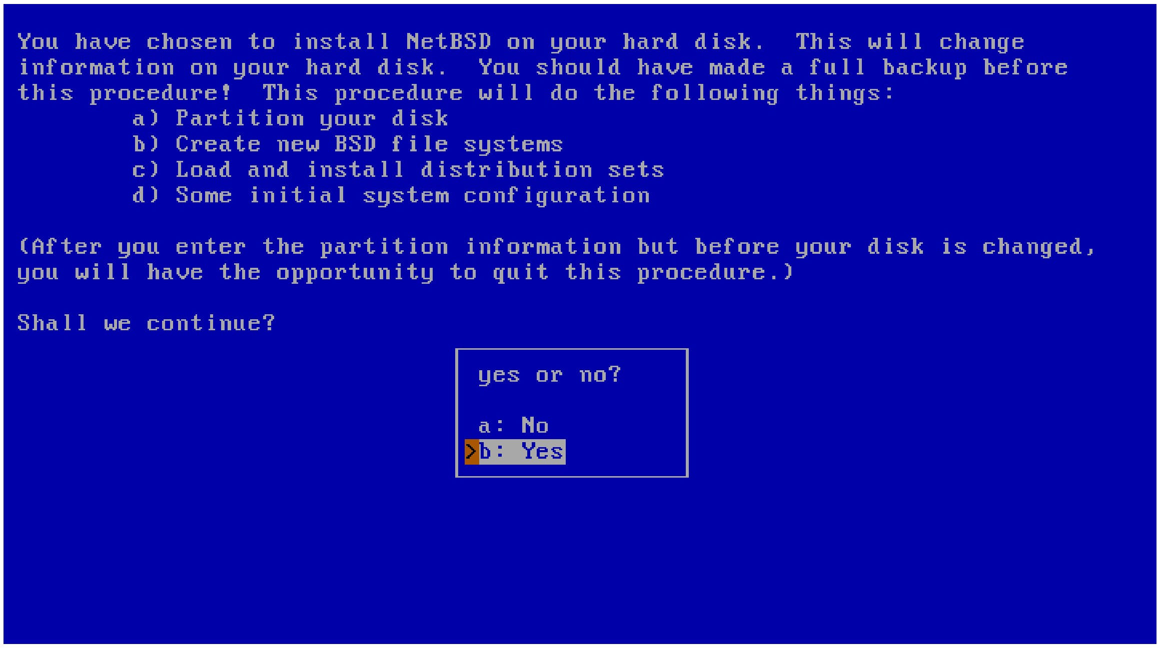
This will bring you to the main menu of the installation program (Figure 3-3).

Figure 3-3. The sysinst main menu



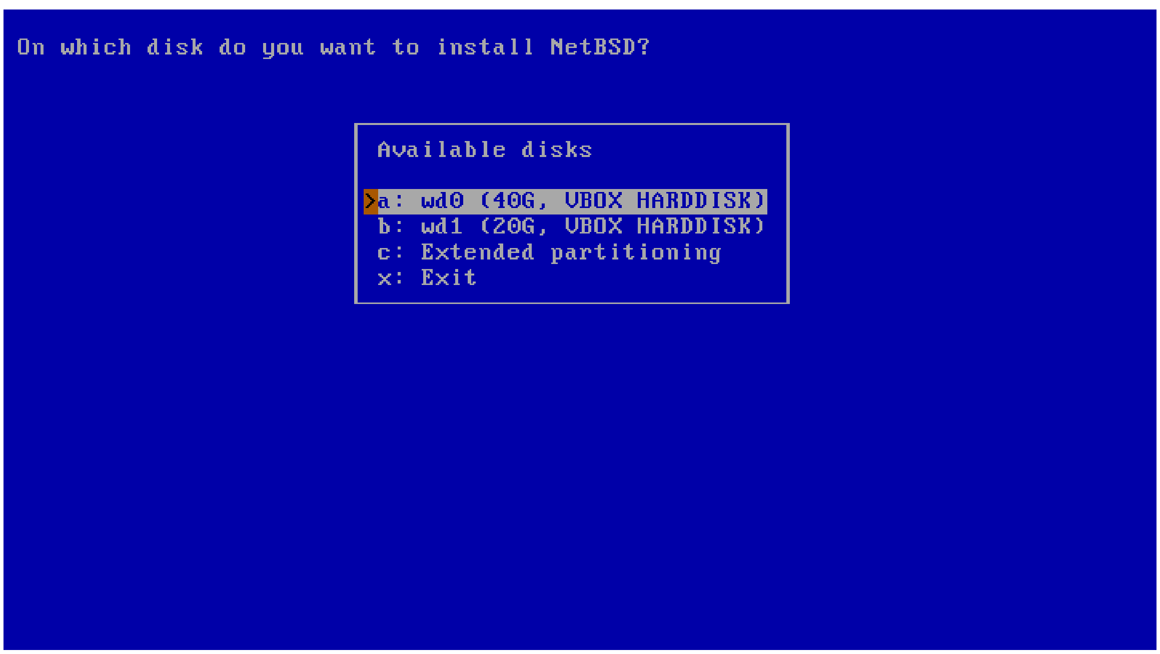
Choosing the “Install NetBSD to hard disk” option brings you to the next screen (Figure 3-4), where you need to confirm that you want to continue the installation.

Figure 3-4. Confirming to install NetBSD



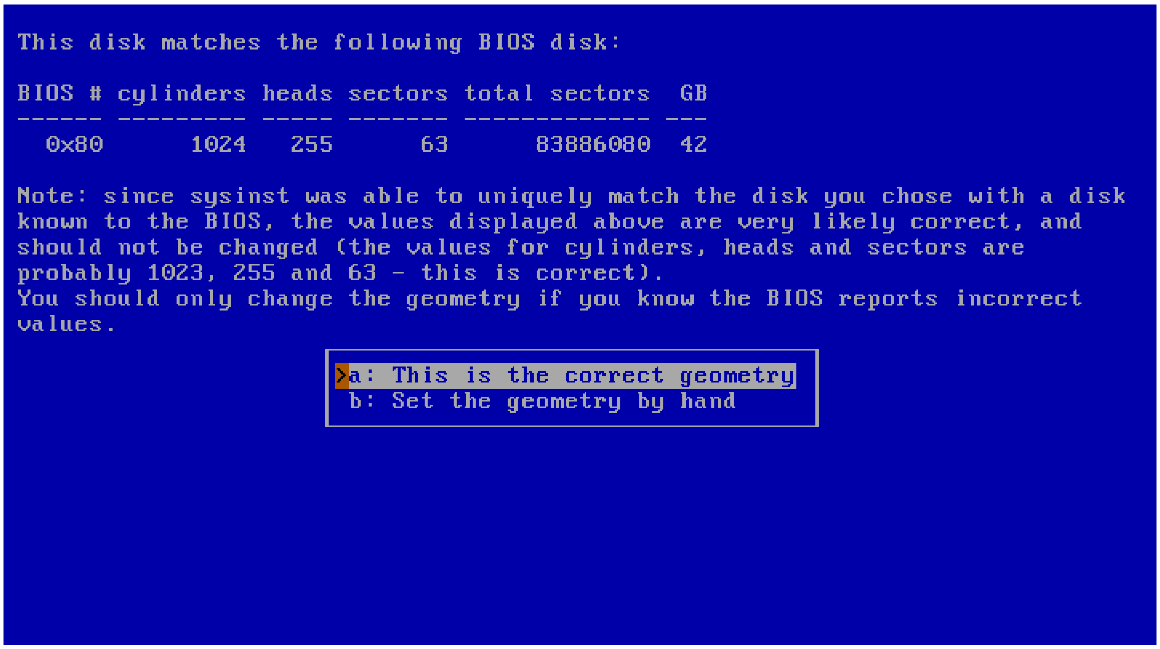
After choosing “Yes” to continue, sysinst displays a list of one or more disks and asks which one you want to install NetBSD on. In the example of Figure 3-5, two disks are listed, and NetBSD will be installed on “wd0”, the first SATA or IDE disk found. If you use SCSI or external USB disks, the first one will be named “sd0”, the second one “sd1” and so on.

Figure 3-5. Choosing a hard disk



Then the installer will ask you to confirm the detected disk geometry from the information provided by the BIOS, as shown in Figure 3-6. It almost always gives the right values. Choose “This is the correct geometry”, unless you know that the information provided by your BIOS is reportedly incorrect.

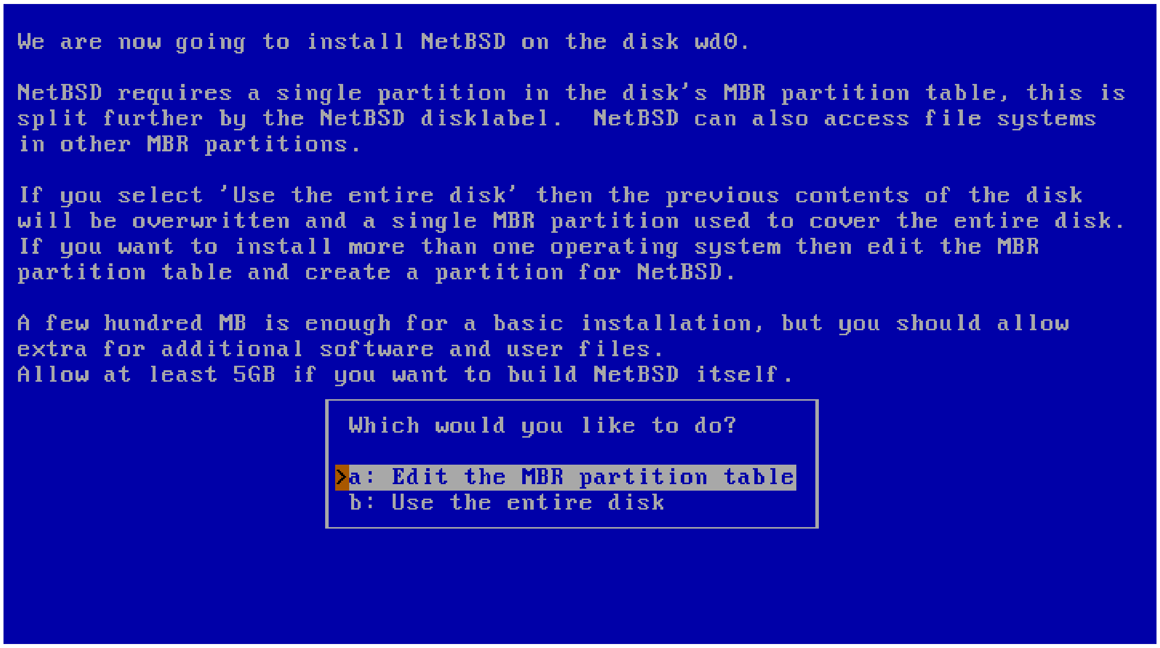
Figure 3-6. Disk geometry



3.5 MBR partitions

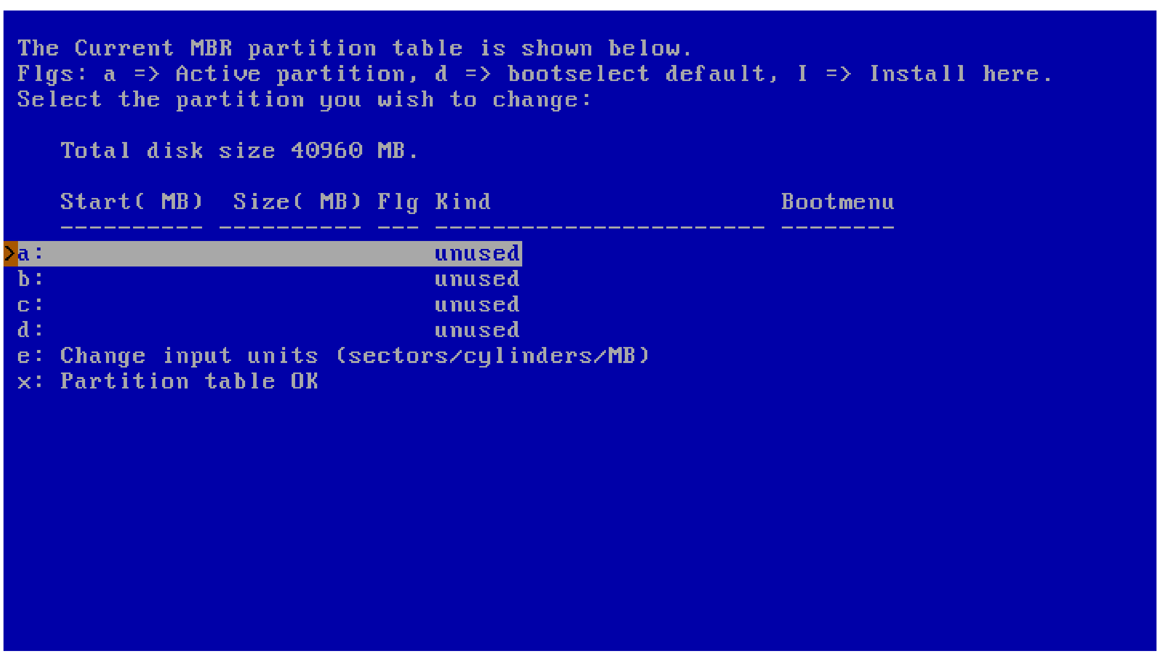
The first important step of the installation has come: the partitioning of the hard disk. First, you need to specify whether NetBSD will use a partition (suggested choice) or the whole disk. In the former case it is still possible to create a partition that uses the whole hard disk (Figure 3-7), so we recommend that you select this option as it keeps the BIOS partition table in a format which is compatible with other operating systems.

Figure 3-7. Choosing the partitioning scheme



The next screen shows the current state of the MBR partition table on the hard disk before the installation of NetBSD. There are four primary partitions, and as you can see, this example disk is currently empty. If you do have other partitions you can leave them around and install NetBSD on a partition that is currently unused, or you can overwrite a partition to use it for NetBSD.

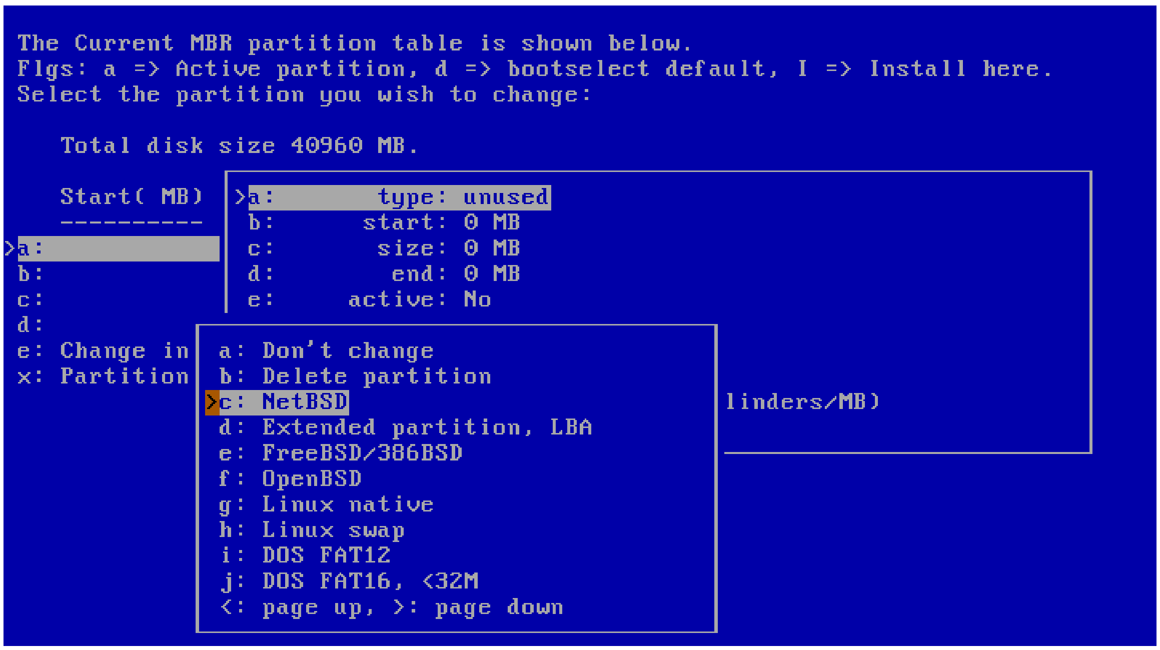
Figure 3-8. fdisk



Deleting a partition is simple: after selecting the partition, a menu with options for that partition will appear (Figure 3-9). Change the partition kind to "Delete partition" to remove the partition. Of course, if you want to use the partition for NetBSD you can set the partition kind to "NetBSD".

You can create a partition for NetBSD by selecting the partition you want to install NetBSD to. The partition names "a" to "d" correspond to the four primary partitions on other operating systems. After selecting a partition, a menu with options for that partition will appear, as shown in Figure 3-9.

Figure 3-9. Partition options



To create a new partition, the following information must be supplied:

- the type (kind) of the new partition
- the first (start) sector of the new partition
- the size of the new partition

Choose the partition type "NetBSD" for the new partition (using the "type" option). The installation program will try to guess the "start" position based on the end of the preceding partition. Change this value if necessary. The same thing applies to the "size" option; the installation program will try to fill in the space that is available until the next partition or the end of the disk (depending on which comes first). You can change this value if it is incorrect, or if you do not want NetBSD to use all the suggested amount of space.

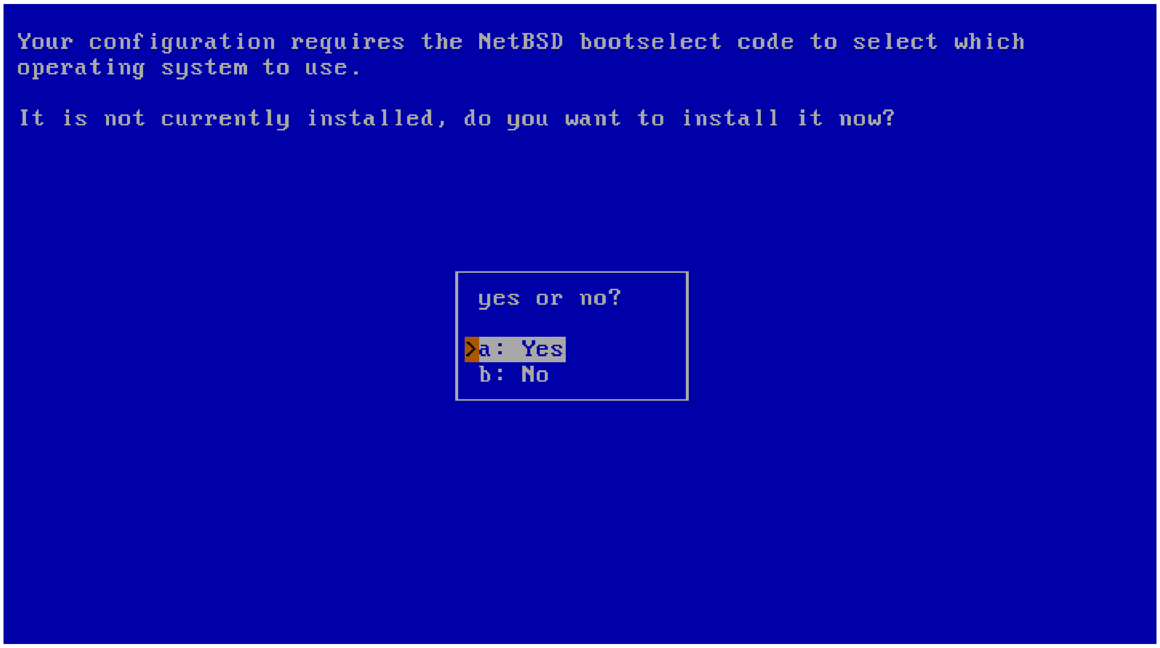
After you have chosen the partition type, start position, and size, it is a good idea to set the name that should be used in the boot menu. You can do this by selecting the "bootmenu" option and providing a label, e.g., "NetBSD". Repeat this step for other bootable partitions, so you can boot both NetBSD and a Windows system (or other operating systems) using the NetBSD bootselector. You can also choose one of the labelled partitions as default for the boot menu. If you are satisfied with the partition options, confirm your choice by selecting “Partition OK”. Choose “Partition table OK” to leave the MBR partition table editor.

If you have made an error in partitioning (for example you have created overlapping partitions) sysinst will display a message and suggest to go back to the MBR partition editor (but you are also allowed to continue). If the data is correct but the NetBSD partition lies outside the range of sectors which is bootable by the BIOS, sysinst will warn you and ask if you want to proceed anyway. Doing so may lead to problems on older PCs.

> **Note:** This is not a limitation of NetBSD. Some old BIOSes cannot boot a partition which lies outside the first 1024 cylinders. To fully understand the problem, you should study the different types of BIOSes and the many addressing schemes that they use (*physical CHS*, *logical CHS*, *LBA*, ...). These topics are not described in this guide.
>
> On modern computers (those with support for *int13 extensions*), it is possible to install NetBSD in partitions that live outside the first 8 GB of the hard disk, provided that the NetBSD boot selector is installed.

Next, sysinst will offer to install a boot selector on the hard disk. This screen is shown in Figure 3-10.

Figure 3-10. Installing the boot selector



At this point, the *BIOS partitions* (called *slices* on BSD systems) have been created. They are also called *PC BIOS partitions*, *MBR partitions* or *fdisk partitions*.

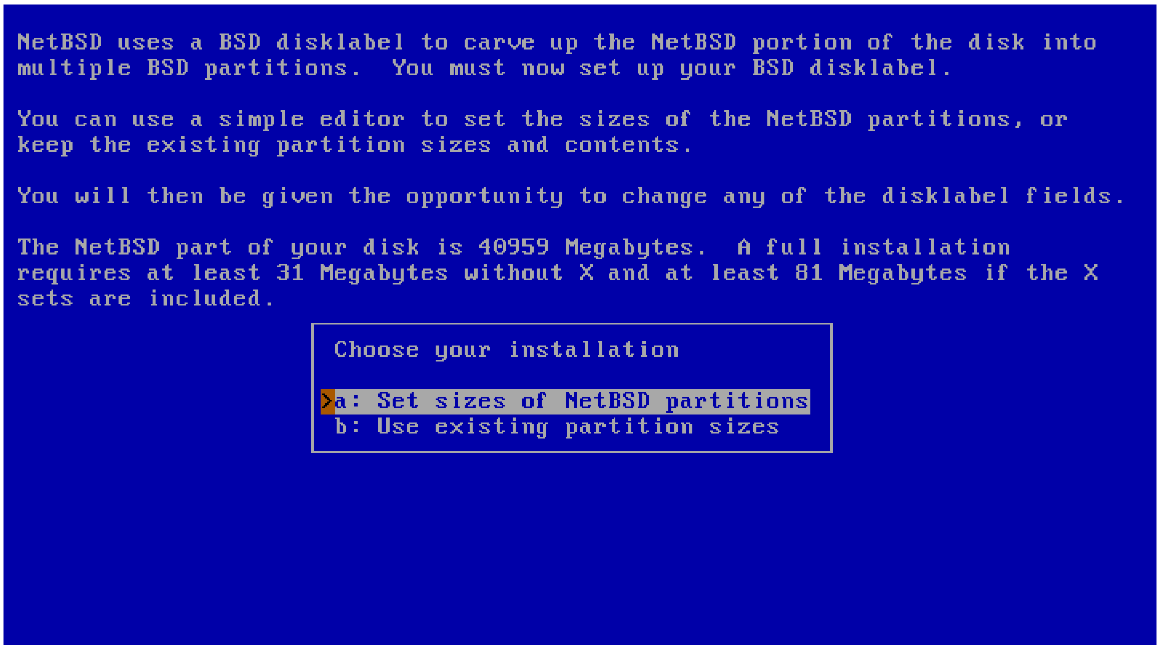
> **Note:** Do not confuse the *slices* or *BIOS partitions* with the *BSD partitions*, which are different things.

3.6 Disklabel partitions

Some platforms, like PC systems (amd64 and i386), use DOS-style MBR partitions to separate file systems. The MBR partition you created earlier in the installation process is necessary to make sure that other operating systems do not overwrite the diskspace that you allocated to NetBSD.

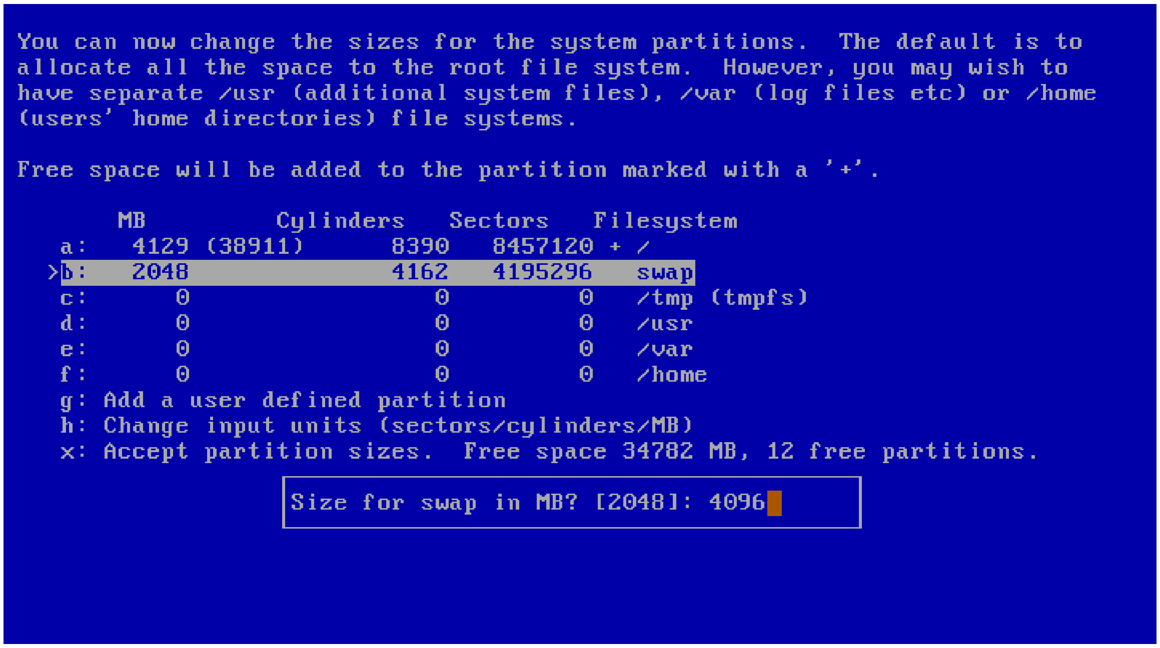
NetBSD uses its own partition scheme, called a *disklabel*, which is stored at the start of the MBR partition: for more information, refer to Section 2.2.2. In the next few steps you will create a disklabel(5) and set the sizes of the NetBSD partitions, or use existing partition sizes, as shown in Figure 3-11.

Figure 3-11. Edit partitions?



When you choose to set the sizes of the NetBSD partitions you can define the partitions you would like to create. The installation program will generate a disklabel based on these settings. This installation screen is shown in Figure 3-12.

Figure 3-12. Setting partition sizes

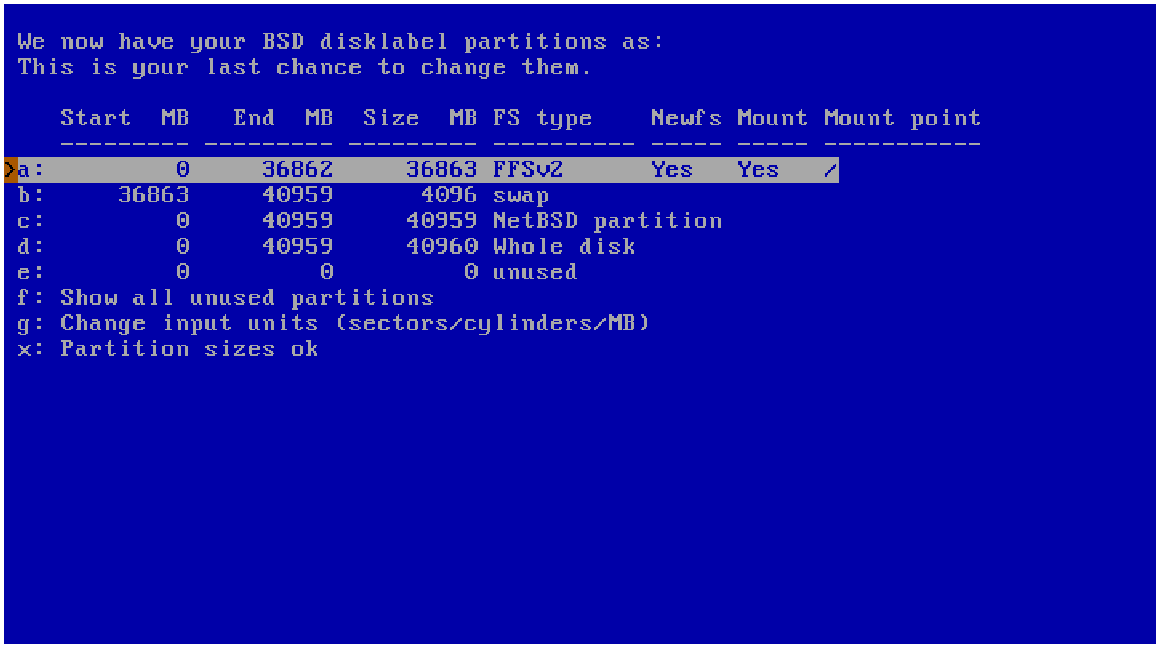


As specified in Figure 3-3, the items of the installation menus can be selected pressing the letter displayed left of them. Be careful that, in these menus, they do not always correspond to the BSD disklabel partition letters. For example, third line (letter "c") of Figure 3-12 does not refer to the whole NetBSD partition, as well as the fourth line (letter "d") does not correspond to BSD disklabel partition "d".

The default partition scheme of just using a big `/` (root) file system (plus swap) works fine with NetBSD, and there is little need to change this. Figure 3-12 shows how to change the size of the swap partition to 4096 MB. Note also that partition `/` is marked with a "+", so it will occupy all the remaining free space (not located for any other partition). Changing `/tmp` to reside on a *RAM disk* (mount_tmpfs(8) or mfs(8)) for extra speed may be a good idea. Other partition schemes may use separate partitions for `/var`, `/usr` and/or `/home`, but you should use your own experience to decide if you need this. When you completed the definition of all the desired partitions, choose "Accept partition sizes".

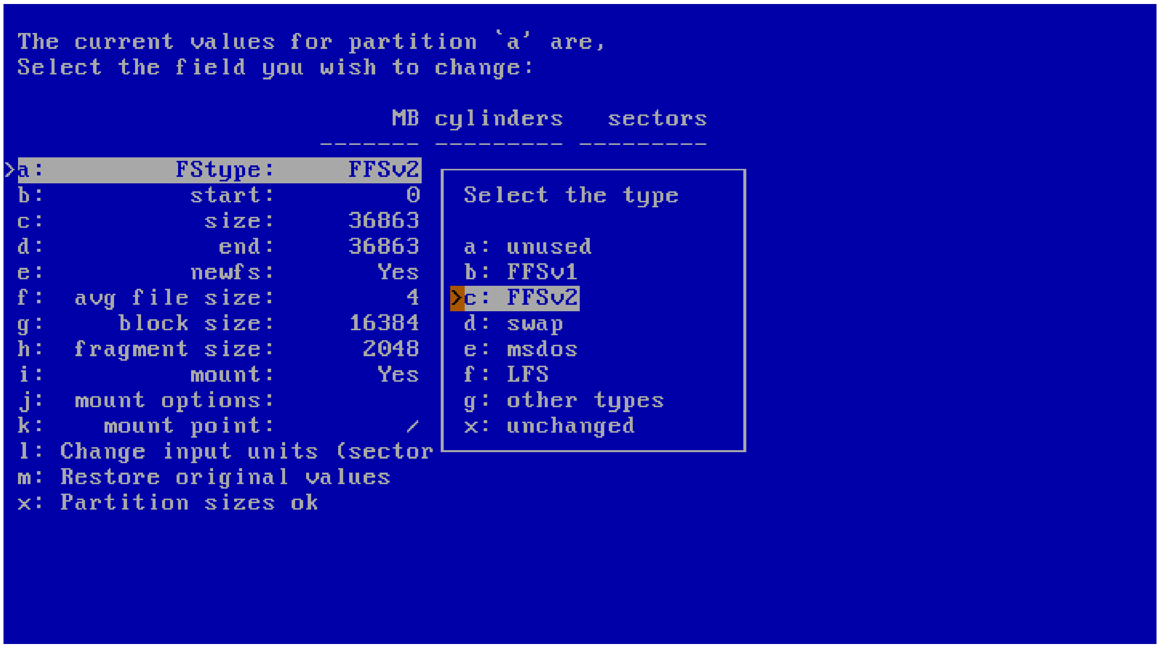
The next step is to create the disklabel and edit its partitions, if necessary, using the disklabel editor (Figure 3-13). If you predefined the partition sizes in the previous step, the resulting disklabel will probably fit your wishes. In that case you can complete the process immediately by selecting "Partition sizes ok".

Figure 3-13. The disklabel editor



Letters in Figure 3-13 are used for line selection *and* to represent the corresponding BSD disklabel partitions, with the meaning specified in Section 2.2.2. In the amd64 port, there are two reserved partitions: “c”, representing the NetBSD partition, and “d”, representing the whole disk. You can edit all the other partitions by using the cursor keys and pressing the Return key, or using their corresponding letters. You can add a partition by selecting an unused slot and setting parameters for that partition. The partition editing screen is shown in Figure 3-14. When you are satisfied with all the values, choose “Partition sizes ok”.

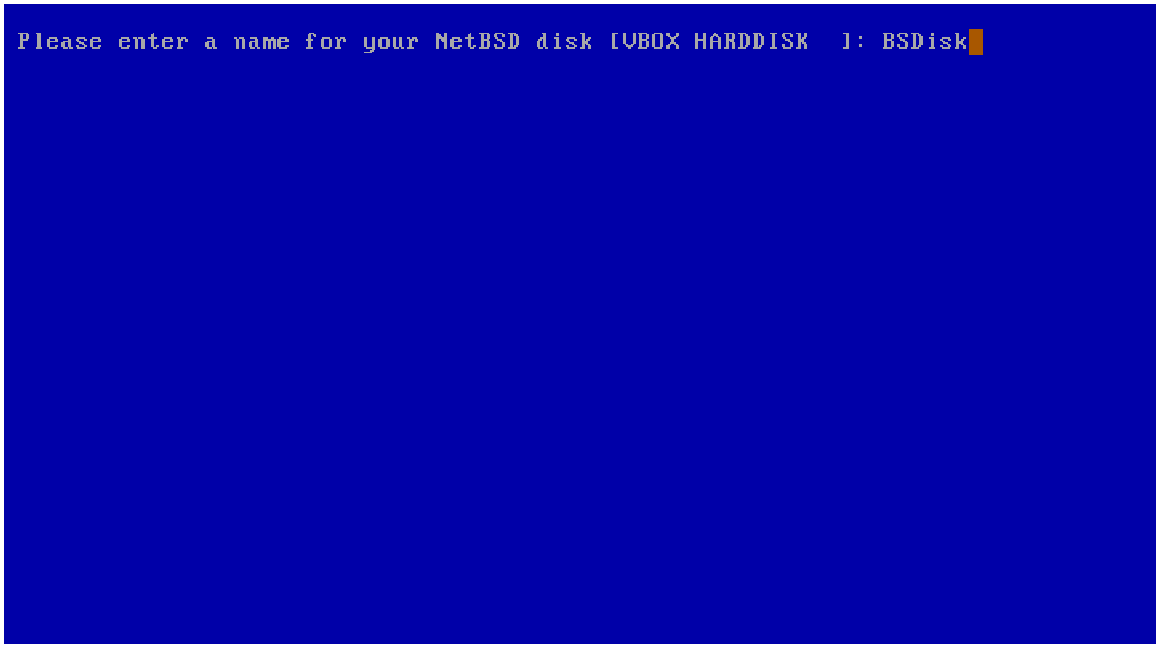
Figure 3-14. Disklabel partition editing



3.7 Setting the disk name

After defining the partitions in the new disklabel, the last item is to enter a name for the NetBSD disk as shown in Figure 3-15. This can be used later to distinguish between disklabels of otherwise identical disks.

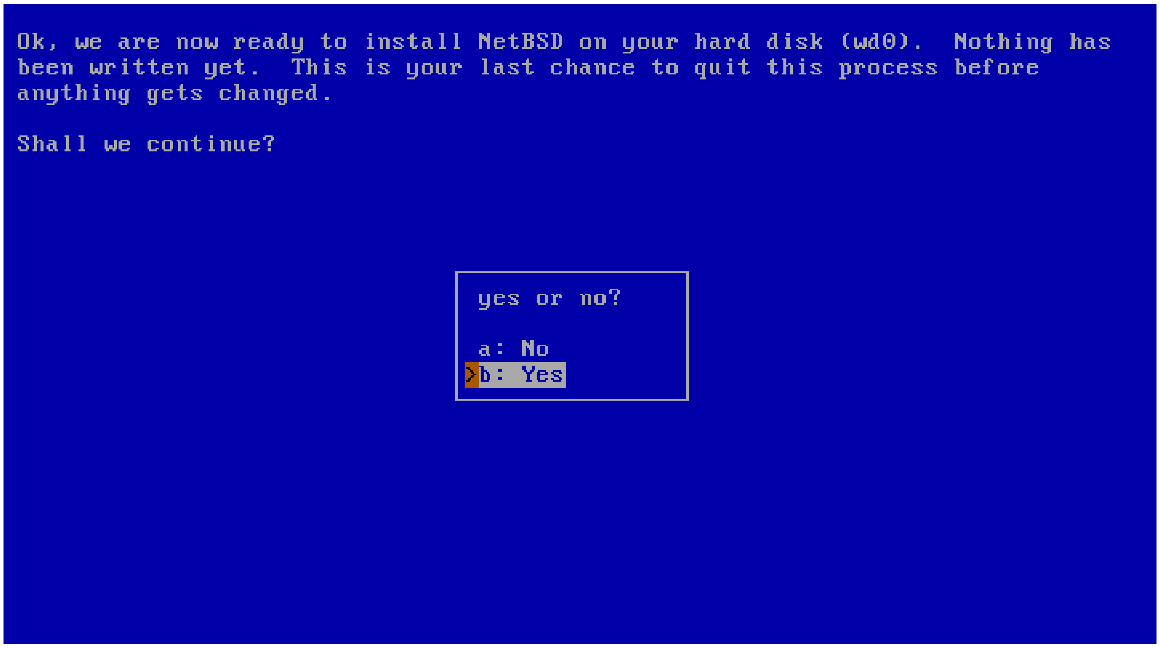
Figure 3-15. Naming the NetBSD disk



3.8 Last chance!

The installer now has all the data it needs to prepare the disk. Nothing has been written to the disk at this point but, and now is your last chance to abort the installation process before actually writing data to the disk. Choose “no” to abort the installation process and return to the main menu, or continue by selecting “yes”.

Figure 3-16. Last chance to abort



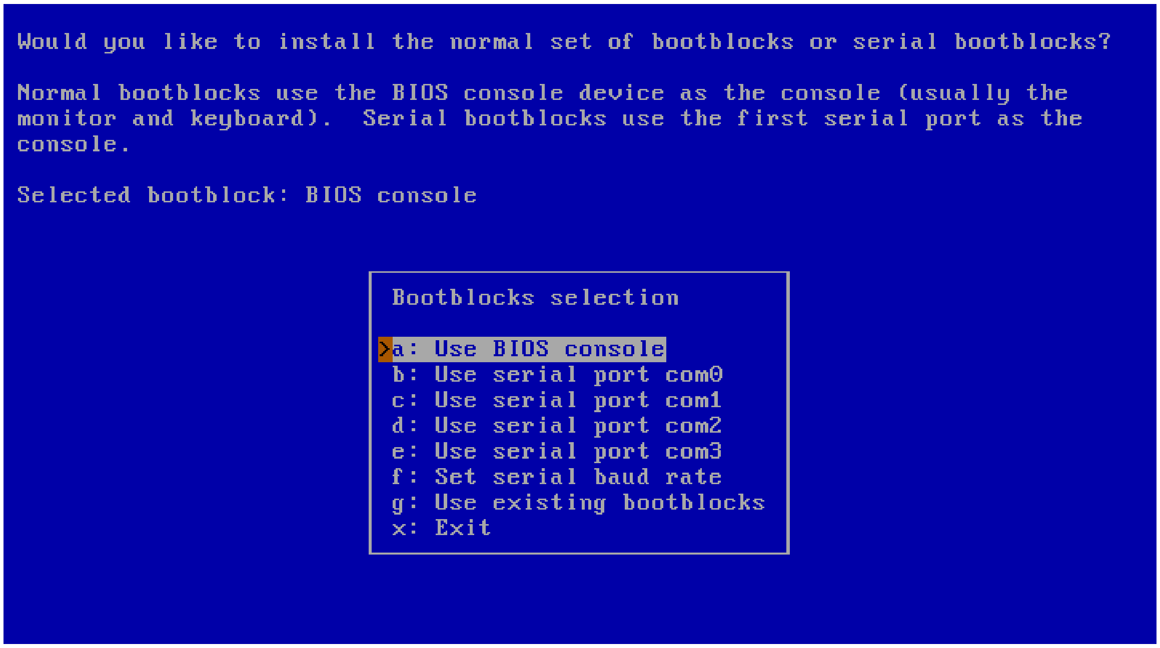
3.9 The disk preparation process

After confirming that sysinst should prepare the disk, it will run disklabel(8) to create the NetBSD partition layout and newfs(8) to create the file systems on the disk.

After preparing the NetBSD partitions and their filesystems, the next question (shown in Figure 3-17) is which *bootblocks* to install. Usually you will choose the default of *BIOS console*, i.e., show boot messages on your computer's display.

If you run a farm of machines without monitor, it may be more convenient to use a serial console running on one of the serial ports. The menu also allows changing the serial port's baud rate from the default of 9600 baud, 8 data bits, no parity and one stopbit.

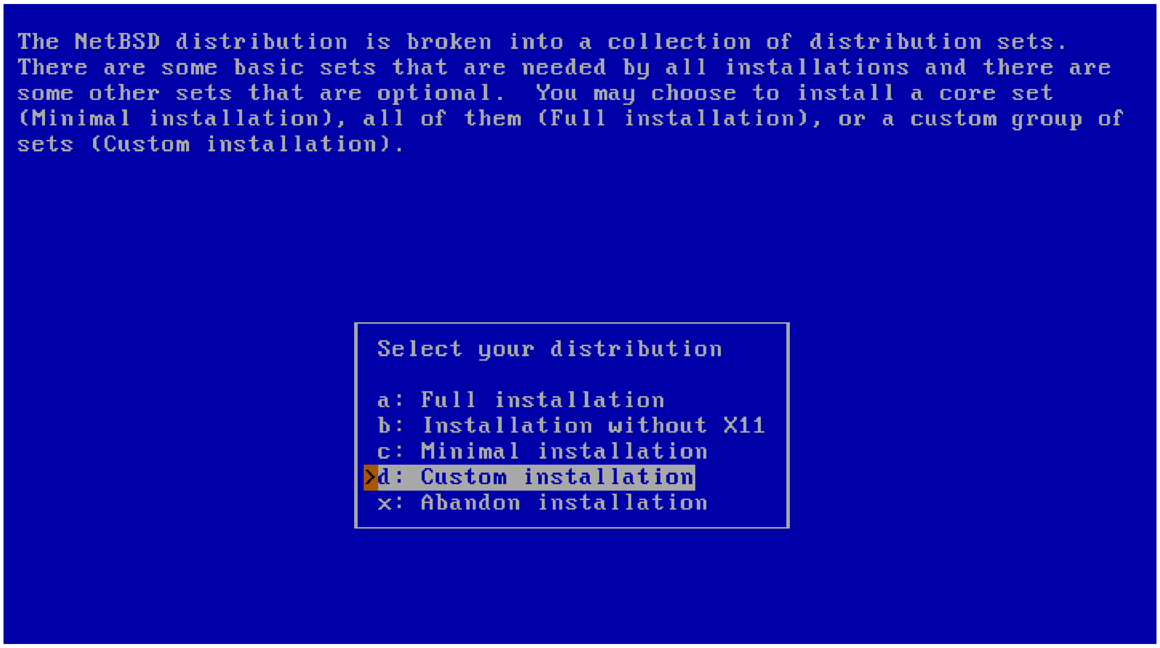
Figure 3-17. Selecting bootblocks



3.10 Installation type

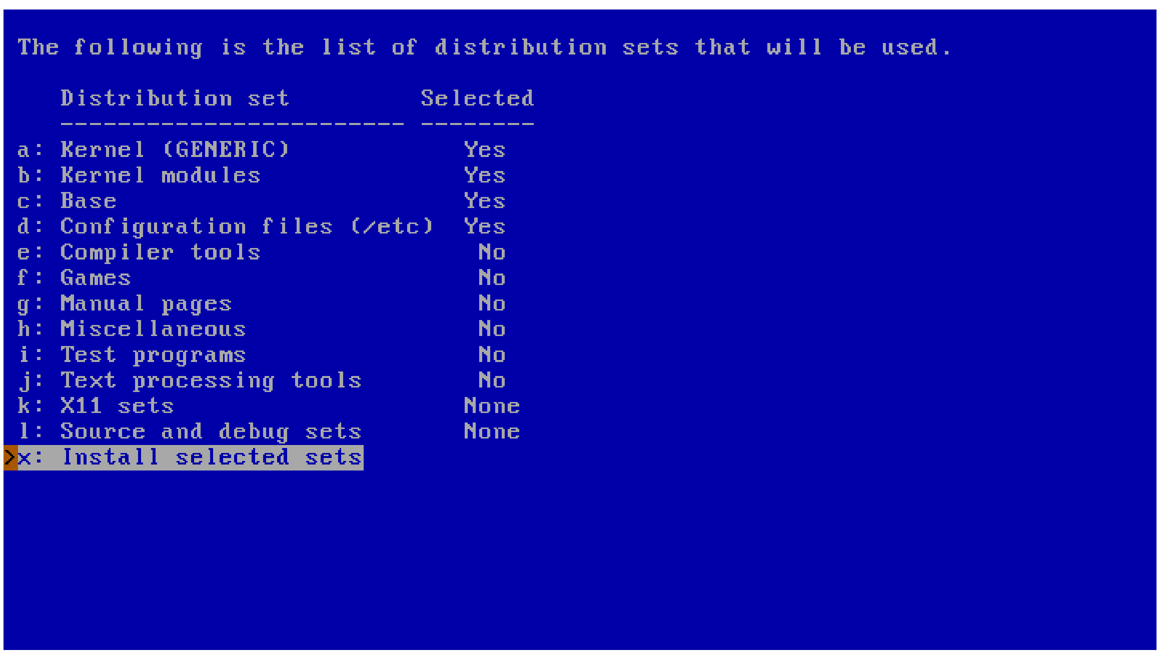
The installer will then ask whether you want to do a full, minimal or custom installation. NetBSD is broken into a collection of distributions sets. “Full installation” is the default and will install all sets; “Minimal installation” will only install a small core set, the minimum of what is needed for a working system. If you select “Custom installation” you can select which sets you would like to have installed. This step is shown in Figure 3-18.

Figure 3-18. Full or custom installation



If you choose to do a custom installation, sysinst will allow you to choose which distribution sets to install, as shown in Figure 3-19. At a minimum, you must select a kernel and the “Base” and “Configuration files (/etc)” sets.

Figure 3-19. Selecting distribution sets

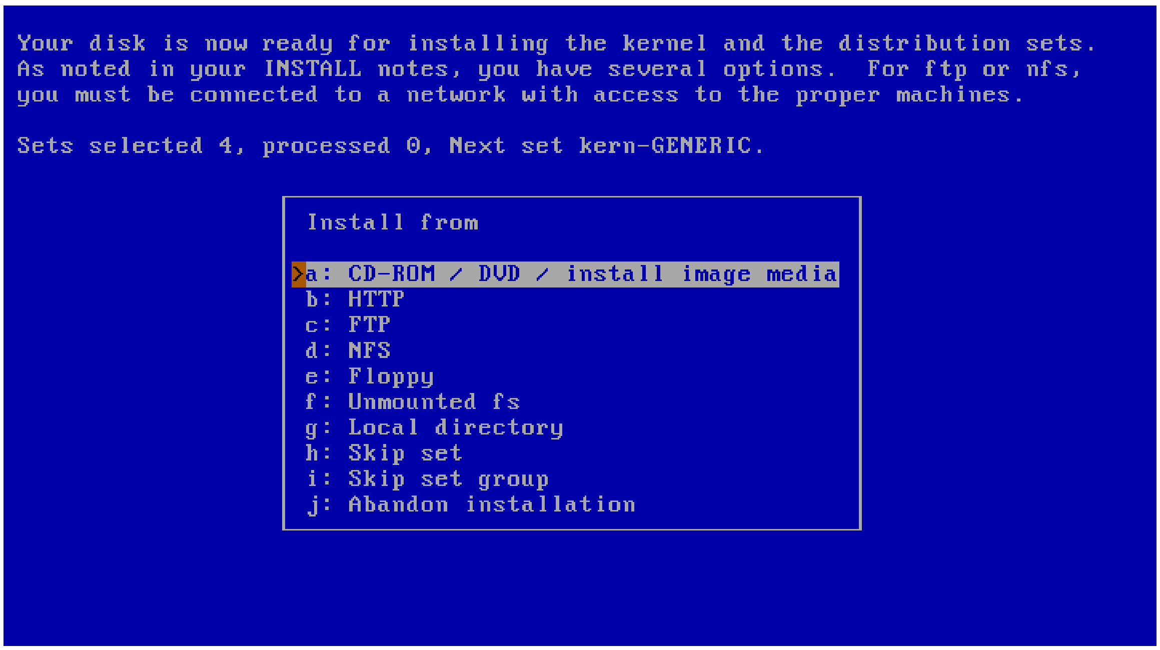


3.11 Choosing the installation medium

At this point, you have finished the first and most difficult part of the installation!

The second half of the installation process consists in populating the file systems by extracting the distribution sets that you selected earlier ("Base", "Compiler tools", "Games", etc.). Now sysinst needs to find the NetBSD sets and you must tell it where to find them: it can be the same medium where sysinst resides, or a different one, according to your preferences. The menu offers several choices, as shown in Figure 3-20. The options are explained in detail in the `INSTALL` documents.

Figure 3-20. Installation media



3.11.1 Installing from CD-ROM / DVD / install image media

Choose this option if you want to install NetBSD from either an optic medium ("CD-ROM / DVD") or another medium, such as an USB drive. If the running sysinst itself has been loaded from there, the corresponding device will be automatically selected and the extraction of the distribution sets will begin.

> **The CD-ROM/DVD or other device name:** If sysinst is not able to detect the CD-ROM/DVD or the USB flash device, you can gather more information about the hardware configuration as follows:
>
> 1. Press "Ctrl+Z" to pause sysinst and go to the shell prompt.
> 2. Type the command:
>
>    ```
>    # dmesg
>    ```
>
>   This will show the kernel startup messages, including information about not detected or not configured devices. When the first CD-ROM or DVD drive in the system is properly working, it is usually named *cd0*, regardless of whether it is IDE or SCSI (or even USB or FireWire). The first USB flash drive is named *sd0* when it is correctly configured.

3. If the display scrolls too quickly, you can also use **more**:

```
# dmesg | more
```

4. As instructed, you can return to the NetBSD installation by typing either “exit” or “^D” (“Ctrl+D”).

3.11.2 Installing from an unmounted file system

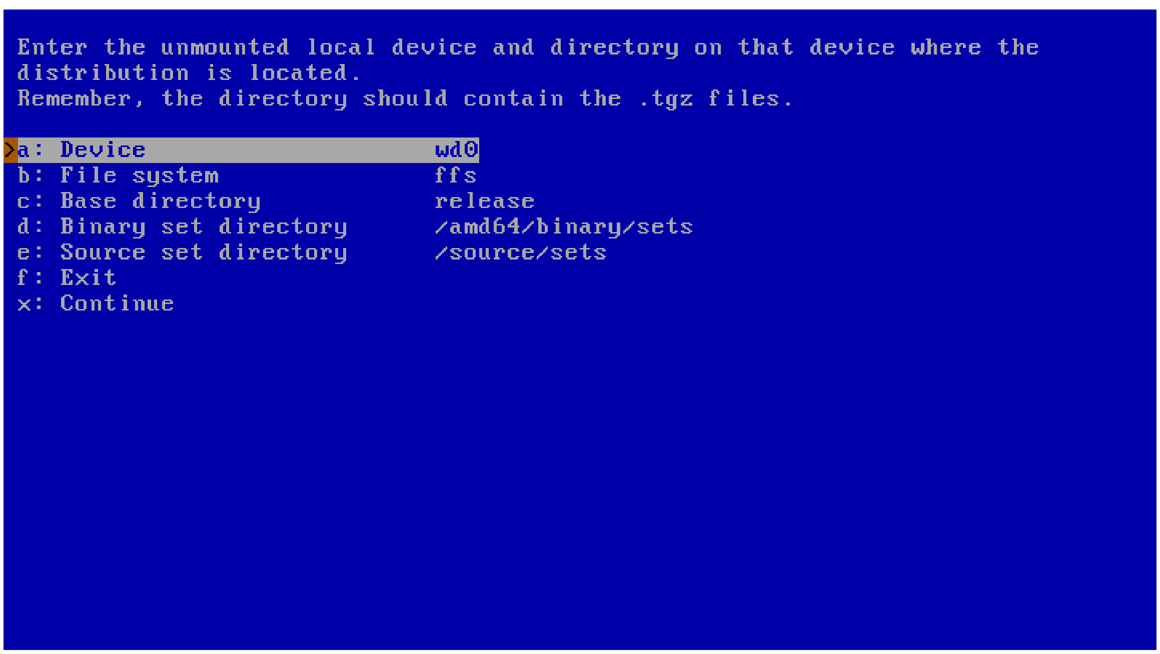
Figure 3-21 shows the menu to install NetBSD from an unmounted file system. It is necessary to specify the device (“Device”), its file system type (“File system”) and a root directory inside it (“Base directory”). The binary installation sets and the source sets are `.tgz` files. The default mountpoint is “mnt” in amd64. The path is formed as follows:

/*<default mountpoint>*/*<Base directory>*/*<Binary set directory> or <Source set directory>*/set.tgz

Choose a combination of “Base directory” and “Binary set directory” (or “Source set directory”) that generates a valid path in your unmounted filesystem. If more than one consecutive / appear, only the first / will actually be considered. You need to specify a “Source set directory” only if you previously chose to install some sources. Source sets are usually not included in the installation images.

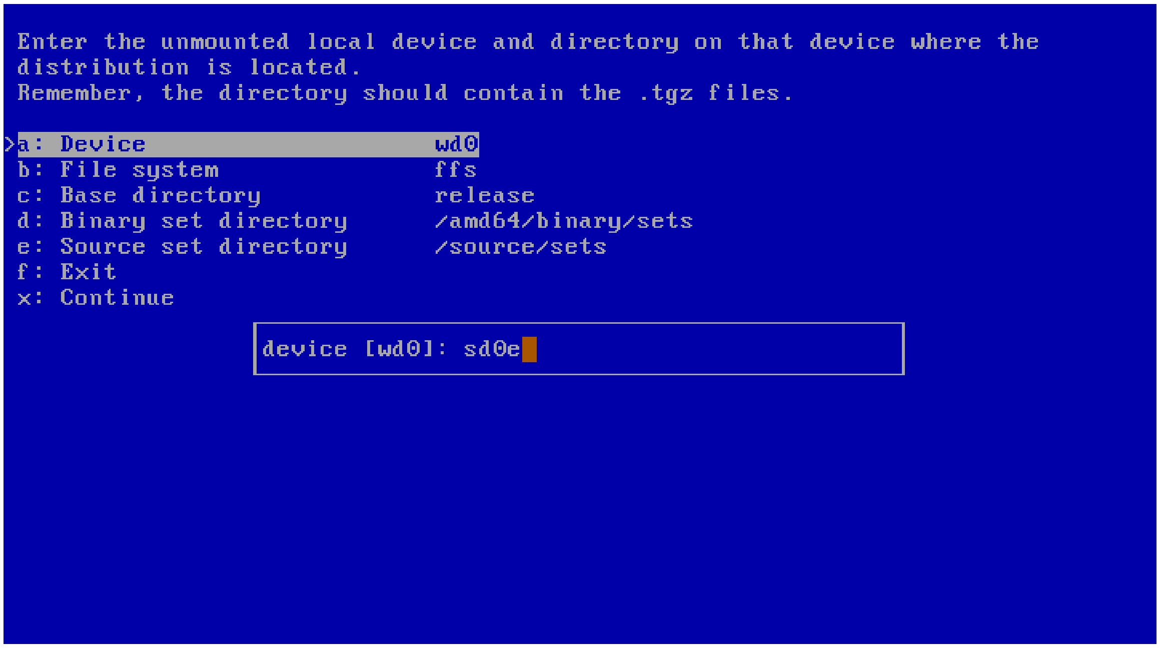
In the following example the install sets are stored on a *MSDOS* file system, on partition “e” on the device “sd0”.

Figure 3-21. Mounting a file system



Specify the device name and the partition. Figure 3-22 shows how to specify device "sd0" with partition "e".

Figure 3-22. Mounting a partition

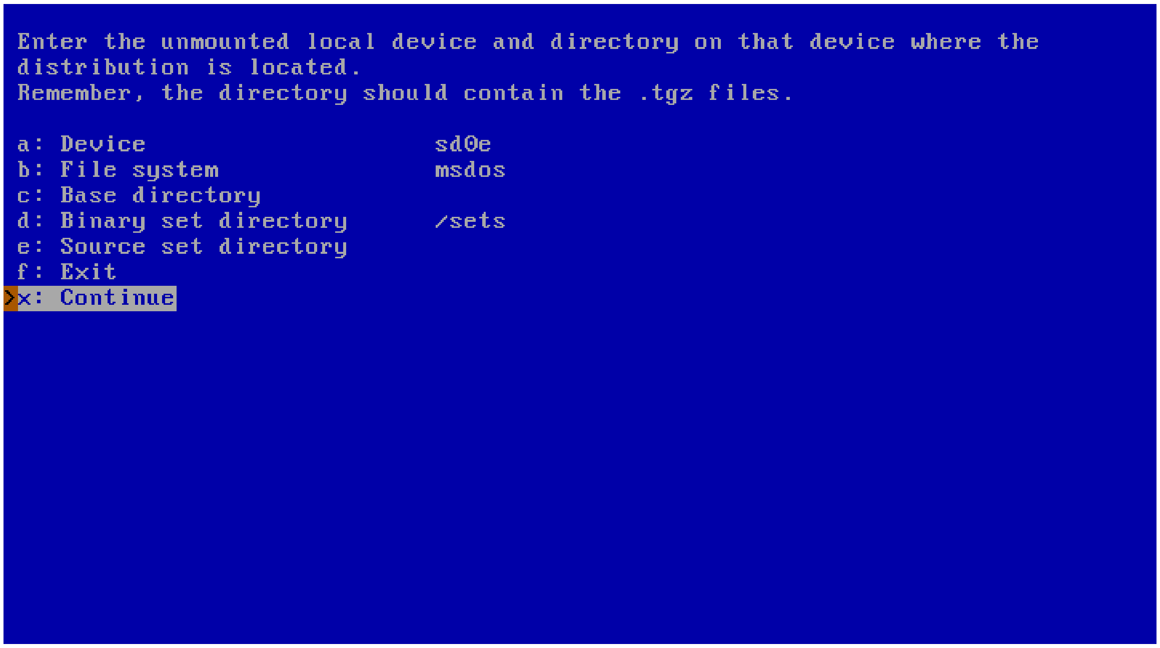


In Figure 3-23 the file system type specified is “msdos”. This value is used to form the command `mount_<File system>` to mount the volume. Any string (representing a “File system” type) which forms a valid command is accepted: for example, the NetBSD file system “ffs” or “ext2fs”, a Linux file system. In this example, the “Base directory” item is left blank and the binary sets are stored under `/sets`, so that the path becomes:

```
/mnt///sets
```

Ignoring the multiple `/`, this is equivalent to `/mnt/sets` and it is a valid one. Choosing “Continue” will start the extraction of the sets.

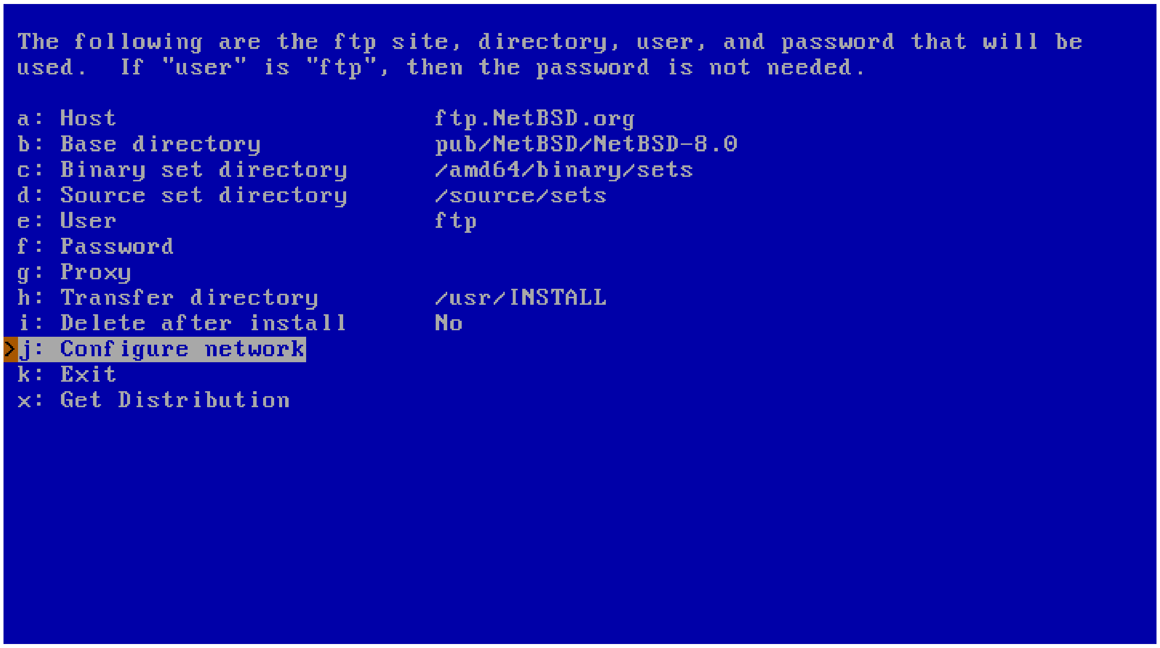
Figure 3-23. Accessing a MSDOS file system



3.11.3 Installing via FTP and Network configuration

If you choose to install from a local network or the Internet via FTP, sysinst must be instructed to properly get the distribution sets, as shown in Figure 3-24.

Figure 3-24. Defining the FTP settings

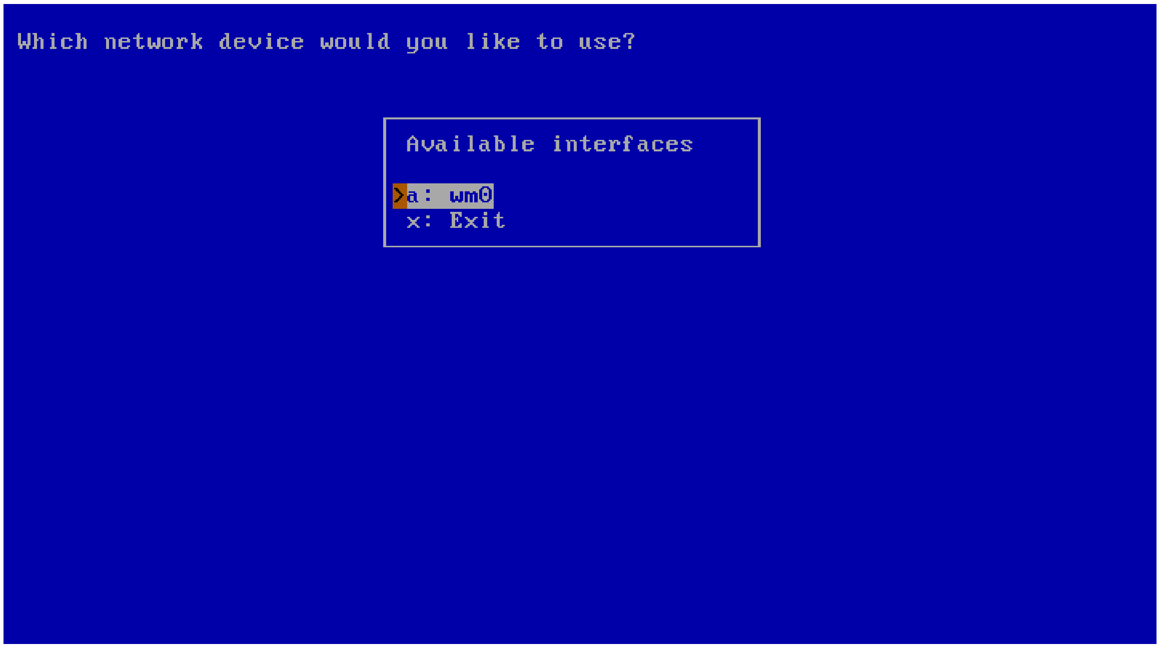


The defaults work most of the time. You also need to configure your network connection, before proceeding: go to the corresponding menu item, pressing letter “j”.

NetBSD currently supports installation via ethernet, USB ethernet or wireless, and wireless LAN. Installation via DSL (PPP over Ethernet) is not supported during installation.

In the first step, shown in Figure 3-25, the network card to be configured must be selected. sysinst will determine a list of available network interfaces, present them and ask which one to use.

Figure 3-25. Which network interface to configure



> **Note:** The exact names of your network interfaces depend on the hardware you use. Example interfaces are “wm” for Intel Gigabit interfaces, “ne” for NE2000 and compatible ethernet cards, and “ath” for Atheros based wireless cards. This list is by no means complete, and NetBSD supports many more network devices.
>
> If your network device is not listed in Figure 3-25, maybe it has not been properly detected. To get a list of network interfaces available on your system, interrupt the installation process by pressing “Ctrl+Z”, then enter
>
> ```
> # ifconfig -a
> wm0: flags=0x8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
>         capabilities=2bf80<TSO4,IP4CSUM_Rx,IP4CSUM_Tx,TCP4CSUM_Rx>
>         capabilities=2bf80<TCP4CSUM_Tx,UDP4CSUM_Rx,UDP4CSUM_Tx,TCP6CSUM_Tx>
>         capabilities=2bf80<UDP6CSUM_Tx>
>         enabled=0
>         ec_capabilities=7<VLAN_MTU,VLAN_HWTAGGING,JUMBO_MTU>
>         ec_enabled=0
>         address: 08:00:27:7e:85:d7
>         media: Ethernet autoselect (1000baseT full-duplex)
>         status: active
> lo0: flags=0x8048<LOOPBACK,RUNNING,MULTICAST> mtu 33624
> ```
>
> If the desired interface has not been shown, get more information about all the devices found during system boot. Type:
>
> ```
> # dmesg | more
> ```
>
> As instructed, you can return to the NetBSD installation by typing either “exit” or “^D” (“Ctrl+D”).

Next, you have a chance to set your network medium. Press “Enter” to choose the default.

Note: It is unlikely that you will need anything other than the default here. If you experience problems like very slow transfers or timeouts, you may, for example, force different duplex settings for ethernet cards. To get a list of supported media and media options for a given network device (“wm0”, for example), escape from sysinst by pressing “Ctrl+Z”, then enter:

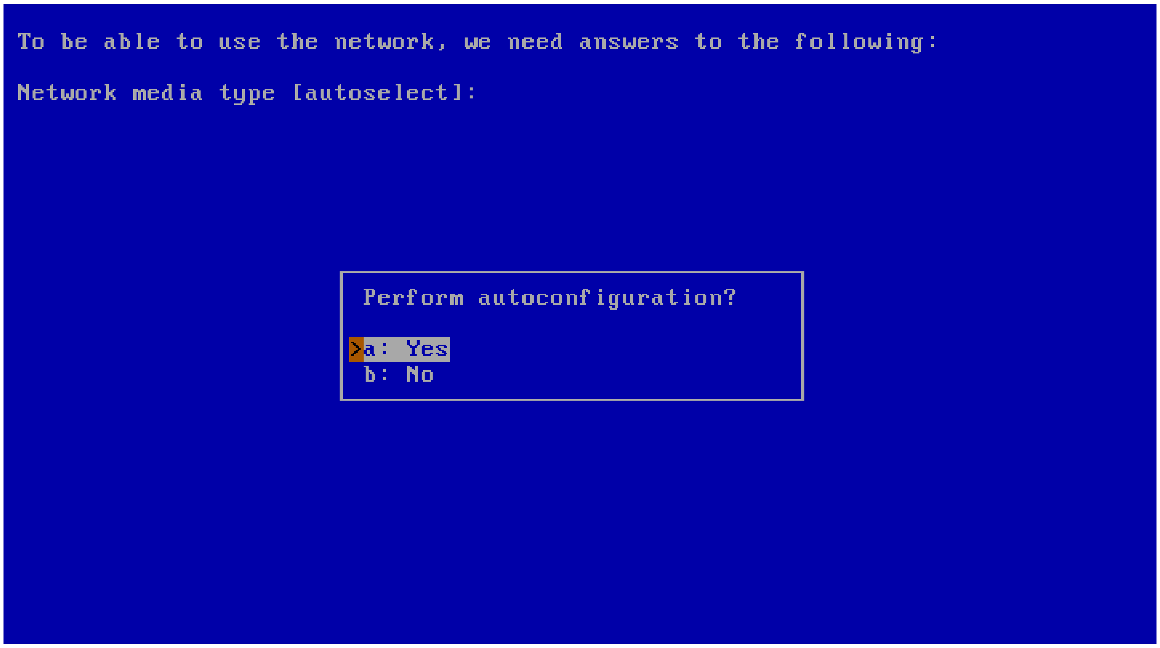
```
# ifconfig -m wm0
wm0: flags=0x8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
        capabilities=2bf80<TSO4,IP4CSUM_Rx,IP4CSUM_Tx,TCP4CSUM_Rx>
        capabilities=2bf80<TCP4CSUM_Tx,UDP4CSUM_Rx,UDP4CSUM_Tx,TCP6CSUM_Tx>
        capabilities=2bf80<UDP6CSUM_Tx>
        enabled=0
        ec_capabilities=7<VLAN_MTU,VLAN_HWTAGGING,JUMBO_MTU>
        ec_enabled=0
        address: 08:00:27:7e:85:d7
        media: Ethernet autoselect (1000baseT full-duplex)
        status: active
        supported Ethernet media:
                media none
                media 10baseT
                media 10baseT mediaopt full-duplex
                media 100baseTX
                media 100baseTX mediaopt full-duplex
                media autoselect
```

The several values printed after “media” may be of interest here, including keywords like “autoselect” but also including any “mediaopt” settings.

Return to the installation by typing “exit” or “^D” (“Ctrl+D”).

The next question, shown in Figure 3-26, is whether you want to perform autoconfiguration. This procedure uses DHCP (*Dynamic Host Configuration Protocol*). sysinst will fetch a number of defaults from it, giving most likely the correct settings. This procedure is recommended, unless you want to set a static IP address, and/or specify some custom parameters.

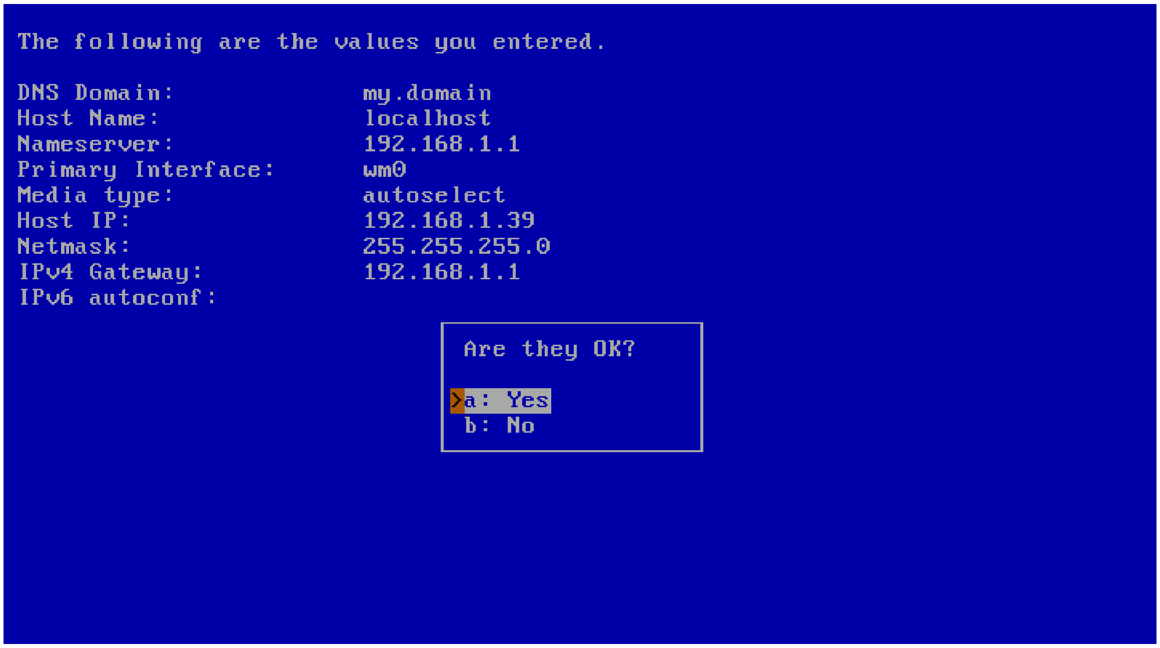
Figure 3-26. Using autoconfiguration



You will then be asked for your “DNS domain”; if the machine is not in a registered public domain, it can be left blank.

At the end of this procedure, a list of all the settings is shown, as in Figure 3-27. If they are correct, choose “Yes”. Otherwise, choosing “No”, the network configuration will restart from the beginning, giving the opportunity to perform again all the steps (and also to perform a manual configuration).

Figure 3-27. Confirm autoconfiguration



If you chose "No" in Figure 3-26, you will be asked several questions to manually configure the network. All the parameters are presented in the form "Parameter_name [default_value]:". Press "Enter" to use the default value. If no default value is provided, the parameter will be left blank.

Your host name:

The name by which other machines can usually address your computer. Not used during installation.

Your DNS Domain:

This is the name of the domain you are in. You may leave it blank if you are not in a public domain.

Your IPv4 address:

Enter your numerical Internet Protocol address in "dotted quad" notation here, for example, 192.168.1.3. It will be used as a static IP for your network card.

IPv4 Netmask:

The netmask for your network, either given as a hex value ("0xffffff00") or in dotted-quad notation ("255.255.255.0").

IPv4 gateway:

Your router's (or default gateway's) IP address. Do not use a hostname here!

Your name server:

Your (first) DNS server's IP address. Again, don't use a hostname.

After answering all of your network configuration info, their list is shown as in Figure 3-27. You will have a chance to go back and make changes. If you are satisfied with your settings, choose “Yes”.

sysinst will now run a few commands (not displayed in detail here) to configure the network: flushing the routing table, setting the default route, and testing if the network connection is operational.

Now that you have a functional network connection, the menu in Figure 3-24 will be shown again. Choose “Get Distribution” to continue: sysinst will download the selected set files to a temporary directory, and then extract them.

3.11.4 Installing via NFS

If you want to install NetBSD from a server in your local network, NFS is an alternative to FTP.

> **Note:** Using this installation method requires the ability to set up an NFS server, a topic which is not discussed here.

As shown in Figure 3-28, you must specify: the IP address of the NFS server as “Host”; the directory *exported* by the NFS server as “Base directory”; the directory containing the install sets as “Set directory”.

Figure 3-28. NFS install screen

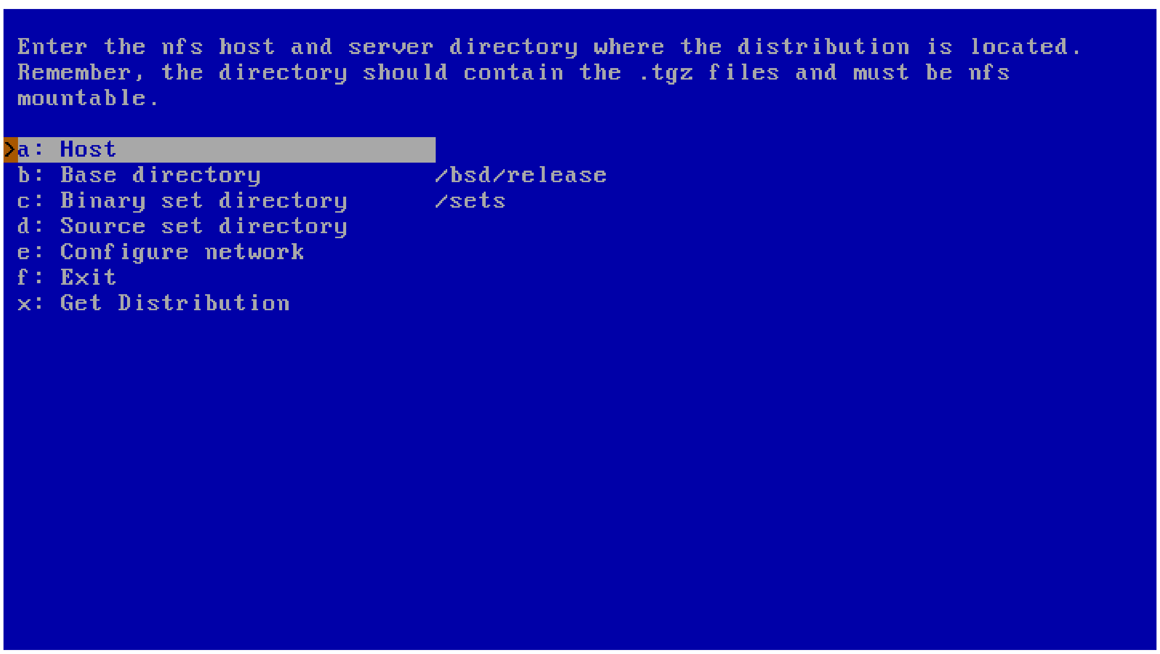
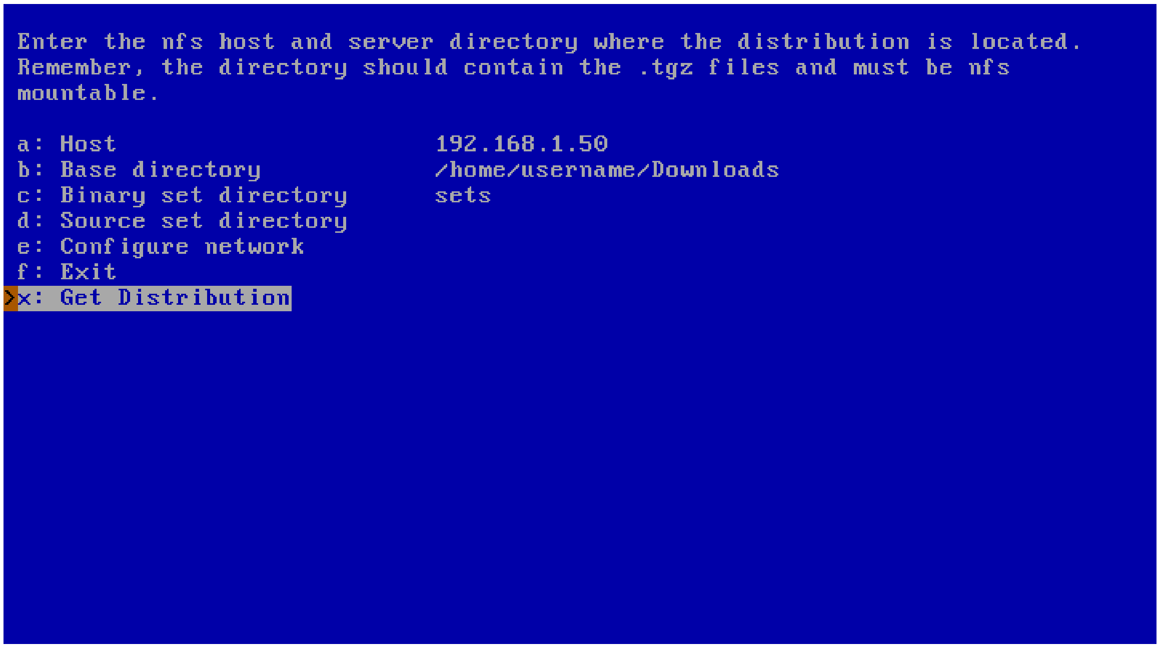


Figure 3-29 shows an example: Host “192.168.1.50” is the NFS server which exports the directory `/home/username/Downloads`. The NetBSD install sets are stored in `/home/username/Downloads/sets` on the NFS server. Choose “Continue” to start the installation of the distribution sets.

Figure 3-29. NFS example

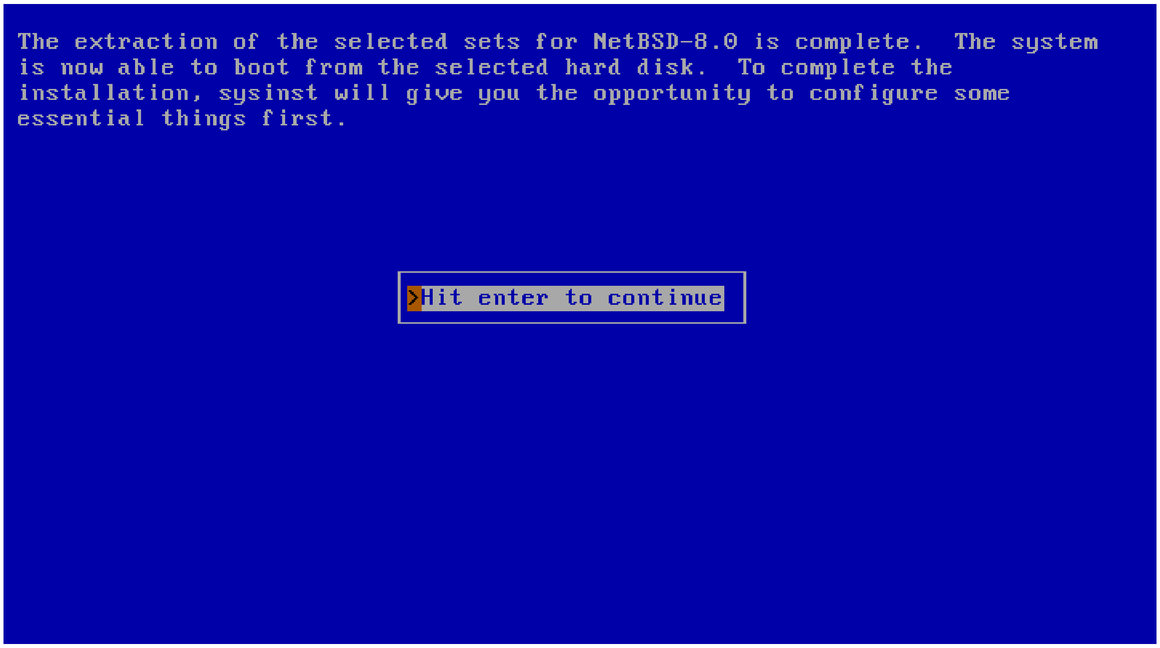


3.12 Extracting sets

After the method to obtain the distribution sets has been chosen, and (if applicable) after those sets have been transferred, they will be extracted into the new NetBSD file system.

A message (see Figure 3-30) will let you know that the set extraction is now completed and that you have the opportunity to perform some essential configuration before finishing the NetBSD installation.

Figure 3-30. Extraction of sets completed



3.13 System configuration

A menu with all the available configuration options is shown like in Figure 3-31. After the configuration of each item, you will get back to this menu, having the chance to select another one.

Figure 3-31. Configuration menu

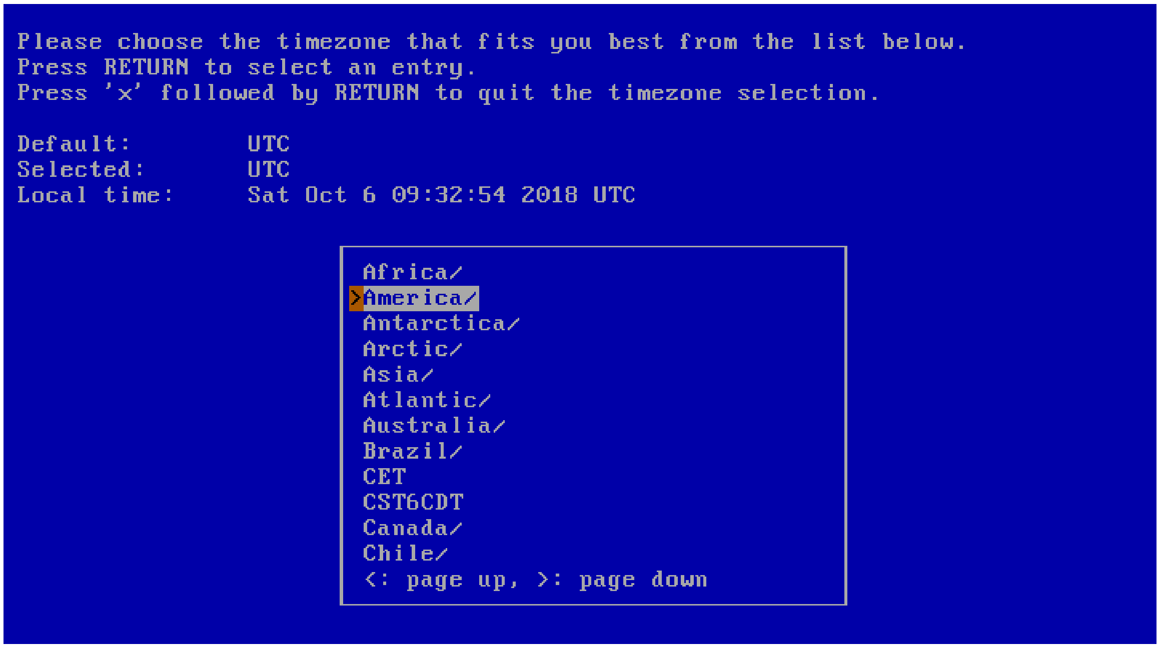
```
Configure the additional items as needed.

>a: Configure network                                  configure
 b: Timezone                                           UTC
 c: Root shell                                         /bin/sh
 d: Change root password                               ***EMPTY***
 e: Enable installation of binary packages             install
 f: Fetch and unpack pkgsrc for building from source   install
 g: Enable sshd                                        NO
 h: Enable ntpd                                        NO
 i: Run ntpdate at boot                                NO
 j: Enable mdnsd                                       NO
 k: Enable xdm                                         NO
 l: Enable cgd                                         YES
 m: Enable lvm                                         NO
 n: Enable raidframe                                   YES
 o: Add a user
 x: Finished configuring
```

If you have not yet configured Network, you can do it now, following the same procedure already presented in Section 3.11.3.

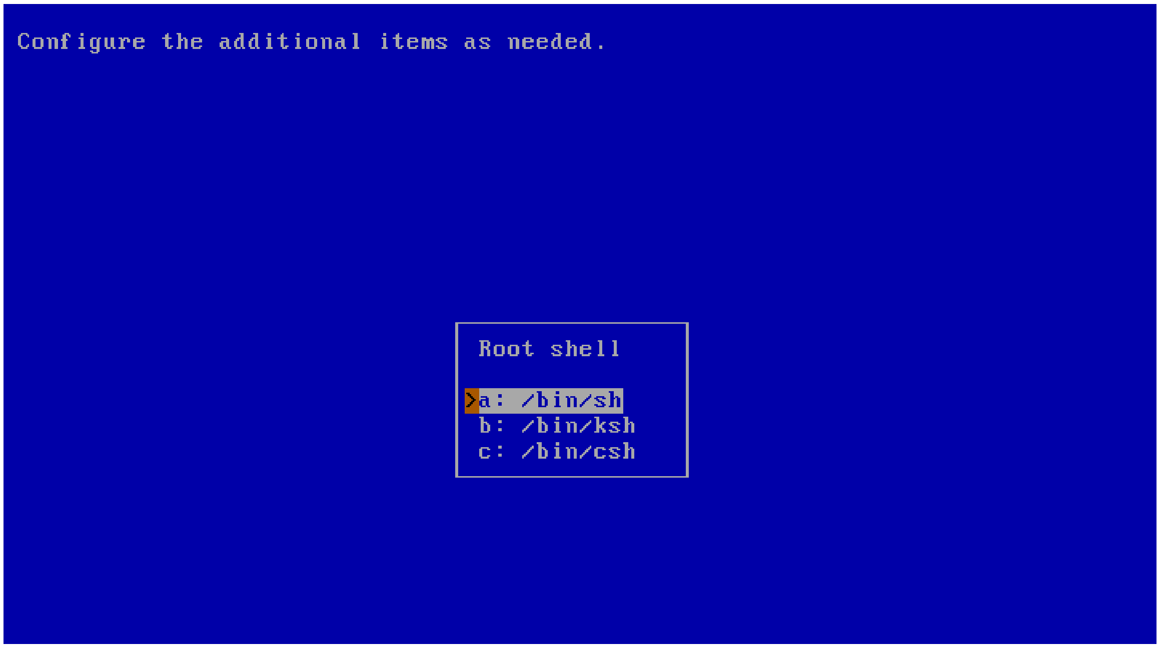
The timezone can also be configured. It is *Universal Time Coordinated* (UTC) by default. Use the two-level menu of *Continents/Countries and cities* shown in Figure 3-32 to select your local timezone with the Return key. After a valid selection, the cursor will automatically be moved to an "Exit" item. Then, simply press Return to exit the timezone selection.

Figure 3-32. Selecting the system's time zone



The next item in Figure 3-31 allows you to choose which command-line interpreter - also known as "shell" - will be used for the root account. The default is the Bourne-compatible *Almquist shell*, sh(1). Other choices are the *Korn shell* (ksh(1)) and the *C shell* (csh(1)). If, upon reading this, you don't have some idea on which shell you prefer, simply use the default, as this is a highly subjective decision. Should you later change your mind, root's shell can always be changed.

Figure 3-33. Choosing a shell

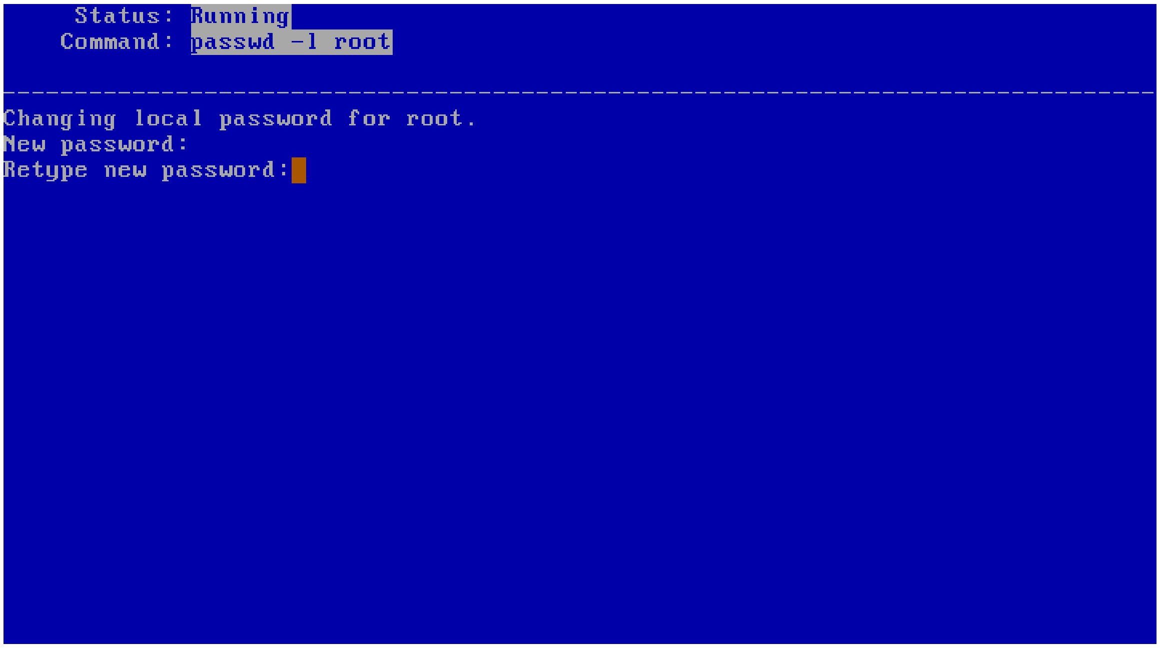


The root account still does not have a password. It is recommended to set it at this point for security reasons, choosing the related item in Figure 3-31.

Figure 3-34. Set a root password?

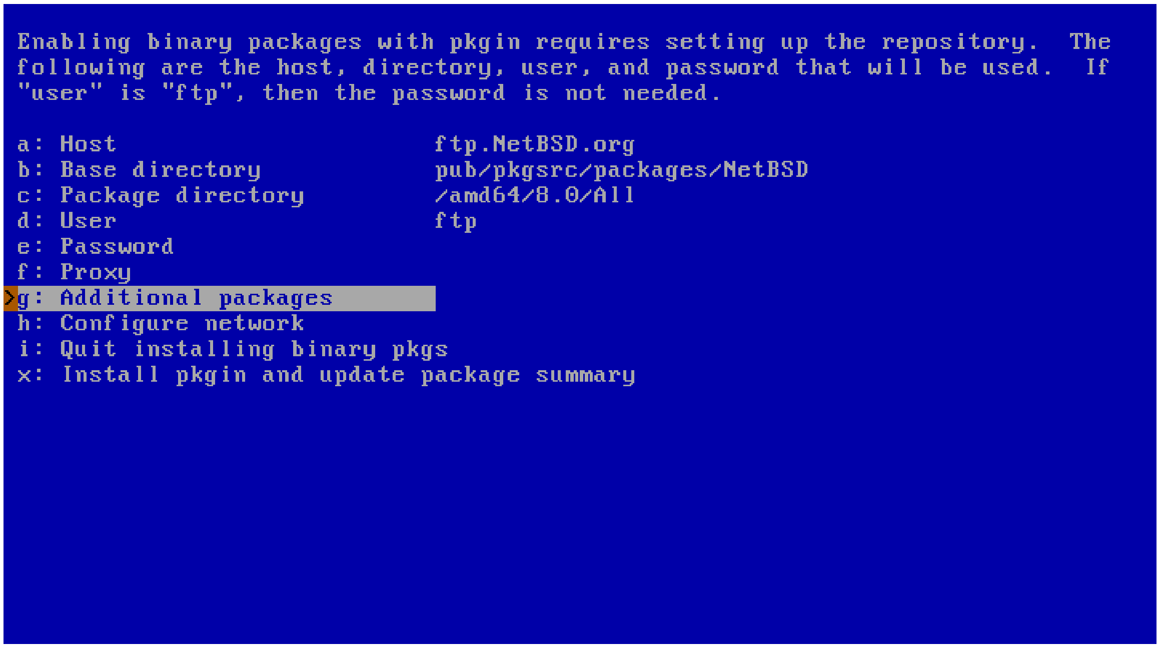
When you agree to set a root password, sysinst will run the passwd(1) utility for you. Please note that the password is not echoed.

Figure 3-35. Setting root password



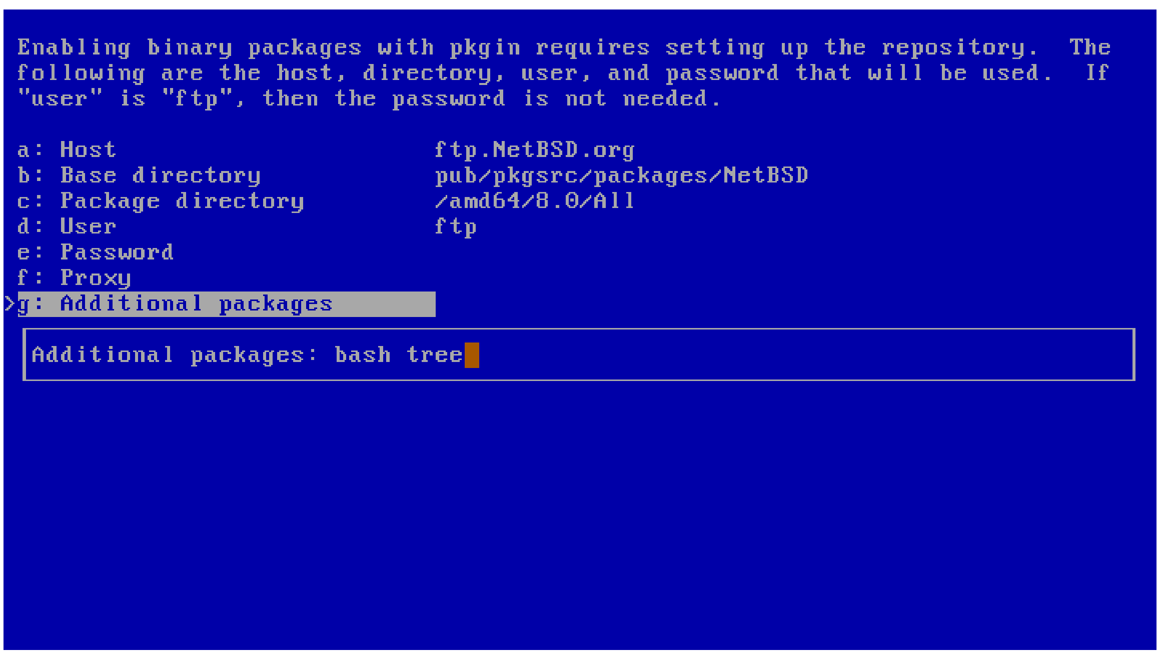
To ease the future installation of binary packages, it is possible to make a preliminary configuration of pkgin: choose “Enable installation of binary packages” in Figure 3-31. pkgin will be fetched and installed from an FTP server, so be sure that the network configuration has already been done. Specify the “Host” name, its “Base directory” (where the packages for all the NetBSD ports are stored), and the “Package directory”, related to your port and your NetBSD version. Usually, the defaults are correct.

Figure 3-36. Enabling installation of binary packages



Choosing “ftp” as “User”, no password will be required. As shown in Figure 3-36, you can also choose to install one or more additional packages, typing their names using a space as separator, pressing “Enter” at the end. To proceed to the installation, type “x” and press “Enter”. A “pkgin update” will be run after the installation of pkgin, to let the repository be immediately up to date.

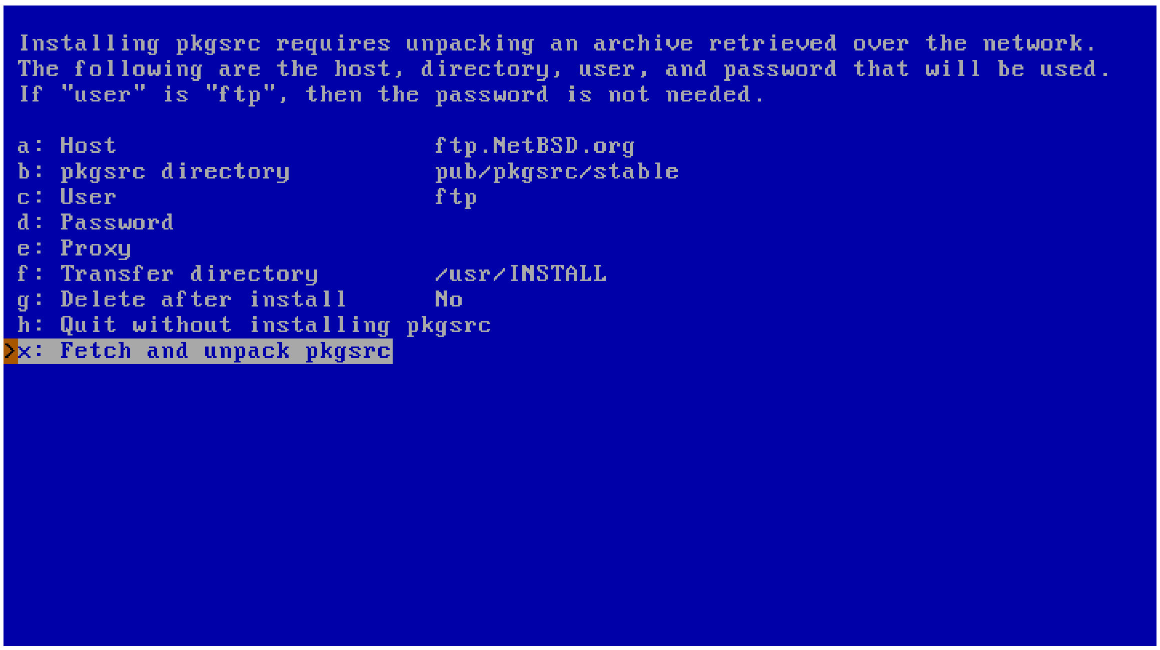
Figure 3-37. Additional packages



After the procedure is completed, sysinst will show the command to install further packages. Hit “Enter” to go back to the configuration menu.

If you need or want to build packages from their source code via pkgsrc, choose “Fetch and unpack pkgsrc for building from source” in Figure 3-31. As before, specify the “Host” name; “pkgsrc directory” is the sources base directory. Defaults are usually the best values. A single archive file will be downloaded, for example `pkgsrc.tgz`: if you want to automatically remove it after the pkgsrc installation, move the cursor on “Delete after install” and press “Enter”. To proceed with the download, type “x” and then press “Enter”.

Figure 3-38. Fetch and unpack pkgsrc



In the initial configuration menu (Figure 3-31), it is also possible to enable some useful services such as the daemon listening for ssh. For information about ntpd and ntpdate, refer to Section 29.2. xdm handles the authentication and the session of users through an X display. Usage of the Cryptographic Device Driver (cgd) is shown in Chapter 14. Logical Volume Manager (lvm) is documented in Chapter 17, raidframe in Chapter 16. mdnsd provides a Multicast DNS service, and also DNS Service Discovery on NetBSD: check mdnsd(8) for more details.

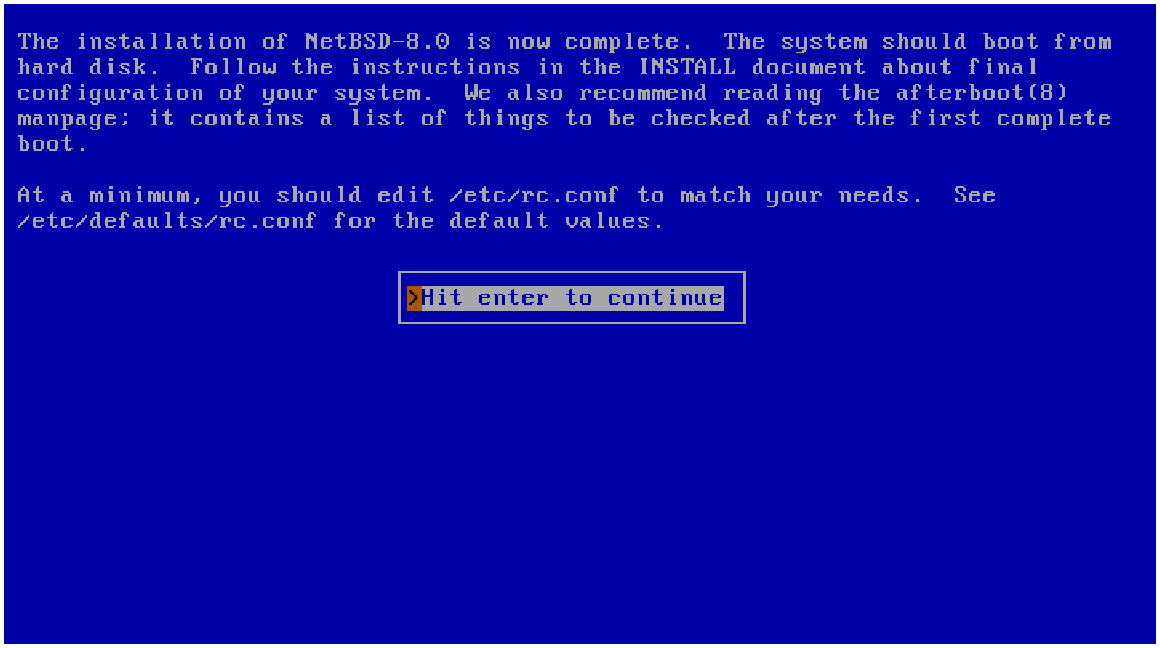
Finally, the menu in Figure 3-31 lets you add a regular user to the system. For all the base information about users and root accounts, as well as the wheel group, refer to Section 5.6.

When you completed the configuration of all the desired items, choose “Finished configuring” in Figure 3-31.

3.14 Finishing the installation

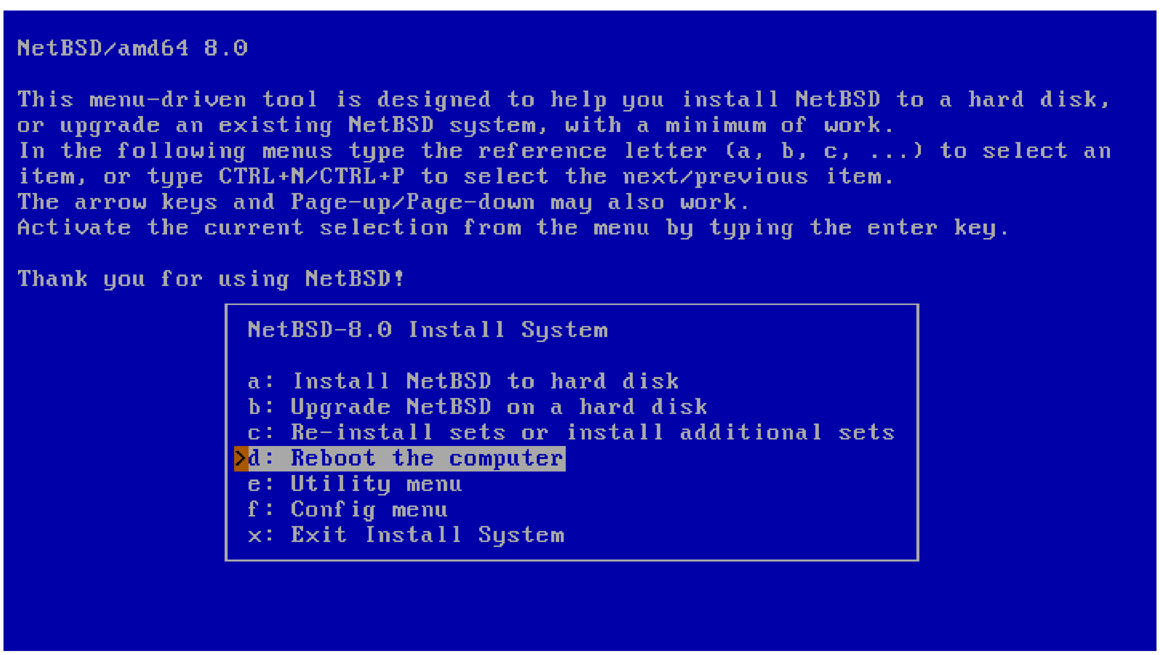
At this point the installation is finished.

Figure 3-39. Installation completed



After passing the dialog that confirms the installation, sysinst will return to the main menu. Remove any installation media (CD, floppy, etc.) and choose “Reboot the computer” to boot your new NetBSD installation.

Figure 3-40. Reboot to finish installation



Chapter 4

Upgrading NetBSD

This chapter describes the binary upgrade of a NetBSD system. There are a variety of alternatives to perform this procedure, and the following sections will guide you through them:

4.1 Using sysinst

4.1.1 Overview

To do the upgrade, you must have some form of bootable media (CD-ROM, USB drive, floppy, etc.) available and at least the base and kern distribution sets. Since files already installed on the system are overwritten in place, you only need additional free space for files which weren't previously installed or to account for growth of the sets between releases. Usually this is not more than a few megabytes.

> **Note:** Since upgrading involves replacing the kernel, boot blocks, and most of the system binaries, it has the potential to cause data loss. Before beginning, you are strongly advised to back up any important data on the NetBSD partition or on any other partitions on your disk.

The upgrade procedure is similar to an installation, but without the hard disk partitioning. sysinst will attempt to merge the settings stored in your `/etc` directory with the new version of NetBSD. Also, file systems are checked before unpacking the sets. Fetching the binary sets is done in the same manner as in the installation procedure.

4.1.2 The INSTALL document

Before doing an upgrade it is essential to read the release information and upgrading notes in one of the `INSTALL` files: this is the official description of the upgrade procedure, with platform specific information and important details. It can be found in the root directory of the NetBSD release (on the install CD or on the FTP server).

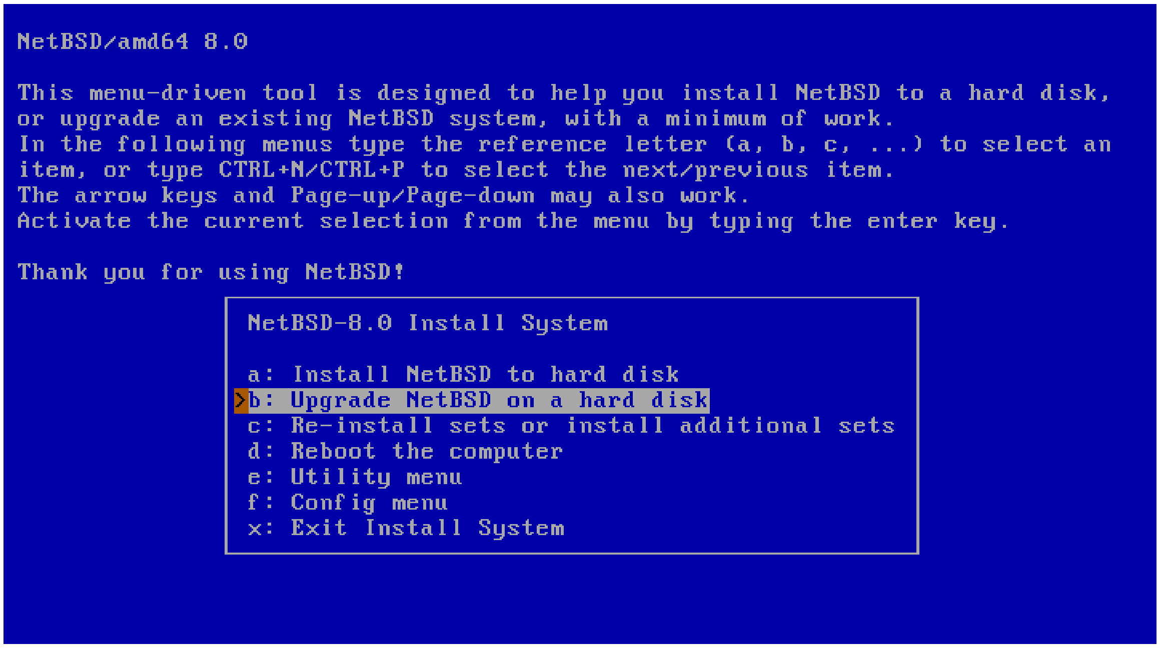
It is advisable to print the INSTALL document out. It is available in four formats: .txt, .ps, .more, and .html.

4.1.3 Performing the upgrade

The following section provides an overview of the binary upgrade process. Most of the following sysinst dialogs are similar to those of the installation process. More verbose descriptions and explanations of the dialogs are available in Chapter 3.

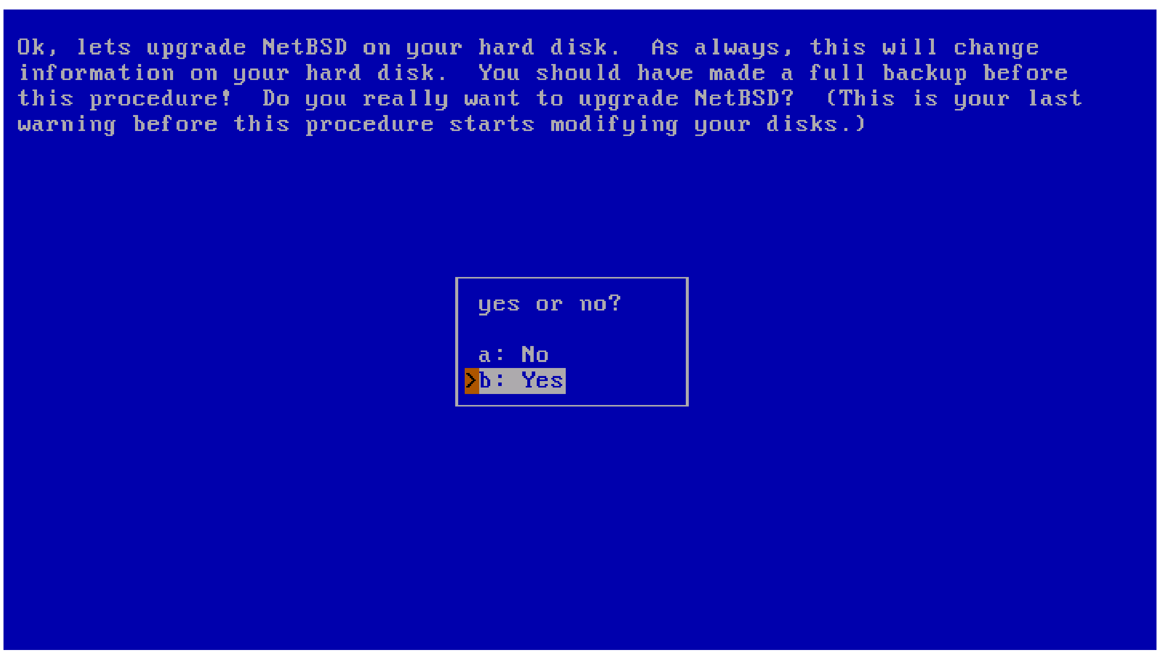
After selecting the installation language and the keyboard type, the main menu appears. Choosing option "b: Upgrade NetBSD on a hard disk" will start the the upgrade process.

Figure 4-1. Starting the upgrade



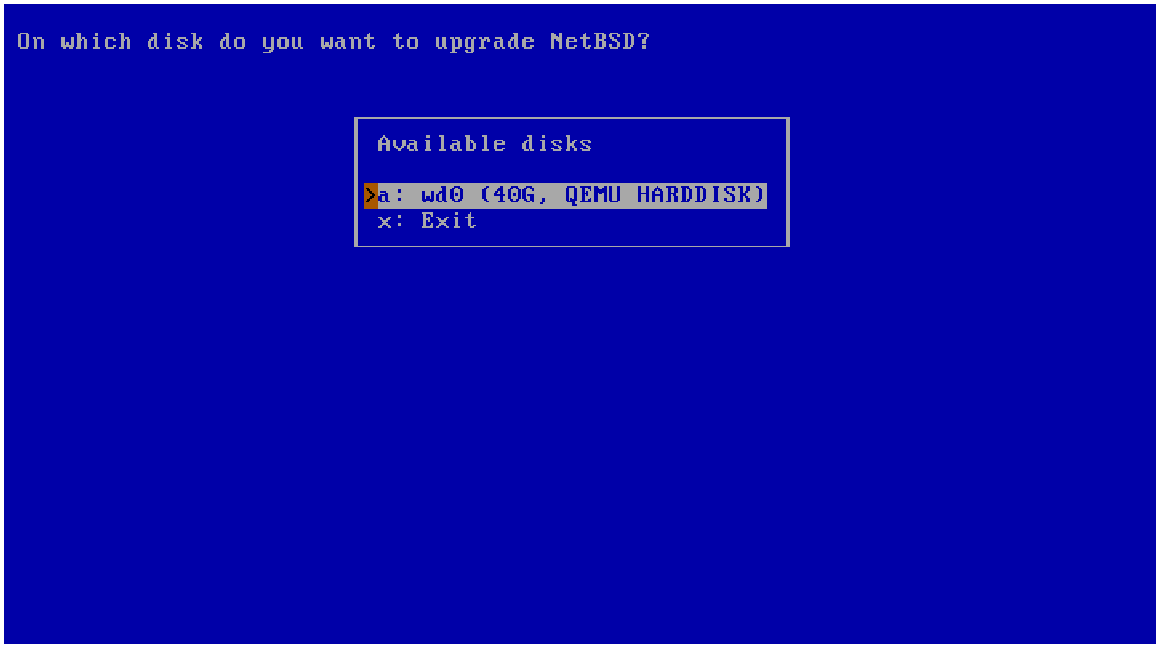
The dialog in Figure 4-2 will request permission to continue with the upgrade. At this point nothing has been changed yet and the upgrade can still be cancelled. This is a good time to ask yourself whether you have made a backup, and if you know for certain that you will be able to restore from it.

Figure 4-2. Continuing the upgrade



After choosing to continue with "Yes", the next dialog will ask you to specify the hard disk with the NetBSD system that shall be upgraded.

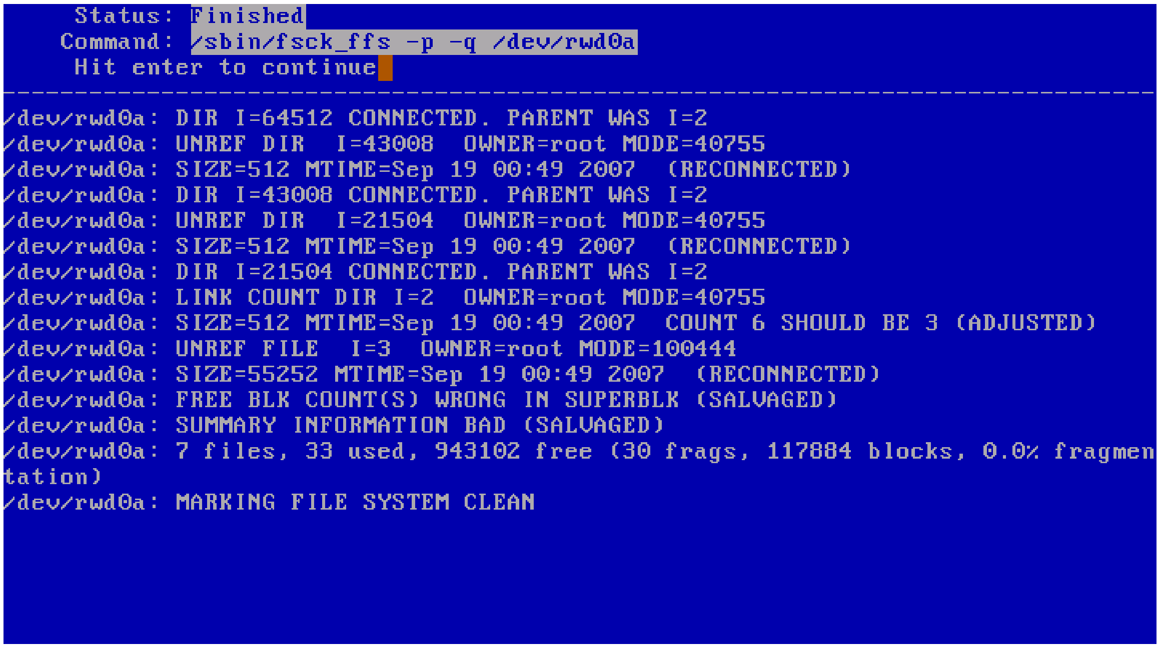
Figure 4-3. Choosing the hard drive



The system used for the example has only one hard disk available: "wd0".

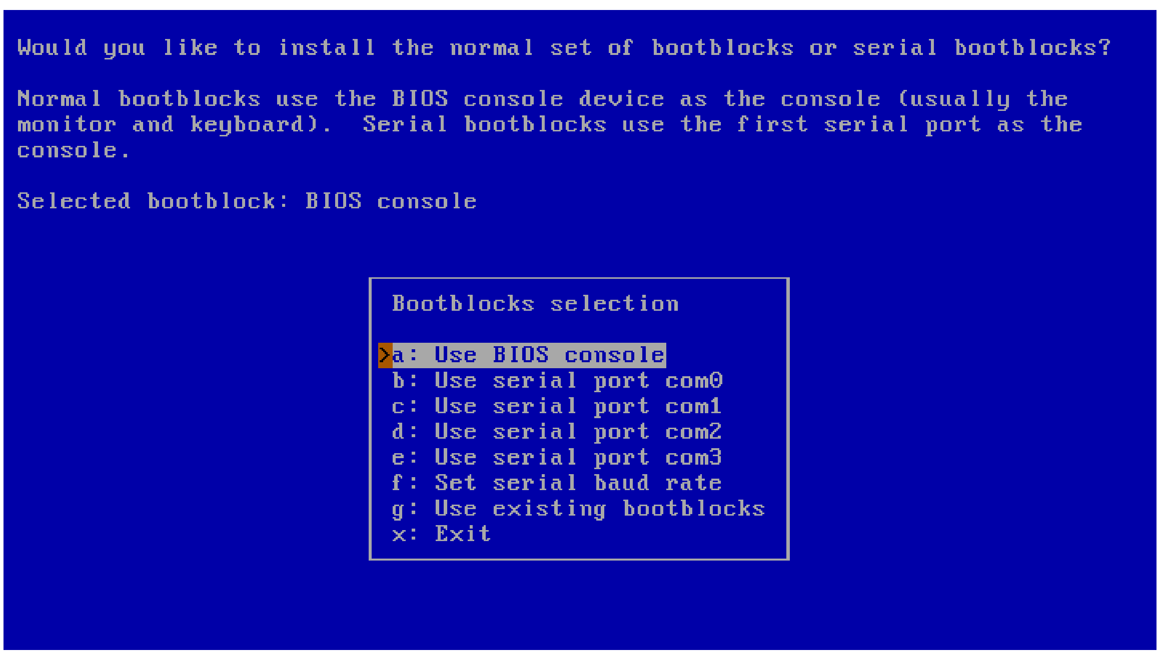
At this point, sysinst will perform a check of the file system to ensure its integrity.

Figure 4-4. File system check



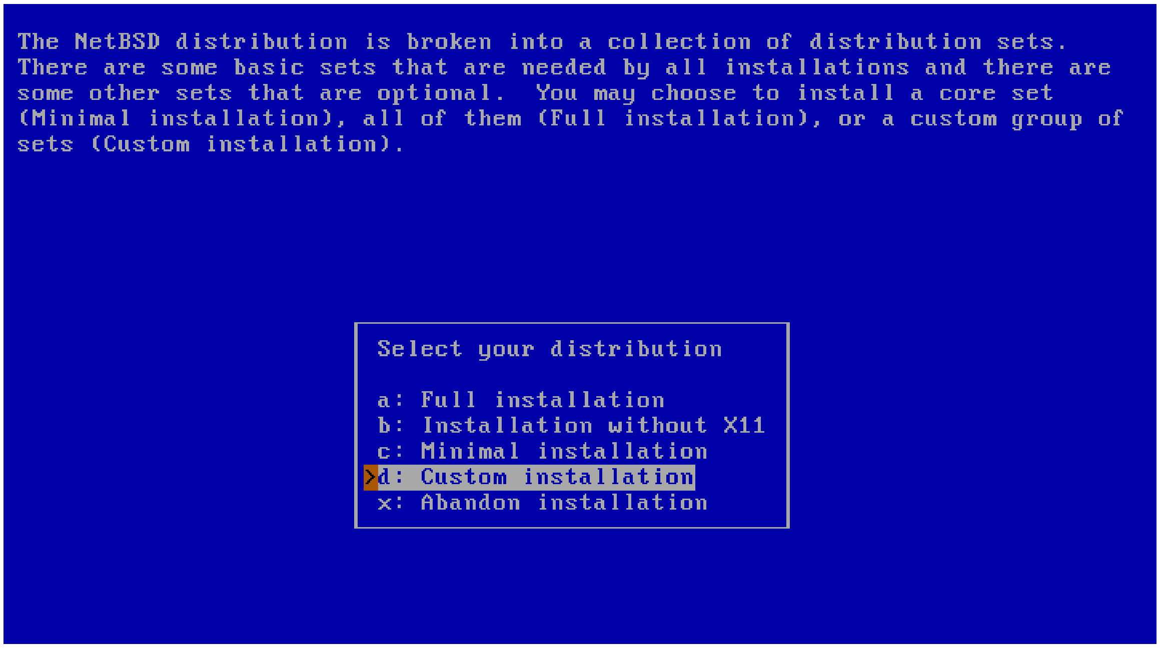
The next step is to choose which type of bootblocks to install.

Figure 4-5. Choosing bootblocks



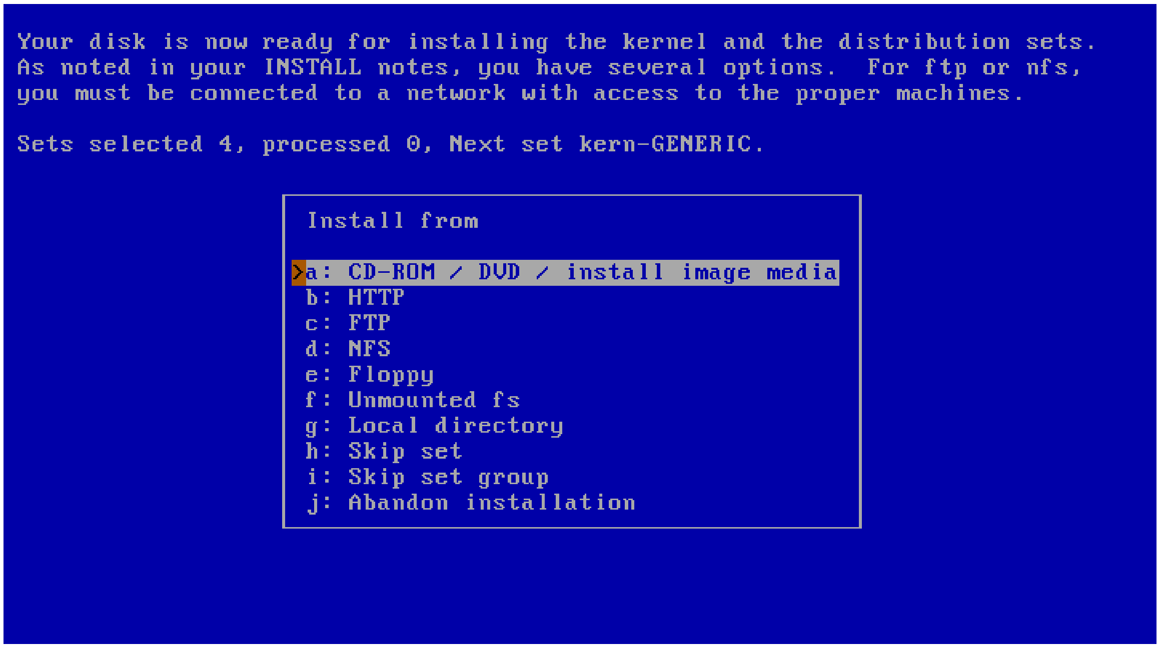
The following dialog provides a menu to choose the installation type. The choices are "Full installation", "Installation without X11", "Minimal installation", or "Custom installation".

Figure 4-6. Choosing the distribution filesets



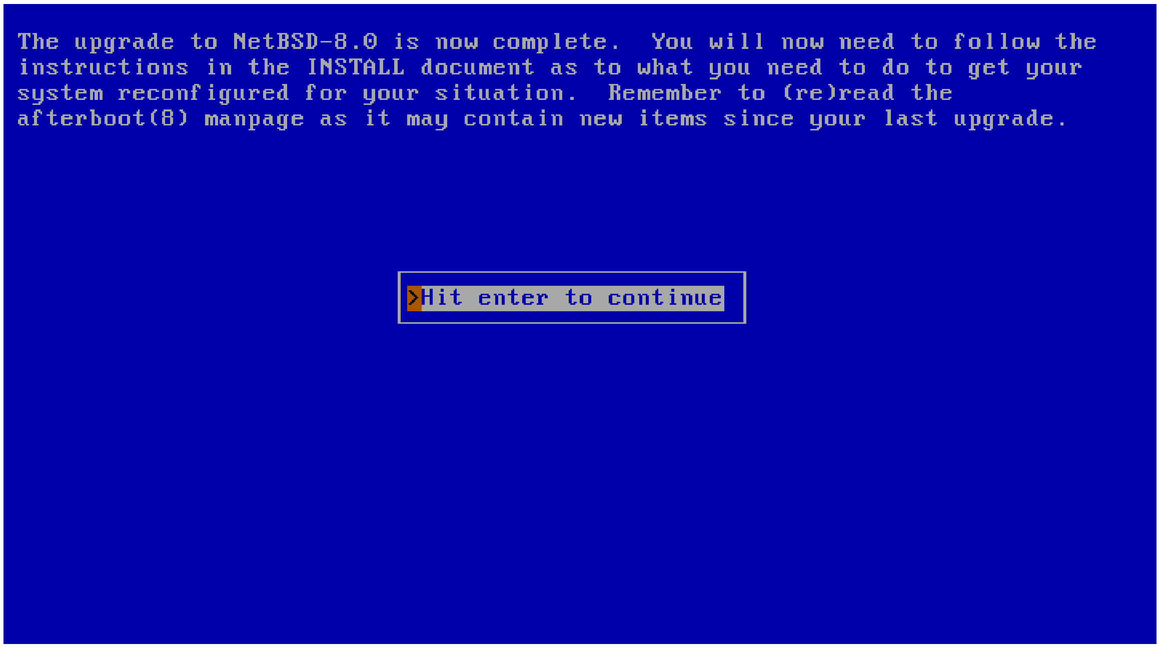
The following dialog asks for the install method of choice and provides a list of possible options. The install medium contains the new NetBSD distribution sets. You will be prompted for different information depending on which option you choose. For example, a CD-ROM or DVD install requires you to specify which device to use and which directory the sets are in, while an FTP install requires you to configure your network and specify the hostname of an FTP server. More details can be found in Section 3.11.

Figure 4-7. Install medium



sysinst will now unpack the distribution sets, replacing your old binaries. After unpacking these sets, it runs the postinstall(8) script to perform various system cleanup and configuration update tasks. If postinstall produces errors, you will have to manually resolve the issues it brings up. See postinstall's man page for more information. Even after a successful postinstall run, it is advisable to use etcupdate(8) to aid in merging any other configuration changes. You should also read the remarks in `INSTALL` about upgrading, as specific compatibility issues are documented there.

Figure 4-8. Upgrade complete



When you are back at the main menu, remove the boot medium (if applicable) and reboot. Have fun with your new version of NetBSD!

4.2 Using sysupgrade

The sysupgrade utility (currently found in `pkgsrc/sysutils/sysupgrade`) allows you to upgrade a running system to a newer binary release.

> **Note:** Take care when upgrading across major releases - ensure your running kernel is never newer than the userspace.

One of the benefits of sysupgrade is that it is an integrated and almost-unattended solution: the tool fetches the new kernel and distribution sets from remote sites if you desire and performs the upgrade without user intervention until new changes to the configuration files need to be merged.

Let's assume you are running NetBSD/amd64 9.1 and you wish to upgrade to NetBSD 9.2. The procedure to do so would be to run the following command:

```
# sysupgrade auto https://cdn.NetBSD.org/pub/NetBSD/NetBSD-9.2/amd64
```

And that's all that it takes. This will proceed to download the kernel and sets appropriate for your machine, unpack them and assist you in merging new configuration changes. Do not forget to reboot afterwards.

When upgrading between major releases (e.g. between NetBSD 8.2 and 9.2), take care to first upgrade the kernel and modules:

```
# sysupgrade fetch https://cdn.NetBSD.org/pub/NetBSD/NetBSD-9.2/amd64
# sysupgrade kernel
# sysupgrade modules
# reboot
# sysupgrade sets
# sysupgrade etcupdate
# sysupgrade postinstall
# sysupgrade clean
# reboot
```

For more details, please see the included sysupgrade(8) manual page and the `/usr/pkg/etc/sysupgrade.conf` configuration file.

III. System configuration, administration and tuning

Chapter 5
The first steps on NetBSD

After installing and rebooting, the computer will boot from the hard disk. If everything went well you'll be looking at the login prompt within a few seconds (or minutes, depending on your hardware). The system is not yet fully configured, but basic configuration is easy. You will see how to quickly configure some important things, and in doing so you will learn some basics about how the system works.

5.1 Troubleshooting

5.1.1 Boot problems

If the system does not boot it could be that the boot manager was not installed correctly or that there is a problem with the *MBR* (*Master Boot Record*). Boot the machine from your install medium (CD, DVD, floppy, etc.) and when you see the boot menu, select the option to drop to the boot prompt.

```
type "?" or "help" for help.
> ?
commands are:
boot [xdNx:][filename] [-12acdqsvxz]
     (ex. "hd0a:netbsd.old -s")
ls [path]
dev xd[N[x]]:
consdev {pc|com[0123]|com[0123]kbd|auto}
modules {enabled|disabled}
load {path_to_module}
multiboot [xdNx:][filename] [<args>]
help|?
quit
> boot hd0a:netbsd
```

The system should now boot from the hard disk. If NetBSD boots correctly from the hard disk, there is probably a Master Boot Record problem. You can install the boot manager or modify its configuration with the **fdisk -B** command. See Section 22.1 for a detailed description.

5.1.2 Misconfiguration of /etc/rc.conf

If you or the installation software haven't done any configuration of `/etc/rc.conf` (sysinst normally will), the system will drop you into *single user mode* and show the message

```
/etc/rc.conf is not configured. Multiuser boot aborted
```

When the system asks you to choose a shell, simply press RETURN to get to a /bin/sh prompt. If you are asked for a terminal type, respond with **vt220** (or whatever is appropriate for your terminal type) and press RETURN. You may need to type one of the following commands to get your delete key to work properly, depending on your keyboard:

```
# stty erase '^h'
# stty erase '^?'
```

At this point, you need to configure at least one file in the `/etc` directory. However, the root file system (`/`) is mounted read-only, so you will first need to make it writable with:

```
# /sbin/mount -u -w /
```

Next, take a look at the `/etc/rc.conf` file. Modify it to your tastes, making sure that you set "`rc_configured=YES` " so that you don't end up in this position again. Default values for the various programs can be found in `/etc/defaults/rc.conf`. More complete documentation can be found in rc.conf(5).

When you have finished, type exit at the prompt to leave the single-user shell and continue with the multi-user boot.

5.2 The man command

If you have never used a Unix(-like) operating system before, your best friend is now the **man** command, which displays a manual page. The NetBSD manual pages are among the best and most detailed you can find, although they are very technical.

A good manual to read after booting a new NetBSD system is afterboot(8). It contains information about various necessary and useful configuration settings.

man *name* shows the man page of the "*name*" command and **man -k *name*** shows a list of man pages dealing with "*name*" (you can also use the **apropos** command).

To learn the basics of the **man** command, type:

```
# man man
```

Manual pages contain not only information about commands but also descriptions of some NetBSD features and structures. For example, take a look at the hier(7) man page, which describes in detail the layout of the filesystem used by NetBSD.

```
# man hier
```

Other similar pages are release(7) and pkgsrc(7).

```
# man 8 intro
```

Manual pages are divided in several sections, depending on what they document:

1. general commands (tools and utilities), see intro(1)
2. system calls and error numbers, see intro(2)

3. C libraries, see intro(3)
4. special files and hardware support, see intro(4)
5. file formats, see intro(5)
6. games, see intro(6)
7. miscellaneous information pages, see intro(7)
8. system maintenance and operation commands, see intro(8)
9. kernel internals, see intro(9)

A subject may appear in more than one section of the manual; to view a specific page, supply the section number as an argument to the man command. For example, *time* appears in section 1 (the time user command) and in section 3 (the time function of the C library). To see the man page for the time C function, write:

```
# man 3 time
```

To see all the available pages:

```
# man -w time
# man -a time
```

5.3 Editing configuration files

Other than a shell, a text editor is the most essential tool for NetBSD system administration.

There are two provided in the base system

- ed(1), a line orientated text editor. ed is a very simplistic text editor. It has a command mode (active when first started) and an input mode. Its primary advantage is that it will work even without a correct terminal type set. In an emergency, ed is worth knowing, but note that vi(1) is available in `/rescue`, which brings us to...
- vi(1), a screen orientated text editor. vi is the only screen editor available in the base install, and requires a valid terminal type to run. Refer to Chapter 6 to learn more about NetBSD's default editor.

> **Advice:** Before you continue you should know or learn how to open, edit and save files within vi. Make sure to read Chapter 6.

5.4 Login

For the first login you will use the `root` user, which is the only user defined at the end of the installation. At the password prompt type the password for root that you set during the installation. If you didn't set a password, just press Enter.

```
NetBSD/i386 (Amnesiac) (ttyE0)
login: root
password:
```

```
We recommend creating a non-root account and using su(1) for
root access.
#
```

5.5 Changing the `root` password

If you did not set a password for `root` during the installation, you should use the **/usr/bin/passwd** command to do so now.

```
# /usr/bin/passwd
Changing local password for root.
New password:
Retype new password:
```

Passwords are not displayed on the screen while you type.

Choose a password that has numbers, digits, and special characters (not space) as well as from the upper and lower case alphabet. Do not choose any word in any language. It is common for an intruder to use dictionary attacks.

5.6 Adding users

For security reasons, it is bad practice to login as root during regular use and maintenance of the system. Instead, administrators are encouraged to add a regular user, add the user to the `wheel` group, then use the su(1) command when root privileges are required. NetBSD offers the useradd(8) utility to create user accounts. For example, to create a new user:

```
# useradd -m joe
```

The defaults for the useradd command can be changed; see the useradd(8) man page.

User accounts that can su to root are required to be in the "wheel" group. This can be done when the account is created by specifying a secondary group:

```
# useradd -m -G wheel joe
```

As an alternative, the usermod(8) command can be used to add a user to an existing group:

```
# usermod -G wheel joe
```

In case you just created a user but forgot to set a password, you can still do that later using the passwd(1) command.

```
# passwd joe
```

> **Note:** You can edit `/etc/group` directly to add users to groups, but do *not* edit the `/etc/passwd` directly; use vipw(8).

5.7 Shadow passwords

Shadow passwords are enabled by default. What this means is that all the passwords in `/etc/passwd` are simply "*"; the encrypted passwords are stored in a file that can only be read by root, `/etc/master.passwd`. When you start vipw(8) to edit the password file, the program opens a copy of `/etc/master.passwd`; when you exit, vipw checks the validity of the copy, creates a new `/etc/passwd` and installs the new `/etc/master.passwd` file. Finally, vipw launches pwd_mkdb(8), which creates the files `/etc/pwd.db` and `/etc/spwd.db`, two databases which are equivalent to `/etc/passwd` and `/etc/master.passwd` but faster to process.

It is very important to *always* use **vipw** and the other tools for account administration (chfn(1), chsh(1), chpass(1), passwd(1)) and to *never* directly modify `/etc/master.passwd` or `/etc/passwd`.

5.8 Changing the keyboard layout

If you do not have a US layout keyboard, you will probably want to change keymaps. For example, to use an italian keyboard, enter the following command:

```
# wsconsctl -k -w encoding=it
encoding -> it
```

To save the keyboard layout permanently, add the following line to the `/etc/wscons.conf` file:

```
encoding it
```

See Section 8.1.2.1 for a list of available keymaps.

5.9 System time

NetBSD, like all Unix systems, uses a system clock based on UTC (Coordinated Universal Time) and this is what you should set your system clock to. If you want to keep the system clock set to the local time (because, for example, you have a dual boot system with Windows installed), you must notify NetBSD, adding `rtclocaltime=YES` to `/etc/rc.conf`:

```
# echo rtclocaltime=YES >> /etc/rc.conf
# sh /etc/rc.d/rtclocaltime restart
```

> **Note:** Alternatively, it is possible to configure Windows 7 and beyond to cope with the RTC being UTC. As alluded to in this Microsoft Knowledge Base article (http://support.microsoft.com/kb/2922223), the way to do this is to add a DWORD registry key named RealTimeIsUniversal, with a value of 1, to HKEY_LOCAL_MACHINE\System\CurrentControlSet\Control\TimeZoneInformation.

The number of minutes west of GMT is calculated automatically and is set in the `kern.rtc_offset` sysctl variable.

To display the current setting of the `kern.rtc_offset` variable:

```
# sysctl kern.rtc_offset
```

```
kern.rtc_offset = -60
```

This automatic configuration only works if you have set the proper time zone with a symbolic link to `/etc/localtime`. Normally this is done as part of the install procedure, but if for some reason it wasn't, you can set it by creating a symbolic link from a file in the `/usr/share/zoneinfo` directory to `/etc/localtime`.

The following example sets the time zone to Eastern Europe Summer Time:

```
# ln -fs /usr/share/zoneinfo/Europe/Helsinki /etc/localtime
```

5.10 Secure Shell (ssh(1))

By default, all services are disabled in a fresh NetBSD installation, and ssh(1) is no exception. You may wish to enable it so you can log in to your system remotely. Set `sshd=YES` in `/etc/rc.conf` and then start the server with the command

```
# /etc/rc.d/sshd start
```

The first time the server is started, it will generate a new keypair, which will be stored inside the directory `/etc/ssh`.

5.11 Basic configuration in `/etc/rc.conf`

NetBSD uses `/etc/rc.conf` to determine what will be executed when the system boots. Understanding this file is important. The rc.conf(5) manual page contains a detailed description of all available options.

The `/etc/defaults/rc.conf` file contains the default values for most settings. To override a default value, the new value must be put into `/etc/rc.conf`. The definitions there override the ones in `/etc/defaults/rc.conf` (which you should leave unchanged).

```
# man rc.conf
```

The first modifications are:

- Set "`rc_configured=YES`" (this modification should already have been done by the installation software.)
- Set "`dhcpcd=YES`" to configure your system's network using DHCP.
- Define a *hostname* for your machine (use a fully qualified hostname, i.e., one including domain). If you have a standalone machine you can use any name (for example, vigor3.your.domain). If your machine is connected to a network, you should supply the correct name.
- If your machine is connected to a local network or the Internet through a router, set the *defaultroute* variable to the IP address of your router (sometimes called a *default gateway*). For example, "`defaultroute=192.168.1.1`".

5.12 Basic network settings

To resolve the names and IP addresses of remote hosts, the system needs access to a (remote or local) *DNS nameserver*. Tell the system which nameserver(s) to use by adding the IP address of one or more nameservers to the `/etc/resolv.conf` file, using the following as an example:

```
nameserver 145.253.2.75
```

To set the names of local hosts that are not available through DNS, edit the `/etc/hosts` file, which has the form:

```
IP-address  hostname  host
```

For example:

```
192.168.1.3 vigor3.your.domain vigor3
```

5.13 Mounting a CD-ROM

New users are often surprised by the fact that although the installation program recognized and mounted their CD-ROM perfectly, the installed system seems to have “forgotten” how to use the CD-ROM. There is no special magic for using a CD-ROM; you can mount it like any other file system. All you need to know is the device name and some options to the mount(8) command. You can find the device name with the aforementioned dmesg(8) command. For example, if dmesg displays:

```
# dmesg | grep ^cd
cd0 at atapibus0 drive 1: <ASUS CD-S400/A, , V2.1H> type 5 cdrom removable
```

the device name is `cd0`, and you can mount the CD-ROM with the following commands:

```
# mkdir /cdrom
# mount -t cd9660 -o ro /dev/cd0a /cdrom
```

To make things easier, you can add a line to the `/etc/fstab` file:

```
/dev/cd0a /cdrom cd9660 ro,noauto 0 0
```

Without the need to reboot, you can now mount the CD-ROM with:

```
# mount /cdrom
```

When the CD-ROM is mounted you can’t eject it manually; you will have to unmount it before you can do that:

```
# umount /cdrom
```

There is also a software command which unmounts the CD-ROM and ejects it:

```
# eject /dev/cd0a
```

5.14 Mounting a floppy

To mount a floppy you must know the name of the floppy device and the file system type of the floppy. Read the fdc(4) manpage for more information about device naming, as this will differ depending on the exact size and kind of your floppy disk. For example, to read and write a floppy in MS-DOS format you use the following command:

```
# mount -t msdos /dev/fd0a /mnt
```

Instead of `/mnt`, you can use another directory of your choice; you could, for example, create a `/floppy` directory like you did for the CD-ROM. If you do a lot of work with MS-DOS floppies, you will want to install the mtools package, which enables you to access a MS-DOS floppy (or hard disk partition) without the need to mount it. It is very handy for quickly copying a file to or from a floppy:

```
# mcopy foo bar a:
# mcopy a:baz.txt baz
# mcopy a:\*.jpg .
```

5.15 Installing additional software

5.15.1. Using packages from pkgsrc

If you wish to install any of the software freely available for UNIX-like systems you are strongly advised to first check the NetBSD package system, pkgsrc (http://www.pkgsrc.org). pkgsrc automatically handles any changes necessary to make the software run on NetBSD. This includes the retrieval and installation of any other packages on which the software may depend.

- See the list of available packages (https://cdn.NetBSD.org/pub/pkgsrc/current/pkgsrc/README-all.html)
- Precompiled binaries are available on the NetBSD FTP server for most ports. To install them the PKG_PATH variable needs to be adjusted in the following way (under the sh(1) shell):

  ```
  # PKG_PATH="https://cdn.NetBSD.org/pub/pkgsrc/packages/NetBSD/$(uname -p)/$(uname -r | cut -d_ -f1)/
  # export PKG_PATH
  ```

  Applications can now be installed by the superuser `root` with the pkg_add command:

  ```
  # pkg_add -v perl
  # pkg_add -v apache
  # pkg_add -v firefox
  ```

  The above commands will install the Perl programming language, Apache web server, and the Firefox web browser as well as all the packages they depend on.

  It is recommended you install and use pkgin for most non-trivial binary package management tasks, and managing upgrades. pkgin can be installed from the post-installation configuration menu in **sysinst**, or afterwards using **pkg_add** on a live system:

  ```
  # pkg_add -v pkgin
  ```

  It maintains a local database of packages that are on the remote server, you can fetch the database with:

```
# pkgin update
```

Its usage is oriented on the package tools you have with other operating systems. To search the package database for a word ‘stat‘, use

```
# pkgin search WORD
```

To install a package (in this case ‘fscd‘), just type

```
# pkgin install fluxbox
```

To upgrade installed packages:

```
# pkgin upgrade
```

You should read the manpage to know about more actions you can do with pkgin.

All details about package management can be found in *The pkgsrc guide* (http://www.NetBSD.org/docs/pkgsrc/index.html)

5.15.2. Storing third-party software

On many UNIX-like systems the directory structure under `/usr/local` is reserved for applications and files which are independent of the system's software management. This convention is the reason why most software developers expect their software to be installed under `/usr/local`. NetBSD has no `/usr/local` directory, but it can be created manually if needed. NetBSD does not care about anything installed under `/usr/local`, so this task is left to you as the system administrator.

5.16 Security alerts

By the time that you have installed your system, it is quite likely that bugs in the release have been found. All significant and easily fixed problems will be reported at http://www.NetBSD.org/support/security/. It is recommended that you check this page regularly.

5.17 Stopping and rebooting the system

Use one of the following two shutdown commands to halt or reboot the system:

```
# shutdown -h now
# shutdown -r now
```

Two other commands to perform the same tasks are:

```
# halt
# reboot
```

halt, reboot and shutdown are not synonyms: the latter is more sophisticated. On a multiuser system you should really use shutdown, which allows you to schedule a shutdown time and notify users. It will also take care to stop processes properly. For more information, see the shutdown(8), halt(8) and reboot(8) manpages.

Chapter 6
Editing

6.1 Introducing vi

It is not like the vi editor needs introducing to seasoned UNIX users. The vi editor, originally developed by Bill Joy of Sun Microsystems, is an endlessly extensible, easy to use *light* ASCII editor and the bane of the newbie existence. This section will introduce the vi editor to the newbie and perhaps toss in a few ideas for the seasoned user as well.

The first half of this section will overview editing, saving, yanking/putting and navigating a file within a vi session. The second half will be a step by step sample vi session to help get started.

This is intended as a primer for using the vi editor, it is *not by any means* a thorough guide. It is meant to get the first time user up and using vi with enough skills to make changes to and create files.

6.1.1 The vi interface

Using the vi editor really is not much different than any other terminal based software with one exception, it does not use a tab type (or curses if you will) style interface, although many versions of vi *do use* curses it does not give the same look and feel of the typical curses based interface. Instead it works in two modes, *command* and *edit*. While this may seem strange, it is not much different than windows based editing if you think about it. Take this as an example, if you are using say gedit and you take the mouse, highlight some text, select cut and then paste, the whole time you are using the mouse you are not editing (even though you can). In vi, the same action is done by simply deleting the whole line with **dd** in command mode, moving to the line you wish to place it below and hitting **p** in command mode. One could almost say the analogy is “mouse mode vs. command mode” (although they are not exactly identical, conceptually the idea is similar).

To start up a vi session, one simply begins the way they might with any terminal based software:

```
$ vi filename
```

One important note to remember here is that when a file is edited, it is loaded into a memory buffer. The rest of the text will make reference to the buffer and file in their proper context. A file *only* changes when the user has committed changes with one of the write commands.

6.1.2 Switching to Edit Mode

The vi editor sports a range of options one can provide at start up, for the time being we will just look at the default startup. When invoked as shown above, the editor’s default startup mode is command mode, so in essence you cannot commence to typing into the buffer. Instead you must switch out out of command mode to enter text. The following text describes edit start modes:

a Append after cursor.
A Append to end of line.
C Change the rest of current line.
cw Change the current word.
i Insert before cursor.
I Insert before first non blank line.
o Open a line below for insert
O Open a line above for insert.

6.1.3 Switching Modes & Saving Buffers to Files

Of course knowing the edit commands does not do much good if you can't switch back to command mode and save a file, to switch back simply hit the **ESC** key. To enter certain commands, the colon must be used. Write commands are one such set of commands. To do this, simply enter **:**.

Hitting the colon then will put the user at the colon (or *command* if you will) prompt at the bottom left corner of the screen. Now let us look at the save commands:

:w Write the buffer to file.
:wq Write the buffer to file and quit.

6.1.4 Yanking and Putting

What good is an editor if you cannot manipulate blocks of text? Of course vi supports this feature as well and as with most of the vi commands it somewhat intuitive. To yank a line but *not* delete it, simply enter **yy** or **Y** in command mode and the current line will be copied into a buffer. To put the line somewhere, navigate to the line above where the line is to be put and hit the **p** key for the "put" command. To move a line, simply delete the whole line with the **dd** command, navigate and put.

6.1.4.1 Oops I Did Not Mean to do that!

Undo is pretty simple, **u** undoes the last action and **U** undoes the last line deleted or changes made on the last line.

6.1.5 Navigation in the Buffer

Most vi primers or tutorials start off with navigation, however, not unlike most editors in order to navigate a file there must be something to navigate to and from (hence why this column sort of went in reverse). Depending on your flavor of vi (or if it even *is* vi and not say elvis, nvi or vim) you can navigate in both edit and command mode.

For the beginner I feel that switching to command mode and then navigating is a bit safer until one has practiced for awhile. The navigation keys for terminals that are not recognized or do not support the use of arrow keys are the following:

k Moves the cursor up one line.
j Moves the cursor down one line.
l Moves the cursor right one character.
h Moves the cursor left one character.

If the terminal is recognized and supports them, the arrow keys can be used to navigate the buffer in command mode.

In addition to simple "one spot navigation" vi supports jumping to a line by simply typing in the line number at the colon prompt. For example, if you wanted to jump to line 223 the keystrokes from editor mode would look like so:

```
ESC
:223
```

6.1.6 Searching a File, the Alternate Navigational Aid

The vi editor supports searching using regular expression syntax, however, it is slightly different to invoke from command mode. One simply hits the **/** key in command mode and enters what they are searching for, as an example let us say I am searching for the expression *foo*:

```
/foo
```

That is it, to illustrate a slightly different expression, let us say I am looking for *foo bar*:

```
/foo bar
```

6.1.6.1 Additional Navigation Commands

Searching and scrolling are not the only ways to navigate a vi buffer. Following is a list of succinct navigation commands available for vi:

0 Move to beginning of line.
$ Move to end of line.
b Back up one word.
w Move forward one word.
G Move to the bottom of the buffer.
H Move to the top line on the screen.
L Move to the last line on the screen.
M Move the cursor to the middle of the screen.
N Scan for next search match but opposite direction.
n Scan for next search match in the same direction.

6.1.7 A Sample Session

Now that we have covered the basics, let us run a sample session using a couple of the items discussed so far. First, we open an empty file into the buffer from the command line like so:

```
# vi foo.txt
```

Next we switch to edit mode and enter two lines separated by an empty line, remember our buffer is empty so we hit the **i** key to insert before cursor and enter some text:

```
This is some text

there we skipped a line
~
~
~
~
```

Now hit the **ESC** key to switch back into command mode.

Now that we are in command mode, let us save the file. First, hit the **:** key, the cursor should be sitting in the lower left corner right after a prompt. At the **:** prompt enter **w** and hit the **ENTER** or **RETURN** key. The file has just been saved. There should have been a message to that effect, some vi editors will also tell you the name, how many lines and the size of the file as well.

It is time to navigate, the cursor should be sitting wherever it was when the file was saved. Try using the arrow keys to move around a bit. If they do not work (or you are just plain curious) try out the **hjkl** keys to see how they work.

Finally, let us do two more things, first, navigate up to the first line and then to the first character. Try out some of the other command mode navigation keys on that line, hit the following keys a couple of times:

```
$
0
$
0
```

The cursor should hop to the end of line, back to the beginning and then to the end again.

Next, search for an expression by hitting the **/** key and an expression like so:

```
/we
```

The cursor should jump to the *first occurrence* of *we*.

Now save the file and exit using write and quit:

```
:wq
```

6.2 Configuring vi

The standard editor supplied with NetBSD is, needless to say, vi, the most loved and hated editor in the world. If you don't use vi, skip this section, otherwise read it before installing other versions of vi. NetBSD's vi (*nvi*) was written by Keith Bostic of UCB to have a freely redistributable version of this editor and has many powerful extensions worth learning while being still very compatible with the original vi. Nvi has become the standard version of vi for BSD.

Amongst the most interesting extensions are:

- Extended regular expressions (egrep style), enabled with option `extended`.
- Tag stacks.
- Infinite undo (to undo, press **u**; to continue undoing, press **.**).
- Incremental search, enabled with the option `searchincr`.
- Left-right scrolling of lines, enabled with the option `leftright`; the number of columns to scroll is defined by the `sidescroll` option.
- Command line history editing, enabled with the option `cedit`.
- Filename completion, enabled by the `filec` option.
- Backgrounded screens and displays.
- Split screen editing.

6.2.1 Extensions to .exrc

The following example shows a `.exrc` file with some extended options enabled.

```
set showmode ruler
set filec=^[
set cedit=^[
```

The first line enables the display of the cursor position (row and column) and of the current mode (Command, Insert, Append) on the status line. The second line (where ^[is the ESC character) enables filename completion with the ESC character. The third line enables command line history editing (also with the ESC character.) For example, writing ":" and then pressing ESC opens a window with a list of the previous commands which can be edited and executed (pressing Enter on a command executes it.)

6.2.2 Documentation

The misc *installation set* (`misc.tgz`) contains a lot of useful documentation on (n)vi and ex, and when installed it is available in `/usr/share/doc` directory. For example:

- Edit: A tutorial - `/usr/share/doc/usd/edit/edit.{ps.gz,txt}`
- Ex Reference Manual - `/usr/share/doc/reference/ref1/ex/reference.{ps.gz,txt}`
- Vi man page - vi(1)

- An Introduction to Display Editing with Vi by William Joy and Mark Horton - `/usr/share/doc/usd/vi/vitut.{ps.gz,txt}`
- Vi/Ex Reference Manual by Keith Bostic - `/usr/share/doc/reference/ref1/vi/vi.{ps.gz,txt}`
- Ex/Vi Quick Reference - `/usr/share/doc/usd/vi/summary.{ps.gz,txt}`

If you have never used vi, *An Introduction to Display Editing with Vi* by William Joy and Mark Horton is a very good starting point.

If you want to learn more about vi and the nvi extensions you should read the *Vi/Ex Reference Manual* by Keith Bostic which documents all the editor's commands and options.

6.3 Using tags with vi

This topic is not directly related to NetBSD but it can be useful, for example, for examining the kernel sources.

When you examine a set of sources in a tree of directories and subdirectories you can simplify your work using the *tag* feature of vi. The method is the following:

1. **cd** to the base directory of the sources.

   ```
   $ cd /path
   ```

2. Write the following commands:

   ```
   $ find . -name "*.[ch]" > filelist
   $ cat filelist | xargs ctags
   ```

3. Add the following line to `.exrc`

   ```
   set tags=/path/tags
   ```

   (substitute the correct path instead of *path*.)

Chapter 7

The rc.d System

NetBSD uses individual scripts for controlling services, similar to what System V does, but without runlevels. This chapter is an overview of the rc.d system and its configuration.

7.1 Basics

The system startup files reside in the `/etc` directory. They are:

- `/etc/rc`
- `/etc/rc.conf`
- `/etc/rc.d/*`
- `/etc/rc.local`
- `/etc/rc.shutdown`
- `/etc/rc.subr`
- `/etc/defaults/*`
- `/etc/rc.conf.d/*`

First, an overview of the control and support scripts (also documented in rc(8)).

- After the kernel has initialized all devices at startup, it starts init(8), which in turn runs `/etc/rc`.
- `/etc/rc` sorts the scripts in `/etc/rc.d` using rcorder(8) and then runs them in that order. See the rcorder(8) man page for details of how the order of rc.d scripts is determined.
- `/etc/rc.subr` contains common functions used by `/etc/rc` and various rc.d scripts.
- When shutting down the system with shutdown(8), `/etc/rc.shutdown` is run, which runs the scripts in `/etc/rc.d` in reverse order (as defined by rcorder(8)). Note that if you shut down the system using the halt(8) command, these scripts will not be run.

Additional scripts outside of the `rc.d` directory:

- `/etc/rc.local` is almost the last script called at boot up. This script can be edited by the administrator to start local daemons that don't fit the rc.d model.

rc.d scripts are controlled by a central configuration file, `/etc/rc.conf`, which loads its default settings from `/etc/defaults/rc.conf`. If you want to change a default setting, do not edit `/etc/defaults/rc.conf`; instead, apply the setting in `/etc/rc.conf`. This will override the default.

It is a good idea to read the rc.conf(5) man page to learn about the services that are available to you.

The following example shows how to enable the SSH daemon, which is disabled by default:

```
# cd /etc; grep ssh defaults/rc.conf
sshd=NO                 sshd_flags=""
# echo "sshd=YES" >> rc.conf
```

Now sshd(8) will be started automatically at system startup. The next section describes how to start and stop services at any time.

Last but not least, files can be created in the `/etc/rc.conf.d/` directory to override the behavior of a given rc.d script without editing the script itself.

7.2 The rc.d Scripts

The actual scripts that control services are in `/etc/rc.d`. These scripts are automatically run at boot time, but they can be called manually if necessary. The following example shows how to start the SSH daemon that we enabled in the previous section:

```
# /etc/rc.d/sshd start
Starting sshd.
```

Later, if you wish to stop the SSH daemon, run the following command:

```
# /etc/rc.d/sshd stop
Stopping sshd.
Waiting for PIDS: 123.
```

The rc.d scripts take one of the following arguments:

- start
- stop
- restart
- status

Some scripts may support other arguments (e.g., “reload”), but every script will support at least the above commands.

As an example, after adding a new record to a named(8) database, the daemon can be told to reload its configuration files with the following command:

```
# /etc/rc.d/named reload
Reloading named config files.
```

Note that all of the commands discussed above will only take action if the particular service is enabled in `/etc/rc.conf`. It is possible to bypass this requirement by prepending “one” to the command, as in:

```
# /etc/rc.d/httpd onestart
Starting httpd.
```

The above command will allow you to start the httpd(8) service one time. To stop a service that has been started in this manner, pass “onestop” to the script.

7.2.1 Packages installing rc.d scripts

Several packages install rc.d scripts. By default package rc.d scripts can be found in /usr/pkg/share/examples/rc.d and need to be manually copied to /etc/rc.d in order to be used. Setting PKG_RCD_SCRIPTS=yes environment variable prior installing packages enable automatic copying rc.d scripts to /etc/rc.d.

7.3 The Role of rcorder and rc.d Scripts

The startup system of every Unix system determines, in one way or another, the order in which services are started. On some Unix systems this is done by numbering the files and/or putting them in separate run level directories. Solaris relies on wildcards like /etc/rc[23].d/S* being sorted numerically when expanded. Some simply put all the commands that should be started into a single monolithic script (this is the traditional BSD method, and is what NetBSD did before the rc.d system). On modern NetBSD this is done by the rc.d scripts and their contents. Please note that NetBSD does not use multiple runlevels.

At the beginning of each rc.d script there is a series of commented out lines that have one of the following items in them:

- REQUIRE
- PROVIDE
- BEFORE
- KEYWORD

These describe the dependencies of that particular script and allow rcorder to easily work either "up" or "down" as the situation requires. As an example, here is the ordering information contained in /etc/rc.d/nfsd:

```
...
 PROVIDE: nfsd
 REQUIRE: rpcbind mountd
...
```

Here we can see that this script provides the "nfsd" service and that it requires "rpcbind" and "mountd" to be running first. The rcorder(8) utility is used at system startup time to read through all the rc.d scripts and determine the order in which they should be run.

7.4 Additional Reading

Luke Mewburn, one of the principal designers of the rc.d system, gave a presentation on the system at USENIX 2001. It is available in PDF (http://www.mewburn.net/luke/papers/rc.d.pdf) format.

Chapter 8

Console drivers

8.1 wscons

Wscons is NetBSD's platform-independent workstation console driver. It handles complete abstraction of keyboards and mice. This means that you can plug in several keyboards or mice and they will be multiplexed onto a single terminal, but also that it can multiplex several virtual terminals onto one physical terminal.

Wscons support is enabled by default on most architectures. This can be done manually by adding `wscons=YES` to your `/etc/rc.conf`. Then configure the desired number of virtual consoles as described in Section 8.1.1.1 and start wscons by entering **`sh /etc/rc.d/wscons start`** followed by **`sh /etc/rc.d/ttys restart`**. You can now switch virtual consoles by pressing Ctrl+Alt+F*n* or similar, depending on the platform.

Wscons comprises three subsystems: wsdisplay, wskbd and wsmouse. These subsystems handle abstraction for all display, keyboard and mouse devices respectively. The following sections discuss the configuration of wscons per subsystem.

8.1.1 wsdisplay

This section will explain how to configure display and screen-related options.

8.1.1.1 Virtual consoles

The number of pre-allocated virtual console is controlled by the following kernel configuration option

```
options     WSDISPLAY_DEFAULTSCREENS=4
```

Other consoles can be added by enabling the relevant lines in the `/etc/wscons.conf` file: the comment mark (#) must be removed from the lines beginning with `screen x`. In the following example a fifth console is added to the four pre-allocated ones:

```
# screens to create
#       idx     screen  emul
#screen 0       -       vt100
screen  1       -       vt100
screen  2       -       vt100
screen  3       -       vt100
screen  4       -       -
#screen 4       80x25bf vt100
#screen 5       80x50   vt100
```

The `/etc/rc.d/wscons` script transforms each of the non commented lines in a call to the **wsconscfg** command: the columns become the parameters of the call. The *idx* column becomes the `index` parameter, the *screen* column becomes the `-t type` parameter (which defines the type of screen: rows and columns, number of colors, ...) and the *emul* column becomes the `-e emul` parameter, which defines the emulation. For example:

```
screen 3       -       vt100
```

becomes a call to:

```
wsconscfg -e vt100 3
```

Please note that it is possible to have a (harmless) conflict between the consoles pre-allocated by the kernel and the consoles allocated at boot time through `/etc/wscons.conf`. If during boot the system tries to allocate an already allocated screen, the following message will be displayed:

```
wsconscfg: WSDISPLAYIO_ADDSCREEN: Device busy
```

The solution is to comment out the offending lines in `/etc/wscons.conf`.

Note that while it is possible to delete a screen and add it with different settings, it is, technically speaking, not possible to actually modify the settings of a screen.

`screen 0` cannot be deleted if used as system console. This implies that the setting of screen 0 cannot be changed in a running system, if used as system console.

The virtual console must also be active in `/etc/ttys`, so that NetBSD runs the getty(8) program to ask for login. For example:

```
console "/usr/libexec/getty Pc"         pc3     off secure
ttyE0   "/usr/libexec/getty Pc"         vt220   on secure
ttyE1   "/usr/libexec/getty Pc"         vt220   on secure
ttyE2   "/usr/libexec/getty Pc"         vt220   on secure
ttyE3   "/usr/libexec/getty Pc"         vt220   off secure
...
```

When starting up the X server, it will look for a virtual console with no getty(8) program running, e.g. one console should left as "off" in `/etc/ttys`. The line

```
ttyE3   "/usr/libexec/getty Pc"         vt220   off secure
```

of `/etc/ttys` is used by the X server for this purpose. To use a screen different from number 4, a parameter of the form vt*n* must be passed to the X server, where *n* is the number of the function key used to activate the screen for X.

For example, `screen 7` could be enabled in `/etc/wscons.conf` and X could be started with `vt8`. If you use xdm you must edit `/etc/X11/xdm/Xservers`. For example:

```
:0 local /usr/X11R7/bin/X +kb dpms -bpp 16 dpms vt8
```

8.1.1.1.1 Getting rid of the message `WSDISPLAYIO_ADDSCREEN: Device busy`

This error message usually occurs when wsconscfg tries to add a screen which already exists. This occurs if you have a `screen 0` line in your `/etc/wscons.conf` file, because the kernel always allocates a screen 0 as the console device. The error message is harmless in this case, and you can get rid of it by deleting (or commenting out) the `screen 0` line.

8.1.1.2 50 lines text mode with wscons

This mode is activated in the `/etc/wscons.conf`. The following line must be uncommented:

```
font ibm  -  8  ibm  /usr/share/pcvt/fonts/vt220l.808
```

Then the following lines must be modified:

```
#screen 0       80x50   vt100
screen  1       80x50   vt100
screen  2       80x50   vt100
screen  3       80x50   vt100
screen  4       80x50   vt100
screen  5       80x50   vt100
screen  6       80x50   vt100
screen  7       80x50   vt100
```

This configuration enables eight screens, which can be accessed with the key combination Ctrl-Alt-F*n* (where *n* varies from 1 to 8); the corresponding devices are ttyE0..ttyE7. To enable them and get a login prompt, `/etc/ttys` must be modified:

```
ttyE0   "/usr/libexec/getty Pc"         vt220   on secure
ttyE1   "/usr/libexec/getty Pc"         vt220   on secure
ttyE2   "/usr/libexec/getty Pc"         vt220   on secure
ttyE3   "/usr/libexec/getty Pc"         vt220   on secure
ttyE4   "/usr/libexec/getty Pc"         vt220   on secure
ttyE5   "/usr/libexec/getty Pc"         vt220   on secure
ttyE6   "/usr/libexec/getty Pc"         vt220   on secure
ttyE7   "/usr/libexec/getty Pc"         vt220   on secure
```

`screen 0` as system console can be set to another screen type at boot time on VGA displays. This is a kernel configuration option. If a non-80x25 setting is selected, it must be made sure that a usable font is compiled into the kernel, which would be an 8x8 one for 80x50.

There is a problem with many ATI graphics cards which don't implement the standard VGA font switching logics: These need another kernel option to make a nonstandard console font work.

An example set of kernel configuration options might be:

```
options VGA_CONSOLE_SCREENTYPE="\"80x50\""
options VGA_CONSOLE_ATI_BROKEN_FONTSEL
options FONT_VT220L8x8
```

8.1.1.3 Enabling framebuffer console

On many architectures, there is only one type of screen mode: a graphical framebuffer mode. On machines with VGA graphics cards, there is a second mode: textmode. This is an optimized mode specially made for displaying text. Hence, this is the default console mode for GENERIC kernels on architectures where the graphics card is typically a VGA card (i386, amd64).

However, you can enable a framebuffer on machines with VGA cards that support the VESA BIOS extension (VBE).

VESA framebuffer mode is configured during boot(8) using the **`vesa`** command.

8.1.1.4 Enabling scrollback on the console

You can enable scrolling back on wscons consoles by compiling the `WSDISPLAY_SCROLLSUPPORT` option into your kernel. Make sure you don't have option `VGA_RASTERCONSOLE` enabled at the same time though! See Chapter 34 for instructions on building a kernel.

When you have a kernel with options `WSDISPLAY_SCROLLSUPPORT` running, you can scroll up on the console by pressing LEFT SHIFT plus PAGE UP/DOWN. Please note that this may not work on your system console (ttyE0)!

8.1.1.5 Wscons and colors

8.1.1.5.1 Changing the color of kernel messages

It is possible to change the foreground and background color of kernel messages by setting the following options in kernel config files:

```
options WS_KERNEL_FG=WSCOL_xxx
options WS_KERNEL_BG=WSCOL_xxx
```

The `WSCOL_xxx` color constants are defined in `src/sys/dev/wscons/wsdisplayvar.h`.

You can easily customize many aspects of your display appearance: the colors used to print normal messages, the colors used to print kernel messages and the color used to draw a border around the screen.

All of these details can be changed either from kernel options or through the wsconsctl(8) utility; the latter may be preferable if you don't want to compile your own kernel, as the default options in `GENERIC` are suitable to get this tip working.

The following options can be set through wsconsctl(8):

- `border`: The color of the screen border. Its respective kernel option is `WSDISPLAY_BORDER_COLOR`.
- `msg.default.attrs`: The attributes used to print normal console messages. Its respective kernel options are `WS_DEFAULT_COLATTR` and `WS_DEFAULT_MONOATTR` (the former is used in color displays, while the latter is used in monochrome displays).
- `msg.default.bg`: The background color used to print normal console messages. Its respective kernel option is `WS_DEFAULT_BG`.
- `msg.default.fg`: The foreground color used to print normal console messages. Its respective kernel option is `WS_DEFAULT_FG`.

- `msg.kernel.attrs`: The attributes used to print kernel messages and warnings. Its respective kernel options are `WS_KERNEL_COLATTR` and `WS_KERNEL_MONOATTR` (the former is used in color displays, while the latter is used in monochrome displays).
- `msg.kernel.bg`: The background color used to print kernel messages and warnings. Its respective kernel option is `WS_KERNEL_BG`.
- `msg.kernel.fg`: The foreground color used to print kernel messages and warnings. Its respective kernel option is `WS_KERNEL_FG`.

The values accepted as colors are: black, red, green, brown, blue, magenta, cyan and white. The attributes are a comma separated list of one or more flags, which can be: reverse, hilit, blink and/or underline.

For example, to emulate the look of one of those old Amstrad machines:

```
wsconsctl -d -w border=blue msg.default.bg=blue msg.default.fg=white msg.default.attrs=hilit
```

Or, to make your kernel messages appear red:

```
wsconsctl -d -w msg.kernel.fg=red
```

Note that, in older versions of NetBSD, only a subset of this functionality is available; more specifically, you can only change the kernel colors by changing kernel options, as explained above. Also note that not all drivers support these features, so you may not get correct results on all architectures.

8.1.1.5.2 Getting applications to use colors on the console

NetBSD uses the terminfo database to tell applications what the current terminal's capabilities are. For example, some terminals don't support colors, some don't support underlining (PC VGA terminals don't, for example) etc. The TERM environment variable tells the terminfo library the type of terminal. It then refers to its database for the options.

The default setting for TERM can be inspected by typing **`echo $TERM`** on the terminal of interest. Usually this is something like `vt220`. This terminal type doesn't support colors. On a typical PC console with 25 lines, you can change this value to `wsvt25` instead, to get colors. This is done in the C shell (csh) by entering:

```
setenv TERM wsvt25
```

In a Bourne-compatible shell (sh, ksh), you can enter:

```
export TERM=wsvt25
```

If this does not work for you, you can try the `ansi` terminal type, which supports ANSI color codes. However, other functionality may be missing with this terminal type. You can have a look at the file `/usr/share/misc/terminfo` to see if you can find a useful match for your console type.

8.1.1.6 Loading alternate fonts

There are several fonts in `/usr/share/wscons/fonts` that can be loaded as console fonts. This can be done with the wsfontload(8) command, for example: **`wsfontload -N ibm -h 8 -e ibm`**

/usr/share/wscons/fonts/vt2201.808. This command loads the IBM-encoded (`-e ibm`) font in the file `vt2201.808` which has a height of eight pixels (`-h 8`). Name it ibm for later reference (`-N ibm`).

To actually display the font on the console, use the command **wsconsctl -dw font=ibm**.

If you want to edit a font, you can use the old pcvt utils that are available in the `sysutils/pcvt-utils` package.

8.1.2 wskbd

8.1.2.1 Keyboard mappings

Wscons also allows setting the keymap to map the keys on various national keyboards to the right characters. E.g. to set the keymap for an Italian keymap, run:

```
# wsconsctl -k -w encoding=it
encoding -> it
```

This setting will last until the next reboot. To make it permanent, add a `encoding` line to `/etc/wscons.conf`: it will be executed automatically the next time you reboot.

```
# cp /etc/wscons.conf /etc/wscons.conf.orig
# echo encoding it >>/etc/wscons.conf
```

Please be careful and type two **>** characters. If you type only one **>**, you will overwrite the file instead of adding a line. But that's why we always make backup files before touching critical files!

A full list of keyboard mappings and variants can be found in wskbd(4).

You can change the compiled in kernel default by adding `options PCKBD_LAYOUT=KB_`*`encoding`* where *encoding* is an uppercase entry from the list above (e.g.: `PCKBD_LAYOUT=KB_FR`). Variants can be bitwise or'd in (e.g.: `PCKBD_LAYOUT=KB_US|KB_SWAPCTRLCAPS`).

Configuring the keyboard layout under X is described elsewhere (http://www.NetBSD.org/docs/x/#x-keyboard-maps).

8.1.2.1.1 Hacking wscons to add a keymap

If your favourite keymap is not supported, you can start digging in `src/sys/dev/wscons/wsksymdef.h` and `src/sys/dev/pckbport/wskbdmap_mfii.c` to make your own. Be sure to send-pr (http://www.NetBSD.org/support/send-pr.html#submitting) a change-request PR with your work, so others can make use of it!

You can test your keymap by using **wsconsctl** instead of directly hacking the keymaps into the keyboard mapping file. For example, to say keycode 51 without any modifiers should map to a comma, with shift it should map to a question mark, with alt it should map to a semicolon and with both alt and shift it should map to colon, issue the following command:

```
wsconsctl -w "map += keycode 51=comma question semicolon colon"
```

8.1.2.2 Changing the keyboard repeat speed

Keyboard repeat speed can be tuned using the **wsconsctl(8)** utility. There are two variables of interest: `repeat.del1`, which specifies the delay before character repetition starts, and `repeat.deln`, which sets the delay between each character repetition (once started).

Let's see an example, assuming you want to accelerate keyboard speed. You could do, from the command line:

```
wsconsctl -w repeat.del1=300
wsconsctl -w repeat.deln=40
```

Or, if you want this to happen automatically every time you boot up the system, you could add the following lines to `/etc/wscons.conf`:

```
setvar repeat.del1=300
setvar repeat.deln=40
```

8.1.3 wsmouse

8.1.3.1 Serial mouse support

The wsmouse device (part of wscons) does not directly support serial mice. The moused(8) daemon is provided to read serial mouse data, convert it into wsmouse events and inject them in wscons' event queue, so the mouse can be used through the abstraction layer provided by wsmouse.

A typical use can be: **`moused -p /dev/tty00`**. This will try to determine the type of mouse connected to the first serial port and start reading its data. The moused(8) man page contains more examples.

8.1.3.2 Cut&paste on the console with wsmoused

It is possible to use the mouse on the wscons console to mark (cut) text with one mouse button, and insert (paste) it again with another button.

To do this, enable "wsmoused" in `/etc/rc.conf`, and start it:

```
# echo wsmoused=yes >>/etc/rc.conf
# sh /etc/rc.d/wsmoused start
```

After that you can use the mouse to mark text with the left mouse button, and paste it with the right one. To tune the behaviour of wsmoused(8) see its manpage, which also describes the format of the wsmoused.conf(5) config file, an example of which can be found in `/usr/share/examples/wsmoused`.

Chapter 9

The X Window System

9.1 What is X11 / Xorg?

NetBSD uses the X Window System to provide a graphical interface.

Please note that the X Window System is a rather bare bones framework. It acts as a base for modern desktop environments like MATE, or Xfce, but they are not part of the X Window System. NetBSD ships with the X Window System, but it does not include these desktop environments; they must be added via pkgsrc.

When you start using X you'll find many new terms which you may find confusing at first. The basic elements are:

- An *X server* running on top of the hardware. The X server provides a standard way to display graphics (including fonts for text display) and get mouse/keyboard/other input. On most NetBSD ports, the Xorg(1) display server is used. Other X servers included with NetBSD include Xnest(1), which runs an X server inside another X server as a window, and Xvfb(1), which runs an off-screen X server, and is typically used to provide a full remote-only desktop with `x11/x11vnc`.
- *X clients*. These are the programs you directly interact with. They run on top of the X server. A web browser like Firefox is an example of an X client. X is network-transparent, which means that you can run X clients on one machine, and the X server (i.e., the display, with video hardware) on another machine. The X client picks a server to use as a display based on the `DISPLAY` environment variable, typically `:0` for the first server, and `:1` for the second.
- A *window manager* running on top of the X server. The window manager is a special X client that is allowed to control the placement of windows. It can also "decorate" windows with standard "widgets" (usually these provide actions like window motion, resizing, iconifying, window killing, etc.). ctwm(1) is NetBSD's default window manager.
- A *desktop environment* such as MATE, or Xfce. These are suites of integrated software designed to give you a well-defined range of software and a more or less common interface to each program. These typically include a window manager, file manager, web browser, email client, multimedia player, text editor, address book, help browser, etc. As you may have guessed, a desktop environment is not needed to use X, but many users will want to install one.
- A *compositor* or *compositing manager* runs on the X server and redirects rendering to an off-screen buffer, typically using the GPU (Graphics Processing Unit) hardware for final rendering. It can provide additional eye-candy and often VSync (vertical sync). Some window managers, typically those included with large desktop environments, include their own compositing managers. **xcompmgr** and `x11/picom` are external compositing managers.

The X Window System is included with NetBSD as separate distribution sets, see Section 3.10. It can be added to an installed system with sysinst(8).

On NetBSD, X11 lives under the filesystem hierarchy /usr/X11R7. Therefore, to use X, /usr/X11R7/bin must be in your shell's PATH. See ~/.profile.

9.2 Configuration

In most cases, you will be able to start using X without any configuration at all, and **startx** will work just fine.

In rare cases, however, configuration of the X server is required. This configuration file is located at /etc/X11/xorg.conf. The structure of the configuration file is described formally in xorg.conf(5).

To generate an initial configuration file for your X server, run the command

```
# X -configure
```

This command should create a configuration file and place it in your home directory. To test the generated configuration file, run, e.g.,

```
# X -config ~/xorg.conf.new
```

If this succeeds, you should see a crosshatched background and a cursor in the shape of an X. Try moving the cursor around to verify that the mouse is functional. You can then switch to another virtual terminal (Ctrl-Alt-F#) or log in remotely and kill the X process.

If the above test was successful, move the file into place as /etc/X11/xorg.conf and you are ready to go.

9.3 The keyboard

Even if you have already configured your keyboard for wscons (see Section 8.1), you need to configure it for X as well, at least if you want to use a non-US layout.

An easy solution is to use setxkbmap(1) .

Here is an example that shows how to use a Hebrew keyboard, with Ctrl-Alt used to switch layouts, and with the position of the Escape and Caps Lock keys swapped as an additional option:

```
setxkbmap -option grp:alt_shift_toggle us,il \
 -option caps:swapescape -option terminate:ctrl_alt_bksp
```

If you wish to change the repeat rate of your keyboard, you can set it with the xset(1) command, which takes two arguments: delay and rate, respectively. The following example sets the initial delay to 200 milliseconds and the repeat rate to 30 per second:

```
$ xset r 200 30
```

You can also run this command in your .xinitrc or .xsession file. See below (Section 9.6) for more information.

9.4 The monitor

If X does not run at the resolution you think it should, first run **xrandr** and see if the resolution you want is listed. If your preferred resolution is listed in that command's output, you can change resolutions with, e.g.,

```
$ xrandr -s 1680x1050
```

xrandr can also be used to enable output to hot-plugged monitors.

Managing outputs can be done graphically with the pkgsrc package `x11/arandr`.

9.5 Starting X

You can start X with the following command:

```
$ startx
```

If your basic X server configuration is correct, you are left in the X environment with the default window manager (ctwm). If you want a more advanced window manager or desktop environment, many are available in pkgsrc. See Section 9.7 for information about adding and changing window managers.

9.6 Customizing X

One of the first things you will want to do is to change the programs that run when X is first started. The easiest way to do this is to copy the default `.xinitrc` file to your home directory and modify it, or create a simple new one from scratch. For example:

```
$ cp /etc/X11/xinit/xinitrc ~/.xinitrc
$ chmod u+w ~/.xinitrc
$ vi ~/.xinitrc
```

If you use xdm(1), `~/.xsession` is used in place of `~/.xinitrc`.

The following example shows how to start the window manager (ctwm) and open an instance of the xterm and xterm programs. The screen background color is set to “bisque4”, which is defined in `/usr/X11R7/lib/X11/rgb.txt`.

```
...
# start some programs - a basic clcok
xclock -geometry 50x50-1-1 &
# change the color of the "root window" ("desktop background")
xsetroot -solid bisque4 &
# spawn a terminal
uxterm -geometry 80x34-1+1 -bg OldLace &
exec ctwm -W   # no '&' here
```

With this type of setup, to quit X you must exit the window manager, which is usually done by selecting "exit" from its menu.

The above example is very simple, but illustrates the basics of controlling the clients that are run when X is started. You can run any number of commands from your `.xinitrc`, including basic X configuration commands like **xset b off** to turn off the bell.

9.7 Other window managers or desktop environments

If you don't like ctwm, which is a very simple window manager, you can install another window manager or a desktop environment from pkgsrc. The following example uses the Openbox window manager, but there are many others available in `pkgsrc/wm`.

Openbox can be installed via binary packages or compiled with pkgsrc. As always, assuming a properly set PKG_PATH, the binary package method is:

```
# pkgin in openbox
```

To build it with pkgsrc, run:

```
# cd /usr/pkgsrc/wm/openbox
# make install
```

Openbox is now installed; to start it you must modify your `.xinitrc` file: substitute the line which calls `ctwm` with a line which calls `openbox`. For example:

```
# start some useful programs
xclock -geometry 50x50-1-1 &
# start window manager:
exec openbox   # no '&' here
```

The **startx** command will start the X11 session with Openbox. As configured in the example `.xinitrc` file above, choosing "Log Out" from Openbox's menu will end the X11 session.

Installing a desktop environment is almost as easy. The following example shows how to use the Xfce desktop environment.

```
# pkgin in xfce4
```

Depending on your requirements, you may wish to enable **dbus** as a system-wide service. The following example demonstates how. (If you don't enable dbus to run as a system-wide service, **startxfce4** will start dbus under your user account during initialization.)

```
# cp /usr/pkg/share/examples/rc.d/dbus /etc/rc.d
# echo dbus=YES >> /etc/rc.conf
# service dbus start
```

If you wish to be able to control your system's power state from within the desktop, the account you intend to run X under must also be a member of the "operator" group (see Section 5.6).

After running the above commands, edit your `.xinitrc` as above and change "openbox" (or "ctwm") to "startxfce4". The next time you run **startx** the Xfce desktop environment will be started.

9.8 Graphical login with xdm

If you always use X and the first thing you do after you log in is run **startx**, you can set up a graphical login to do this automatically. It is very easy:

1. Create the `.xsession` file in your home directory. This file is similar to `.xinitrc` and can, in fact, be a link to it.

   ```
   $ ln -s .xinitrc ~/.xsession
   ```

2. Modify `/etc/rc.conf`, adding the following line:

   ```
   xdm=YES       # x11 display manager
   ```

3. Start xdm(1) (or reboot your system, as this will be done automatically from now on):

   ```
   # service xdm start
   ```

The configuration files for xdm are in the `/etc/X11/xdm` directory. The `Xservers` file specifies the virtual console that X is started on. It defaults to “vt05”, which is the console you reach via “Ctrl+Alt+F5”. If you want to use a different virtual console, change vt05 as desired. In order to avoid keyboard contention between getty and xdm, be sure to start xdm on a virtual terminal where getty is disabled. For example, if in `Xservers` you have:

```
:0 local /usr/X11R7/bin/X :0 vt04
```

then in `/etc/ttys` you should have

```
ttyE3   "/usr/libexec/getty Pc"         wsvt25   off secure
```

(Please note that vt04 corresponds to ttyE3; in `/etc/X11/xdm/Xservers`, numbering starts at 1, but in `/etc/ttys`, numbering starts at 0.)

If you are using xdm to start various modern desktop environments, such as Xfce or MATE, you will need to override its default permitted authorization mechanisms, by adding the following to `/etc/X11/xdm/xdm-config`:

```
DisplayManager*authName:    MIT-MAGIC-COOKIE-1
```

If you want to change the look of your xdm login screen, you can modify the xdm configuration file. For example, to change the background color you can add the following line to the `Xsetup_0` file:

```
xsetroot -solid SeaGreen
```

9.9 Using multiple or remote X servers

This is intended as a simple example of how to use multiple X servers. For illustration purposes, we’ll simply use Xnest(1), which creates a new X server `:1` as a window on the existing server `:0`:

```
$ Xnest :1 &
```

It’s then possible to run programs on the second server, or even a different window manager:

```
$ DISPLAY=:1 uxterm &
```

```
$ DISPLAY=:1 ctwm &
```

Using *X11 forwarding*, programs can run on a remote machine while displaying on the local machine. This must typically be enabled in `/etc/ssh/sshd_config`:

```
X11Forwarding yes
```

Log in with ssh(1) and run X programs the normal way:

```
$ ssh -X remote.machine.example.com
$ uxterm &
```

On a completely headless system (with no monitor), Xvfb(1) (*X virtual framebuffer*) can be used in a similar manner. The fully virtual screen of the X server can be exported over the network with `x11/x11vnc`:

```
$ Xvfb :1 &
$ DISPLAY=:1 ctwm &
$ x11vnc -display :1 -localhost -passwdfile /path/to/password &
```

Notice we use the `-localhost` option. In theory this stops remote connections, however, in practice we're using a SSH tunnel to forward the VNC port, adding an extra layer of security. To connect to the headless machine:

```
$ ssh -L 5900:hostname:5900 hostname
$ vncviewer localhost &
```

9.10 Further resources

- *An X Window System Tutorial* (https://www.youtube.com/playlist?list=PLA8E036608C60B7E5) is a video series that attempts to explain basic concepts of the X Window System, including the role of the window manager.
- *X Window System User's Guide for X11R3 and R4* (PDF (https://ia802609.us.archive.org/29/items/xwindowsystem03quermiss/xwindowsystem03quermiss.pdf), Web (https://www.oreilly.com/library/view/x-window-system/9780937175149/)) by Valerie Quercia and Tim O'Reilley is a classic book describing some X features that is now available to read for free online.

Chapter 10
Audio

10.1 Configuring the default audio device

audiocfg(1) can be used to list, test and set default audio devices.

All available audio devices can be listed with **audiocfg list**:

```
$ audiocfg list
0: [*] audio0 @ hdafg0: Realtek ALC292
       playback: 2ch, 48000Hz
       record:   2ch, 48000Hz
       (PR) slinear_le 16/16, 2ch, { 32000, 44100, 48000, 88200, 96000, 192000 }
       (PR) slinear_le 20/32, 2ch, { 32000, 44100, 48000, 88200, 96000, 192000 }
       (PR) slinear_le 24/32, 2ch, { 32000, 44100, 48000, 88200, 96000, 192000 }
       (  ) ac3 16/16, 2ch, { 32000, 44100, 48000, 88200, 96000, 192000 }
1: [ ] audio1 @ uaudio0: USB audio
       playback: 2ch, 48000Hz
       record:   1ch, 48000Hz
       (P-) slinear_le 16/16, 2ch, { 48000, 44100 }
       (-R) slinear_le 16/16, 1ch, { 48000, 44100 }
```

The asterisk next to the *Realtek ALC292* device indicates it is currently the default device, so if any application writes or reads to `/dev/audio` it will play or record from it. It is also available as `/dev/audio0`, and for mixer commands, `/dev/mixer0`.

The other device, *USB audio*, is a secondary device that has been plugged in. Since it isn't the default, it is only used if specifically selected in an application. It is available as `/dev/audio1`, and for mixer commands, `/dev/mixer1`.

The *playback:* and *record:* rows indicate the currently selected hardware audio format. Below this, the other supported formats are listed. Some devices set the playback and recording formats separately, while others set both at the same time. This is indicated by *PR*.

audiocfg test *`index`* can be used to test playback, and plays a tone of 2 seconds for each channel of the *`index`* device:

```
$ audiocfg test 0
0: [*] audio0 @ hdafg0: Realtek ALC292
  testing channel 0... done
  testing channel 1... done
```

If more than one audio device is available, **audiocfg default *`index`*** can be used to change the default one. This persists between reboots. Please note that unlike other audiocfg(1) commands, **audiocfg default** needs to be run as root.

10.2 Configuring the mixer and volume

In NetBSD, mixerctl(1) is used to adjust audio mixing, e.g. volume for recording and playback, and the sources and sinks currently in use.

Set the current playback volume:

```
$ mixerctl -w outputs.master=50
```

List the available controls and settings:

```
$ mixerctl -av
outputs.master=255,255 volume
inputs.dac=255,255 volume
outputs.auto=255,255 volume delta=13
outputs.headphones=0,0 volume delta=13
outputs.hdmi=255,255 volume delta=13
outputs.select=headphones  [ auto headphones hdmi ]
```

Secondary devices can also be configured using mixerctl(1). For example, if you've just plugged in an USB audio device, it may have attached as `/dev/audio1` and `/dev/mixer1` - this is visible using audiocfg(1). You would therefore configure it with **mixerctl -d /dev/mixer1**.

10.2.1 Setting default mixer settings on boot

Default mixer device settings can be applied on boot by setting `mixerctl=YES` in `/etc/rc.conf`, then providing arguments in `/etc/mixerctl.conf`. For example, this `/etc/mixerctl.conf` sets the playback volume and playback sink:

```
outputs.master=120,120
outputs.select=headphones
```

To automatically load and save the settings of mixer devices on boot and shutdown, you can specify each device to save individually in `/etc/rc.conf`:

```
mixerctl=YES
mixerctl_mixers="mixer0 mixer1"
```

10.3 Pseudo audio devices

NetBSD's pad(4) device allows feeding back data from an application using a virtual audio device. It can be used to redirect playback elsewhere, or record an application's playback.

`/dev/padN` devices produce a raw stream of audio in a fixed format when opened for reading. At the time of opening, they also create a `/dev/audioN` device for an application to use for output. You can observe the device creation happening with dmesg(8).

The following example records the output of a game, `games/jumpnbump`, using the program `multimedia/ffmpeg4` for encoding the data from the pad device to a file and writing it back to the real audio device simultaneously. Both are available from the NetBSD Packages Collection.

```
$ ffmpeg4 -f s16le -ar 44100 -ac 2 -i /dev/pad0 \
    -f wav output.wav -f oss /dev/audio
$ SDL_PATH_DSP=/dev/audio1 jumpnbump
```

10.4 Recording and playback commands

NetBSD comes with a number of commands that allow users to play and record audio from scripts or the command-line interface.

10.4.1 audioplay(1)

With this command you can play audio files in simple formats like ULAW and WAVE. For more sophisticated needs you might want to install one of the many programs available in the package system which let you play audio files in different formats (e.g. MP3, etc.)

10.4.2 audiorecord(1)

Allows recording audio from a microphone or other input to the same simple or raw formats that audioplay(1) supports.

The following command records CD quality audio to a WAVE file from the default audio device. Recording will stop when the process is terminated:

```
$ audiorecord -d /dev/audio -F wav -e linear -c 2 -P 16 -s 44100 recording.wav
```

Play the recording back (its format is inferred from the WAVE headers):

```
$ audioplay recording.wav
```

10.4.3 audioctl(1)

audioctl(1) is used to manually set some variables regarding audio I/O, like the frequencies for playing and recording. This is useful when writing raw samples to `/dev/sound` without access to the full audio(4) API, e.g. from a shell script, but otherwise is not used during regular operation.

10.5 MIDI support

NetBSD includes built-in MIDI support through the machine-independent midi(4) system. This includes support for USB MIDI devices.

Access to MIDI devices is supported through raw access to the `/dev/rmidiX` devices, or through the sequencer device, `/dev/music`.

Digital Audio Workstations and other software with support for NetBSD MIDI in the Packages Collection include `audio/lmms` and `audio/fluidsynth`. Several MIDI programs are also included with NetBSD:

10.5.1 midirecord(1)

A program that allows recording MIDI events from a device to files in the Standard MIDI (SMF) format. It can also be used to test a device and verify it works as expected with the **-D** and **-V** options.

10.5.2 midiplay(1)

A program that allows playing Standard MIDI and RMID files to the MIDI sequencer device.

10.6 Intel HD Audio devices

Since the 2010s, most x86 machines have hardware compliant with the *Intel HD Audio* specification. These use NetBSD's hdaudio(4) driver and require some special consideration.

10.6.1 Built-in and jacks: DACs/ADCs

For hdaudio(4) devices, the currently selected playback ports (or, e.g. internal speaker and headphone jack on a laptop) are controlled by selecting a DAC/ADC. The available DACs and ADCs can be seen in `/var/run/dmesg.boot`:

```
hdafg0 at hdaudio1: Realtek ALC292
hdafg0: DAC00 2ch: Speaker [Built-In], HP Out [Jack]
hdafg0: ADC01 2ch: Mic In [Jack]
hdafg0: ADC02 2ch: Mic In [Built-In]
```

Therefore, to use only the built-in mic for recording:

```
$ mixerctl -w record.source=ADC02
```

Use all available sources:

```
$ mixerctl -w record.source=ADC01,ADC02
```

Some laptops may need **`outputs.dacsel`** changed to only play audio from the headphone jack, others have hardware speaker mute and there's no need for this.

10.6.2 HDMI/DisplayPort audio

Currently, HDMI/DisplayPort output with hdaudio(4) is not enabled in the default kernel because it interferes with default device selection. This can be changed by enabling these options in the kernel configuration, and rebuilding. See Chapter 34 for more information.

```
options HDAUDIO_ENABLE_DISPLAYPORT
options HDAUDIO_ENABLE_HDMI
```

With other drivers (e.g. on ARM boards) this is not necessary.

Chapter 11
Power management

For power management, NetBSD supports sensor monitoring (including battery state, CPU temperature, and so on), CPU frequency adjustment, low-power mode for devices, hardware poweroff, and sleep (suspend-to-RAM) on some hardware.

Power management on NetBSD primarily takes the form of acpi(4) (Advanced Configuration and Power Interface) support, although sensors are also supported on many other types of non-ACPI hardware.

11.1 Basic power management commands

11.1.1 Powering off or rebooting the system

A NetBSD system with ACPI support can be physically powered off by running the poweroff(8) and reboot(8) commands, however, it is usually best to use shutdown(8) so the system shuts down with appropriate warning and has time to properly stop any running applications and services.

Shut the system down immediately:

```
# shutdown -p now
```

Reboot with a 10 minute warning to any users:

```
# shutdown -r +10
```

11.1.2 Using ACPI sleep states (suspend and resume)

An ACPI system is always in one of any "sleep states":

S0

fully running

S1

power on suspend (CPU and hard disks are off)

S2

similar to S3, usually not implemented

S3

suspend-to-RAM ("sleep", most of the system is inactive to save power, but can quickly be brought back up)

S4

suspend-to-disk ("hibernate", not currently supported on NetBSD)

S5

powered off

The sleep state can be modified with sysctl(8), e.g. to suspend-to-RAM:

```
# sysctl -w hw.acpi.sleep.state=3
```

The way the system wakes up is dependent on the hardware, and may include pressing the power button or lifting the lid. If supported, the system can resume from a suspended state much quicker than a full reboot.

If you’ve tested this and verified it works as expected, you may wish to trigger it automatically through a powerd(8) event, such as closing the lid of a laptop.

11.1.3 Suspending and resuming individual devices

If your machine does not support full ACPI suspend and resume, it may still be possible to suspend and resume individual devices to save power while they are inactive. This can be accomplished with drvctl(8).

For example, `/var/run/dmesg.boot` reports our hardware has a SD card reader, `rtsx0`.

```
rtsx0 at pci1 dev 0 function 0: Realtek Semiconductor RTS5227 PCI-E Card Reader (rev. 0x01)
rtsx0: interrupting at msi4 vec 0
sdmmc0 at rtsx0
```

We can suspend it:

```
# drvctl -S rtsx0
```

And we can also resume it:

```
# drvctl -R rtsx0
```

If a specific device is failing to suspend or resume, this can also be used for debugging.

11.1.4 Adjusting CPU frequency at runtime

Many modern machines allow the CPU frequency to be dynamically adjusted. A higher frequency provides better performance, but increased battery usage and generates more heat. On NetBSD, CPU frequency can be adjusted at runtime with sysctl(8).

For example, this machine is currently running at 1400 MHz, but also supports a 600 MHz low-power mode:

```
$ sysctl -a | grep freq
machdep.cpu.frequency.target = 1400
machdep.cpu.frequency.current = 1400
machdep.cpu.frequency.min = 600
machdep.cpu.frequency.max = 1400
```

```
machdep.cpu.frequency.available = 600 1400
```

We can enter the low power mode by setting the target frequency:

```
# sysctl -w machdep.cpu.frequency.target=600
```

Many modern hardware supports an "automatic adjustment" frequency, usually this will be a reported frequency that ends in 1. On systems without this functionality, `sysutils/estd` can be installed from pkgsrc to perform automatic adjustment depending on load in software, although it will be less efficient than hardware scaling.

11.1.5 Using IEEE 802.11 (Wi-Fi) power saving mode

Some IEEE 802.11 (Wi-Fi) networking devices support a low power mode, which can be enabled with ifconfig(8):

```
# ifconfig iwm0 powersave
```

You may notice an increase in reported latency from ping(8) and a decrease in performance. However, it may improve your device's battery life, as the radios in such devices can consume a lot of energy. It can be disabled again with **ifconfig**:

```
# ifconfig iwm0 -powersave
```

11.2 Sensors and monitoring

The primary command-line frontend to NetBSD's sensor monitoring framework is envstat(8). Here is a typical example of **envstat** output:

```
$ envstat
                      Current  CritMax  WarnMax  WarnMin  CritMin  Unit
[acpiacad0]
         connected:     FALSE
[acpibat0]
           present:      TRUE
    design voltage:    11.100                                          V
           voltage:    12.270                                          V
        design cap:    23.200                                         Wh
     last full cap:    16.940                                         Wh
            charge:    16.770                      5.000%   1.181%    Wh (99.00%)
       charge rate:       N/A
    discharge rate:       N/A
          charging:     FALSE
      charge state:    NORMAL
[acpitz0]
       temperature:    48.000  128.000
```

`acpiacad0` is the machine's AC adapter. It is not currently connected.

`acpibat0` is the machine's battery, currently 99% full. At 5%, a warning will be printed to the console and an event sent to powerd(8). At 1%, the system will shut down to prevent data loss from loss of power.

A CPU temperature sensor is also detected, `acpitz0`. It indicates that the CPU's current temperature is 48 degrees Celsius, and the critical temperature is 128 degrees Celsius. If the critical temperature is reached, the system will shut down to prevent damage to hardware. powerd(8) can be notified of changes in temperature.

11.3 An introduction to powerd

powerd(8) is a daemon that allows the system to respond to power management events, such as the AC adapter being unplugged, battery state changing, a laptop's lid being closed, or a "sleep" button being pressed.

As with other services, powerd can be enabled by editing `/etc/rc.conf`:

```
powerd=YES
```

And started with service(8):

```
# service powerd start
```

powerd works by executing a named sh(1) script from the directory `/etc/powerd/scripts` whenever a power event occurs. We can use commands we learned in previous sections of this chapter to our advantage in the scripts.

11.3.1 Example: using powerd to suspend on lid close

Example 11-1. `/etc/powerd/scripts/lid_switch`

```
#!/bin/sh -
#
# Generic script for lid switch events.
#
# Arguments passed by powerd(8):
#
# device event

case "${2}" in
pressed)
 # Lock the X11 display to prevent tampering
 DISPLAY=:0 /usr/pkg/bin/xlock -mode blank &
 # Wait for 1 second
 sleep 1
 # Suspend
 /sbin/sysctl -w hw.acpi.sleep.state=3
 exit 0
 ;;

released)
```

```
 exit 0
 ;;

*)
 logger -p warning "${0}: unsupported event ${2} on device ${1}" >&1
 exit 1
esac
```

11.3.2 Example: reducing CPU frequency when unplugged

Example 11-2. `/etc/powerd/scripts/acadapter`

```
#!/bin/sh -
#
# Generic script for acadapter events.
#
# Arguments passed by powerd(8):
#
# device event

case "${2}" in
pressed)
 logger -p info "${0}: Full performance mode" >&1

 # Disable power saving mode on all network interfaces.
 for intf in $(/sbin/ifconfig -l); do
  /sbin/ifconfig $intf -powersave >/dev/null 2>&1
 done

 # Increase CPU frequency
 /sbin/sysctl -w machdep.cpu.frequency.target=2300

 exit 0
 ;;

released)
 logger -p info "${0}: Power saving mode" >&1

 # Enable power saving mode on all network interfaces.
 for intf in $(/sbin/ifconfig -l); do
  /sbin/ifconfig $intf powersave >/dev/null 2>&1
 done

 # Reduce CPU frequency
 /sbin/sysctl -w machdep.cpu.frequency.target=1400

 exit 0
 ;;

*)
 logger -p warning "${0}: unsupported event ${2} on device ${1}" >&1
```

```
 exit 1
 ;;
esac
```

Chapter 12
Printing

This chapter describes a simple configuration for printing, using an HP Deskjet 690C printer connected to the first parallel port and the lpd printing system that comes with NetBSD. First, the system will be configured to print text documents, and next the configuration will be extended to print PostScript documents using the Ghostscript program (`print/ghostscript`). Please note that there are other, alternative printing systems available from the packages collection (http://www.NetBSD.org/docs/software/packages.html), like LPRng (`print/LPRng`) and the Common Unix Printing System (CUPS) (`print/cups`) which are not covered here.

12.1 Enabling the printer daemon

After installation it is not yet possible to print, because the **lpd** printer spooler daemon is not enabled. To enable **lpd**, one line in the `/etc/rc.conf` file must be changed from:

```
lpd=NO
```

to

```
lpd=YES
```

The change will come into effect at the next boot, but the daemon can be started manually now:

```
# service lpd start
```

To check if **lpd** is active, type the following command:

```
# service lpd status
```

If you don't see an entry for lpd in the output of the previous command, the daemon is not active.

The lpd system is configured via `/etc/printcap`. Before configuring `/etc/printcap` it is a good idea to make a printer test, to check if the physical connection between your computer and the printer is working. The test sends out some data directly to the printer device. Assuming you use a printer connected to the parallel port, this is `/dev/lpt0`; if you use an USB printer try `/dev/ulpt0`. Please check the manpages of these devices (lpt(4), ulpt(4)) for more information!

In our example we have a printer attached to the parallel port, so we run this:

```
# lptest 70 5 > /dev/lpt0
```

To see what the output should look like, try the same command without redirecting the output to the printer:

```
# lptest 70 5
!"#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdef
```

```
"#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefg
#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefgh
$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghi
%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghij
```

A frequent problem is that the output on the printer is not correctly aligned in columns but has a "staircase" configuration. This usually means that the printer is configured to begin a new line at the left margin after receiving both a <CR> (carriage return, ASCII 13) character and a <LF> (line feed, ASCII 10) character. NetBSD only sends a <LF> character. You can fix this problem in two ways:

- by changing the configuration of the printer
- by using a simple printer filter (described later)

> **Note:** In the previous example the lpd spooler is not involved because the program output is sent directly to the printer device (`/dev/lpt0`) and is not spooled.

12.2 Configuring `/etc/printcap`

This section explains how to configure the example printer to print text documents.

The printer must have an entry in the `/etc/printcap` file; the entry contains the printer id (the name of the printer) and the printer description. The *lp* id is the default used by many programs. Here is an example entry:

Example 12-1. `/etc/printcap`

```
lp|local printer|HP DeskJet 690C:\
        :lp=/dev/lpa0:sd=/var/spool/lpd/lp:lf=/var/log/lpd-errs:\
        :sh:pl#66:pw#80:if=/usr/local/libexec/lpfilter:
```

The file format and options are described in detail in the printcap(5) manpage. Please note that an *input filter* has been specified (with the *if* option) which will take care of eliminating the staircase problem:

```
if=/usr/local/libexec/lpfilter
```

> **Printer driver and HP printers:** Example 12-1 uses the *lpa0* device (polled driver) for the printer, instead of the *lpd0* (interrupt driven driver). Using interrupts there is a communication problem with some printers, and the HP Deskjet 690C is one of them: printing is very slow and one PostScript page can take hours. The problem is solved using the *lpa* driver. It is also possible to compile a custom kernel where lpt is polled.

The printcap entry for the printer also specifies a spool directory, which must be created; this directory will be used by the lpd daemon to accumulate the data to be printed:

```
# cd /var/spool/lpd
# mkdir lp
# chown daemon:daemon lp
# chmod 770 lp
```

The only missing part is the `lpfilter` input filter, which must be written. The only task performed by this filter is to configure the printer for the elimination of the staircase problem before sending the text to be printed. The printer used in this example requires the following initialization string: "`<ESC>&k2G`".

Example 12-2. `/usr/local/libexec/lpfilter`

```
#!/bin/sh
# Treat LF as CR+LF
printf "\033&k2G" && cat && exit 0
exit 2
```

After saving this script into the name you used in `/etc/printcap`, you need to make sure it's executable:

```
# chmod 755 /usr/local/libexec/lpfilter*
```

> **Note:** There is another filter that can be used:
>
> `if=/usr/libexec/lpr/lpf:`
>
> This filter is much more complex than the one presented before. It is written to process the output of **nroff** and handles underline and overprinting, expands tab characters and converts LF to CR + LF. The source to this filter program can be found in `/usr/src/usr.sbin/lpr/filters/lpf.c`.

After everything is in place now, the **lptest** command can be run again now, this time using the **lpr** command, which will first send the data to the lpd spooler, then runs the filter and sends the data off to the printer:

```
# lptest 70 5 | lpr -h
```

The **lpr** program prints text using the spooler to send data to the printer; the `-h` option turns off the printing of a banner page (not really necessary, because of the *sh* option in `/etc/printcap`). Users more familiar with the System V printing system can also use the lp(1) command that comes as an alternative to lpr(1).

12.3 Configuring Ghostscript

Now that basic printing works, the functionality for printing PostScript files can be added. The simple printer used in this example does not support native printing of PostScript files; a program must be used which is capable of converting a PostScript document in a sequence of commands that the printer understands. The Ghostscript program, which can be found in packages collection, can be used to this purpose. This section explains how to configure lpd to use Ghostscript to print PostScript files on the HP Deskjet 690C.

A second id for the printer will be created in `/etc/printcap`: this new id will use a different input filter, which will call Ghostscript to perform the actual print of the PostScript document. Therefore, text documents will be printed on the *lp* printer and PostScript documents on the *ps* printer: both entries use the same physical printer but have different printing filters.

The same result can be achieved using different configurations. For example, a single entry with only one filter could be used. For this, the filter should be able to automatically determine the format of the document being printed, and use the appropriate printing program. This approach is simpler but leads to a more complex filter; if you like it you should consider installing the magicfilter program from the packages collection: it does this and many other things automatically.

For our approach, the new `/etc/printcap` file looks like this:

Example 12-3. `/etc/printcap`

```
lp|local printer|HP DeskJet 690C:\
        :lp=/dev/lpa0:sd=/var/spool/lpd/lp:lf=/var/log/lpd-errs:\
        :sh:pl#66:pw#80:if=/usr/local/libexec/lpfilter:

ps|Ghostscript driver:\
        :lp=/dev/lpa0:sd=/var/spool/lpd/ps:lf=/var/log/lpd-errs:\
        :mx#0:sh:if=/usr/local/libexec/lpfilter-ps:
```

Option `mx#0` is very important for printing PostScript files because it eliminates size restrictions on the input file; PostScript documents tend to be very big. The `if` option points to the new filter. There is also a new spool directory.

The next steps are the creation of the new spool directory and of the filter program. The procedure for the spool directory is the same as above:

```
# cd /var/spool/lpd
# mkdir ps
# chown daemon:daemon ps
# chmod 770 ps
```

The filter program for PostScript output is more complex than the text base one: the file to be printed is fed to the interpreter which converts it into a sequence of commands in the printer's control language, and then sends that off to the printer. We have achieved to transform a cheap color printer in a device suitable for PostScript output, by virtue of the NetBSD operating system and some powerful freeware packages. The options used to configure Ghostscript are described in the Ghostscript documentation: `cdj550` is the device used to drive the HP printer.

Example 12-4. `/usr/local/libexec/lpfilter-ps`

```
#!/bin/sh
# Treat LF as CR+LF
printf "\033&k2G" || exit 2
# Print the postscript file
/usr/pkg/bin/gs -dSAFER -dBATCH -dQUIET -dNOPAUSE -q -sDEVICE=cdj550 \
-sOutputFile=- -sPAPERSIZE=a4 - && exit 0
exit 2
```

To summarize: two different printer names have been created on the system, which point to the same physical printer but use different options, different filters and different spool directories. Text files and PostScript files can be printed. To print PostScript files the Ghostscript package must be installed on the system.

12.4 Printer management commands

This section lists some useful BSD commands for printer and print jobs administration. Besides the already mentioned **lpr** and **lpd** commands, we have:

lpq

examine the printer job queue.

lprm

delete jobs from the printer's queue.

lpc

check the printing system, enable/disable printers and printer features.

12.5 Remote printing

It is possible to configure the printing system in order to print on a printer connected to a remote host. Let's say that, for example, you work on the *wotan* host and you want to print on the printer connected to the *loge* host. The `/etc/printcap` file of loge is the one of Example 12-3. From wotan it will be possible to print Postscript files using Ghostscript on loge.

The first step is to accept the print jobs submitted from the wotan host to the loge host. To accomplish this, a line with the wotan host name must be added to the `/etc/hosts.lpd` file on loge:

```
# hostname
loge
# cat /etc/hosts.lpd
wotan
```

The format of this file is very simple: each line contains the name of a host which is permitted to print on the local system. By default the lpd daemon only listens on UNIX domain sockets for local connections, it won't accept any network connects. To ensure the daemon also accepts incoming network traffic, the following will need to be added to `/etc/rc.conf`:

```
lpd_flags=""
```

Next, the `/etc/printcap` file on wotan must be configured in order to send print jobs to loge. For example:

```
lp|line printer on loge:\
 :lp=:sd=/var/spool/lpd/lp:lf=/var/log/lp-errs:\
 :rm=loge:rp=lp

ps|Ghostscript driver on loge:\
 :lp=:sd=/var/spool/lpd/ps:lf=/var/log/lp-errs:\
 :mx#0:\
 :rm=loge:rp=ps
```

There are four main differences between this configuration and the one of Example 12-3.

1. The definition of “lp” is empty.
2. The “rm” (remote machine) entry defines the name of the host to which the printer is connected.
3. The “rp” (remote printer) entry defines the name of the printer connected to the remote host.
4. It is not necessary to specify input filters because the definitions on the loge host will be used.
5. The spool directories must still be created locally on wotan:

```
# cd /var/spool/lpd
# mkdir lp
# chown daemon:daemon lp
# chmod 770 lp
# mkdir ps
# chown daemon:daemon ps
# chmod 770 ps
```

Now the print jobs for the “lp” and “ps” queues on wotan will be sent automatically to the printer connected to loge.

Chapter 13

Using removable media

13.1 Initializing and using USB flash drives

USB flash drives can be used to share data among machines. After attaching it we can see via dmesg(8) that it is recognised as `sd0`:

```
# dmesg
[...]
sd0 at scsibus0 target 0 lun 0: <Kingston, DataTraveler 3.0, > disk removable
sd0: fabricating a geometry
sd0: 14755 MB, 14755 cyl, 64 head, 32 sec, 512 bytes/sect x 30218842 sectors
sd0: fabricating a geometry
[...]
```

> **Warning**
>
> Please note that the following commands will erase all the previous contents on the USB flash drive!

To initialize it we can write zeros in the first 1MB of the USB flash drive:

```
# dd if=/dev/zero of=/dev/rsd0d bs=1m count=1
1+0 records in
1+0 records out
1048576 bytes transferred in 0.118 secs (8886237 bytes/sec)
```

Via fdisk(8) we can create a partition table. MS-DOS partition and filesystem is supported by most operating systems and devices that accept an USB disk, so let's update the partition table (`-u`), creating an MS-DOS partition and set the new partition as active (`-a`):

```
# fdisk -au sd0
fdisk: primary partition table invalid, no magic in sector 0
fdisk: Cannot determine the number of heads
Disk: /dev/rsd0d
NetBSD disklabel disk geometry:
cylinders: 14755, heads: 64, sectors/track: 32 (2048 sectors/cylinder)
total sectors: 30218842, bytes/sector: 512

BIOS disk geometry:
cylinders: 1023, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 30218842

Partitions aligned to 16065 sector boundaries, offset 63
```

```
Do you want to change our idea of what BIOS thinks? [n]

Partition table:
0: <UNUSED>
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.
No active partition.
Drive serial number: 0 (0x00000000)
Which partition do you want to change?: [none] 0
The data for partition 0 is:
<UNUSED>
sysid: [0..255 default: 169] 11
start: [0..1881cyl default: 63, 0cyl, 0MB]
size: [0..1881cyl default: 30218779, 1881cyl, 14755MB]
bootmenu: [] (space to clear)

Partition table:
0: Primary DOS with 32 bit FAT (sysid 11)
    start 63, size 30218779 (14755 MB, Cyls 0-1881/9/10)
        PBR is not bootable: All bytes are identical (0x00)
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.
No active partition.
Drive serial number: 0 (0x00000000)
Which partition do you want to change?: [none]
Do you want to change the active partition? [n] y
Choosing 4 will make no partition active.
active partition: [0..4 default: 4] 0
Are you happy with this choice? [n] y

We haven't written the MBR back to disk yet.  This is your last chance.
Partition table:
0: Primary DOS with 32 bit FAT (sysid 11)
    start 63, size 30218779 (14755 MB, Cyls 0-1881/9/10), Active
        PBR is not bootable: All bytes are identical (0x00)
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.
First active partition: 0
Drive serial number: 0 (0x00000000)
Should we write new partition table? [n] y
```

Then we can see via disklabel(8):

```
# disklabel sd0
# /dev/rsd0d:
type: SCSI
```

```
disk: DataTraveler 3.0
label: fictitious
flags: removable
bytes/sector: 512
sectors/track: 32
tracks/cylinder: 64
sectors/cylinder: 2048
cylinders: 14755
total sectors: 30218842
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0

5 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 d:  30218842         0     unused      0     0        # (Cyl.      0 -  14755*)
 e:  30218779        63      MSDOS                     # (Cyl.      0*-  14755*)
disklabel: boot block size 0
disklabel: super block size 0
```

that an `sd0e` MSDOS partition is present.

We can finally create an MS-DOS filesystem via newfs_msdos(8):

```
# newfs_msdos /dev/rsd0e
/dev/rsd0e: 30189264 sectors in 1886829 FAT32 clusters (8192 bytes/cluster)
MBR type: 11
bps=512 spc=16 res=32 nft=2 mid=0xf0 spt=32 hds=64 hid=0 bsec=30218779 bspf=14741 rdcl=2 inf
```

It is ready to be used and mounted via mount_msdos(8).

13.2 Initializing and using floppy disks

PC-style floppy disks work mostly like other disk devices like hard disks, except that you need to low-level format them first. To use an common 1440 KB floppy in the first floppy drive, first (as root) format it:

```
# fdformat -f /dev/rfd0a
```

Then create a single partition on the disk using disklabel(8):

```
# disklabel -rw /dev/rfd0a floppy3
```

Creating a small filesystem optimized for space:

```
# newfs -m 0 -o space -i 16384 -c 80 /dev/rfd0a
```

Now the floppy disk can be mounted like any other disk. Or if you already have a floppy disk with an MS-DOS filesystem on it that you just want to access from NetBSD, you can just do something like this:

```
# mount -t msdos /dev/fd0a /mnt
```

However, rather than using floppies like normal (bigger) disks, it is often more convenient to bypass the filesystem altogether and just splat an archive of files directly to the raw device. E.g.:

```
# tar cvfz /dev/rfd0a file1 file2 ...
```

A variation of this can also be done with MS-DOS floppies using the `sysutils/mtools` package which has the benefit of not going through the kernel buffer cache and thus not being exposed to the danger of the floppy being removed while a filesystem is mounted on it.

13.3 How to use a ZIP disk

1. See if your system has a ZIP drive:

   ```
   # dmesg | grep -i zip
   sd0 at atapibus0 drive 1: <IOMEGA  ZIP 100       ATAPI, , 14.A> type 0 direct removable
   ```

   Seems it has one, and it's recognized as sd0, just like any SCSI disk. The fact that the ZIP here is an ATAPI one doesn't matter - a SCSI ZIP will show up here, too. The ZIP is marked as "removable", which means you can eject it with:

   ```
   # eject sd0
   ```

2. Insert ZIP disk

3. Check out what partitions are on the ZIP:

   ```
   # disklabel sd0
   # /dev/rsd0d:
   type: ATAPI
    ...
   8 partitions:
   #        size   offset     fstype   [fsize bsize   cpg]
     d:   196608        0     unused        0     0         # (Cyl.    0 - 95)
     h:   196576       32      MSDOS                        # (Cyl.    0*- 95)
   disklabel: boot block size 0
   disklabel: super block size 0
   ```

   Partition d

   : is the whole disk, as usual on i386.

   Partition h

   : is what you want, and you can see it's a msdos filesystem even.

   Hence, use /dev/sd0h to access the zip's partition.

4. Mount it:

   ```
   # mount -t msdos /dev/sd0h /mnt
   ```

5. Access your files:

```
# ls -la /mnt
total 40809
drwxr-xr-x   1 root  wheel     16384 Dec 31  1979 .
drwxr-xr-x  28 root  wheel      1024 Aug  2 22:06 ..
-rwxr-xr-x   1 root  wheel   1474560 Feb 23  1999 boot1.fs
-rwxr-xr-x   1 root  wheel   1474560 Feb 23  1999 boot2.fs
-rwxr-xr-x   1 root  wheel    548864 Feb 23  1999 boot3.fs
-rwxr-xr-x   1 root  wheel  38271173 Feb 23  1999 netbsd19990223.tar.gz
```

6. Unmount the ZIP:

```
# umount /mnt
#
```

7. Eject the ZIP:

```
# eject sd0
#
```

13.4 Reading data CDs with NetBSD

Data CDs can contain anything from programs, sound files (MP3, wav), movies (MP3, QuickTime) to source code, text files, etc. Before accessing these files, a CD must be mounted on a directory, much like hard disks are. Just as hard disks can use different filesystems (ffs, lfs, ext2fs, ...), CDs have their own filesystem, "cd9660". The NetBSD cd9660 filesystem can handle filesystems without and with Rockridge and Joliet extensions.

CD devices are named /dev/cd0a for both SCSI and IDE (ATAPI).

With this information, we can start:

1. See if your system has some CD drive:

```
# dmesg | grep 'cd[0-9]*:'
     cd0 at atapibus0 drive 0: <CD-R/RW RW8040A, , 1.12> type 5 cdrom removable
     cd0: 32-bit data port
     cd0: drive supports PIO mode 4, DMA mode 0
```

   We have one drive here, "cd0". It is an IDE/ATAPI drive, as it is found on atapibus0. Of course the drive (rather, its medium) is removable, i.e., you can eject it. See below.

2. Insert a CD

3. Mount the CD manually:

```
# mount -t cd9660 /dev/cd0a /mnt
#
```

   This command shouldn't print anything. It instructs the system to mount the CD found on /dev/cd0a on /mnt, using the "cd9660" filesystem. The mountpoint "/mnt" must be an existing directory.

4. Check the contents of the CD:

```
# ls /mnt
INSTALL.html INSTALL.ps   TRANS.TBL    boot.catalog
INSTALL.more INSTALL.txt  binary       installation
```

```
#
```

Everything looks fine! This is a NetBSD CD, of course. :)

5. Unmount the CD:

```
# umount /mnt
#
```

If the CD is still accessed (e.g. some other shell's still "cd"'d into it), this will not work. If you shut down the system, the CD will be unmounted automatically for you, there's nothing to worry about there.

6. Making an entry in /etc/fstab:

If you don't want to type the full "mount" command each time, you can put most of the values into a line in /etc/fstab:

```
# Device        mountpoint      filesystem  mount options
/dev/cd0a       /cdrom          cd9660      ro,noauto
```

Make sure that the mountpoint, `/cdrom` in our example, exists:

```
# mkdir /cdrom
#
```

Now you can mount the cd with the following command:

```
# mount /cdrom
#
```

Access and unmount as before.

The CD is not mounted at boot time due to the "noauto" mount option - this is useful as you'll probably not have a CD in the drive all the time. See mount(8) and mount_cd9660(8) for some other useful options.

7. Eject the CD:

```
# eject cd0
#
```

If the CD is still mounted, it will be unmounted if possible, before being ejected.

13.5 Reading multi-session CDs with NetBSD

Use mscdlabel(8) to add all sessions to the CDs disklabel, and then use the appropriate device node to mount the session you want. You might have to create the corresponding device nodes in `/dev` manually. For example:

```
# mscdlabel cd1
track (ctl=4) at sector 142312
 adding as 'a'
track (ctl=4) at sector 0
 adding as 'b'
# ls -l /dev/cd1b
ls: /dev/cd1b: No such file or directory
# cd /dev
# ls -l cd1*
```

```
brw-r-----  1 root  operator       6,  8 Mar 18 21:55 cd1a
brw-r-----  1 root  operator       6, 11 Mar 18 21:55 cd1d
# mknod cd1b b 6 9
```

to create `/dev/cd1b`. Make sure you fix the permissions of any new device nodes you create:

```
# ls -l cd1*
brw-r-----  1 root  operator       6,  8 Mar 18 21:55 cd1a
brw-r--r--  1 root  wheel          6,  9 Mar 18 22:23 cd1b
brw-r-----  1 root  operator       6, 11 Mar 18 21:55 cd1d
# chgrp operator cd1b
# chmod 640 cd1b
# ls -l cd1*
brw-r-----  1 root  operator       6,  8 Mar 18 21:55 cd1a
brw-r-----  1 root  operator       6,  9 Mar 18 22:24 cd1b
brw-r-----  1 root  operator       6, 11 Mar 18 21:55 cd1d
```

Now you should be able to mount it.

```
# mount /dev/cd1b /mnt
```

13.6 Allowing normal users to access CDs

By default, NetBSD only allows "root" to mount a filesystem. If you want any user to be able to do this, perform the following steps:

- Give groups and other the access rights to the device.

  ```
  # chmod go+rw /dev/cd0a
  ```

- Ask NetBSD to let users mounting filesystems.

  ```
  # sysctl -w vfs.generic.usermount=1
  ```

  Note that this works for any filesystem and device, not only for CDs with a ISO 9660 filesystem.

To perform the mount operation after these commands, the user must own the mount point. So, for example:

```
$ cd $HOME
$ mkdir cdrom
$ mount -t cd9660 -o nodev,nosuid /dev/cd0a `pwd`/cdrom
```

Please also see mount(8) and as an alternative the *auto mount daemon* amd(8), for which example config files can be found in `/usr/share/examples/amd`.

13.7 Mounting an ISO image

Sometimes, it is interesting to mount an ISO9660 image file before you burn the CD; this way, you can examine its contents or even copy files to the outside. If you are a Linux user, you should know that this is done with the special *loop* filesystem. NetBSD does it another way, using the *vnode* pseudo-disk.

We will illustrate how to do this with an example. Suppose you have an ISO image in your home directory, called "mycd.iso":

1. Start by setting up a new vnode, "pointing" to the ISO file:

   ```
   # vnconfig -c vnd0 ~/mycd.iso
   ```

2. Now, mount the vnode:

   ```
   # mount -t cd9660 /dev/vnd0a /mnt
   ```

3. Yeah, image contents appear under `/mnt`! Go to that directory and explore the image.
4. When you are happy, you have to umount the image:

   ```
   # umount /mnt
   ```

5. And at last, deconfigure the vnode:

   ```
   # vnconfig -u vnd0
   ```

Note that these steps can also be used for any kind of file that contains a filesystem, not just ISO images.

See the vnd(4) and vnconfig(8) man pages for more information.

13.8 Using video CDs with NetBSD

To play MPEG Video streams as many DVD players can play them under NetBSD, mount the CD as you would do with any normal (data) CD (see Section 13.4), then use the `multimedia/xine-ui`, `multimedia/mplayer` or `multimedia/gmplayer` package to play the mpeg files stored on the CD.

13.9 Using audio CDs with NetBSD

There are two ways to handle audio CDs:

1. Tell the CD drive to play to the headphone or to a soundcard, to which CDROMs are usually connected internally. Use programs like cdplay(1), `audio/xmcd`, "kscd" from the `multimedia/kdemultimedia3` package, mixer programs like mixerctl(1), `audio/xmix`, `audio/xmmix`, the Curses based `audio/cam`, or kmix, which is part of `multimedia/kdemultimedia3`.

   This usually works well on both SCSI and IDE (ATAPI) CDROMs, CDRW and DVD drives.

2. To read ("rip") audio tracks in binary form without going through digital->analog conversion and back. There are several programs available to do this:

   - For most ATAPI, SCSI and several proprietary CDROM drives, the `audio/cdparanoia` package can be used. With cdparanoia the data can be saved to a file or directed to standard output in WAV, AIFF, AIFF-C or raw format. Currently the -g option is required by the NetBSD version of cdparanoia. A hypothetical example of how to save track 2 as a WAV file is as follows:

     ```
     $ cdparanoia -g /dev/rcd0d 2 track-02.wav
     ```

     If you want to grab all files from a CD, cdparanoia's batch mode is useful:

     ```
     $ cdparanoia -g /dev/rcd0d -B
     ```

- For ATAPI or SCSI CD-ROMs the `audio/cdd` package can be used. To extract track 2 with cdd, type:

  ```
  # cdd -t 2 `pwd`
  ```

  This will put a file called `track-02.cda` in the current directory.

- For SCSI CD-ROMS the `audio/tosha` package can be used. To extract track 2 with tosha, you should be able to type:

  ```
  # tosha -d CD-ROM-device -t 2 -o track-02.cda
  ```

The data can then be post-processed e.g. by encoding it into MP3 streams (see Section 13.10) or by writing them to CD-Rs (see Section 13.12).

- To streamline the process, from obtaining audio to populating the metadata for a track to normalising audio and such, the `audio/abcde` package can be used.

  ```
  # abcde -d /dev/rcd0d -o mp3 -p -P
  ```

  This will encode the disc track-by-track padding the tracknumbers with a leading 0 and using UNIX pipes to read+encode without leaving the WAV files

13.10 Creating an MP3 (MPEG layer 3) file from an audio CD

The basic steps in creating an MPEG layer 3 (MP3) file from an audio CD (using software from the NetBSD packages collection (http://www.NetBSD.org/docs/pkgsrc/)) are:

1. Extract (*rip*) the audio data of the CD as shown in Section 13.9.
2. Convert the CD audio format file to WAV format. You only need to perform this job if your ripping program (e.g. tosha, cdd) didn't already do the job for you!
   - Using the `audio/sox` package, type:

     ```
     $ sox -s -w -c 2 -r 44100 -t cdr track-02.cda track-02.wav
     ```

     This will convert `track-02.cda` in raw CD format to `track-02.wav` in WAV format, using **s**igned 16-bit **w**ords with 2 **c**hannels at a sampling **r**ate of 44100kHz.

3. Encode the WAV file into MP3 format.
   - Using the `audio/bladeenc` package, type:

     ```
     $ bladeenc -128 -QUIT track-02.wav
     ```

     This will encode `track-02.wav` into `track-02.mp3` in MP3 format, using a bit rate if **128**kBit/sec. The documentation for bladeenc describes bit-rates in more detail.
   - Using the `audio/lame` package, type:

     ```
     $ lame -p -o -v -V 5 -h track-02.wav track-02.mp3
     ```

     You may wish to use a lower quality, depending on your taste and hardware.

The resultant MP3 file can be played with any of the `audio/gqmpeg`, `audio/maplay`, `audio/mpg123` or `audio/splay` packages.

13.11 Using a CD-R writer with data CDs

The process of writing a CD consists of two steps: First, a "image" of the data must be generated, which can then be written to CD-R in a second step.

1. Reading a pre-existing ISO image

   ```
   # dd if=/dev/rcd0a of=filename.iso bs=2k
   #
   ```

   Alternatively, you can create a new ISO image yourself:

2. Generating the ISO image

   Put all the data you want to put on CD into one directory. Next you need to generate a disk-like ISO image of your data. The image stores the data in the same form as they're later put on CD, using the ISO 9660 format. The basic ISO9660 format only understands 8+3 filenames (max. eight letters for filename, plus three more for an extension). As this is not practical for Unix filenames, a so-called "Rockridge Extension" needs to be employed to get longer filenames. (A different set of such extension exists in the Microsoft world, to get their long filenames right; that's what's known as Joliet filesystem).

   The ISO image is created using the mkisofs command, which is part of the `sysutils/cdrtools` package.

   Example: if you have your data in /usr/tmp/data, you can generate a ISO image file in /usr/tmp/data.iso with the following command:

   ```
   $ cd /usr/tmp
   $ mkisofs -o data.iso -r data
   Using NETBS000.GZ;1 for  data/binary/kernel/netbsd.INSTALL.gz (netbsd.INSTALL_TINY.gz)
   Using NETBS001.GZ;1 for  data/binary/kernel/netbsd.GENERIC.gz (netbsd.GENERIC_TINY.gz)
     5.92% done, estimate finish Wed Sep 13 21:28:11 2000
    11.83% done, estimate finish Wed Sep 13 21:28:03 2000
    17.74% done, estimate finish Wed Sep 13 21:28:00 2000
    23.64% done, estimate finish Wed Sep 13 21:28:03 2000
    ...
    88.64% done, estimate finish Wed Sep 13 21:27:55 2000
    94.53% done, estimate finish Wed Sep 13 21:27:55 2000
   Total translation table size: 0
   Total rockridge attributes bytes: 5395
   Total directory bytes: 16384
   Path table size(bytes): 110
   Max brk space used 153c4
   84625 extents written (165 Mb)
   $
   ```

   Please see the mkisofs(8) man page for other options like noting publisher and preparer. The Bootable CD ROM How-To (http://www.NetBSD.org/docs/bootcd.html) explains how to generate a bootable CD.

3. Writing the ISO image to CD-R

   When you have the ISO image file, you just need to write it on a CD. This is done with the "cdrecord" command from the `sysutils/cdrtools` package. Insert a blank CD-R, and off we go:

   ```
   # cdrecord -v dev=/dev/rcd0d data.iso
   ```

```
...
#
```

After starting the command, 'cdrecord' shows you a lot of information about your drive, the disk and the image you're about to write. It then does a 10 seconds countdown, which is your last chance to stop things - type ^C if you want to abort. If you don't abort, the process will write the whole image to the CD and return with a shell prompt.

Note that cdrecord(8) works on both SCSI and IDE (ATAPI) drives.

4. Test

   Mount the just-written CD and test it as you would do with any "normal" CD, see Section 13.4.

13.12 Using a CD-R writer to create audio CDs

If you want to make a backup copy of one of your audio CDs, you can do so by extracting ("ripping") the audio tracks from the CD, and then writing them back to a blank CD. Of course this also works fine if you only extract single tracks from various CDs, creating your very own mix CD!

The steps involved are:

1. Extract ("rip") the audio tracks as described as in Section 13.9 to get a couple of .wav files.
2. Write the .wav files using cdrecord command from the `sysutils/cdrtools` package:

   ```
   # cdrecord -v dev=/dev/rcd0d -audio -pad *.wav
   ```

13.13 Creating an audio CD from MP3s

If you have converted all your audio CDs to MP3 and now want to make a mixed CD for your (e.g.) your car, you can do so by first converting the .mp3 files back to .wav format, then write them as a normal audio CD.

The steps involved here are:

1. Create .wav files from your .mp3 files:

   ```
   $ mpg123 -w foo.wav foo.mp3
   ```

   Do this for all of the MP3 files that you want to have on your audio CD. The .wav filenames you use don't matter.
2. Write the .wav files to CD as described under Section 13.12.

13.14 Copying an audio CD

To copy an audio CD while not introducing any pauses as mandated by the CDDA standard, you can use cdrdao for that:

```
# cdrdao read-cd --device /dev/rcd0d data.toc
# cdrdao write   --device /dev/rcd1d data.toc
```

13.15 Copying a data CD with two drives

If you have both a CD-R and a CD-ROM drive in your machine, you can copy a data CD with the following command:

```
# cdrecord dev=/dev/rcd1d /dev/rcd0d
```

Here the CD-ROM (cd0) contains the CD you want to copy, and the CD-R (cd1) contains the blank disk. Note that this only works with computer disks that contain some sort of data, it does *not* work with audio CDs! In practice you'll also want to add something like "*speed=8*" to make things a bit faster.

13.16 Using CD-RW rewritables

You can treat a CD-RW drive like a CD-R drive (see Section 13.11) in NetBSD, creating images with mkisofs(8) and writing them on a CD-RW medium with cdrecord(8).

If you want to blank a CD-RW, you can do this with cdrecord's "`blank`" option:

```
# cdrecord dev=/dev/rcd0d blank=fast
```

There are several other ways to blank the CD-RW, call cdrecord(8) with "*blank=help*" for a list. See the cdrecord(8) man page for more information.

13.17 DVD support

Currently, NetBSD supports ISO 9660 and UDF DVD media. Information about mounting ISO 9660 and UDF filesystems can be found in the mount_cd9660(8) and mount_udf(8) manual pages respectively. DVDs, DivX and many avi files be played with `multimedia/ogle` or `multimedia/gmplayer`.

For some hints on creating DVDs, see this postings about growisofs (http://mail-index.NetBSD.org/current-users/2004/01/06/0021.html) and this article about recording CDs and DVDs with NetBSD (http://www.mreriksson.net/blog/archive/15/).

13.18 Creating ISO images from a CD

To create an ISO image and save the checksum do this:

```
# readcd dev=/dev/cd0d f=/tmp/cd.iso
```

Here is an alternative using dd(1):

```
# dd if=/dev/cd0d of=/tmp/cd.iso bs=2048
```

If the CD has errors you can recover the rest with this:

```
# dd if=/dev/cd0d of=/tmp/cd.iso bs=2048 conv=noerror
```

To create an ISO image from a mounted data CD first, mount the CD disk by:

```
# mount -t cd9660 -r /dev/cd0d /mnt/cdrom
```

Second, get the image:

```
# mkhybrid -v -l -J -R -o /tmp/my_cd.iso /mnt/cdrom/
```

13.19 Getting volume information from CDs and ISO images

You can read the volume data from an unmounted CD with this command:

```
# file -s /dev/cd0d
```

You can read the volume data from an ISO image with this command:

```
# isoinfo -d -i /tmp/my_cd.iso
```

You can get the unique disk number from an unmounted CD with this:

```
# cd-discid /dev/cd0d
```

You can read the table of contents of an unmounted CD with this command:

```
# cdrecord -v dev=/dev/cd0d -toc
```

Chapter 14

The cryptographic device driver (CGD)

The `cgd` driver provides functionality which allows you to use disks or partitions for encrypted storage. After providing the appropriate key, the encrypted partition is accessible using `cgd` pseudo-devices.

14.1 Overview

People often store sensitive information on their hard disks and are concerned about this information falling into the wrong hands. This is particularly relevant to users of laptops and other portable devices, or portable media, which might be stolen or accidentally misplaced.

14.1.1 Why use disk encryption?

File-oriented encryption tools like GnuPG are great for encrypting individual files, which can then be sent across untrusted networks as well as stored encrypted on disk. But sometimes they can be inconvenient, because the file must be decrypted each time it is to be used; this is especially cumbersome when you have a large collection of files to protect. Any time a security tool is cumbersome to use, there's a chance you'll forget to use it properly, leaving the files unprotected for the sake of convenience.

Worse, readable copies of the encrypted contents might still exist on the hard disk. Even if you overwrite these files (using **rm -P**) before unlinking them, your application software might make temporary copies you don't know about, or have been paged to swapspace—and even your hard disk might have silently remapped failing sectors with data still in them.

The solution is to simply never write the information unencrypted to the hard disk. Rather than taking a file-oriented approach to encryption, consider a block-oriented approach—a virtual hard disk, that looks just like a normal hard disk with normal filesystems, but which encrypts and decrypts each block on the way to and from the real disk.

14.1.2 Logical Disk Drivers

The `cgd` device looks and behaves to the rest of the operating system like any other disk driver. Rather than driving real hardware directly, it provides a logical function layered on top of another block device. It has a special configuration program, **cgdconfig**, to create and configure a `cgd` device and point it at the underlying disk device that will hold the encrypted data.

NetBSD includes several other similar logical block devices, each of which provides some other function where `cgd` provides encryption. You can stack several of these logical block devices together: `cgd` on top of vnd is handy to make an encrypted volume in a regular file without repartitioning, or you can make an encrypted raid to protect your encrypted data against hard disk failure as well.

Once you have created a cgd disk, you can use **disklabel** to divide it up into partitions, **swapctl** to enable swapping to those partitions or **newfs** to make filesystems, then **mount** and use those filesystems, just like any other new disk.

14.1.3 Availability

The cgd driver was written by Roland C. Dowdeswell, and introduced in the NetBSD 2.0 release.

14.2 Components of the Crypto-Graphic Disk system

A number of components and tools work together to make the cgd system effective.

14.2.1 Kernel driver pseudo-device

To use cgd you need a kernel with support for the cgd pseudo-device. Make sure the sure the module is loaded:

```
# modload cgd
```

If the cgd driver was not already present/loaded (it is loaded by default in some ports), add **cgd** to /etc/modules.conf.

14.2.2 Ciphers

The following ciphers are supported:

adiantum (key size: 256 bits)

> The Adiantum tweakable wide-block cipher. The Adiantum tweak for each disk sector is taken to be the little-endian encoding of the disk sector number.
>
> Adiantum provides the best security by encrypting entire disk sectors at a time (512 bytes), and generally provides the best performance on machines without CPU support for accelerating AES.

aes-cbc (key sizes: 128, 192, or 256 bits)

> AES in CBC mode. The CBC initialization vector for each disk sector is chosen to be the encryption under AES of the little-endian encoding of the disk sector number. The default key length is 128 bits.

aes-xts (key sizes: 256 or 512 bits)

> AES in XTS mode. The XTS tweak for each disk sector is chosen to be the little-endian encoding of the disk sector number. AES-XTS uses a 256-bit or 512-bit key, composed of a pair of AES-128 or AES-256 keys. The default key length is 256, meaning AES-128.

14.2.3 Obsolete Ciphers

The following obsolete ciphers are supported for compatibility with old disks.

WARNING: These obsolete ciphers are implemented without timing side channel protection, so, for example, JavaScript code in a web browser that can measure the timing of disk activity may be able to recover the secret key. These are also based on 64-bit block ciphers and are therefore unsafe for disks much larger than a gigabyte. You should not use these except where compatibility with old disks is necessary.

`3des-cbc` (key size: 192 bits)

> 3DES (Triple DES with EDE3) in CBC mode. The CBC initialization vector for each disk sector is chosen to be the encryption under 3DES of the little-endian encoding of the disk sector number, which has no impact on security but reduces performance.
>
> Note: Internally, the “parity bits” of the 192-bit key are ignored, so there are only 168 bits of key material, and owing to generic attacks on 64-bit block ciphers and to meet-in-the-middle attacks on compositions of ciphers as in EDE3 the security is much lower than one might expect even for a 168-bit key.

`blowfish-cbc` (key sizes: 40, 48, 56, 64, . . . , 432, 440, or 448 bits)

> Blowfish in CBC mode. The CBC initialization vector for each disk sector is chosen to be the encryption under Blowfish of the little-endian encoding of the disk sector number. It is strongly encouraged that keys be at least 128 bits long. There are no performance advantages of using shorter keys. The default key length is 128 bits.

14.2.4 Verification Methods

cgdconfig can examine the disk to verify that it was decrypted using the correct key. The following verification methods are available:

`none`

> No verification is performed. This is dangerous unless you are configuring a new `cgd` device for the first time, because the key is not verified at all. Entering the wrong passphrase, for example, may destroy any data on the volume—any data read will be garbage, and any data written will turn into garbage if you ever re-open the `cgd` volume with the correct passphrase.

`disklabel`

> **cgdconfig** scans for a valid BSD disklabel; see disklabel(5) and disklabel(8).

`mbr`

> **cgdconfig** scans for a valid Master Boot Record, traditionally used on PCs; see fdisk(8).

`gpt`

> **cgdconfig** scans for a valid GUID partition table; see gpt(8).

`ffs`

cgdconfig scans for a valid FFS file system, the default file system used in NetBSD; see mount_ffs(8).

`re-enter`

Rather than scanning anything on disk, **cgdconfig** will compute the key twice—for example, by asking the user to enter the passphrase twice—and fail if the results are different.

14.3 Example: encrypting your disk

This section works through a step-by-step example of converting an existing system to use `cgd`, performing the following actions:

1. Preparing the disk and partitions
2. Scrub off all data
3. Create the cgd
4. Adjust config-files
5. Restoring your backed-up files to the encrypted disk

14.3.1 Preparing the disk

First, decide which filesystems you want to move to an encrypted device. You're going to need to leave at least the small root (`/`) filesystem unencrypted, in order to load the kernel and run **init**, **cgdconfig** and the **rc.d** scripts that configure your `cgd`. In this example, we'll encrypt everything except the root (`/`) filesystem.

We are going to delete and re-make partitions and filesystems, and will require a backup to restore the data. So make sure you have a current, reliable backup stored on a different disk or machine. Do your backup in single-user mode, with the filesystems unmounted, to ensure you get a clean **dump**. Make sure you back up the disklabel of your hard disk as well, so you have a record of the partition layout before you started.

With the system at single user, `/` mounted read-write and everything else unmounted, use **disklabel** to delete all the data partitions you want to move into `cgd`.

Then make a single new partition in all the space you just freed up, say, *`wd0e`*. Set the partition type for this partition to `cgd` Though it doesn't really matter what it is, it will help remind you that it's not a normal filesystem later. When finished, label the disk to save the new partition table.

14.3.2 Scrubbing the disk

We have removed the partition table information, but the existing filesystems and data are still on disk. Even after we make a `cgd` device, create filesystems, and restore our data, some of these disk blocks might not yet be overwritten and still contain our data in plaintext. This is especially likely if the filesystems are mostly empty. We want to scrub the disk before we go further.

We could use **dd** to copy `/dev/zero` over the new *wd0e* partition, but this will leave our disk full of zeros, except where we've written encrypted data later. We might not want to give an attacker any clues about which blocks contain real data, and which are free space, so we want to write "noise" into all the disk blocks. So we'll create a temporary `cgd`, configured with a random, unknown key.

First, we configure a `cgd` to use a random key:

```
# cgdconfig -s cgd0 /dev/wd0e aes-xts 256 < /dev/urandom
```

Now we can write zeros into the raw partition of our `cgd` (`/dev/rcgd0d` on NetBSD/i386 and amd64, `/dev/rcgd0c` on most other platforms):

```
# dd if=/dev/zero of=/dev/rcgd0d bs=64k
```

The encrypted zeros will look like random data on disk. This might take a while if you have a large disk. Once finished, unconfigure the random-key `cgd`:

```
# cgdconfig -u cgd0
```

14.3.3 Creating the cgd

The **cgdconfig** program, which manipulates `cgd` devices, uses parameters files to store such information as the encryption type, key length, and a random password salt for each `cgd`. These files are very important, and need to be kept safe—without them, you will not be able to decrypt the data!

We'll generate a parameters file and write it into the default location (make sure the directory `/etc/cgd` exists and is mode 700):

```
# cgdconfig -g -V disklabel -o /etc/cgd/wd0e aes-cbc 256
```

This creates a parameters file `/etc/cgd/wd0e` describing a `cgd` using the `aes-cbc` cipher method, a key verification method of `disklabel`, and a key length of `256` bits. It will look something like this:

```
algorithm aes-cbc;
iv-method encblkno;
keylength 256;
verify_method disklabel;
keygen pkcs5_pbkdf2/sha1 {
        iterations 6275;
        salt AAAAgHTg/jKCd2ZJiOSGrgnadGw=;
};
```

> **Note:** Consider this file being *SACRED, BACK IT UP* , and *BACK IT UP AGAIN!*

> **Tip:** When creating the parameters file, **cgdconfig** reads from `/dev/random` to create the password salt. This read may block if there is not enough collected entropy in the random pool. This is unlikely, especially if you just finished overwriting the disk as in the previous step, but if it happens you can press keys on the console and/or move your mouse until the `rnd` device gathers enough entropy.

Now it's time to create our `cgd`, for which we'll need a passphrase. This passphrase needs to be entered every time the `cgd` is opened, which is usually at each reboot. The encryption key is derived from this passphrase and the salt. Make sure you choose something you won't forget, and others won't guess.

The first time we configure the `cgd`, there is no valid disklabel on the logical device, so the validation mechanism we want to use later won't work. We override it this one time:

```
# cgdconfig -V re-enter cgd0 /dev/wd0e
```

This will prompt twice for a matching passphrase, just in case you make a typo, which would otherwise leave you with a `cgd` encrypted with a passphrase that's different to what you expected.

Now that we have a new `cgd`, we need to partition it and create filesystems. Recreate your previous partitions with all the same sizes, with the same letter names.

> **Tip:** Remember to use the **disklabel -I** argument, because you're creating an initial label for a new disk.

> **Note:** Although you want the sizes of your new partitions to be the same as the old, unencrypted ones, the offsets will be different because they're starting at the beginning of this virtual disk.

Then, use **newfs** to create filesystems on all the relevant partitions. This time your partitions will reflect the `cgd` disk names, for example:

```
# newfs /dev/rcgd0h
```

14.3.4 Modifying configuration files

We've moved several filesystems to another (logical) disk, and we need to update `/etc/fstab` accordingly. Each partition will have the same letter (in this example), but will be on `cgd0` rather than `wd0`. So you'll have `/etc/fstab` entries something like this:

```
/dev/wd0a   /     ffs     rw    1 1
/dev/cgd0b  none  swap    sw             0 0
/dev/cgd0b  /tmp  mfs     rw,-s=132m     0 0
/dev/cgd0e  /var  ffs     rw             1 2
/dev/cgd0f  /usr  ffs     rw             1 2
/dev/cgd0h  /home ffs     rw             1 2
```

> **Note:** `/tmp` should be a separate filesystem, either `mfs` or `ffs`, inside the `cgd`, so that your temporary files are not stored in plain text in the `/` filesystem.

Each time you reboot, you're going to need your `cgd` configured early, before **fsck** runs and filesystems are mounted.

Put the following line in `/etc/cgd/cgd.conf`:

```
cgd0    /dev/wd0e
```

This will use `/etc/cgd/wd0e` as config file for `cgd0`.

To finally enable cgd on each boot, put the following line into `/etc/rc.conf`:

```
cgd=YES
```

You should now be prompted for `/dev/cgd0`'s passphrase whenever `/etc/rc` starts.

14.3.5 Restoring data

Next, **mount** your new filesystems, and **restore** your data into them. It often helps to have `/tmp` mounted properly first, as **restore** can use a fair amount of temporary space when extracting a large dumpfile.

To test your changes to the boot configuration, **umount** the filesystems and unconfigure the `cgd`, so when you exit the single-user shell, **rc** will run like on a clean boot, prompting you for the passphrase and mounting your filesystems correctly. Now you can bring the system up to multi-user, and make sure everything works as before.

14.4 Example: encrypted CDs/DVDs

14.4.1 Creating an encrypted CD/DVD

cgd(4) provides highly secure encryption of whole partitions or disks. Unfortunately, creating "normal" CDs is not disklabeling something and running newfs on it. Neither can you just put a CDR into the drive, configure cgd and assume it to write encrypted data when syncing. Standard CDs contain at least an ISO-9660 filesystem created with mkisofs(8) from the `sysutils/cdrtools` package. ISO images may *not* contain disklabels or cgd partitions.

But of course CD reader/writer hardware doesn't care about filesystems at all. You can write raw data to the CD if you like—or an encrypted FFS filesystem, which is what we'll do here. But be warned, there is NO way to read this CD with any OS except NetBSD—not even other BSDs due to the lack of cgd.

The basic steps when creating an encrypted CD are:

- Create an (empty) imagefile
- Register it as a virtual disk using vnd(4)
- Configure cgd inside the vnd disk
- Copy content to the cgd
- Unconfigure all (flush!)
- Write the image on a CD

The first step when creating an encrypted CD is to create a single image file with dd. The image may not grow, so make it large enough to allow all CD content to fit into. Note that the whole image gets written to the CD later, so creating a 700 MB image for 100 MB content will still require a 700 MB write operation to the CD. Some info on DVDs here: DVDs are only 4.7 GB in marketing language. 4.7GB = 4.7 x 1024 x 1024 x 1024 = 5046586573 bytes. In fact, a DVD can only approximately hold 4.7 x 1000 x

1000 x 1000 = 4700000000 bytes, which is about 4482 MB or about 4.37 GB. Keep this in mind when creating DVD images. Don't worry for CDs, they hold "real" 700 MB (734003200 Bytes).

Invoke all following commands as root!

For a CD:

```
# dd if=/dev/zero of=image.img bs=1m count=700
```

or, for a DVD:

```
# dd if=/dev/zero of=image.img bs=1m count=4482
```

Now configure a vnd(4)-pseudo disk with the image:

```
# vnconfig vnd0 image.img
```

In order to use cgd, a so-called parameter file, describing encryption parameters and a containing "password salt" must be generated. We'll call it `/etc/cgd/image` here. You can use one parameter file for several encrypted partitions (I use one different file for each host and a shared file `image` for all removable media, but that's up to you).

AES-CBC with a keylength of 256 bits will be used in this example. Refer to cgd(4) and cgdconfig(8) for further details and alternative ciphers.

The following command will create the parameter file as `/etc/cgd/image`. *YOU DO NOT WANT TO INVOKE THE FOLLOWING COMMAND AGAIN* after you burnt any CD, since a recreated parameter file is a lost parameter file and you'll never access your encrypted CD again (the "salt" this file contains will differ among each call). Consider this file being *SACRED, BACK IT UP* and *BACK IT UP AGAIN!* Use switch -V to specify verification method "disklabel" for the CD (cgd cannot detect whether you entered a valid password for the CD later when mounting it otherwise).

```
# cgdconfig -g -V disklabel aes-cbc 256 > /etc/cgd/image
```

Now it's time to configure a cgd for our vnd drive. (Replace slice "d" with "c" for all platforms that use "c" as the whole disk (where "**sysctl kern.rawpartition**" prints "2", not "3"); if you're on i386 or amd64, "d" is OK for you):

```
# cgdconfig -V re-enter cgd1 /dev/vnd0d /etc/cgd/image
```

The "`-V re-enter`" option is necessary as long as the cgd doesn't have a disklabel yet so we can access and configure it. This switch asks for a password twice and uses it for encryption.

Now it's time to create a disklabel inside the cgd. The defaults of the label are ok, so invoking disklabel with

```
# disklabel -e -I cgd1
```

and leaving vi with "**:wq**" immediately will do.

Let's create a filesystem on the cgd, and finally mount it somewhere:

```
# newfs /dev/rcgd1a
# mount /dev/cgd1a /mnt
```

The cgd is alive! Now fill `/mnt` with content. When finished, reverse the configuration process. The steps are:

1. Unmounting the cgd1a:

   ```
   # umount /mnt
   ```

2. Unconfiguring the cgd:

   ```
   # cgdconfig -u cgd1
   ```

3. Unconfiguring the vnd:

   ```
   # vnconfig -u vnd0
   ```

The following commands are examples to burn the images on CD or DVD. Please adjust the *`dev=`* for cdrecord or the `/dev/rcd0d` for growisofs. Note the "*r*`cd0d`" *is* necessary with NetBSD. Growisofs is available in the `sysutils/dvd+rw-tools` package. Again, use "`c`" instead of "`d`" if this is the raw partition on your platform.

Finally, write the image file to a CD:

```
# cdrecord dev=/dev/rcd0d -v image.img
```

...or to a DVD:

```
# growisofs -dvd-compat -Z /dev/rcd0d=image.img
```

Congratulations! You've just created a really secure CD!

14.4.2 Using an encrypted CD/DVD

After creating an encrypted CD as described above, we're not done yet—what about mounting it again? One might guess, configuring the cgd on `/dev/cd0d` is enough—no, it is not.

NetBSD cannot access FFS file systems on media that is not 512 bytes/sector format. It doesn't matter that the cgd on the CD is, since the CD's disklabel the cgd resides in has 2048 bytes/sector.

But the CD driver cd(4) is smart enough to grant "write" access to the (emulated) disklabel on the CD. So before configuring the cgd, let's have a look at the disklabel and modify it a bit:

```
# disklabel -e cd0
# /dev/rcd0d:
type: ATAPI
disk: mydisc
label: fictitious
flags: removable
bytes/sector: 2048    # -- Change to 512 (= orig / 4)
sectors/track: 100    # -- Change to 400 (= orig * 4)
tracks/cylinder: 1
sectors/cylinder: 100 # -- Change to 400 (= orig * 4)
cylinders: 164
total sectors: 16386  # -- Change to value of slice "d" (=65544)
rpm: 300
interleave: 1
trackskew: 0
```

```
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0

4 partitions:
#      size  offset  fstype [fsize bsize cpg/sgs]
 a:   65544   0     4.2BSD  0     0     0  # (Cyl. 0 - 655+)
 d:   65544   0     ISO9660 0     0        # (Cyl. 0 - 655+)
```

If you don't want to do these changes every time by hand, you can use Florian Stoehr's tool **neb-cd512** which is (at time of writing this) in pkgsrc-wip and will move to `sysutils/neb-cd512` soon. You can also download the neb-cd512 source from http://sourceforge.net/projects/neb-stoehr/ (http://sourceforge.net/projects/neb-stoehr/) (be sure to use neb-cd512, not neb-wipe!).

It is invoked with the disk name as parameter, by root:

```
# neb-cd512 cd0
```

Now as the disklabel is in 512 b/s format, accessing the CD is as easy as:

```
# cgdconfig cgd1 /dev/cd0d /etc/cgd/image
# mount -o ro /dev/cgd1a /mnt
```

Note that the cgd *MUST* be mounted read-only or you'll get illegal command errors from the cd(4) driver which can in some cases make even mounting a CD-based cgd impossible!

Now we're done! Enjoy your secure CD!

```
# ls /mnt
```

Remember you have to reverse all steps to remove the CD:

```
# umount /mnt
# cgdconfig -u cgd1
# eject cd0
```

14.5 Example: encrypted iSCSI devices

14.5.1 Creating an encrypted iSCSI device

To encrypt the iSCSI device, we use the NetBSD iSCSI initiator, available in NetBSD-6 and newer, and the standard cgd device. In all, setting up an encrypted device in this manner should take less than 15 minutes, even for someone unfamiliar with iSCSI or cgd.

The approach is to layer a vnd on top of the "storage" file presented by the iSCSI target. This is exactly the same as normal. On top of that vnd, we layer a cgd device, which ensures that all data is encrypted on the iSCSI device.

WARNING: `cgd` only keeps the content of the volume secret—it doesn't keep the access patterns secret, and it doesn't prevent or even detect a malicious network or iSCSI target tampering with the volume.

14.5.2 Device Initialisation

Firstly, the initiator is started, pointing at the machine which is presenting the iSCSI storage (i.e. the machine on which the iSCSI target is running). In this example, the target is running on the same machine as the initiator (a laptop called, in a moment of inspiration, inspiron1300). A 50 MB iSCSI target is being presented as target1.

```
# iscsi-initiator -u agc -h inspiron1300.wherever.co.uk /mnt &
[1] 11196

# df
Filesystem   1K-blocks       Used      Avail %Cap Mounted on
/dev/dk0      28101396   20862004    5834324  78% /
kernfs               1          1          0 100% /kern
procfs               4          4          0 100% /proc
ptyfs                1          1          0 100% /dev/pts
/dev/puffs           0          0          0 100% /mnt
```

Looking at the last line, we can see that the initiator is running via the puffs device.

A vnd device is created on top of the storage which the target is presenting:

```
# vnconfig vnd0 /mnt/inspiron1300.wherever.co.uk/target1/storage
```

A disklabel which is offset 63 blocks into the iSCSI device needs to be added. This is so that the encrypted device which we shall put on top of the vnd does not clash with the vnd's label. The cgd's type should be set to "cgd".

```
# disklabel -e vnd0
# /dev/rvnd0d:
type: vnd
disk: vnd
label: fictitious
flags:
bytes/sector: 512
sectors/track: 32
tracks/cylinder: 64
sectors/cylinder: 2048
cylinders: 50
total sectors: 102400
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0

4 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:    102336        63        cgd   2048 16384 28360  # (Cyl.      0 -     49)
 d:    102400         0     unused      0     0        # (Cyl.      0 -     49)
```

The cgd device can now be created on the vnd device

```
# cgdconfig -s cgd0 /dev/vnd0a aes-xts 256 < /dev/urandom
```

and the cgd device's storage zeroed

```
# dd if=/dev/zero of=/dev/rcgd0d bs=32k
dd: /dev/rcgd0d: Invalid argument
1601+0 records in
1600+0 records out
52428800 bytes transferred in 16.633 secs (3152095 bytes/sec)
```

Unconfigure the cgd device and write a disklabel using the verification method onto the cgd. Note: sometimes, this process does not always complete properly, and so it has to be repeated.

```
# cgdconfig -g -V disklabel -o /etc/cgd/vnd0a aes-cbc 256
cgdconfig: could not calibrate pkcs5_pbkdf2
cgdconfig: Failed to generate defaults for keygen
# cgdconfig -g -V disklabel -o /etc/cgd/vnd0a aes-cbc 256
```

A password can then be added to the cgd device

```
# cgdconfig -V re-enter cgd0 /dev/vnd0a
/dev/vnd0a's passphrase:
re-enter device's passphrase:
```

Then create a disklabel inside the cgd itself

```
# disklabel -I -e cgd0

# /dev/rcgd0d:
type: cgd
disk: cgd
label: fictitious
flags:
bytes/sector: 512
sectors/track: 2048
tracks/cylinder: 1
sectors/cylinder: 2048
cylinders: 49
total sectors: 102336
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0

4 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:    102336         0     4.2BSD   2048 16384 28360  # (Cyl.      0 -     49*)
 d:    102336         0     unused      0     0        # (Cyl.      0 -     49*)
```

Having placed a disklabel inside the cgd, we can now make a filesystem on there:

```
# newfs /dev/rcgd0a
/dev/rcgd0a: 50.0MB (102336 sectors) block size 8192, fragment size 1024
using 4 cylinder groups of 12.49MB, 1599 blks, 3136 inodes.
super-block backups (for fsck_ffs -b #) at:
32, 25616, 51200, 76784,
```

the new file system in the cgd can now be mounted

```
# df
Filesystem   1K-blocks       Used      Avail %Cap Mounted on
/dev/dk0      28101396   20910216    5786112  78% /
kernfs               1          1          0 100% /kern
procfs               4          4          0 100% /proc
ptyfs                1          1          0 100% /dev/pts
/dev/puffs           0          0          0 100% /mnt
# mount /dev/cgd0a /iscsi
# df
Filesystem   1K-blocks       Used      Avail %Cap Mounted on
/dev/dk0      28101396   20910216    5786112  78% /
kernfs               1          1          0 100% /kern
procfs               4          4          0 100% /proc
ptyfs                1          1          0 100% /dev/pts
/dev/puffs           0          0          0 100% /mnt
/dev/cgd0a       49519          1      47043   0% /iscsi
```

The new file system, mounted on /iscsi, can now be used as normal.

14.5.3 Unmounting the Encrypted Device

The device can be freed up using the following commands

```
# umount /iscsi
# cgdconfig -u cgd0
# vnconfig -u vnd0
```

14.5.4 Normal Usage

In normal usage, the device can be mounted. Firstly, the initiator must be configured to connect to the device:

```
# vnconfig vnd0 /mnt/inspiron1300.wherever.co.uk/target1/storage
# cgdconfig cgd0 /dev/vnd0a
/dev/vnd0a's passphrase:
# mount /dev/cgd0a /iscsi
# ls -al /iscsi
total 3
drwxr-xr-x   2 root  wheel   512 Jan  1  1970 .
drwxr-xr-x  35 root  wheel  1536 Jan  5 08:59 ..
# df
Filesystem   1K-blocks       Used      Avail %Cap Mounted on
/dev/dk0      28101396   20910100    5786228  78% /
```

```
kernfs                1          1          0 100% /kern
procfs                4          4          0 100% /proc
ptyfs                 1          1          0 100% /dev/pts
/dev/puffs            0          0          0 100% /mnt
/dev/cgd0a        49519          1      47043   0% /iscsi
```

14.6 Suggestions and Warnings

You now have your filesystems encrypted within a `cgd`. When your machine is shut down, the data is protected, and can't be decrypted without the passphrase. However, there are still some dangers you should be aware of, and more you can do with `cgd`. This section documents several further suggestions and warnings that will help you use `cgd` effectively.

- Use multiple `cgd`'s for different kinds of data, one mounted all the time and others mounted only when needed.
- Use a `cgd` configured on top of a `vnd` made from a file on a remote network fileserver (NFS, SMBFS, CODA, etc) to safely store private data on a shared system. This is similar to the procedure for using encrypted CDs and DVDs described in Section 14.4.

14.6.1 Using a random-key cgd for swap

The following section will be replaced in NetBSD 10 by a sysctl knob "vm.swap_encrypt=1", which provides better security and simpler setup.

You may want to use a dedicated random-key `cgd` for swap space, regenerating the key each reboot. The advantage of this is that once your machine is rebooted, any sensitive program memory contents that may have been paged out are permanently unrecoverable, because the decryption key is never known to you.

We created a temporary `cgd` with a random key when scrubbing the disk in the example above, using a shorthand **cgdconfig -s** invocation to avoid creating a parameters file.

The **cgdconfig** params file includes a "randomkey" keygen method. This is more appropriate for "permanent" random-key configurations, and facilitates the easy automatic configuration of these volumes at boot time.

For example, if you wanted to convert your existing `/dev/wd0b` partition to a dedicated random-key cgd1, use the following command to generate `/etc/cgd/wd0b`:

```
# cgdconfig -g -o /etc/cgd/wd0b -V none -k randomkey blowfish-cbc
```

When using the randomkey keygen method, only verification method "none" can be used, because the contents of the new `cgd` are effectively random each time (the previous data decrypted with a random key). Likewise, the new disk will not have a valid label or partitions, and **swapctl** will complain about configuring swap devices not marked as such in a disklabel.

In order to automate the process of labeling the disk, prepare an appropriate disklabel and save it to a file, for example `/etc/cgd/wd0b.disklabel`. Please refer to disklabel(8) for information about how to use **disklabel** to set up a swap partition.

On each reboot, to restore this saved label to the new `cgd`, create the `/etc/rc.conf.d/cgd` file as below:

```
swap_device="cgd1"
swap_disklabel="/etc/cgd/wd0b.disklabel"
start_postcmd="cgd_swap"

cgd_swap()
{
 if [ -f $swap_disklabel ]; then
  disklabel -R -r $swap_device $swap_disklabel
 fi
}
```

The same technique could be extended to encompass using **newfs** to re-create an `ffs` filesystem for `/tmp` if you didn't want to use `mfs`.

14.6.2 Warnings

Avoid data loss by making sure you can always recover your passphrase and parameters file. Protect the parameters file from disclosure, perhaps by storing it on removable media as above, because the salt it contains helps protect against dictionary attacks on the passphrase.

Keeping the data encrypted on your disk is all very well, but what about other copies? You already have at least one other such copy (the backup we used during this setup), and it's not encrypted. Piping **dump** through file-based encryption tools like **gpg** can be one way of addressing this issue, but make sure you have all the keys and tools you need to decrypt it to **restore** after a disaster.

Like any form of software encryption, the `cgd` key stays in kernel memory while the device is configured, and may be accessible to privileged programs and users, such as `/dev/kmem` grovellers. Taking other system security steps, such as running with elevated securelevel, is highly recommended.

Once the `cgd` volumes are mounted as normal filesystems, their contents are accessible like any other file. Take care of file permissions and ensure your running system is protected against application and network security attack.

Avoid using suspend/resume, especially for laptops with a BIOS suspend-to-disk function. If an attacker can resume your laptop with the key still in memory, or read it from the suspend-to-disk memory image on the hard disk later, the whole point of using `cgd` is lost.

14.7 Further Reading

The following resources contain more information on CGD and the cryptography underlying it:

Bibliography

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Chapter 15

Concatenated Disk Device (CCD) configuration

The CCD driver allows the user to “concatenate” several physical disks into one pseudo volume. While RAIDframe (see Chapter 16) also allows doing this to create RAID level 0 sets, it does not allow you to do striping across disks of different geometry, which is where CCD comes in handy. CCD also allows for an “interleave” to improve disk performance with a gained space loss. This example will not cover that feature.

The steps required to setup a CCD are as follows:

1. Install physical media
2. Configure kernel support
3. Disklabel each volume member of the CCD
4. Configure the CCD conf file
5. Initialize the CCD device
6. Create a filesystem on the new CCD device
7. Mount the CCD filesystem

This example features a CCD setup on NetBSD/sparc 1.5. The CCD will reside on 4 SCSI disks in a generic external Sun disk pack chassis connected to the external 50 pin SCSI port.

15.1 Install physical media

This step is at your own discretion, depending on your platform and the hardware at your disposal.

From my DMESG:

```
Disk #1:
  probe(esp0:0:0): max sync rate 10.00MB/s
  sd0 at scsibus0 target 0 lun 0: <SEAGATE, ST32430N SUN2.1G, 0444> SCSI2 0/direct fixed
  sd0: 2049 MB, 3992 cyl, 9 head, 116 sec, 512 bytes/sect x 4197405 sectors

Disk #2
  probe(esp0:1:0): max sync rate 10.00MB/s
  sd1 at scsibus0 target 1 lun 0: <SEAGATE, ST32430N SUN2.1G, 0444> SCSI2 0/direct fixed
  sd1: 2049 MB, 3992 cyl, 9 head, 116 sec, 512 bytes/sect x 4197405 sectors

Disk #3
  probe(esp0:2:0): max sync rate 10.00MB/s
```

```
  sd2 at scsibus0 target 2 lun 0: <SEAGATE, ST11200N SUN1.05, 9500> SCSI2 0/direct fixed
  sd2: 1005 MB, 1872 cyl, 15 head, 73 sec, 512 bytes/sect x 2059140 sectors

Disk #4
  probe(esp0:3:0): max sync rate 10.00MB/s
  sd3 at scsibus0 target 3 lun 0: <SEAGATE, ST11200N SUN1.05, 8808 > SCSI2 0
  sd3: 1005 MB, 1872 cyl, 15 head, 73 sec, 512 bytes/sect x 2059140 sectors
```

15.2 Configure Kernel Support

The following kernel configuration directive is needed to provide CCD device support. It is enabled in the GENERIC kernel:

```
pseudo-device  ccd  4    # concatenated disk devices
```

In my kernel config, I also hard code SCSI ID associations to `/dev` device entries to prevent bad things from happening:

```
sd0     at scsibus0 target 0 lun ?
# SCSI disk drives
sd1     at scsibus0 target 1 lun ?
# SCSI disk drives
sd2     at scsibus0 target 2 lun ?
# SCSI disk drives
sd3     at scsibus0 target 3 lun ?
# SCSI disk drives
sd4     at scsibus0 target 4 lun ?
# SCSI disk drives
sd5     at scsibus0 target 5 lun ?
# SCSI disk drives
sd6     at scsibus0 target 6 lun ?
# SCSI disk drives
```

15.3 Disklabel each volume member of the CCD

Each member disk of the CCD will need a special file system established. In this example, I will need to disklabel:

```
/dev/rsd0c
/dev/rsd1c
/dev/rsd2c
/dev/rsd3c
```

> **Note:** Always remember to disklabel the character device, not the block device, in `/dev/r{s,w}d*`

> **Note:** On all platforms, the `c` slice is symbolic of the entire NetBSD partition and is reserved.

You will probably want to remove any pre-existing disklabels on the disks in the CCD. This can be accomplished in one of two ways with the dd(1) command:

```
# dd if=/dev/zero of=/dev/rsd0c bs=8k count=1
# dd if=/dev/zero of=/dev/rsd1c bs=8k count=1
# dd if=/dev/zero of=/dev/rsd2c bs=8k count=1
# dd if=/dev/zero of=/dev/rsd3c bs=8k count=1
```

If your port uses a MBR (Master Boot Record) to partition the disks so that the NetBSD partitions are only part of the overall disk, and other OSs like Windows or Linux use other parts, you can void the MBR and all partitions on disk by using the command:

```
# dd if=/dev/zero of=/dev/rsd0d bs=8k count=1
# dd if=/dev/zero of=/dev/rsd1d bs=8k count=1
# dd if=/dev/zero of=/dev/rsd2d bs=8k count=1
# dd if=/dev/zero of=/dev/rsd3d bs=8k count=1
```

This will make all data on the entire disk inaccessible. Note that the entire disk is slice `d` on i386 (and some other ports), and `c` elsewhere (e.g. on sparc). See the "kern.rawpartition" sysctl - "3" means "d", "2" means "c".

The default disklabel for the disk will look similar to this:

```
# disklabel -r sd0
[...snip...]
bytes/sector: 512
sectors/track: 116
tracks/cylinder: 9
sectors/cylinder: 1044
cylinders: 3992
total sectors: 4197405
[..snip...]
3 partitions:
#        size   offset    fstype   [fsize bsize   cpg]
  c:  4197405       0     unused     1024  8192        # (Cyl.    0 - 4020*)
```

You will need to create one "slice" on the NetBSD partition of the disk that consumes the entire partition. The slice must begin at least one cylinder offset from the beginning of the disk/partition to provide space for the special CCD disklabel. The offset should be 1x sectors/cylinder (see following note). Therefore, the "size" value should be "total sectors" minus 1x "sectors/cylinder". Edit your disklabel accordingly:

```
# disklabel -e sd0
```

> **Note:** The offset of a slice of type "ccd" must be a multiple of the "sectors/cylinder" value.

> **Note:** Be sure to **export EDITOR=[path to your favorite editor]** before editing the disklabels.

> **Note:** The slice must be fstype `ccd`.

Because there will only be one slice on this partition, you can recycle the `c` slice (normally reserved for symbolic uses). Change your disklabel to the following:

```
3 partitions:
#        size   offset    fstype   [fsize bsize   cpg]
  c:  4196361     1044       ccd                        # (Cyl. 1 - 4020*)
```

Optionally you can setup a slice other than `c` to use, simply adjust accordingly below:

```
3 partitions:
#        size   offset    fstype   [fsize bsize   cpg]
  a:  4196361     1044       ccd                        # (Cyl. 1 - 4020*)
  c:  4197405        0     unused     1024  8192        # (Cyl. 0 - 4020*)
```

Be sure to write the label when you have completed. Disklabel will object to your disklabel and prompt you to re-edit if it does not pass its sanity checks.

15.4 Configure the CCD

Once all disks are properly labeled, you will need to generate a configuration file, `/etc/ccd.conf`. The file does not exist by default, and you will need to create a new one. The format is:

```
#ccd    ileave    flags   component    devices
```

> **Note:** For the "ileave", if a value of zero is used then the disks are concatenated, but if you use a value equal to the "sectors/track" number the disks are interleaved.

Example in this case:

```
# more /etc/ccd.conf
ccd0  0  none /dev/sd0c /dev/sd1c /dev/sd2c /dev/sd3c
```

> **Note:** The CCD driver expects block device files as components. Be sure not to use character device files in the configuration.

15.5 Initialize the CCD device

Once you are confident that your CCD configuration is sane, you can initialize the device using the ccdconfig(8) command: Configure:

```
# ccdconfig -C -f /etc/ccd.conf
```

Unconfigure:

```
# ccdconfig -u -f /etc/ccd.conf
```

Initializing the CCD device will activate `/dev` entries: `/dev/{,r}ccd#:`

```
# ls -la  /dev/{,r}ccd0*
brw-r-----  1 root  operator   9, 0 Apr 28 21:35 /dev/ccd0a
brw-r-----  1 root  operator   9, 1 Apr 28 21:35 /dev/ccd0b
brw-r-----  1 root  operator   9, 2 May 12 00:10 /dev/ccd0c
brw-r-----  1 root  operator   9, 3 Apr 28 21:35 /dev/ccd0d
brw-r-----  1 root  operator   9, 4 Apr 28 21:35 /dev/ccd0e
brw-r-----  1 root  operator   9, 5 Apr 28 21:35 /dev/ccd0f
brw-r-----  1 root  operator   9, 6 Apr 28 21:35 /dev/ccd0g
brw-r-----  1 root  operator   9, 7 Apr 28 21:35 /dev/ccd0h
crw-r-----  1 root  operator  23, 0 Jun 12 20:40 /dev/rccd0a
crw-r-----  1 root  operator  23, 1 Apr 28 21:35 /dev/rccd0b
crw-r-----  1 root  operator  23, 2 Jun 12 20:58 /dev/rccd0c
crw-r-----  1 root  operator  23, 3 Apr 28 21:35 /dev/rccd0d
crw-r-----  1 root  operator  23, 4 Apr 28 21:35 /dev/rccd0e
crw-r-----  1 root  operator  23, 5 Apr 28 21:35 /dev/rccd0f
crw-r-----  1 root  operator  23, 6 Apr 28 21:35 /dev/rccd0g
crw-r-----  1 root  operator  23, 7 Apr 28 21:35 /dev/rccd0h
```

15.6 Create a 4.2BSD/UFS filesystem on the new CCD device

You may now disklabel the new virtual disk device associated with your CCD:

```
# disklabel -e ccd0
```

Once again, there will be only one slice, so you may either recycle the `c` slice or create a separate slice for use.

```
# disklabel -r ccd0
# /dev/rccd0c:
type: ccd
disk: ccd
label: default label
flags:
bytes/sector: 512
sectors/track: 2048
tracks/cylinder: 1
sectors/cylinder: 2048
cylinders: 6107
total sectors: 12508812
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0
#        size   offset    fstype   [fsize bsize   cpg]
  c: 12508812        0    4.2BSD     1024  8192    16  # (Cyl. 0 - 6107*)
```

The filesystem will then need to be formatted:

```
# newfs /dev/rccd0c
Warning: 372 sector(s) in last cylinder unallocated
/dev/rccd0c:    12508812 sectors in 6108 cylinders of 1 tracks, 2048 sectors
        6107.8MB in 382 cyl groups (16 c/g, 16.00MB/g, 3968 i/g)

super-block backups (for fsck -b #) at:
[...]
```

15.7 Mount the filesystem

Once you have a created a file system on the CCD device, you can then mount the file system against a mount point on your system. Be sure to mount the slice labeled type `ffs` or `4.2BSD`:

```
# mount /dev/ccd0c /mnt
```

Then:

```
# export BLOCKSIZE=1024; df
Filesystem  1K-blocks     Used   Avail Capacity  Mounted on
/dev/sd6a      376155   320290   37057    89%    /
/dev/ccd0c    6058800        1  5755859     0%    /mnt
```

Congratulations, you now have a working CCD. To configure the CCD device at boot time, set `ccd=yes` in `/etc/rc.conf`. You can adjust `/etc/fstab` to get the filesystem mounted at boot:

```
/dev/ccd0c  /home ffs     rw    1 2
```

Chapter 16

NetBSD RAIDframe

16.1 RAIDframe Introduction

16.1.1 About RAIDframe

NetBSD uses the CMU RAIDframe (http://www.pdl.cmu.edu/RAIDframe/) software for its RAID subsystem. NetBSD is the primary platform for RAIDframe development. NetBSD also has another in-kernel RAID level 0 system in its ccd(4) subsystem (see Chapter 15). You should possess some basic knowledge (http://www.acnc.com/04_00.html) about RAID concepts and terminology before continuing. You should also be at least familiar with the different levels of RAID - Adaptec provides an excellent reference (http://www.adaptec.com/en-US/_common/compatibility/_education/RAID_level_compar_wp.htm), and the raid(4) manpage contains a short overview too.

16.1.2 A warning about Data Integrity, Backups, and High Availability

RAIDframe is a Software RAID implementation, as opposed to Hardware RAID. As such, it does not need special disk controllers supported by NetBSD. System administrators should give a great deal of consideration to whether software RAID or hardware RAID is more appropriate for their “Mission Critical” applications. For some projects you might consider the use of many of the hardware RAID devices supported by NetBSD (http://www.NetBSD.org/support/hardware/). It is truly at your discretion what type of RAID you use, but it is recommend that you consider factors such as: manageability, commercial vendor support, load-balancing and failover, etc.

Depending on the RAID level used, RAIDframe does provide redundancy in the event of a hardware failure. However, it is *not* a replacement for reliable backups! Software and user-error can still cause data loss. RAIDframe may be used as a mechanism for facilitating backups in systems without backup hardware, but this is not an ideal configuration. Finally, with regard to "high availability", RAID is only a very small component to ensuring data availability.

Once more for good measure: *Back up your data!*

16.1.3 Getting Help

If you encounter problems using RAIDframe, you have several options for obtaining help.

1. Read the RAIDframe man pages: raid(4) and raidctl(8) thoroughly.
2. Search the mailing list archives. Unfortunately, there is no NetBSD list dedicated to RAIDframe support. Depending on the nature of the problem, posts tend to end up in a variety of lists. At a very

minimum, search netbsd-users@NetBSD.org (http://mail-index.NetBSD.org/netbsd-users/), current-users@NetBSD.org (http://mail-index.NetBSD.org/current-users/). Also search the list for the NetBSD platform on which you are using RAIDframe: port-*${ARCH}*@NetBSD.org.

3. Search the Problem Report database (http://www.NetBSD.org/support/send-pr.html).
4. If your problem persists: Post to the mailing list most appropriate (judgment call). Collect as much verbosely detailed information as possible before posting: Include your dmesg(8) output from `/var/run/dmesg.boot`, your kernel config(5) , your `/etc/raid[0-9].conf`, any relevant errors on `/dev/console`, `/var/log/messages`, or to `stdout/stderr` of raidctl(8). The output of **raidctl -s** (if available) will be useful as well. Also include details on the troubleshooting steps you've taken thus far, exactly when the problem started, and any notes on recent changes that may have prompted the problem to develop. Remember to be patient when waiting for a response.

16.2 Setup RAIDframe Support

The use of RAID will require software and hardware configuration changes.

16.2.1 Kernel Support

The GENERIC kernel already has support for RAIDframe. If you have built a custom kernel for your environment the kernel configuration must have the following options:

```
pseudo-device   raid            8       # RAIDframe disk driver
options         RAID_AUTOCONFIG         # auto-configuration of RAID components
```

The RAID support must be detected by the NetBSD kernel, which can be checked by looking at the output of the dmesg(8) command.

```
# dmesg|grep -i raid
Kernelized RAIDframe activated
```

Historically, the kernel must also contain static mappings between bus addresses and device nodes in `/dev`. This used to ensure consistency of devices within RAID sets in the event of a device failure after reboot. Since NetBSD 1.6, however, using the auto-configuration features of RAIDframe has been recommended over statically mapping devices. The auto-configuration features allow drives to move around on the system, and RAIDframe will automatically determine which components belong to which RAID sets.

16.2.2 Power Redundancy and Disk Caching

If your system has an Uninterruptible Power Supply (UPS), and/or if your system has redundant power supplies, you should consider enabling the read and write caches on your drives. On systems with redundant power, this will improve drive performance. On systems without redundant power, the write cache could endanger the integrity of RAID data in the event of a power loss.

The dkctl(8) utility can be used for this on all kinds of disks that support the operation (SCSI, EIDE, SATA, ...):

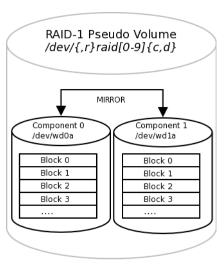
```
# dkctl wd0 getcache
/dev/rwd0d: read cache enabled
/dev/rwd0d: read cache enable is not changeable
/dev/rwd0d: write cache enable is changeable
/dev/rwd0d: cache parameters are not savable
# dkctl wd0 setcache rw
# dkctl wd0 getcache
/dev/rwd0d: read cache enabled
/dev/rwd0d: write-back cache enabled
/dev/rwd0d: read cache enable is not changeable
/dev/rwd0d: write cache enable is changeable
/dev/rwd0d: cache parameters are not savable
```

16.3 Example: RAID-1 Root Disk

This example explains how to setup RAID-1 root disk. With RAID-1 components are mirrored and therefore the server can be fully functional in the event of a single component failure. The goal is to provide a level of redundancy that will allow the system to encounter a component failure on either component disk in the RAID and:

- Continue normal operations until a maintenance window can be scheduled.
- Or, in the unlikely event that the component failure causes a system reboot, be able to quickly reconfigure the system to boot from the remaining component (platform dependent).

Figure 16-1. RAID-1 Disk Logical Layout



Because RAID-1 provides both redundancy and performance improvements, its most practical application is on critical "system" partitions such as `/`, `/usr`, `/var`, `swap`, etc., where read operations are more frequent than write operations. For other file systems, such as `/home` or `/var/{application}`, other RAID levels might be considered (see the references above). If one were simply creating a generic RAID-1 volume for a non-root file system, the cookie-cutter examples from the man page could be followed, but because the root volume must be bootable, certain special steps must be taken during initial setup.

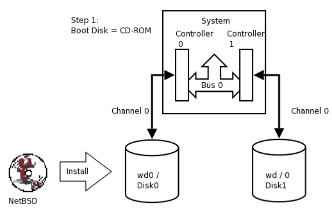
> **Note:** This example will outline a process that differs only slightly between the x86 and sparc64 platforms. In an attempt to reduce excessive duplication of content, where differences do exist and are cosmetic in nature, they will be pointed out using a section such as this. If the process is drastically different, the process will branch into separate, platform dependent steps.

16.3.1 Pseudo-Process Outline

Although a much more refined process could be developed using a custom copy of NetBSD installed on custom-developed removable media, presently the NetBSD install media lacks RAIDframe tools and support, so the following pseudo process has become the de facto standard for setting up RAID-1 Root.

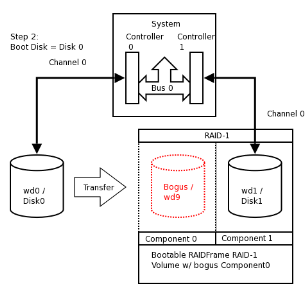
1. Install a stock NetBSD onto Disk0 of your system.

Figure 16-2. Perform generic install onto Disk0/wd0



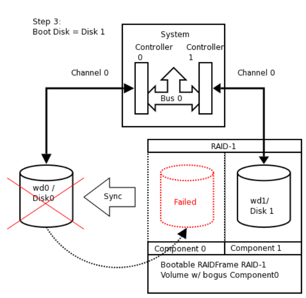
2. Use the installed system on Disk0/wd0 to setup a RAID Set composed of Disk1/wd1 only.

Figure 16-3. Setup RAID Set



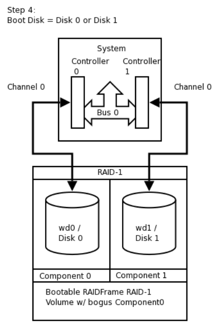
3. Reboot the system off the Disk1/wd1 with the newly created RAID volume.

Figure 16-4. Reboot using Disk1/wd1 of RAID



4. Add / re-sync Disk0/wd0 back into the RAID set.

Figure 16-5. Mirror Disk1/wd1 back to Disk0/wd0



16.3.2 Hardware Review

At present, the alpha, amd64, i386, pmax, sparc, sparc64, and vax NetBSD platforms support booting from RAID-1. Booting is not supported from any other RAID level. Booting from a RAID set is accomplished by teaching the 1st stage boot loader to understand both 4.2BSD/FFS and RAID partitions. The 1st boot block code only needs to know enough about the disk partitions and file systems to be able to read the 2nd stage boot blocks. Therefore, at any time, the system's BIOS / firmware must be able to read a drive with 1st stage boot blocks installed. On the x86 platform, configuring this is entirely dependent on the vendor of the controller card / host bus adapter to which your disks are connected. On sparc64 this is controlled by the IEEE 1275 Sun OpenBoot Firmware.

This article assumes two identical IDE disks (`/dev/wd{0,1}`) which we are going to mirror (RAID-1). These disks are identified as:

```
# grep ^wd /var/run/dmesg.boot
wd0 at atabus0 drive 0: <WDC WD100BB-75CLB0>
wd0: drive supports 16-sector PIO transfers, LBA addressing
wd0: 9541 MB, 19386 cyl, 16 head, 63 sec, 512 bytes/sect x 19541088 sectors
wd0: drive supports PIO mode 4, DMA mode 2, Ultra-DMA mode 5 (Ultra/100)
wd0(piixide0:0:0): using PIO mode 4, Ultra-DMA mode 2 (Ultra/33) (using DMA data transfers)

wd1 at atabus1 drive 0: <WDC WD100BB-75CLB0>
wd1: drive supports 16-sector PIO transfers, LBA addressing
wd1: 9541 MB, 19386 cyl, 16 head, 63 sec, 512 bytes/sect x 19541088 sectors
wd1: drive supports PIO mode 4, DMA mode 2, Ultra-DMA mode 5 (Ultra/100)
wd1(piixide0:1:0): using PIO mode 4, Ultra-DMA mode 2 (Ultra/33) (using DMA data transfers)
```

> **Note:** If you are using SCSI, replace `/dev/{,r}wd{0,1}` with `/dev/{,r}sd{0,1}`

In this example, both disks are jumpered as Master on separate channels on the same controller. You would never want to have both disks on the same bus on the same controller; this creates a single point of failure. Ideally you would have the disks on separate channels on separate controllers. Some SCSI controllers have multiple channels on the same controller, however, a SCSI bus reset on one channel could adversely affect the other channel if the ASIC/IC becomes overloaded. The trade-off with two controllers is that twice the bandwidth is used on the system bus. For purposes of simplification, this example shows two disks on different channels on the same controller.

> **Note:** RAIDframe requires that all components be of the same size. Actually, it will use the lowest common denominator among components of dissimilar sizes. For purposes of illustration, the example uses two disks of identical geometries. Also, consider the availability of replacement disks if a component suffers a critical hardware failure.

> **Tip:** Two disks of identical vendor model numbers could have different geometries if the drive possesses "grown defects". Use a low-level program to examine the grown defects table of the disk. These disks are obviously suboptimal candidates for use in RAID and should be avoided.

16.3.3 Initial Install on Disk0/wd0

Perform a very generic installation onto your Disk0/wd0. Follow the INSTALL instructions for your platform. Install all the sets but do not bother customizing anything other than the kernel as it will be overwritten. See also Chapter 2.

> **Tip:** On x86, during the sysinst install, when prompted if you want to "use the entire disk for NetBSD", answer "yes".

Once the installation is complete, you should examine the disklabel(8) and fdisk(8) / sunlabel(8) outputs on the system:

```
# df
Filesystem   1K-blocks        Used       Avail %Cap Mounted on
/dev/wd0a      9487886      502132     8511360   5% /
```

On x86:

```
# disklabel -r wd0
type: unknown
disk: Disk00
label:
flags:
bytes/sector: 512
sectors/track: 63
tracks/cylinder: 16
sectors/cylinder: 1008
cylinders: 19386
total sectors: 19541088
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0           # microseconds
track-to-track seek: 0  # microseconds
drivedata: 0
```

```
16 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19276992        63     4.2BSD   1024  8192 46568  # (Cyl.      0* - 19124*)
 b:    264033  19277055       swap                     # (Cyl.  19124* - 19385)
 c:  19541025        63     unused      0     0        # (Cyl.      0* - 19385)
 d:  19541088         0     unused      0     0        # (Cyl.      0 - 19385)

# fdisk /dev/rwd0d
Disk: /dev/rwd0d
NetBSD disklabel disk geometry:
cylinders: 19386, heads: 16, sectors/track: 63 (1008 sectors/cylinder)
total sectors: 19541088

BIOS disk geometry:
cylinders: 1023, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 19541088

Partition table:
0: NetBSD (sysid 169)
    start 63, size 19541025 (9542 MB, Cyls 0-1216/96/1), Active
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.
First active partition: 0
```

On Sparc64 the command / output differs slightly:

```
# disklabel -r wd0
type: unknown
disk: Disk0
[...snip...]
8 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19278000         0     4.2BSD   1024  8192 46568  # (Cyl.      0 -  19124)
 b:    263088  19278000       swap                     # (Cyl.  19125 -  19385)
 c:  19541088         0     unused      0     0        # (Cyl.      0 -  19385)

# sunlabel /dev/rwd0c
sunlabel> P
a: start cyl =      0, size = 19278000 (19125/0/0 - 9413.09Mb)
b: start cyl =  19125, size =   263088 (261/0/0 - 128.461Mb)
c: start cyl =      0, size = 19541088 (19386/0/0 - 9541.55Mb)
```

16.3.4 Preparing Disk1/wd1

Once you have a stock install of NetBSD on Disk0/wd0, you are ready to begin. Disk1/wd1 will be visible and unused by the system. To setup Disk1/wd1, you will use disklabel(8) to allocate the entire second disk to the RAID-1 set.

Tip: The best way to ensure that Disk1/wd1 is completely empty is to 'zero' out the first few sectors of the disk with dd(1) . This will erase the MBR (x86) or Sun disk label (sparc64), as well as the NetBSD disk label. If you make a mistake at any point during the RAID setup process, you can always refer to this process to restore the disk to an empty state.

Note: On sparc64, use `/dev/rwd1c` instead of `/dev/rwd1d`!

```
# dd if=/dev/zero of=/dev/rwd1d bs=8k count=1
1+0 records in
1+0 records out
8192 bytes transferred in 0.003 secs (2730666 bytes/sec)
```

Once this is complete, on x86, verify that both the MBR and NetBSD disk labels are gone. On sparc64, verify that the Sun Disk label is gone as well.

On x86:

```
# fdisk /dev/rwd1d

fdisk: primary partition table invalid, no magic in sector 0
Disk: /dev/rwd1d
NetBSD disklabel disk geometry:
cylinders: 19386, heads: 16, sectors/track: 63 (1008 sectors/cylinder)
total sectors: 19541088

BIOS disk geometry:
cylinders: 1023, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 19541088

Partition table:
0: <UNUSED>
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.

# disklabel -r wd1

[...snip...]
16 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 c:  19541025        63     unused      0     0        # (Cyl.      0* - 19385)
 d:  19541088         0     unused      0     0        # (Cyl.      0 - 19385)
```

On sparc64:

```
# sunlabel /dev/rwd1c

sunlabel: bogus label on '/dev/wd1c' (bad magic number)

# disklabel -r wd1
```

```
[...snip...]
3 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 c:  19541088         0     unused      0     0        # (Cyl.      0 -  19385)
disklabel: boot block size 0
disklabel: super block size 0
```

Now that you are certain the second disk is empty, on x86 you must establish the MBR on the second disk using the values obtained from Disk0/wd0 above. We must remember to mark the NetBSD partition active or the system will not boot. You must also create a NetBSD disklabel on Disk1/wd1 that will enable a RAID volume to exist upon it. On sparc64, you will need to simply disklabel(8) the second disk which will write the proper Sun Disk Label.

> **Tip:** disklabel(8) will use your shell' s environment variable `$EDITOR` variable to edit the disklabel. The default is vi(1)

On x86:

```
# fdisk -0ua /dev/rwd1d
fdisk: primary partition table invalid, no magic in sector 0
Disk: /dev/rwd1d
NetBSD disklabel disk geometry:
cylinders: 19386, heads: 16, sectors/track: 63 (1008 sectors/cylinder)
total sectors: 19541088

BIOS disk geometry:
cylinders: 1023, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 19541088

Do you want to change our idea of what BIOS thinks? [n]

Partition 0:
<UNUSED>
The data for partition 0 is:
<UNUSED>
sysid: [0..255 default: 169]
start: [0..1216cyl default: 63, 0cyl, 0MB]
size: [0..1216cyl default: 19541025, 1216cyl, 9542MB]
bootmenu: []
Do you want to change the active partition? [n] y
Choosing 4 will make no partition active.
active partition: [0..4 default: 0] 0
Are you happy with this choice? [n] y

We haven't written the MBR back to disk yet.  This is your last chance.
Partition table:
0: NetBSD (sysid 169)
    start 63, size 19541025 (9542 MB, Cyls 0-1216/96/1), Active
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
```

```
Bootselector disabled.
Should we write new partition table? [n] y

# disklabel -r -e -I wd1
type: unknown
disk: Disk1
label:
flags:
bytes/sector: 512
sectors/track: 63
tracks/cylinder: 16
sectors/cylinder: 1008
cylinders: 19386
total sectors: 19541088
[...snip...]
16 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19541025        63       RAID                     # (Cyl.      0*-19385)
 c:  19541025        63     unused      0     0        # (Cyl.      0*-19385)
 d:  19541088         0     unused      0     0        # (Cyl.      0 -19385)
```

On sparc64:

```
# disklabel -r -e -I wd1
type: unknown
disk: Disk1
label:
flags:
bytes/sector: 512
sectors/track: 63
tracks/cylinder: 16
sectors/cylinder: 1008
cylinders: 19386
total sectors: 19541088
[...snip...]
3 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19541088         0       RAID                     # (Cyl.      0 -  19385)
 c:  19541088         0     unused      0     0        # (Cyl.      0 -  19385)

# sunlabel /dev/rwd1c
sunlabel> P
a: start cyl =      0, size = 19541088 (19386/0/0 - 9541.55Mb)
c: start cyl =      0, size = 19541088 (19386/0/0 - 9541.55Mb)
```

> **Note:** On x86, the **c:** and **d:** slices are reserved. **c:** represents the NetBSD portion of the disk. **d:** represents the entire disk. Because we want to allocate the entire NetBSD MBR partition to RAID, and because **a:** resides within the bounds of **c:**, the **a:** and **c:** slices have same size and offset values. The offset must start at a track boundary (an increment of sectors matching the sectors/track value in the disk label). On sparc64 however, **c:** represents the entire NetBSD partition in the Sun disk label and **d:** is not reserved. Also note that sparc64's **c:** and **a:** require no offset from the

beginning of the disk, however if they should need to be, the offset must start at a cylinder boundary (an increment of sectors matching the sectors/cylinder value).

16.3.5 Initializing the RAID Device

Next we create the configuration file for the RAID set / volume. Traditionally, RAIDframe configuration files belong in `/etc` and would be read and initialized at boot time, however, because we are creating a bootable RAID volume, the configuration data will actually be written into the RAID volume using the "auto-configure" feature. Therefore, files are needed only during the initial setup and should not reside in `/etc`.

```
# vi /var/tmp/raid0.conf
START array
1 2 0

START disks
absent
/dev/wd1a

START layout
128 1 1 1

START queue
fifo 100
```

Note that `absent` means a non-existing disk. This will allow us to establish the RAID volume with a bogus component that we will substitute for Disk0/wd0 at a later time.

Next we configure the RAID device and initialize the serial number to something unique. In this example we use a "YYYYMMDD*Revision*" scheme. The format you choose is entirely at your discretion, however the scheme you choose should ensure that no two RAID sets use the same serial number at the same time.

After that we initialize the RAID set for the first time, safely ignoring the errors regarding the bogus component.

```
# raidctl -v -C /var/tmp/raid0.conf raid0
Ignoring missing component at column 0
raid0: Component absent being configured at col: 0
         Column: 0 Num Columns: 0
         Version: 0 Serial Number: 0 Mod Counter: 0
         Clean: No Status: 0
Number of columns do not match for: absent
absent is not clean!
raid0: Component /dev/wd1a being configured at col: 1
         Column: 0 Num Columns: 0
         Version: 0 Serial Number: 0 Mod Counter: 0
         Clean: No Status: 0
Column out of alignment for: /dev/wd1a
Number of columns do not match for: /dev/wd1a
/dev/wd1a is not clean!
```

```
raid0: There were fatal errors
raid0: Fatal errors being ignored.
raid0: RAID Level 1
raid0: Components: component0[**FAILED**] /dev/wd1a
raid0: Total Sectors: 19540864 (9541 MB)
# raidctl -v -I 2009122601 raid0
# raidctl -v -i raid0
Initiating re-write of parity
raid0: Error re-writing parity!
Parity Re-write status:

# tail -1 /var/log/messages
Dec 26 00:00:30  /netbsd: raid0: Error re-writing parity!
# raidctl -v -s raid0
Components:
          component0: failed
           /dev/wd1a: optimal
No spares.
component0 status is: failed.  Skipping label.
Component label for /dev/wd1a:
   Row: 0, Column: 1, Num Rows: 1, Num Columns: 2
   Version: 2, Serial Number: 2009122601, Mod Counter: 7
   Clean: No, Status: 0
   sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
   Queue size: 100, blocksize: 512, numBlocks: 19540864
   RAID Level: 1
   Autoconfig: No
   Root partition: No
   Last configured as: raid0
Parity status: DIRTY
Reconstruction is 100% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
```

16.3.6 Setting up Filesystems

> **Caution**
>
> The root filesystem must begin at sector 0 of the RAID device. Else, the primary boot loader will be unable to find the secondary boot loader.

The RAID device is now configured and available. The RAID device is a pseudo disk-device. It will be created with a default disk label. You must now determine the proper sizes for disklabel slices for your production environment. For purposes of simplification in this example, our system will have 8.5 gigabytes dedicated to `/` as **/dev/raid0a** and the rest allocated to `swap` as **/dev/raid0b**.

Caution

This is an unrealistic disk layout for a production server; the NetBSD Guide can expand on proper partitioning technique. See Chapter 2

Note: Note that 1 GB is 2*1024*1024=2097152 blocks (1 block is 512 bytes, or 0.5 kilobytes). Despite what the underlying hardware composing a RAID set is, the RAID pseudo disk will always have 512 bytes/sector.

Note: In our example, the space allocated to the underlying `a:` slice composing the RAID set differed between x86 and sparc64, therefore the total sectors of the RAID volumes differs:

On x86:

```
 # disklabel -r -e -I raid0
type: RAID
disk: raid
label: fictitious
flags:
bytes/sector: 512
sectors/track: 128
tracks/cylinder: 8
sectors/cylinder: 1024
cylinders: 19082
total sectors: 19540864
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0 # microseconds
track-to-track seek: 0 # microseconds
drivedata: 0

#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19015680         0     4.2BSD      0     0     0  # (Cyl.      0 - 18569)
 b:    525184  19015680       swap                     # (Cyl.  18570 - 19082*)
 d:  19540864         0     unused      0     0        # (Cyl.      0 - 19082*)
```

On sparc64:

```
# disklabel -r -e -I raid0
[...snip...]
total sectors: 19539968
[...snip...]
3 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
 a:  19251200         0     4.2BSD      0     0     0  # (Cyl.      0 -  18799)
 b:    288768  19251200       swap                     # (Cyl.  18800 -  19081)
 c:  19539968         0     unused      0     0        # (Cyl.      0 -  19081)
```

Next, format the newly created / partition as a 4.2BSD FFSv1 File System:

```
# newfs -O 1 /dev/rraid0a
/dev/rraid0a: 9285.0MB (19015680 sectors) block size 16384, fragment size 2048
        using 51 cylinder groups of 182.06MB, 11652 blks, 23040 inodes.
super-block backups (for fsck -b #) at:
32, 372896, 745760, 1118624, 1491488, 1864352, 2237216, 2610080, 2982944,
...............................................................................

# fsck -fy /dev/rraid0a
** /dev/rraid0a
** File system is already clean
** Last Mounted on
** Phase 1 - Check Blocks and Sizes
** Phase 2 - Check Pathnames
** Phase 3 - Check Connectivity
** Phase 4 - Check Reference Counts
** Phase 5 - Check Cyl groups
1 files, 1 used, 4679654 free (14 frags, 584955 blocks, 0.0% fragmentation)
```

16.3.7 Migrating System to RAID

The new RAID filesystems are now ready for use. We mount them under `/mnt` and copy all files from the old system. This can be done using dump(8) or pax(1).

```
# mount /dev/raid0a /mnt
# df -h /mnt
Filesystem        Size       Used      Avail %Cap Mounted on
/dev/raid0a       8.9G       2.0K       8.5G   0% /mnt
# cd /; pax -v -X -rw -pe . /mnt
[...snip...]
```

The NetBSD install now exists on the RAID filesystem. We need to fix the mount-points in the new copy of `/etc/fstab` or the system will not come up correctly. Replace instances of `wd0` with `raid0`.

The swap should be unconfigured upon shutdown to avoid parity errors on the RAID device. This can be done with a simple, one-line setting in `/etc/rc.conf`.

```
# vi /mnt/etc/rc.conf
swapoff=YES
```

Next the boot loader must be installed on Disk1/wd1. Failure to install the loader on Disk1/wd1 will render the system un-bootable if Disk0/wd0 fails making the RAID-1 pointless.

> **Tip:** Because the BIOS/CMOS menus in many x86 based systems are misleading with regard to device boot order. I highly recommend utilizing the "-o timeout=X" option supported by the x86 1st stage boot loader. Setup unique values for each disk as a point of reference so that you can easily determine from which disk the system is booting.

Caution

Although it may seem logical to install the 1st stage boot block into `/dev/rwd1{c,d}` with installboot(8) , this is no longer the case since NetBSD 1.6.x. If you make this mistake, the boot sector will become irrecoverably damaged and you will need to start the process over again.

On x86, install the boot loader into `/dev/rwd1a` :

```
# /usr/sbin/installboot -o timeout=30 -v /dev/rwd1a /usr/mdec/bootxx_ffsv2
File system:         /dev/rwd1a
Primary bootstrap:   /usr/mdec/bootxx_ffsv2
Ignoring PBR with invalid magic in sector 0 of '/dev/rwd1a'
Boot options:        timeout 30, flags 0, speed 9600, ioaddr 0, console pc
```

Note: As of NetBSD 6.x, the default filesystem type on x86 platforms is FFSv2 instead of FFSv1. Make sure you use the correct 1st stage boot block file `/usr/mdec/bootxx_ffsv{1,2}` when running the installboot(8) command.

To find out which filesystem type is currently in use, the command file(1) or dumpfs(8) can be used:

```
# /usr/bin/file -s /dev/rwd1a
/usr/bin/file -s /dev/rwd1a
/dev/rwd1a: Unix Fast File system [v2] (little-endian), last mounted on ...
```

or

```
# /usr/sbin/dumpfs -s /dev/rwd1a
file system: /dev/rwd1a
format  FFSv2
endian  little-endian
...
```

On sparc64, install the boot loader into `/dev/rwd1a` as well, however the "-o" flag is unsupported (and un-needed thanks to OpenBoot):

```
# /usr/sbin/installboot -v /dev/rwd1a /usr/mdec/bootblk
File system:         /dev/rwd1a
Primary bootstrap:   /usr/mdec/bootblk
Bootstrap start sector: 1
Bootstrap byte count:   5140
Writing bootstrap
```

Finally the RAID set must be made auto-configurable and the system should be rebooted. After the reboot everything is mounted from the RAID devices.

```
# raidctl -v -A root raid0
raid0: Autoconfigure: Yes
raid0: Root: Yes
# tail -2 /var/log/messages
raid0: New autoconfig value is: 1
raid0: New rootpartition value is: 1
```

```
# raidctl -v -s raid0
[...snip...]
   Autoconfig: Yes
   Root partition: Yes
   Last configured as: raid0
[...snip...]
# shutdown -r now
```

Warning

Always use shutdown(8) when shutting down. Never simply use reboot(8). reboot(8) will not properly run shutdown RC scripts and will not safely disable swap. This will cause dirty parity at every reboot.

16.3.8 The first boot with RAID

At this point, temporarily configure your system to boot Disk1/wd1. See notes in Section 16.3.10 for details on this process. The system should boot now and all filesystems should be on the RAID devices. The RAID will be functional with a single component, however the set is not fully functional because the bogus drive (wd9) has failed.

```
# egrep -i "raid|root" /var/run/dmesg.boot
raid0: RAID Level 1
raid0: Components: component0[**FAILED**] /dev/wd1a
raid0: Total Sectors: 19540864 (9541 MB)
boot device: raid0
root on raid0a dumps on raid0b
root file system type: ffs

# df -h
Filesystem    Size     Used     Avail Capacity  Mounted on
/dev/raid0a   8.9G     196M      8.3G     2%    /
kernfs        1.0K     1.0K        0B   100%    /kern

# swapctl -l
Device      1K-blocks     Used    Avail Capacity  Priority
/dev/raid0b    262592        0   262592     0%    0
# raidctl -s raid0
Components:
          component0: failed
           /dev/wd1a: optimal
No spares.
component0 status is: failed.  Skipping label.
Component label for /dev/wd1a:
   Row: 0, Column: 1, Num Rows: 1, Num Columns: 2
   Version: 2, Serial Number: 2009122601, Mod Counter: 65
   Clean: No, Status: 0
   sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
   Queue size: 100, blocksize: 512, numBlocks: 19540864
   RAID Level: 1
```

```
   Autoconfig: Yes
   Root partition: Yes
   Last configured as: raid0
Parity status: DIRTY
Reconstruction is 100% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
```

16.3.9 Adding Disk0/wd0 to RAID

We will now add Disk0/wd0 as a component of the RAID. This will destroy the original file system structure. On x86, the MBR disklabel will be unaffected (remember we copied wd0's label to wd1 anyway) , therefore there is no need to "zero" Disk0/wd0. However, we need to relabel Disk0/wd0 to have an identical NetBSD disklabel layout as Disk1/wd1. Then we add Disk0/wd0 as "hot-spare" to the RAID set and initiate the parity reconstruction for all RAID devices, effectively bringing Disk0/wd0 into the RAID-1 set and "synching up" both disks.

```
# disklabel -r wd1 > /tmp/disklabel.wd1
# disklabel -R -r wd0 /tmp/disklabel.wd1
```

As a last-minute sanity check, you might want to use diff(1) to ensure that the disklabels of Disk0/wd0 match Disk1/wd1. You should also backup these files for reference in the event of an emergency.

```
# disklabel -r wd0 > /tmp/disklabel.wd0
# disklabel -r wd1 > /tmp/disklabel.wd1
# diff /tmp/disklabel.wd0 /tmp/disklabel.wd1
# fdisk /dev/rwd0 > /tmp/fdisk.wd0
# fdisk /dev/rwd1 > /tmp/fdisk.wd1
# diff /tmp/fdisk.wd0 /tmp/fdisk.wd1
# mkdir /root/RFbackup
# cp -p /tmp/{disklabel,fdisk}* /root/RFbackup
```

Once you are certain, add Disk0/wd0 as a spare component, and start reconstruction:

```
# raidctl -v -a /dev/wd0a raid0
/netbsd: Warning: truncating spare disk /dev/wd0a to 241254528 blocks
# raidctl -v -s raid0
Components:
          component0: failed
           /dev/wd1a: optimal
Spares:
           /dev/wd0a: spare
[...snip...]
# raidctl -F component0 raid0
RECON: initiating reconstruction on col 0 -> spare at col 2
 11% |****                                  | ETA:    04:26 \
```

Depending on the speed of your hardware, the reconstruction time will vary. You may wish to watch it on another terminal:

```
# raidctl -S raid0
```

```
Reconstruction is 0% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
Reconstruction status:
  17% |******                                | ETA: 03:08 -
```

After reconstruction, both disks should be “optimal”.

```
# tail -f /var/log/messages
raid0: Reconstruction of disk at col 0 completed
raid0: Recon time was 1290.625033 seconds, accumulated XOR time was 0 us (0.000000)
raid0:  (start time 1093407069 sec 145393 usec, end time 1093408359 sec 770426 usec)
raid0: Total head-sep stall count was 0
raid0: 305318 recon event waits, 1 recon delays
raid0: 1093407069060000 max exec ticks

# raidctl -v -s raid0
Components:
           component0: spared
           /dev/wd1a: optimal
Spares:
     /dev/wd0a: used_spare
     [...snip...]
```

When the reconstruction is finished we need to install the boot loader on the Disk0/wd0. On x86, install the boot loader into `/dev/rwd0a`:

```
# /usr/sbin/installboot -o timeout=15 -v /dev/rwd0a /usr/mdec/bootxx_ffsv2
File system:         /dev/rwd0a
Primary bootstrap:   /usr/mdec/bootxx_ffsv2
Boot options:        timeout 15, flags 0, speed 9600, ioaddr 0, console pc
```

On sparc64:

```
# /usr/sbin/installboot -v /dev/rwd0a /usr/mdec/bootblk
File system:         /dev/rwd0a
Primary bootstrap:   /usr/mdec/bootblk
Bootstrap start sector: 1
Bootstrap byte count:   5140
Writing bootstrap
```

And finally, reboot the machine one last time before proceeding. This is required to migrate Disk0/wd0 from status "used_spare" as "Component0" to state "optimal". Refer to notes in the next section regarding verification of clean parity after each reboot.

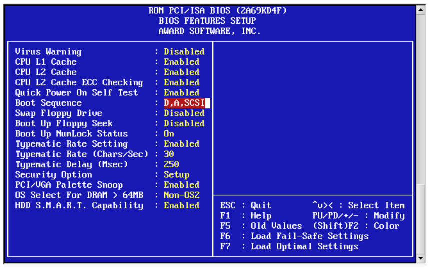
```
# shutdown -r now
```

16.3.10 Testing Boot Blocks

At this point, you need to ensure that your system’s hardware can properly boot using the boot blocks on either disk. On x86, this is a hardware-dependent process that may be done via your motherboard CMOS/BIOS menu or your controller card’s configuration menu.

On x86, use the menu system on your machine to set the boot device order / priority to Disk1/wd1 before Disk0/wd0. The examples here depict a generic Award BIOS.

Figure 16-6. Award BIOS i386 Boot Disk1/wd1

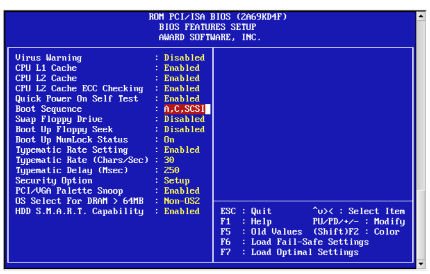


Save changes and exit.

```
>> NetBSD/i386 BIOS Boot, Revision 5.2 (from NetBSD 5.0.2)
>> (builds@b7, Sun Feb 7 00:30:50 UTC 2010)
>> Memory: 639/130048 k
Press return to boot now, any other key for boot menu
booting hd0a:netbsd - starting in 30
```

You can determine that the BIOS is reading Disk1/wd1 because the timeout of the boot loader is 30 seconds instead of 15. After the reboot, re-enter the BIOS and configure the drive boot order back to the default:

Figure 16-7. Award BIOS i386 Boot Disk0/wd0



Save changes and exit.

```
>> NetBSD/x86 BIOS Boot, Revision 5.9 (from NetBSD 6.0)
>> Memory: 640/261120 k

     1. Boot normally
     2. Boot single use
     3. Disable ACPI
     4. Disable ACPI and SMP
     5. Drop to boot prompt

Choose an option; RETURN for default; SPACE to stop countdown.Option 1 will be chosen in 0 s
```

Notice how your custom kernel detects controller/bus/drive assignments independent of what the BIOS assigns as the boot disk. This is the expected behavior.

On sparc64, use the Sun OpenBoot **devalias** to confirm that both disks are bootable:

```
Sun Ultra 5/10 UPA/PCI (UltraSPARC-IIi 400MHz), No Keyboard
OpenBoot 3.15, 128 MB memory installed, Serial #nnnnnnnn.
Ethernet address 8:0:20:a5:d1:3b, Host ID: nnnnnnnn.

ok devalias
[...snip...]
cdrom /pci@1f,0/pci@1,1/ide@3/cdrom@2,0:f
disk /pci@1f,0/pci@1,1/ide@3/disk@0,0
disk3 /pci@1f,0/pci@1,1/ide@3/disk@3,0
disk2 /pci@1f,0/pci@1,1/ide@3/disk@2,0
disk1 /pci@1f,0/pci@1,1/ide@3/disk@1,0
disk0 /pci@1f,0/pci@1,1/ide@3/disk@0,0
[...snip...]

ok boot disk0 netbsd
Initializing Memory [...]
Boot device /pci/pci/ide@3/disk@0,0 File and args: netbsd
NetBSD IEEE 1275 Bootblock
>> NetBSD/sparc64 OpenFirmware Boot, Revision 1.13
>> (builds@b7.netbsd.org, Wed Jul 29 23:43:42 UTC 2009)
loadfile: reading header
elf64_exec: Booting [...]
symbols @ [....]
 Copyright (c) 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005,
     2006, 2007, 2008, 2009
     The NetBSD Foundation, Inc.  All rights reserved.
 Copyright (c) 1982, 1986, 1989, 1991, 1993
     The Regents of the University of California.  All rights reserved.
[...snip...]
```

And the second disk:

```
ok boot disk2 netbsd
Initializing Memory [...]
Boot device /pci/pci/ide@3/disk@2,0: File and args:netbsd
NetBSD IEEE 1275 Bootblock
>> NetBSD/sparc64 OpenFirmware Boot, Revision 1.13
>> (builds@b7.netbsd.org, Wed Jul 29 23:43:42 UTC 2009)
loadfile: reading header
elf64_exec: Booting [...]
symbols @ [....]
 Copyright (c) 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005,
     2006, 2007, 2008, 2009
     The NetBSD Foundation, Inc.  All rights reserved.
 Copyright (c) 1982, 1986, 1989, 1991, 1993
     The Regents of the University of California.  All rights reserved.
[...snip...]
```

At each boot, the following should appear in the NetBSD kernel dmesg(8) :

```
Kernelized RAIDframe activated
raid0: RAID Level 1
raid0: Components: /dev/wd0a /dev/wd1a
raid0: Total Sectors: 19540864 (9541 MB)
boot device: raid0
root on raid0a dumps on raid0b
root file system type: ffs
```

Once you are certain that both disks are bootable, verify the RAID parity is clean after each reboot:

```
# raidctl -v -s raid0
Components:
          /dev/wd0a: optimal
          /dev/wd1a: optimal
No spares.
[...snip...]
Component label for /dev/wd0a:
   Row: 0, Column: 0, Num Rows: 1, Num Columns: 2
   Version: 2, Serial Number: 2009122601, Mod Counter: 67
   Clean: No, Status: 0
   sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
   Queue size: 100, blocksize: 512, numBlocks: 19540864
   RAID Level: 1
   Autoconfig: Yes
   Root partition: Yes
   Last configured as: raid0
Component label for /dev/wd1a:
   Row: 0, Column: 1, Num Rows: 1, Num Columns: 2
   Version: 2, Serial Number: 2009122601, Mod Counter: 67
   Clean: No, Status: 0
   sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
   Queue size: 100, blocksize: 512, numBlocks: 19540864
   RAID Level: 1
   Autoconfig: Yes
   Root partition: Yes
   Last configured as: raid0
Parity status: clean
Reconstruction is 100% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
```

Chapter 17

NetBSD Logical Volume Manager (LVM) configuration

NetBSD LVM allows logical volume management on NetBSD systems, with a well known user interface, which is the same as the Linux LVM2 tools.

NetBSD LVM is built on Linux lvm2tools and libdevmapper, together with a BSD-licensed device-mapper kernel driver specially written for NetBSD.

The LVM driver allows the user to manage available disk space effectively and efficiently. Disk space from several disks, and partitions, known as "Physical Volumes", can be added to "Volume Groups", which is the pool of available disk space for "Logical Partitions" aka Logical Volumes.

Logical Volumes can be grown and shrunk at will using the LVM utilities.

The basic building block is the Physical Volume. This is a disk, or a part of a disk, which is used to store data.

Physical Volumes are aggregated together to make Volume Groups, or VGs. Typically, Volume Groups are used to aggregate storage for the same functional unit. Typical Volume Groups could thus be named "Audio", "Multimedia" or "Documents". By segregating storage requirements in this functional way, the same type of resilience and redundancy is applied to the whole of the functional unit.

The steps required to setup a LVM are as follows:

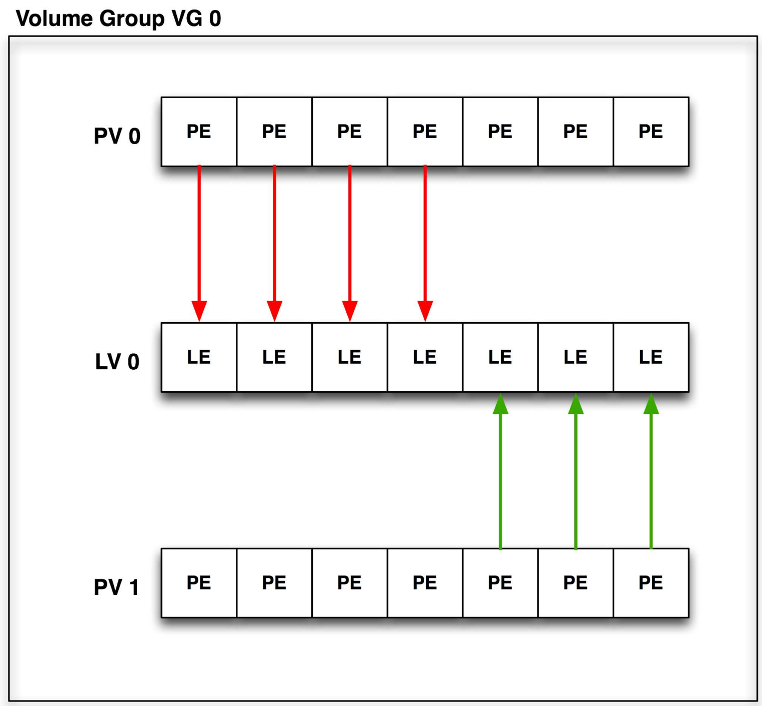
1. Install physical media
2. Configure kernel support
3. Configure system, install tools
4. *Optional step*

   Disklabel each volume member of the LVM
5. Initialize the LVM disk devices
6. Create a volume group from initialized disks
7. Create Logical volume from created Volume group
8. Create a filesystem on the new LV device
9. Mount the LV filesystem

This example features a LVM setup on NetBSD/i386.

17.1 Anatomy of NetBSD Logical Volume Manager

Figure 17-1. Anatomy of Logical Volume Management



1. Volume Group

   The Volume Group is a disk space pool from which the user creates Logical Volumes and to which Physical Volumes can be added. It is the basic administration unit of the NetBSD LVM implementation.

2. Physical Volume

   A physical volume is the basic unit in a LVM structure. Every PV consists of small disk space chunks called Physical Extends. Every Volume Group must have at least one PV. A PV can be created on hard disks or hard disk like devices such as raid, ccd, or cgd device.

3. Logical Volume

   The Logical Volume is a logical partition created from disk space assigned to the Volume Group. LV can be newfsed and mounted as any other pseudo-disk device. Lvm tools use functionality exported by the device-mapper driver in the kernel to create the LV.

4. Physical Extents

   Each physical volume is divided chunks of disk space. The default size is 4MB. Every LV size is rounded by PE size. The LV is created by mapping Logical Extends in the LV to Physical extends in a Volume group.

5. Logical Extents

   Each logical volume is split into chunks of disk space, known as logical extents. The extent size is the same for all logical volumes in the volume group.

6. Physical Extents mapping

   Every LV consists of “LEs” mapped to “PEs” mapped by a target mapping. Currently, the following mappings are defined.

   - **Linear Mapping**

     will linearly assign range of PEs to LEs.

     ```
     For example it can map 100 PEs from PV 1 to LV 1 and
                        another 100 PEs from PV 0.
     ```

   - **Stripe Mapping**

     will interleave the chunks of the logical extents across a number of physical volumes.

7. Snapshots

   A facility provided by LVM is ’snapshots’. Whilst in standard NetBSD, the “fss” driver can be used to provide filesystem snapshots at a filesystem level, the snapshot facility in the LVM allows the administrator to create a logical block device which presents an exact copy of a logical volume, frozen at some point in time. This facility does require that the snapshot be made at a time when the data on the logical volume is in a consistent state.

   Warning

   Snapshot feature is not fully implemented in LVM in NetBSD and should not be used in production.

17.2 Install physical media

This step is at your own discretion, depending on your platform and the hardware at your disposal. LVM can be used with disklabel partitions or even with standard partitions created with fdisk.

From my “dmesg”:

```
Disk #1:
            probe(esp0:0:0): max sync rate 10.00MB/s
            sd0 at scsibus0 target 0 lun 0: <SEAGATE, ST32430N SUN2.1G, 0444> SCSI2 0/direct
            sd0: 2049 MB, 3992 cyl, 9 head, 116 sec, 512 bytes/sect x 4197405 sectors

            Disk #2
            probe(esp0:1:0): max sync rate 10.00MB/s
            sd1 at scsibus0 target 1 lun 0: <SEAGATE, ST32430N SUN2.1G, 0444> SCSI2 0/direct
            sd1: 2049 MB, 3992 cyl, 9 head, 116 sec, 512 bytes/sect x 4197405 sectors

            Disk #3
            probe(esp0:2:0): max sync rate 10.00MB/s
```

```
sd2 at scsibus0 target 2 lun 0: <SEAGATE, ST11200N SUN1.05, 9500> SCSI2 0/direct
sd2: 1005 MB, 1872 cyl, 15 head, 73 sec, 512 bytes/sect x 2059140 sectors

Disk #4
probe(esp0:3:0): max sync rate 10.00MB/s
sd3 at scsibus0 target 3 lun 0: <SEAGATE, ST11200N SUN1.05, 8808 > SCSI2 0
sd3: 1005 MB, 1872 cyl, 15 head, 73 sec, 512 bytes/sect x 2059140 sectors
```

17.3 Configure Kernel Support

The following kernel configuration directive is needed to provide LVM device support. It is provided as a kernel module, so that no extra modifications need be made to a standard NetBSD kernel.

```
pseudo-device dm
```

If you do not want to rebuild your kernel only because of LVM support you can use dm kernel module. The devmapper kernel module can be loaded on your system. To get the current status of modules in the kernel, the **modstat** is used:

```
vm1# modstat
        NAME            CLASS   SOURCE  REFS    SIZE    REQUIRES
        cd9660          vfs     filesys 0       21442   -
        coredump        misc    filesys 1       2814    -
        exec_elf32      misc    filesys 0       6713    coredump
        exec_script     misc    filesys 0       1091    -
        ffs             vfs     boot    0       163040  -
        kernfs          vfs     filesys 0       10201   -
        ptyfs           vfs     filesys 0       7852    -
```

When the **modload dm** is issued, the dm kernel module will be loaded:

```
vm1# modstat
          NAME            CLASS   SOURCE  REFS    SIZE    REQUIRES
          cd9660          vfs     filesys 0       21442   -
          coredump        misc    filesys 1       2814    -
          dm              misc    filesys 0       14448   -
          exec_elf32      misc    filesys 0       6713    coredump
          exec_script     misc    filesys 0       1091    -
          ffs             vfs     boot    0       163040  -
          kernfs          vfs     filesys 0       10201   -
          ptyfs           vfs     filesys 0       7852    -
```

17.4 Disklabel each physical volume member of the LVM

Each physical volume disk in LVM will need a special filesystem established. In this example, I will need to disklabel:

```
/dev/rsd0d
```

```
/dev/rsd1d
/dev/rsd2d
/dev/rsd3d
```

It should be borne in mind that it is possible to use the NetBSD vnd driver to make standard filesystem space appear in the system as a disk device.

> **Note:** Always remember to disklabel the character device, not the block device, in `/dev/r{s,w}d*`

> **Note:** On all platforms except amd64 and i386 where the `d` partition is used for this, the `c` slice is symbolic of the entire NetBSD partition and is reserved.

You will probably want to remove any pre-existing disklabels on the physical volume disks in the LVM. This can be accomplished in one of two ways with the dd(1) command:

```
# dd if=/dev/zero of=/dev/rsd0d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd1d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd2d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd3d bs=8k count=1
```

If your port uses a MBR (Master Boot Record) to partition the disks so that the NetBSD partitions are only part of the overall disk, and other OSs like Windows or Linux use other parts, you can void the MBR and all partitions on disk by using the command:

```
# dd if=/dev/zero of=/dev/rsd0d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd1d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd2d bs=8k count=1
            # dd if=/dev/zero of=/dev/rsd3d bs=8k count=1
```

This will make all data on the entire disk inaccessible. Note that the entire disk is slice `d` on i386 (and some other ports), and `c` elsewhere (e.g. on sparc). See the “kern.rawpartition” sysctl - "3" means "d", "2" means "c".

The default disklabel for the disk will look similar to this:

```
# disklabel -r sd0
            [...snip...]
            bytes/sector: 512
            sectors/track: 63
            tracks/cylinder: 16
            sectors/cylinder: 1008
            cylinders: 207
            total sectors: 208896
            rpm: 3600
            interleave: 1
            trackskew: 0
            cylinderskew: 0
            headswitch: 0           # microseconds
            track-to-track seek: 0  # microseconds
```

```
drivedata: 0

4 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
a:    208896         0     4.2BSD      0     0     0  # (Cyl.      0 -    207*)
d:    208896         0     unused      0     0        # (Cyl.      0 -    207*)
```

You will need to create one “slice” on the NetBSD partition of the disk that consumes the entire partition. The slice must begin at least two sectors after end of disklabel part of disk. On i386 it is sector “63”. Therefore, the “size” value should be “total sectors” minus 2x “sectors”. Edit your disklabel accordingly:

```
# disklabel -e sd0
```

> **Note:** The offset of a slice of type “4.2BSD” must be a multiple of the “sectors” value.

> **Note:** Be sure to **export EDITOR=[path to your favorite editor]** before editing the disklabels.

> **Note:** The slice must be fstype `4.2BSD`.

Because there will only be one slice on this partition, you can recycle the `d` slice (normally reserved for symbolic uses). Change your disklabel to the following:

```
3 partitions:
            #        size   offset    fstype   [fsize bsize   cpg]
            d:  4197403       65      4.2BSD                        # (Cyl. 1 - 4020*)
```

Optionally you can setup a slice other than `d` to use, simply adjust accordingly below:

```
3 partitions:
            #        size   offset    fstype   [fsize bsize   cpg]
            a:  4197403       65      4.2BSD                        # (Cyl. 1 - 4020*)
            c:  4197405       0       unused     1024  8192         # (Cyl. 0 - 4020*)
```

Be sure to write the label when you have completed. Disklabel will object to your disklabel and prompt you to re-edit if it does not pass its sanity checks.

17.5 Create Physical Volumes

Once all disks are properly labeled, you will need to create physical volume on them. Every partition/disk added to LVM must have physical volume header on start of it. All informations, like Volume group where Physical volume belongs are stored in this header.

```
# lvm pvcreate /dev/rwd1[ad]
```

Status of physical volume can be viewed with pvdisplay command.

```
# lvm pvdisplay
```

17.6 Create Volume Group

Once all disks are properly labeled with physical volume header, volume group must be created from them. Volume Group is pool of PEs from which administrator can create Logical Volumes “partitions”.

```
# lvm vgcreate vg0 /dev/rwd1[ad]
```

- vg0 is name of Volume Group
- /dev/rwd1[ad] is Physical Volume

Volume group can be later extended/reduced with vgextend and vgreduce commands. These commands adds physical volumes to VG.

```
# lvm vgextend vg0 /dev/rwd1[ad]

# lvm vgreduce vg0 /dev/rwd1[ad]
```

Status of Volume group can be viewed with vgdisplay command.

```
# lvm vgdisplay vg0
```

17.7 Create Logical Volume

Once Volume Group was created administrator can create “logical partitions” volumes.

```
# lvm lvcreate  -L 20M -n lv1 vg0
```

- vg0 is name of Volume Group
- -L 20M is size of Logical Volume
- -n lv1 is name of Logical Volume

Logical Volume can be later extended/reduced with lvextend and lvreduce commands.

```
# lvm lvextend -L+20M /dev/vg0/lv1

# lvm lvreduce -L-20M /dev/vg0/lv1
```

> **Note:** To shrink the lv partition, you must first shrink the filesystem using resize_ffs(8) (which as of NetBSD 9.0 does not support shrinking of FFSv2 yet).

Status of Logical Volume can be viewed with lvdisplay command.

```
# lvm lvdisplay lv0/lv1
```

After reboot all functional LV's in defined Volume group can be activated with command

```
# lvm vgchange -a y
```

17.8 Example: LVM with Volume groups located on raid1

Motivation for using raid 1 disk as physical volume disk for Volume Group is disk reliability. With PV on raid 1 disk it is possible to use Logical Volumes even after disk failure.

17.8.1 Loading Device-Mapper driver

Before we can start work with the LVM tools. We have to be sure that NetBSD dm driver was properly compiled into the kernel or loaded as a module. Easiest way how to find if we have dm driver available is run modstat. For more information see Configure Kernel Support chapter.

17.8.2 Preparing raid1 installation

Following example raid configuration defined in Raid 1 configuration user will set up clean raid1 disk device. With 2 disks in a mirror mode.

Figure 17-2. Example raid 1 configuration

```
# vi /var/tmp/raid0.conf
START array
1 2 0

START disks
/dev/wd2a
/dev/wd1a

START layout
128 1 1 1

START queue
fifo 100
# raidctl -v -C /var/tmp/raid0.conf raid0
raid0: Component /dev/wd1a being configured at col: 0
Column: 0 Num Columns: 0
Version: 0 Serial Number: 0 Mod Counter: 0
Clean: No Status: 0
```

```
Column out of alignment for: /dev/wd2a
Number of columns do not match for: /dev/wd2a
/dev/wd2a is not clean!
raid0: Component /dev/wd1a being configured at col: 1
Column: 0 Num Columns: 0
Version: 0 Serial Number: 0 Mod Counter: 0
Clean: No Status: 0
Column out of alignment for: /dev/wd1a
Number of columns do not match for: /dev/wd1a
/dev/wd1a is not clean!
raid0: There were fatal errors
raid0: Fatal errors being ignored.
raid0: RAID Level 1
raid0: Components: /dev/wd2a /dev/wd1a
raid0: Total Sectors: 19540864 (9541 MB)
# raidctl -v -I 2004082401 raid0
# raidctl -v -i raid0
Initiating re-write of parity
# tail -1 /var/log/messages
raid0: Error re-writing parity!
# raidctl -v -s raid0
Components:
/dev/wd2a: optimal
/dev/wd1a: optimal
No spares.
Component label for /dev/wd1a:
Row: 0, Column: 1, Num Rows: 1, Num Columns: 2
Version: 2, Serial Number: 2004082401, Mod Counter: 7
Clean: No, Status: 0
sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
Queue size: 100, blocksize: 512, numBlocks: 19540864
RAID Level: 1
Autoconfig: No
Root partition: No
Last configured as: raid0
Parity status: DIRTY
Reconstruction is 100% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
Component label for /dev/wd2a:
Row: 0, Column: 1, Num Rows: 1, Num Columns: 2
Version: 2, Serial Number: 2004082401, Mod Counter: 7
Clean: No, Status: 0
sectPerSU: 128, SUsPerPU: 1, SUsPerRU: 1
Queue size: 100, blocksize: 512, numBlocks: 19540864
RAID Level: 1
Autoconfig: No
Root partition: No
Last configured as: raid0
Parity status: DIRTY
Reconstruction is 100% complete.
Parity Re-write is 100% complete.
Copyback is 100% complete.
```

After setting up raid we need to create disklabel on raid disk.

On i386:

```
 # disklabel -r -e -I raid0
type: RAID
disk: raid
label: fictitious
flags:
bytes/sector: 512
sectors/track: 128
tracks/cylinder: 8
sectors/cylinder: 1024
cylinders: 19082
total sectors: 19540864
rpm: 3600
interleave: 1
trackskew: 0
cylinderskew: 0
headswitch: 0 # microseconds
track-to-track seek: 0 # microseconds
drivedata: 0

#        size    offset     fstype [fsize bsize cpg/sgs]
a:  19540789        65     4.2BSD      0     0     0  # (Cyl.      0 - 18569)
d:  19540864         0     unused      0     0        # (Cyl.      0 - 19082*)
```

On sparc64:

```
# disklabel -r -e -I raid0
[...snip...]
total sectors: 19539968
[...snip...]
2 partitions:
#        size    offset     fstype [fsize bsize cpg/sgs]
a:  19540793        65     4.2BSD      0     0     0  # (Cyl.      0 -  18799)
c:  19539968         0     unused      0     0        # (Cyl.      0 -  19081)
```

Partitions should be created with offset 65, because sectors < than 65 sector are marked as readonly and therefore can’t be rewritten.

17.8.3 Creating PV, VG on raid disk

Physical volumes can be created on any disk like device and on any partition on it we can use a or d on sparc64 c partitions. PV will label selected partition as LVM used and add needed information to it.

PV is created on char disk device entry. As any other disk operation in the NetBSD.

```
# lvm pvcreate /dev/rraid0a
```

For our example purpose I will create vg00 Volume Group. The first parameter of vgcreate command is Volume Group name and second is PV created on raid. If you later found that VG size is no sufficient and you need more space we will can add it with **vgextend** command.

```
# lvm vgcreate vg00 /dev/rraid0a
```

```
# lvm vgextend vg00 /dev/rraid1a
```

> **Warning**
>
> If you add non-raid PV to your Volume Group your data are not safe anymore. Therefore you should add raid based PV to VG if you want to keep your data safe.

17.8.4 Creating LV's from VG located on raid disk

For our example purpose we will create Logical Volume named lv0. If you later found that LV size is not sufficient for you can add it with **lvresize** command.

> **Note:** You must also resize the filesystem, when you resize LV, otherwise you will not see any filesystem change when you mount LV.

> **Warning**
>
> Be aware that to shrink LV you must first shrink the filesystem (and shrinking of FFSv2 filesystems is not supported yet as of NetBSD 9.0).
>
> This means that for FFSv2 filesystems, the -L-* option is not available in NetBSD.

```
# lvm lvcreate -n lv0 -L 2G vg00
```

```
# lvm lvresize -L+2G vg00/lv0
```

All lv device nodes are created in the `/dev/vg00/` directory. File system can be create on LV with this command. After filesystem creation LV can be mounted to system.

```
# newfs -O2 /dev/vg00/rlv0
```

```
# mount /dev/vg00/lv0 /mnt/
```

17.8.5 Integration of LV's in to the system

For Proper LVM integration you have to enable lvm rc.d script, which detect LVs during boot and enables them. You have to add entry for Logical Volume to the `/etc/fstab` file.

```
# cat /etc/rc.conf
[snip]
lvm=yes


# cat /etc/fstab
/dev/wd0a           /       ffs     rw           1 1
/dev/vg00/lv0       /lv0/   ffs     rw           1 1
[snip]
```

Chapter 18

Pluggable Authentication Modules (PAM)

18.1 About

This article describes the underlying principles and mechanisms of the Pluggable Authentication Modules (PAM) library, and explains how to configure PAM, how to integrate PAM into applications, and how to write PAM modules.

See Section D.3.2 for the license of this chapter.

18.2 Introduction

The Pluggable Authentication Modules (PAM) library is a generalized API for authentication-related services which allows a system administrator to add new authentication methods simply by installing new PAM modules, and to modify authentication policies by editing configuration files.

PAM was defined and developed in 1995 by Vipin Samar and Charlie Lai of Sun Microsystems, and has not changed much since. In 1997, the Open Group published the X/Open Single Sign-on (XSSO) preliminary specification, which standardized the PAM API and added extensions for single (or rather integrated) sign-on. At the time of this writing, this specification has not yet been adopted as a standard.

Although this article focuses primarily on FreeBSD 5.x and NetBSD 3.x, which both use OpenPAM, it should be equally applicable to FreeBSD 4.x, which uses Linux-PAM, and other operating systems such as Linux and Solaris™.

18.3 Terms and conventions

18.3.1 Definitions

The terminology surrounding PAM is rather confused. Neither Samar and Lai's original paper nor the XSSO specification made any attempt at formally defining terms for the various actors and entities involved in PAM, and the terms that they do use (but do not define) are sometimes misleading and ambiguous. The first attempt at establishing a consistent and unambiguous terminology was a whitepaper written by Andrew G. Morgan (author of Linux-PAM) in 1999. While Morgan's choice of terminology was a huge leap forward, it is in this author's opinion by no means perfect. What follows is an attempt, heavily inspired by Morgan, to define precise and unambiguous terms for all actors and entities involved in PAM.

account

The set of credentials the applicant is requesting from the arbitrator.

applicant

The user or entity requesting authentication.

arbitrator

The user or entity who has the privileges necessary to verify the applicant's credentials and the authority to grant or deny the request.

chain

A sequence of modules that will be invoked in response to a PAM request. The chain includes information about the order in which to invoke the modules, what arguments to pass to them, and how to interpret the results.

client

The application responsible for initiating an authentication request on behalf of the applicant and for obtaining the necessary authentication information from him.

facility

One of the four basic groups of functionality provided by PAM: authentication, account management, session management and authentication token update.

module

A collection of one or more related functions implementing a particular authentication facility, gathered into a single (normally dynamically loadable) binary file and identified by a single name.

policy

The complete set of configuration statements describing how to handle PAM requests for a particular service. A policy normally consists of four chains, one for each facility, though some services do not use all four facilities.

server

The application acting on behalf of the arbitrator to converse with the client, retrieve authentication information, verify the applicant's credentials and grant or deny requests.

service

A class of servers providing similar or related functionality and requiring similar authentication. PAM policies are defined on a per-service basis, so all servers that claim the same service name will be subject to the same policy.

session

The context within which service is rendered to the applicant by the server. One of PAM's four facilities, session management, is concerned exclusively with setting up and tearing down this context.

token

A chunk of information associated with the account, such as a password or passphrase, which the applicant must provide to prove his identity.

transaction

A sequence of requests from the same applicant to the same instance of the same server, beginning with authentication and session set-up and ending with session tear-down.

18.3.2 Usage examples

This section aims to illustrate the meanings of some of the terms defined above by way of a handful of simple examples.

18.3.2.1 Client and server are one

This simple example shows `alice` su(1)'ing to `root`.

```
$ whoami
alice
$ ls -l `which su`
-r-sr-xr-x  1 root  wheel  10744 Dec  6 19:06 /usr/bin/su
$ su -
Password: xi3kiune
# whoami
root
```

- The applicant is `alice`.
- The account is `root`.
- The su(1) process is both client and server.
- The authentication token is `xi3kiune`.
- The arbitrator is `root`, which is why su(1) is setuid `root`.

18.3.2.2 Client and server are separate

The example below shows `eve` try to initiate an ssh(1) connection to `login.example.com`, ask to log in as `bob`, and succeed. Bob should have chosen a better password!

```
$ whoami
eve
$ ssh bob@login.example.com
bob@login.example.com's password: god
Last login: Thu Oct 11 09:52:57 2001 from 192.168.0.1
NetBSD 3.0 (LOGIN) #1: Thu Mar 10 18:22:36 WET 2005

Welcome to NetBSD!
$
```

- The applicant is `eve`.
- The client is Eve's ssh(1) process.
- The server is the sshd(8) process on `login.example.com`
- The account is `bob`.
- The authentication token is `god`.
- Although this is not shown in this example, the arbitrator is `root`.

18.3.2.3 Sample policy

The following is FreeBSD's default policy for `sshd`:

```
sshd auth  required pam_nologin.so no_warn
sshd auth  required pam_unix.so no_warn try_first_pass
sshd account  required pam_login_access.so
sshd account  required pam_unix.so
sshd session  required pam_lastlog.so no_fail
sshd password required pam_permit.so
```

- This policy applies to the `sshd` service (which is not necessarily restricted to the sshd(8) server.)
- `auth`, `account`, `session` and `password` are facilities.
- `pam_nologin.so`, `pam_unix.so`, `pam_login_access.so`, `pam_lastlog.so` and `pam_permit.so` are modules. It is clear from this example that `pam_unix.so` provides at least two facilities (authentication and account management.)

There are some differences between FreeBSD and NetBSD PAM policies:

- By default, every configuration is done under `/etc/pam.d`.
- If configuration is non-existent, you will not have access to the system, in contrast with FreeBSD that has a default policy of allowing authentication.
- For authentication, NetBSD forces at least one `required`, `requisite` or `binding` module to be present.

18.4 PAM Essentials

18.4.1 Facilities and primitives

The PAM API offers six different authentication primitives grouped in four facilities, which are described below.

`auth`

Authentication. This facility concerns itself with authenticating the applicant and establishing the account credentials. It provides two primitives:

- pam_authenticate(3) authenticates the applicant, usually by requesting an authentication token and comparing it with a value stored in a database or obtained from an authentication server.
- pam_setcred(3) establishes account credentials such as user ID, group membership and resource limits.

`account`

Account management. This facility handles non-authentication-related issues of account availability, such as access restrictions based on the time of day or the server's work load. It provides a single primitive:

- pam_acct_mgmt(3) verifies that the requested account is available.

`session`

Session management. This facility handles tasks associated with session set-up and tear-down, such as login accounting. It provides two primitives:

- pam_open_session(3) performs tasks associated with session set-up: add an entry in the `utmp` and `wtmp` databases, start an SSH agent, etc.
- pam_close_session(3) performs tasks associated with session tear-down: add an entry in the `utmp` and `wtmp` databases, stop the SSH agent, etc.

`password`

Password management. This facility is used to change the authentication token associated with an account, either because it has expired or because the user wishes to change it. It provides a single primitive:

- pam_chauthtok(3) changes the authentication token, optionally verifying that it is sufficiently hard to guess, has not been used previously, etc.

18.4.2 Modules

Modules are a very central concept in PAM; after all, they are the "M" in "PAM". A PAM module is a self-contained piece of program code that implements the primitives in one or more facilities for one particular mechanism; possible mechanisms for the authentication facility, for instance, include the UNIX® password database, NIS, LDAP and Radius.

18.4.2.1 Module Naming

FreeBSD and NetBSD implement each mechanism in a single module, named `pam_mechanism.so` (for instance, `pam_unix.so` for the UNIX® mechanism.) Other implementations sometimes have separate modules for separate facilities, and include the facility name as well as the mechanism name in the module name. To name one example, Solaris™ has a `pam_dial_auth.so.1` module which is commonly used to authenticate dialup users. Also, almost every module has a man page with the same name, i.e.: pam_unix(8) explains how the `pam_unix.so` module works.

18.4.2.2 Module Versioning

FreeBSD's original PAM implementation, based on Linux-PAM, did not use version numbers for PAM modules. This would commonly cause problems with legacy applications, which might be linked against older versions of the system libraries, as there was no way to load a matching version of the required modules.

OpenPAM, on the other hand, looks for modules that have the same version number as the PAM library (currently 2 in FreeBSD and 0 in NetBSD), and only falls back to an unversioned module if no versioned module could be loaded. Thus legacy modules can be provided for legacy applications, while allowing new (or newly built) applications to take advantage of the most recent modules.

Although Solaris™ PAM modules commonly have a version number, they're not truly versioned, because the number is a part of the module name and must be included in the configuration.

18.4.2.3 Module Path

There isn't a common directory for storing PAM modules. Under FreeBSD, they are located at `/usr/lib` and, under NetBSD, you can find them in `/usr/lib/security`.

18.4.3 Chains and policies

When a server initiates a PAM transaction, the PAM library tries to load a policy for the service specified in the pam_start(3) call. The policy specifies how authentication requests should be processed, and is defined in a configuration file. This is the other central concept in PAM: the possibility for the admin to tune the system security policy (in the wider sense of the word) simply by editing a text file.

A policy consists of four chains, one for each of the four PAM facilities. Each chain is a sequence of configuration statements, each specifying a module to invoke, some (optional) parameters to pass to the module, and a control flag that describes how to interpret the return code from the module.

Understanding the control flags is essential to understanding PAM configuration files. There are a number of different control flags:

`binding`

  If the module succeeds and no earlier module in the chain has failed, the chain is immediately terminated and the request is granted. If the module fails, the rest of the chain is executed, but the request is ultimately denied.

This control flag was introduced by Sun in Solaris™ 9 (SunOS™ 5.9), and is also supported by OpenPAM.

`required`

If the module succeeds, the rest of the chain is executed, and the request is granted unless some other module fails. If the module fails, the rest of the chain is also executed, but the request is ultimately denied.

`requisite`

If the module succeeds, the rest of the chain is executed, and the request is granted unless some other module fails. If the module fails, the chain is immediately terminated and the request is denied.

`sufficient`

If the module succeeds and no earlier module in the chain has failed, the chain is immediately terminated and the request is granted. If the module fails, the module is ignored and the rest of the chain is executed.

As the semantics of this flag may be somewhat confusing, especially when it is used for the last module in a chain, it is recommended that the `binding` control flag be used instead if the implementation supports it.

`optional`

The module is executed, but its result is ignored. If all modules in a chain are marked `optional`, all requests will always be granted.

When a server invokes one of the six PAM primitives, PAM retrieves the chain for the facility the primitive belongs to, and invokes each of the modules listed in the chain, in the order they are listed, until it reaches the end, or determines that no further processing is necessary (either because a `binding` or `sufficient` module succeeded, or because a `requisite` module failed.) The request is granted if and only if at least one module was invoked, and all non-optional modules succeeded.

Note that it is possible, though not very common, to have the same module listed several times in the same chain. For instance, a module that looks up user names and passwords in a directory server could be invoked multiple times with different parameters specifying different directory servers to contact. PAM treat different occurrences of the same module in the same chain as different, unrelated modules.

18.4.4 Transactions

The lifecycle of a typical PAM transaction is described below. Note that if any of these steps fails, the server should report a suitable error message to the client and abort the transaction.

1. If necessary, the server obtains arbitrator credentials through a mechanism independent of PAM—most commonly by virtue of having been started by `root`, or of being setuid `root`.
2. The server calls pam_start(3) to initialize the PAM library and specify its service name and the target account, and register a suitable conversation function.
3. The server obtains various information relating to the transaction (such as the applicant's user name and the name of the host the client runs on) and submits it to PAM using pam_set_item(3).

4. The server calls pam_authenticate(3) to authenticate the applicant.
5. The server calls pam_acct_mgmt(3) to verify that the requested account is available and valid. If the password is correct but has expired, pam_acct_mgmt(3) will return `PAM_NEW_AUTHTOK_REQD` instead of `PAM_SUCCESS`.
6. If the previous step returned `PAM_NEW_AUTHTOK_REQD`, the server now calls pam_chauthtok(3) to force the client to change the authentication token for the requested account.
7. Now that the applicant has been properly authenticated, the server calls pam_setcred(3) to establish the credentials of the requested account. It is able to do this because it acts on behalf of the arbitrator, and holds the arbitrator's credentials.
8. Once the correct credentials have been established, the server calls pam_open_session(3) to set up the session.
9. The server now performs whatever service the client requested—for instance, provide the applicant with a shell.
10. Once the server is done serving the client, it calls pam_close_session(3) to tear down the session.
11. Finally, the server calls pam_end(3) to notify the PAM library that it is done and that it can release whatever resources it has allocated in the course of the transaction.

18.5 PAM Configuration

18.5.1 PAM policy files

18.5.1.1 The `/etc/pam.conf` file

The traditional PAM policy file is `/etc/pam.conf`. This file contains all the PAM policies for your system. Each line of the file describes one step in a chain, as shown below:

```
login   auth    required        pam_nologin.so  no_warn
```

The fields are, in order: service name, facility name, control flag, module name, and module arguments. Any additional fields are interpreted as additional module arguments.

A separate chain is constructed for each service / facility pair, so while the order in which lines for the same service and facility appear is significant, the order in which the individual services and facilities are listed is not. The examples in the original PAM paper grouped configuration lines by facility, and the Solaris™ stock `pam.conf` still does that, but FreeBSD's stock configuration groups configuration lines by service. Either way is fine; either way makes equal sense.

18.5.1.2 The `/etc/pam.d` directory

OpenPAM and Linux-PAM support an alternate configuration mechanism, which is the preferred mechanism in FreeBSD and NetBSD. In this scheme, each policy is contained in a separate file bearing the name of the service it applies to. These files are stored in `/etc/pam.d/`.

These per-service policy files have only four fields instead of `pam.conf`'s five: the service name field is omitted. Thus, instead of the sample `pam.conf` line from the previous section, one would have the following line in `/etc/pam.d/login`:

```
auth    required        pam_nologin.so  no_warn
```

As a consequence of this simplified syntax, it is possible to use the same policy for multiple services by linking each service name to a same policy file. For instance, to use the same policy for the `su` and `sudo` services, one could do as follows:

```
# cd /etc/pam.d
# ln -s su sudo
```

This works because the service name is determined from the file name rather than specified in the policy file, so the same file can be used for multiple differently-named services.

Since each service's policy is stored in a separate file, the `pam.d` mechanism also makes it very easy to install additional policies for third-party software packages.

18.5.1.3 The policy search order

As we have seen above, PAM policies can be found in a number of places. If no configuration file is found for a particular service, the `/etc/pam.d/other` is used instead. If that file does not exist, `/etc/pam.conf` is searched for entries matching he specified service or, failing that, the "other" service.

It is essential to understand that PAM's configuration system is centered on chains.

18.5.2 Breakdown of a configuration line

As explained in the *PAM policy files* section, each line in `/etc/pam.conf` consists of four or more fields: the service name, the facility name, the control flag, the module name, and zero or more module arguments.

The service name is generally (though not always) the name of the application the statement applies to. If you are unsure, refer to the individual application's documentation to determine what service name it uses.

Note that if you use `/etc/pam.d/` instead of `/etc/pam.conf`, the service name is specified by the name of the policy file, and omitted from the actual configuration lines, which then start with the facility name.

The facility is one of the four facility keywords described in the *Facilities and primitives* section.

Likewise, the control flag is one of the four keywords described in the *Chains and policies* section, describing how to interpret the return code from the module. Linux-PAM supports an alternate syntax that lets you specify the action to associate with each possible return code, but this should be avoided as it is non-standard and closely tied in with the way Linux-PAM dispatches service calls (which differs greatly from the way Solaris™ and OpenPAM do it.) Unsurprisingly, OpenPAM does not support this syntax.

18.5.3 Policies

To configure PAM correctly, it is essential to understand how policies are interpreted.

When an application calls pam_start(3), the PAM library loads the policy for the specified service and constructs four module chains (one for each facility.) If one or more of these chains are empty, the corresponding chains from the policy for the `other` service are substituted.

When the application later calls one of the six PAM primitives, the PAM library retrieves the chain for the corresponding facility and calls the appropriate service function in each module listed in the chain, in the order in which they were listed in the configuration. After each call to a service function, the module type and the error code returned by the service function are used to determine what happens next. With a few exceptions, which we discuss below, the following table applies:

Table 18-1. PAM chain execution summary

	PAM_SUCCESS	**PAM_IGNORE**	**other**
binding	if (!fail) break;	-	fail = true;
required	-	-	fail = true;
requisite	-	-	fail = true; break;
sufficient	if (!fail) break;	-	-
optional	-	-	-

If `fail` is true at the end of a chain, or when a “break” is reached, the dispatcher returns the error code returned by the first module that failed. Otherwise, it returns `PAM_SUCCESS`.

The first exception of note is that the error code `PAM_NEW_AUTHTOK_REQD` is treated like a success, except that if no module failed, and at least one module returned `PAM_NEW_AUTHTOK_REQD`, the dispatcher will return `PAM_NEW_AUTHTOK_REQD`.

The second exception is that pam_setcred(3) treats `binding` and `sufficient` modules as if they were `required`.

The third and final exception is that pam_chauthtok(3) runs the entire chain twice (once for preliminary checks and once to actually set the password), and in the preliminary phase it treats `binding` and `sufficient` modules as if they were `required`.

18.6 PAM modules

18.6.1 Common Modules

18.6.1.1 pam_deny(8)

The pam_deny(8) module is one of the simplest modules available; it responds to any request with `PAM_AUTH_ERR`. It is useful for quickly disabling a service (add it to the top of every chain), or for terminating chains of `sufficient` modules.

18.6.1.2 pam_echo(8)

The pam_echo(8) module simply passes its arguments to the conversation function as a `PAM_TEXT_INFO` message. It is mostly useful for debugging, but can also serve to display messages such as "Unauthorized access will be prosecuted" before starting the authentication procedure.

18.6.1.3 pam_exec(8)

The pam_exec(8) module takes its first argument to be the name of a program to execute, and the remaining arguments are passed to that program as command-line arguments. One possible application is to use it to run a program at login time which mounts the user's home directory.

18.6.1.4 pam_ftpusers(8)

The pam_ftpusers(8) module successes if and only if the user is listed in `/etc/ftpusers`. Currently, in NetBSD, this module doesn't understand the extended syntax of ftpd(8), but this will be fixed in the future.

18.6.1.5 pam_group(8)

The pam_group(8) module accepts or rejects applicants on the basis of their membership in a particular file group (normally `wheel` for su(1)). It is primarily intended for maintaining the traditional behaviour of BSD su(1), but has many other uses, such as excluding certain groups of users from a particular service.

In NetBSD, there is an argument called `authenticate` in which the user is asked to authenticate using his own password.

18.6.1.6 pam_guest(8)

The pam_guest(8) module allows guest logins using fixed login names. Various requirements can be placed on the password, but the default behaviour is to allow any password as long as the login name is that of a guest account. The pam_guest(8) module can easily be used to implement anonymous FTP logins.

18.6.1.7 pam_krb5(8)

The pam_krb5(8) module provides functions to verify the identity of a user and to set user specific credentials using Kerberos 5. It prompts the user for a password and obtains a new Kerberos TGT for the principal. The TGT is verified by obtaining a service ticket for the local host. The newly acquired credentials are stored in a credential cache and the environment variable KRB5CCNAME is set appropriately. The credentials cache should be destroyed by the user at logout with kdestroy(1).

18.6.1.8 pam_ksu(8)

The pam_ksu(8) module provides only authentication services for Kerberos 5 to determine whether or not the applicant is authorized to obtain the privileges of the target account.

18.6.1.9 pam_lastlog(8)

The pam_lastlog(8) module provides only session management services. It records the session in utmp(5), utmpx(5), wtmp(5), wtmpx(5), lastlog(5) and lastlogx(5) databases.

18.6.1.10 pam_login_access(8)

The pam_login_access(8) module provides an implementation of the account management primitive which enforces the login restrictions specified in the login.access(5) table.

18.6.1.11 pam_nologin(8)

The pam_nologin(8) module refuses non-root logins when `/var/run/nologin` exists. This file is normally created by shutdown(8) when less than five minutes remain until the scheduled shutdown time.

18.6.1.12 pam_permit(8)

The pam_permit(8) module is one of the simplest modules available; it responds to any request with `PAM_SUCCESS`. It is useful as a placeholder for services where one or more chains would otherwise be empty.

18.6.1.13 pam_radius(8)

The pam_radius(8) module provides authentication services based upon the RADIUS (Remote Authentication Dial In User Service) protocol.

18.6.1.14 pam_rhosts(8)

The pam_rhosts(8) module provides only authentication services. It reports success if and only if the target user's ID is not 0 and the remote host and user are listed in `/etc/hosts.equiv` or in the target user's `~/.rhosts`.

18.6.1.15 pam_rootok(8)

The pam_rootok(8) module reports success if and only if the real user id of the process calling it (which is assumed to be run by the applicant) is 0. This is useful for non-networked services such as su(1) or passwd(1), to which the `root` should have automatic access.

18.6.1.16 pam_securetty(8)

The pam_securetty(8) module provides only account services. It is used when the applicant is attempting to authenticate as superuser, and the process is attached to an insecure TTY.

18.6.1.17 pam_self(8)

The pam_self(8) module reports success if and only if the names of the applicant matches that of the target account. It is most useful for non-networked services such as su(1), where the identity of the applicant can be easily verified.

18.6.1.18 pam_ssh(8)

The pam_ssh(8) module provides both authentication and session services. The authentication service allows users who have passphrase-protected SSH secret keys in their `~/.ssh` directory to authenticate themselves by typing their passphrase. The session service starts ssh-agent(1) and preloads it with the keys that were decrypted in the authentication phase. This feature is particularly useful for local logins, whether in X (using xdm(1) or another PAM-aware X login manager) or at the console.

This module implements what is fundamentally a password authentication scheme. Care should be taken to only use this module over a secure session (secure TTY, encrypted session, etc.), otherwise the user's SSH passphrase could be compromised.

Additional consideration should be given to the use of pam_ssh(8). Users often assume that file permissions are sufficient to protect their SSH keys, and thus use weak or no passphrases. Since the system administrator has no effective means of enforcing SSH passphrase quality, this has the potential to expose the system to security risks.

18.6.1.19 pam_unix(8)

The pam_unix(8) module implements traditional UNIX® password authentication, using getpwnam(3) under FreeBSD or getpwnam_r(3) under NetBSD to obtain the target account's password and compare it with the one provided by the applicant. It also provides account management services (enforcing account and password expiration times) and password-changing services. This is probably the single most useful module, as the great majority of admins will want to maintain historical behaviour for at least some services.

18.6.2 NetBSD-specific PAM Modules

18.6.2.1 pam_skey(8)

The pam_skey(8) module implements S/Key One Time Password (OTP) authentication methods, using the `/etc/skeykeys` database.

18.7 PAM Application Programming

This section has not yet been written.

18.8 PAM Module Programming

This section has not yet been written.

18.9 Sample PAM Application

The following is a minimal implementation of su(1) using PAM. Note that it uses the OpenPAM-specific openpam_ttyconv(3) conversation function, which is prototyped in `security/openpam.h`. If you wish build this application on a system with a different PAM library, you will have to provide your own conversation function. A robust conversation function is surprisingly difficult to implement; the one presented in the *Sample PAM Conversation Function* sub-chapter is a good starting point, but should not be used in real-world applications.

```
#include <sys/param.h>
#include <sys/wait.h>

#include <err.h>
#include <pwd.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <syslog.h>
#include <unistd.h>

#include <security/pam_appl.h>
#include <security/openpam.h> /* for openpam_ttyconv() */

extern char **environ;

static pam_handle_t *pamh;
static struct pam_conv pamc;

static void
usage(void)
{

 fprintf(stderr, "Usage: su [login [args]]\n");
 exit(1);
}

int
main(int argc, char *argv[])
{
 char hostname[MAXHOSTNAMELEN];
 const char *user, *tty;
 char **args, **pam_envlist, **pam_env;
 struct passwd *pwd;
 int o, pam_err, status;
 pid_t pid;

 while ((o = getopt(argc, argv, "h")) != -1)
```

```
 switch (o) {
 case 'h':
 default:
  usage();
 }

argc -= optind;
argv += optind;

if (argc > 0) {
 user = *argv;
 --argc;
 ++argv;
} else {
 user = "root";
}

/* initialize PAM */
pamc.conv = &openpam_ttyconv;
pam_start("su", user, &pamc, &pamh);

/* set some items */
gethostname(hostname, sizeof(hostname));
if ((pam_err = pam_set_item(pamh, PAM_RHOST, hostname)) != PAM_SUCCESS)
 goto pamerr;
user = getlogin();
if ((pam_err = pam_set_item(pamh, PAM_RUSER, user)) != PAM_SUCCESS)
 goto pamerr;
tty = ttyname(STDERR_FILENO);
if ((pam_err = pam_set_item(pamh, PAM_TTY, tty)) != PAM_SUCCESS)
 goto pamerr;

/* authenticate the applicant */
if ((pam_err = pam_authenticate(pamh, 0)) != PAM_SUCCESS)
 goto pamerr;
if ((pam_err = pam_acct_mgmt(pamh, 0)) == PAM_NEW_AUTHTOK_REQD)
 pam_err = pam_chauthtok(pamh, PAM_CHANGE_EXPIRED_AUTHTOK);
if (pam_err != PAM_SUCCESS)
 goto pamerr;

/* establish the requested credentials */
if ((pam_err = pam_setcred(pamh, PAM_ESTABLISH_CRED)) != PAM_SUCCESS)
 goto pamerr;

/* authentication succeeded; open a session */
if ((pam_err = pam_open_session(pamh, 0)) != PAM_SUCCESS)
 goto pamerr;

/* get mapped user name; PAM may have changed it */
pam_err = pam_get_item(pamh, PAM_USER, (const void **)&user);
if (pam_err != PAM_SUCCESS || (pwd = getpwnam(user)) == NULL)
 goto pamerr;
```

```
 /* export PAM environment */
 if ((pam_envlist = pam_getenvlist(pamh)) != NULL) {
  for (pam_env = pam_envlist; *pam_env != NULL; ++pam_env) {
   putenv(*pam_env);
   free(*pam_env);
  }
  free(pam_envlist);
 }

 /* build argument list */
 if ((args = calloc(argc + 2, sizeof *args)) == NULL) {
  warn("calloc()");
  goto err;
 }
 *args = pwd->pw_shell;
 memcpy(args + 1, argv, argc * sizeof *args);

 /* fork and exec */
 switch ((pid = fork())) {
 case -1:
  warn("fork()");
  goto err;
 case 0:
  /* child: give up privs and start a shell */

  /* set uid and groups */
  if (initgroups(pwd->pw_name, pwd->pw_gid) == -1) {
   warn("initgroups()");
   _exit(1);
  }
  if (setgid(pwd->pw_gid) == -1) {
   warn("setgid()");
   _exit(1);
  }
  if (setuid(pwd->pw_uid) == -1) {
   warn("setuid()");
   _exit(1);
  }
  execve(*args, args, environ);
  warn("execve()");
  _exit(1);
 default:
  /* parent: wait for child to exit */
  waitpid(pid, &status, 0);

  /* close the session and release PAM resources */
  pam_err = pam_close_session(pamh, 0);
  pam_end(pamh, pam_err);

  exit(WEXITSTATUS(status));
 }

pamerr:
```

```
 fprintf(stderr, "Sorry\n");
err:
 pam_end(pamh, pam_err);
 exit(1);
}
```

18.10 Sample PAM Module

The following is a minimal implementation of pam_unix(8), offering only authentication services. It should build and run with most PAM implementations, but takes advantage of OpenPAM extensions if available: note the use of pam_get_authtok(3), which enormously simplifies prompting the user for a password.

```
#include <sys/param.h>

#include <pwd.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <unistd.h>

#include <security/pam_modules.h>
#include <security/pam_appl.h>

#ifndef _OPENPAM
static char password_prompt[] = "Password:";
#endif

#ifndef PAM_EXTERN
#define PAM_EXTERN
#endif

PAM_EXTERN int
pam_sm_authenticate(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
{
#ifndef _OPENPAM
 const void *ptr;
 const struct pam_conv *conv;
 struct pam_message msg;
 const struct pam_message *msgp;
 struct pam_response *resp;
#endif
 struct passwd *pwd;
 const char *user;
 char *crypt_password, *password;
 int pam_err, retry;

 /* identify user */
 if ((pam_err = pam_get_user(pamh, &user, NULL)) != PAM_SUCCESS)
  return (pam_err);
```

```
 if ((pwd = getpwnam(user)) == NULL)
  return (PAM_USER_UNKNOWN);

 /* get password */
#ifndef _OPENPAM
 pam_err = pam_get_item(pamh, PAM_CONV, &ptr);
 if (pam_err != PAM_SUCCESS)
  return (PAM_SYSTEM_ERR);
 conv = ptr;
 msg.msg_style = PAM_PROMPT_ECHO_OFF;
 msg.msg = password_prompt;
 msgp = &msg;
#endif
 password = NULL;
 for (retry = 0; retry < 3; ++retry) {
#ifdef _OPENPAM
  pam_err = pam_get_authtok(pamh, PAM_AUTHTOK,
      (const char **)&password, NULL);
#else
  resp = NULL;
  pam_err = (*conv->conv)(1, &msgp, &resp, conv->appdata_ptr);
  if (resp != NULL) {
   if (pam_err == PAM_SUCCESS)
    password = resp->resp;
   else
    free(resp->resp);
   free(resp);
  }
#endif
  if (pam_err == PAM_SUCCESS)
   break;
 }
 if (pam_err == PAM_CONV_ERR)
  return (pam_err);
 if (pam_err != PAM_SUCCESS)
  return (PAM_AUTH_ERR);

 /* compare passwords */
 if ((!pwd->pw_passwd[0] && (flags & PAM_DISALLOW_NULL_AUTHTOK)) ||
     (crypt_password = crypt(password, pwd->pw_passwd)) == NULL ||
     strcmp(crypt_password, pwd->pw_passwd) != 0)
  pam_err = PAM_AUTH_ERR;
 else
  pam_err = PAM_SUCCESS;
#ifndef _OPENPAM
 free(password);
#endif
 return (pam_err);
}

PAM_EXTERN int
pam_sm_setcred(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
```

```
{

 return (PAM_SUCCESS);
}

PAM_EXTERN int
pam_sm_acct_mgmt(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
{

 return (PAM_SUCCESS);
}

PAM_EXTERN int
pam_sm_open_session(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
{

 return (PAM_SUCCESS);
}

PAM_EXTERN int
pam_sm_close_session(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
{

 return (PAM_SUCCESS);
}

PAM_EXTERN int
pam_sm_chauthtok(pam_handle_t *pamh, int flags,
 int argc, const char *argv[])
{

 return (PAM_SERVICE_ERR);
}

#ifdef PAM_MODULE_ENTRY
PAM_MODULE_ENTRY("pam_unix");
#endif
```

18.11 Sample PAM Conversation Function

The conversation function presented below is a greatly simplified version of OpenPAM's openpam_ttyconv(3). It is fully functional, and should give the reader a good idea of how a conversation function should behave, but it is far too simple for real-world use. Even if you're not using OpenPAM, feel free to download the source code and adapt openpam_ttyconv(3) to your uses; we believe it to be as robust as a tty-oriented conversation function can reasonably get.

```
#include <stdio.h>
#include <stdlib.h>
```

```
#include <string.h>
#include <unistd.h>

#include <security/pam_appl.h>

int
converse(int n, const struct pam_message **msg,
 struct pam_response **resp, void *data)
{
 struct pam_response *aresp;
 char buf[PAM_MAX_RESP_SIZE];
 int i;

 data = data;
 if (n <= 0 || n > PAM_MAX_NUM_MSG)
  return (PAM_CONV_ERR);
 if ((aresp = calloc(n, sizeof *aresp)) == NULL)
  return (PAM_BUF_ERR);
 for (i = 0; i < n; ++i) {
  aresp[i].resp_retcode = 0;
  aresp[i].resp = NULL;
  switch (msg[i]->msg_style) {
  case PAM_PROMPT_ECHO_OFF:
   aresp[i].resp = strdup(getpass(msg[i]->msg));
   if (aresp[i].resp == NULL)
    goto fail;
   break;
  case PAM_PROMPT_ECHO_ON:
   fputs(msg[i]->msg, stderr);
   if (fgets(buf, sizeof buf, stdin) == NULL)
    goto fail;
   aresp[i].resp = strdup(buf);
   if (aresp[i].resp == NULL)
    goto fail;
   break;
  case PAM_ERROR_MSG:
   fputs(msg[i]->msg, stderr);
   if (strlen(msg[i]->msg) > 0 &&
       msg[i]->msg[strlen(msg[i]->msg) - 1] != '\n')
    fputc('\n', stderr);
   break;
  case PAM_TEXT_INFO:
   fputs(msg[i]->msg, stdout);
   if (strlen(msg[i]->msg) > 0 &&
       msg[i]->msg[strlen(msg[i]->msg) - 1] != '\n')
    fputc('\n', stdout);
   break;
  default:
   goto fail;
  }
 }
 *resp = aresp;
 return (PAM_SUCCESS);
```

```
 fail:
        for (i = 0; i < n; ++i) {
                if (aresp[i].resp != NULL) {
                        memset(aresp[i].resp, 0, strlen(aresp[i].resp));
                        free(aresp[i].resp);
                }
        }
        memset(aresp, 0, n * sizeof *aresp);
 *resp = NULL;
 return (PAM_CONV_ERR);
}
```

18.12 Further Reading

Bibliography

Papers

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Chapter 19
Tuning NetBSD

19.1 Introduction

19.1.1 Overview

This section covers a variety of performance tuning topics. It attempts to span tuning from the perspective of the system administrator to systems programmer. The art of performance tuning itself is very old. To tune something means to make it operate more efficiently, whether one is referring to a NetBSD based technical server or a vacuum cleaner, the goal is to improve something, whether that be the way something is done, how it works or how it is put together.

19.1.1.1 What is Performance Tuning?

A view from 10,000 feet pretty much dictates that everything we do is task oriented, this pertains to a NetBSD system as well. When the system boots, it automatically begins to perform a variety of tasks. When a user logs in, they usually have a wide variety of tasks they have to accomplish. In the scope of these documents, however, performance tuning strictly means to improve how efficient a NetBSD system performs.

The most common thought that crops into someone's mind when they think "tuning" is some sort of speed increase or decreasing the size of the kernel - while those are ways to improve performance, they are not the only ends an administrator may have to take for increasing efficiency. For our purposes, performance tuning means this: *To make a NetBSD system operate in an optimum state.*

Which could mean a variety of things, not necessarily speed enhancements. A good example of this is filesystem formatting parameters, on a system that has a lot of small files (say like a source repository) an administrator may need to increase the number of inodes by making their size smaller (say down to 1024k) and then increasing the amount of inodes. In this case the number of inodes was increased, however, it keeps the administrator from getting those nasty out of inodes messages, which ultimately makes the system more efficient.

Tuning normally revolves around finding and eliminating bottlenecks. Most of the time, such bottlenecks are spurious, for example, a release of Mozilla that does not quite handle java applets too well can cause Mozilla to start crunching the CPU, especially applets that are not done well. Occasions when processes seem to spin off into nowhere and eat CPU are almost always resolved with a kill. There are instances, however, when resolving bottlenecks takes a lot longer, for example, say an rsynced server is just getting larger and larger. Slowly, performance begins to fade and the administrator may have to take some sort of action to speed things up, however, the situation is relative to say an emergency like an instantly spiked CPU.

19.1.1.2 When does one tune?

Many NetBSD users rarely have to tune a system. The GENERIC kernel may run just fine and the layout/configuration of the system may do the job as well. By the same token, as a pragma it is always good to know how to tune a system. Most often tuning comes as a result of a sudden bottleneck issue (which may occur randomly) or a gradual loss of performance. It does happen in a sense to everyone at some point, one process that is eating the CPU is a bottleneck as much as a gradual increase in paging. So, the question should not be when to tune so much as when to learn to tune.

One last time to tune is if you can tune in a preventive manner (and you think you might need to) then do it. One example of this was on a system that needed to be able to reboot quickly. Instead of waiting, I did everything I could to trim the kernel and make sure there was absolutely nothing running that was not needed, I even removed drivers that did have devices, but were never used (lp). The result was reducing reboot time by nearly two-thirds. In the long run, it was a smart move to tune it before it became an issue.

19.1.1.3 What these Documents Will Not Cover

Before I wrap up the introduction, I think it is important to note what these documents will not cover. This guide will pertain only to the core NetBSD system. In other words, it will not cover tuning a web server's configuration to make it run better; however, it might mention how to tune NetBSD to run better as a web server. The logic behind this is simple: web servers, database software, etc. are third party and almost limitless. I could easily get mired down in details that do not apply to the NetBSD system. Almost all third party software have their own documentation about tuning anyhow.

19.1.1.4 How Examples are Laid Out

Since there is ample man page documentation, only used options and arguments with examples are discussed. In some cases, material is truncated for brevity and not thoroughly discussed because, quite simply, there is too much. For example, every single device driver entry in the kernel will not be discussed, however, an example of determining whether or not a given system needs one will be. Nothing in this Guide is concrete, tuning and performance are very subjective, instead, it is a guide for the reader to learn what some of the tools available to them can do.

19.2 Tuning Considerations

Tuning a system is not really too difficult when pro-active tuning is the approach. This document approaches tuning from a "before it comes up" approach. While tuning in spare time is considerably easier versus say, a server that is almost completely bogged down to 0.1% idle time, there are still a few things that should be mulled over about tuning before actually doing it, hopefully, before a system is even installed.

19.2.1 General System Configuration

Of course, how the system is setup makes a big difference. Sometimes small items can be overlooked which may in fact cause some sort of long term performance problem.

19.2.1.1 Filesystems and Disks

How the filesystem is laid out relative to disk drives is very important. On hardware RAID systems, it is not such a big deal, but, many NetBSD users specifically use NetBSD on older hardware where hardware RAID simply is not an option. The idea of `/` being close to the first drive is a good one, but for example if there are several drives to choose from that will be the first one, is the best performing the one that `/` will be on? On a related note, is it wise to split off `/usr`? Will the system see heavy usage say in `/usr/pkgsrc`? It might make sense to slap a fast drive in and mount it under `/usr/pkgsrc`, or it might not. Like all things in performance tuning, this is subjective.

19.2.1.2 Swap Configuration

There are three schools of thought on swap size and about fifty on using split swap files with prioritizing and how that should be done. In the swap size arena, the vendor schools (at least most commercial ones) usually have their own formulas per OS. As an example, on a particular version of HP-UX with a particular version of Oracle the formula was:

2.5 GB * Number_of_processor

Well, that all really depends on what type of usage the database is having and how large it is, for instance if it is so large that it must be distributed, that formula does not fit well.

The next school of thought about swap sizing is sort of strange but makes some sense, it says, if possible, get a reference amount of memory used by the system. It goes something like this:

1. Startup a machine and estimate total memory needs by running everything that may ever be needed at once. Databases, web servers .... whatever. Total up the amount.
2. Add a few MB for padding.
3. Subtract the amount of physical RAM from this total.

If the amount leftover is 3 times the size of physical RAM, consider getting more RAM. The problem, of course, is figuring out what is needed and how much space it will take. There is also another flaw in this method, some programs do not behave well. A glaring example of misbehaved software is web browsers. On certain versions of Netscape, when something went wrong it had a tendency to runaway and eat swap space. So, the more spare space available, the more time to kill it.

Last and not least is the tried and true PHYSICAL_RAM * 2 method. On modern machines and even older ones (with limited purpose of course) this seems to work best.

All in all, it is hard to tell when swapping will start. Even on small 16MB RAM machines (and less) NetBSD has always worked well for most people until misbehaving software is running.

19.2.2 System Services

On servers, system services have a large impact. Getting them to run at their best almost always requires some sort of network level change or a fundamental speed increase in the underlying system (which of course is what this is all about). There are instances when some simple solutions can improve services. One example, an ftp server is becoming slower and a new release of the ftp server that is shipped with the system comes out that, just happens to run faster. By upgrading the ftp software, a performance boost is accomplished.

Another good example where services are concerned is the age old question: “To use inetd or not to use inetd?” A great service example is pop3. Pop3 connections can conceivably clog up inetd. While the pop3 service itself starts to degrade slowly, other services that are multiplexed through inetd will also degrade (in some case more than pop3). Setting up pop3 to run outside of inetd and on its own may help.

19.2.3 The NetBSD Kernel

The NetBSD kernel obviously plays a key role in how well a system performs, while rebuilding and tuning the kernel is covered later in the text, it is worth discussing in the local context from a high level.

Tuning the NetBSD kernel really involves three main areas:

1. removing unrequired drivers
2. configuring options
3. system settings

19.2.3.1 Removing Unrequired Drivers

Taking drivers out of the kernel that are not needed achieves several results; first, the system boots faster since the kernel is smaller, second again since the kernel is smaller, more memory is free to users and processes and third, the kernel tends to respond quicker.

19.2.3.2 Configuring Options

Configuring options such as enabling/disabling certain subsystems, specific hardware and filesystems can also improve performance pretty much the same way removing unrequired drivers does. A very simple example of this is a FTP server that only hosts ftp files - nothing else. On this particular server there is no need to have anything but native filesystem support and perhaps a few options to help speed things along. Why would it ever need NTFS support for example? Besides, if it did, support for NTFS could be added at some later time. In an opposite case, a workstation may need to support a lot of different filesystem types to share and access files.

19.2.3.3 System Settings

System wide settings are controlled by the kernel, a few examples are filesystem settings, network settings and core kernel settings such as the maximum number of processes. Almost all system settings can be at least looked at or modified via the sysctl facility. Examples using the sysctl facility are given later on.

19.3 Visual Monitoring Tools

NetBSD ships a variety of performance monitoring tools with the system. Most of these tools are common on all UNIX systems. In this section some example usage of the tools is given with interpretation of the output.

19.3.1 The top Process Monitor

The top monitor does exactly what it says: it displays the CPU hogs on the system. To run the monitor, simply type top at the prompt. Without any arguments, it should look like:

```
load averages:  0.09,  0.12,  0.08                                     20:23:41
21 processes:  20 sleeping, 1 on processor
CPU states:  0.0% user,  0.0% nice,  0.0% system,  0.0% interrupt,  100% idle
Memory: 15M Act, 1104K Inact, 208K Wired, 22M Free, 129M Swap free

  PID USERNAME PRI NICE   SIZE   RES STATE     TIME   WCPU    CPU COMMAND
13663 root       2    0  1552K 1836K sleep     0:08  0.00%  0.00% httpd
  127 root      10    0   129M 4464K sleep     0:01  0.00%  0.00% mount_mfs
22591 root       2    0   388K 1156K sleep     0:01  0.00%  0.00% sshd
  108 root       2    0   132K  472K sleep     0:01  0.00%  0.00% syslogd
22597 jrf       28    0   156K  616K onproc    0:00  0.00%  0.00% top
22592 jrf       18    0   828K 1128K sleep     0:00  0.00%  0.00% tcsh
  203 root      10    0   220K  424K sleep     0:00  0.00%  0.00% cron
    1 root      10    0   312K  192K sleep     0:00  0.00%  0.00% init
  205 root       3    0    48K  432K sleep     0:00  0.00%  0.00% getty
  206 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
  208 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
  207 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
13667 nobody     2    0  1660K 1508K sleep     0:00  0.00%  0.00% httpd
 9926 root       2    0   336K  588K sleep     0:00  0.00%  0.00% sshd
  200 root       2    0    76K  456K sleep     0:00  0.00%  0.00% inetd
  182 root       2    0    92K  436K sleep     0:00  0.00%  0.00% portsentry
  180 root       2    0    92K  436K sleep     0:00  0.00%  0.00% portsentry
13666 nobody    -4    0  1600K 1260K sleep     0:00  0.00%  0.00% httpd
```

The top utility is great for finding CPU hogs, runaway processes or groups of processes that may be causing problems. The output shown above indicates that this particular system is in good health. Now, the next display should show some very different results:

```
load averages:  0.34,  0.16,  0.13                                     21:13:47
25 processes:  24 sleeping, 1 on processor
CPU states:  0.5% user,  0.0% nice,  9.0% system,  1.0% interrupt, 89.6% idle
Memory: 20M Act, 1712K Inact, 240K Wired, 30M Free, 129M Swap free

  PID USERNAME PRI NICE   SIZE   RES STATE     TIME   WCPU    CPU COMMAND
 5304 jrf       -5    0    56K  336K sleep     0:04 66.07% 19.53% bonnie
 5294 root       2    0   412K 1176K sleep     0:02  1.01%  0.93% sshd
  108 root       2    0   132K  472K sleep     1:23  0.00%  0.00% syslogd
  187 root       2    0  1552K 1824K sleep     0:07  0.00%  0.00% httpd
 5288 root       2    0   412K 1176K sleep     0:02  0.00%  0.00% sshd
 5302 jrf       28    0   160K  620K onproc    0:00  0.00%  0.00% top
```

```
 5295 jrf       18    0   828K 1116K sleep     0:00  0.00%  0.00% tcsh
 5289 jrf       18    0   828K 1112K sleep     0:00  0.00%  0.00% tcsh
  127 root      10    0   129M 8388K sleep     0:00  0.00%  0.00% mount_mfs
  204 root      10    0   220K  424K sleep     0:00  0.00%  0.00% cron
    1 root      10    0   312K  192K sleep     0:00  0.00%  0.00% init
  208 root       3    0    48K  432K sleep     0:00  0.00%  0.00% getty
  210 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
  209 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
  211 root       3    0    48K  424K sleep     0:00  0.00%  0.00% getty
  217 nobody     2    0  1616K 1272K sleep     0:00  0.00%  0.00% httpd
  184 root       2    0   336K  580K sleep     0:00  0.00%  0.00% sshd
  201 root       2    0    76K  456K sleep     0:00  0.00%  0.00% inetd
```

At first, it should seem rather obvious which process is hogging the system, however, what is interesting in this case is why. The bonnie program is a disk benchmark tool which can write large files in a variety of sizes and ways. What the previous output indicates is only that the bonnie program is a CPU hog, but not why.

19.3.1.1 Other Neat Things About Top

A careful examination of the manual page top(1) shows that there is a lot more that can be done with top, for example, processes can have their priority changed and killed. Additionally, filters can be set for looking at processes.

19.3.2 The sysstat utility

As the man page sysstat(1) indicates, the sysstat utility shows a variety of system statistics using the curses library. While it is running the screen is shown in two parts, the upper window shows the current load average while the lower screen depends on user commands. The exception to the split window view is when vmstat display is on which takes up the whole screen. Following is what sysstat looks like on a fairly idle system with no arguments given when it was invoked:

```
                  /0   /1   /2   /3   /4   /5   /6   /7   /8   /9   /10
     Load Average   |

                        /0   /10  /20  /30  /40  /50  /60  /70  /80  /90  /100
                 <idle> XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Basically a lot of dead time there, so now have a look with some arguments provided, in this case, **sysstat inet.tcp** which looks like this:

```
                   /0   /1   /2   /3   /4   /5   /6   /7   /8   /9   /10
     Load Average   |

        0 connections initiated          19 total TCP packets sent
        0 connections accepted           11   data
        0 connections established         0   data (retransmit)
                                          8   ack-only
        0 connections dropped             0   window probes
        0   in embryonic state            0   window updates
```

```
        0   on retransmit timeout          0   urgent data only
        0   by keepalive                   0   control
        0   by persist
                                          29 total TCP packets received
       11 potential rtt updates           17   in sequence
       11 successful rtt updates           0   completely duplicate
        9 delayed acks sent                0   with some duplicate data
        0 retransmit timeouts              4   out of order
        0 persist timeouts                 0   duplicate acks
        0 keepalive probes                11   acks
        0 keepalive timeouts               0   window probes
                                           0   window updates
```

Now that is informative. The first poll is accumulative, so it is possible to see quite a lot of information in the output when sysstat is invoked. Now, while that may be interesting, how about a look at the buffer cache with **sysstat bufcache**:

```
                    /0   /1   /2   /3   /4   /5   /6   /7   /8   /9   /10
     Load Average

There are 1642 buffers using 6568 kBytes of memory.

File System          Bufs used   %   kB in use   %  Bufsize kB   %  Util %
/                          877  53        6171  93        6516  99      94
/var/tmp                     5   0          17   0          28   0      60

Total:                     882  53        6188  94        6544  99
```

Again, a pretty boring system, but great information to have available. While this is all nice to look at, it is time to put a false load on the system to see how sysstat can be used as a performance monitoring tool. As with top, bonnie++ will be used to put a high load on the I/O subsystems and a little on the CPU. The bufcache will be looked at again to see of there are any noticeable differences:

```
                    /0   /1   /2   /3   /4   /5   /6   /7   /8   /9   /10
     Load Average   |||

There are 1642 buffers using 6568 kBytes of memory.

File System          Bufs used   %   kB in use   %  Bufsize kB   %  Util %
/                          811  49        6422  97        6444  98      99

Total:                     811  49        6422  97        6444  98
```

First, notice that the load average shot up, this is to be expected of course, then, while most of the numbers are close, notice that utilization is at 99%. Throughout the time that bonnie++ was running the utilization percentage remained at 99, this of course makes sense, however, in a real troubleshooting situation, it could be indicative of a process doing heavy I/O on one particular file or filesystem.

19.4 Monitoring Tools

In addition to screen oriented monitors and tools, the NetBSD system also ships with a set of command line oriented tools. Many of the tools that ship with a NetBSD system can be found on other UNIX and UNIX-like systems.

19.4.1 fstat

The fstat(1) utility reports the status of open files on the system, while it is not what many administrators consider a performance monitor, it can help find out if a particular user or process is using an inordinate amount of files, generating large files and similar information.

Following is a sample of some fstat output:

```
USER     CMD          PID   FD MOUNT      INUM MODE         SZ|DV R/W
jrf      tcsh       21607   wd /         29772 drwxr-xr-x     512 r
jrf      tcsh       21607    3* unix stream c057acc0<-> c0553280
jrf      tcsh       21607    4* unix stream c0553280 <-> c057acc0
root     sshd       21597   wd /             2 drwxr-xr-x     512 r
root     sshd       21597    0 /         11921 crw-rw-rw-    null rw
nobody   httpd       5032   wd /             2 drwxr-xr-x     512 r
nobody   httpd       5032    0 /         11921 crw-rw-rw-    null r
nobody   httpd       5032    1 /         11921 crw-rw-rw-    null w
nobody   httpd       5032    2 /         15890 -rw-r--r--  353533 rw
...
```

The fields are pretty self explanatory, again, this tool while not as performance oriented as others, can come in handy when trying to find out information about file usage.

19.4.2 iostat

The iostat(8) command does exactly what it sounds like, it reports the status of the I/O subsystems on the system. When iostat is employed, the user typically runs it with a certain number of counts and an interval between them like so:

```
$ iostat -c 5 -w 5
      tty            wd0             cd0             fd0             md0             cpu
 tin tout  KB/t t/s MB/s   KB/t t/s MB/s   KB/t t/s MB/s   KB/t t/s MB/s  us ni sy in id
   0    1  5.13   1 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
   0   54  0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
   0   18  0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
   0   18  8.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
   0   28  0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
```

The above output is from a very quiet ftp server. The fields represent the various I/O devices, the tty (which, ironically, is the most active because iostat is running), wd0 which is the primary IDE disk, cd0, the cdrom drive, fd0, the floppy and the memory filesystem.

Now, let’s see if we can pummel the system with some heavy usage. First, a large ftp transaction consisting of a tarball of netbsd-current source along with the bonnie++ disk benchmark program running at the same time.

```
$ iostat -c 5 -w 5
      tty            wd0             cd0             fd0             md0             cpu
 tin tout  KB/t t/s MB/s   KB/t t/s MB/s   KB/t t/s MB/s   KB/t t/s MB/s  us ni sy in id
   0    1  5.68   1 0.00   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  0  0 100
   0   54 61.03 150 8.92   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   1  0 18  4 78
   0   26 63.14 157 9.71   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   1  0 20  4 75
   0   20 43.58  26 1.12   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   0  0  9  2 88
   0   28 19.49  82 1.55   0.00   0 0.00   0.00   0 0.00   0.00   0 0.00   1  0  7  3 89
```

As can be expected, notice that wd0 is very active, what is interesting about this output is how the processor's I/O seems to rise in proportion to wd0. This makes perfect sense, however, it is worth noting that only because this ftp server is hardly being used can that be observed. If, for example, the cpu I/O subsystem was already under a moderate load and the disk subsystem was under the same load as it is now, it could appear that the cpu is bottlenecked when in fact it would have been the disk. In such a case, we can observe that "one tool" is rarely enough to completely analyze a problem. A quick glance at processes probably would tell us (after watching iostat) which processes were causing problems.

19.4.3 ps

Using the ps(1) command or process status, a great deal of information about the system can be discovered. Most of the time, the ps command is used to isolate a particular process by name, group, owner etc. Invoked with no options or arguments, ps simply prints out information about the user executing it.

```
$ ps
  PID TT STAT    TIME COMMAND
21560 p0 Is   0:00.04 -tcsh
21564 p0 I+   0:00.37 ssh jrf.odpn.net
21598 p1 Ss   0:00.12 -tcsh
21673 p1 R+   0:00.00 ps
21638 p2 Is+  0:00.06 -tcsh
```

Not very exciting. The fields are self explanatory with the exception of STAT which is actually the state a process is in. The flags are all documented in the man page, however, in the above example, I is idle, S is sleeping, R is runnable, the + means the process is in a foreground state, and the s means the process is a session leader. This all makes perfect sense when looking at the flags, for example, PID 21560 is a shell, it is idle and (as would be expected) the shell is the process leader.

In most cases, someone is looking for something very specific in the process listing. As an example, looking at all processes is specified with -a, to see all processes plus those without controlling terminals is -ax and to get a much more verbose listing (basically everything plus information about the impact processes are having) aux:

```
# ps aux
USER     PID %CPU %MEM    VSZ  RSS TT STAT STARTED    TIME COMMAND
root       0  0.0  9.6      0 6260 ?? DLs  16Jul02 0:01.00 (swapper)
root   23362  0.0  0.8    144  488 ?? S    12:38PM 0:00.01 ftpd -l
root   23328  0.0  0.4    428  280 p1 S    12:34PM 0:00.04 -csh
jrf    23312  0.0  1.8    828 1132 p1 Is   12:32PM 0:00.06 -tcsh
root   23311  0.0  1.8    388 1156 ?? S    12:32PM 0:01.60 sshd: jrf@ttyp1
jrf    21951  0.0  1.7    244 1124 p0 S+    4:22PM 0:02.90 ssh jrf.odpn.net
```

```
jrf    21947  0.0  1.7    828 1128 p0 Is    4:21PM 0:00.04 -tcsh
root   21946  0.0  1.8    388 1156 ?? S     4:21PM 0:04.94 sshd: jrf@ttyp0
nobody  5032  0.0  2.0   1616 1300 ?? I    19Jul02 0:00.02 /usr/pkg/sbin/httpd
...
```

Again, most of the fields are self explanatory with the exception of VSZ and RSS which can be a little confusing. RSS is the real size of a process in 1024 byte units while VSZ is the virtual size. This is all great, but again, how can ps help? Well, for one, take a look at this modified version of the same output:

```
# ps aux
USER      PID %CPU %MEM    VSZ  RSS TT STAT STARTED    TIME COMMAND
root        0  0.0  9.6      0 6260 ?? DLs  16Jul02 0:01.00 (swapper)
root   23362  0.0  0.8    144  488 ?? S    12:38PM 0:00.01 ftpd -l
root   23328  0.0  0.4    428  280 p1 S    12:34PM 0:00.04 -csh
jrf    23312  0.0  1.8    828 1132 p1 Is   12:32PM 0:00.06 -tcsh
root   23311  0.0  1.8    388 1156 ?? S    12:32PM 0:01.60 sshd: jrf@ttyp1
jrf    21951  0.0  1.7    244 1124 p0 S+    4:22PM 0:02.90 ssh jrf.odpn.net
jrf    21947  0.0  1.7    828 1128 p0 Is    4:21PM 0:00.04 -tcsh
root   21946  0.0  1.8    388 1156 ?? S     4:21PM 0:04.94 sshd: jrf@ttyp0
nobody  5032  9.0  2.0   1616 1300 ?? I    19Jul02 0:00.02 /usr/pkg/sbin/httpd
...
```

Given that on this server, our baseline indicates a relatively quiet system, the PID 5032 has an unusually large amount of %CPU. Sometimes this can also cause high TIME numbers. The ps command can be grepped on for PIDs, username and process name and hence help track down processes that may be experiencing problems.

19.4.4 vmstat

Using vmstat(1), information pertaining to virtual memory can be monitored and measured. Not unlike iostat, vmstat can be invoked with a count and interval. Following is some sample output using -c 5 -w 5 like the iostat example:

```
# vmstat -c 5 -w 5
 procs   memory     page                       disks         faults      cpu
 r b w   avm   fre  flt  re  pi   po   fr   sr w0 c0 f0 m0   in   sy  cs us sy id
 0 7 0 17716 33160    2   0   0    0    0    0  1  0  0  0  105   15   4  0  0 100
 0 7 0 17724 33156    2   0   0    0    0    0  1  0  0  0  109    6   3  0  0 100
 0 7 0 17724 33156    1   0   0    0    0    0  1  0  0  0  105    6   3  0  0 100
 0 7 0 17724 33156    1   0   0    0    0    0  0  0  0  0  107    6   3  0  0 100
 0 7 0 17724 33156    1   0   0    0    0    0  0  0  0  0  105    6   3  0  0 100
```

Yet again, relatively quiet, for posterity, the exact same load that was put on this server in the iostat example will be used. The load is a large file transfer and the bonnie benchmark program.

```
# vmstat -c 5 -w 5
 procs   memory     page                       disks         faults      cpu
 r b w   avm   fre  flt  re  pi   po   fr   sr w0 c0 f0 m0   in   sy  cs us sy id
 1 8 0 18880 31968    2   0   0    0    0    0  1  0  0  0  105   15   4  0  0 100
 0 8 0 18888 31964    2   0   0    0    0    0 130  0  0  0 1804 5539 1094 31 22 47
 1 7 0 18888 31964    1   0   0    0    0    0 130  0  0  0 1802 5500 1060 36 16 49
 1 8 0 18888 31964    1   0   0    0    0    0 160  0  0  0 1849 5905 1107 21 22 57
```

```
 1 7 0 18888 31964    1   0   0    0    0    0 175  0  0  0 1893 6167 1082  1 25 75
```

Just a little different. Notice, since most of the work was I/O based, the actual memory used was not very much. Since this system uses mfs for `/tmp`, however, it can certainly get beat up. Have a look at this:

```
# vmstat -c 5 -w 5
 procs   memory     page                       disks         faults      cpu
 r b w   avm   fre  flt  re  pi   po   fr   sr w0 c0 f0 m0   in   sy  cs us sy id
 0 2 0 99188   500    2   0   0    0    0    0  1  0  0  0  105   16   4  0  0 100
 0 2 0111596   436  592   0 587  624  586 1210 624  0  0  0  741  883 1088  0 11 89
 0 3 0123976   784  666   0 662  643  683 1326 702  0  0  0  828  993 1237  0 12 88
 0 2 0134692  1236  581   0 571  563  595 1158 599  0  0  0  722  863 1066  0  9 90
 2 0 0142860   912  433   0 406  403  405  808 429  0  0  0  552  602 768  0  7 93
```

Pretty scary stuff. That was created by running bonnie in `/tmp` on a memory based filesystem. If it continued for too long, it is possible the system could have started thrashing. Notice that even though the VM subsystem was taking a beating, the processors still were not getting too battered.

19.5 Network Tools

Sometimes a performance problem is not a particular machine, it is the network or some sort of device on the network such as another host, a router etc. What other machines that provide a service or some sort of connectivity to a particular NetBSD system do and how they act can have a very large impact on performance of the NetBSD system itself, or the perception of performance by users. A really great example of this is when a DNS server that a NetBSD machine is using suddenly disappears. Lookups take long and they eventually fail. Someone logged into the NetBSD machine who is not experienced would undoubtedly (provided they had no other evidence) blame the NetBSD system. One of my personal favorites, “the Internet is broke” usually means either DNS service or a router/gateway has dropped offline. Whatever the case may be, a NetBSD system comes adequately armed to deal with finding out what network issues may be cropping up whether the fault of the local system or some other issue.

19.5.1 ping

The classic ping(8) utility can tell us if there is just plain connectivity, it can also tell if host resolution (depending on how `nsswitch.conf` dictates) is working. Following is some typical ping output on a local network with a count of 3 specified:

```
# ping -c 3 marie
PING marie (172.16.14.12): 56 data bytes
64 bytes from 172.16.14.12: icmp_seq=0 ttl=255 time=0.571 ms
64 bytes from 172.16.14.12: icmp_seq=1 ttl=255 time=0.361 ms
64 bytes from 172.16.14.12: icmp_seq=2 ttl=255 time=0.371 ms

----marie PING Statistics----
3 packets transmitted, 3 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.361/0.434/0.571/0.118 ms
```

Not only does ping tell us if a host is alive, it tells us how long it took and gives some nice details at the very end. If a host cannot be resolved, just the IP address can be specified as well:

```
# ping -c 1 172.16.20.5
PING ash (172.16.20.5): 56 data bytes
64 bytes from 172.16.20.5: icmp_seq=0 ttl=64 time=0.452 ms

----ash PING Statistics----
1 packets transmitted, 1 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.452/0.452/0.452/0.000 ms
```

Now, not unlike any other tool, the times are very subjective, especially in regards to networking. For example, while the times in the examples are good, take a look at the localhost ping:

```
# ping -c 4 localhost
PING localhost (127.0.0.1): 56 data bytes
64 bytes from 127.0.0.1: icmp_seq=0 ttl=255 time=0.091 ms
64 bytes from 127.0.0.1: icmp_seq=1 ttl=255 time=0.129 ms
64 bytes from 127.0.0.1: icmp_seq=2 ttl=255 time=0.120 ms
64 bytes from 127.0.0.1: icmp_seq=3 ttl=255 time=0.122 ms

----localhost PING Statistics----
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.091/0.115/0.129/0.017 ms
```

Much smaller because the request never left the machine. Pings can be used to gather information about how well a network is performing. It is also good for problem isolation, for instance, if there are three relatively close in size NetBSD systems on a network and one of them simply has horrible ping times, chances are something is wrong on that one particular machine.

19.5.2 traceroute

The traceroute(8) command is great for making sure a path is available or detecting problems on a particular path. As an example, here is a trace between the example ftp server and ftp.NetBSD.org:

```
# traceroute ftp.NetBSD.org
traceroute to ftp.NetBSD.org (204.152.184.75), 30 hops max, 40 byte packets
 1  208.44.95.1 (208.44.95.1)  1.646 ms  1.492 ms  1.456 ms
 2  63.144.65.170 (63.144.65.170)  7.318 ms  3.249 ms  3.854 ms
 3  chcg01-edge18.il.inet.qwest.net (65.113.85.229)  35.982 ms  28.667 ms  21.971 ms
 4  chcg01-core01.il.inet.qwest.net (205.171.20.1)  22.607 ms  26.242 ms  19.631 ms
 5  snva01-core01.ca.inet.qwest.net (205.171.8.50)  78.586 ms  70.585 ms  84.779 ms
 6  snva01-core03.ca.inet.qwest.net (205.171.14.122)  69.222 ms  85.739 ms  75.979 ms
 7  paix01-brdr02.ca.inet.qwest.net (205.171.205.30)  83.882 ms  67.739 ms  69.937 ms
 8  198.32.175.3 (198.32.175.3)  72.782 ms  67.687 ms  73.320 ms
 9  so-1-0-0.orpa8.pf.isc.org (192.5.4.231)  78.007 ms  81.860 ms  77.069 ms
10  tun0.orrc5.pf.isc.org (192.5.4.165)  70.808 ms  75.151 ms  81.485 ms
11  ftp.NetBSD.org (204.152.184.75)  69.700 ms  69.528 ms  77.788 ms
```

All in all, not bad. The trace went from the host to the local router, then out onto the provider network and finally out onto the Internet looking for the final destination. How to interpret traceroutes, again, are subjective, but abnormally high times in portions of a path can indicate a bottleneck on a piece of network equipment. Not unlike ping, if the host itself is suspect, run traceroute from another host to the same destination. Now, for the worst case scenario:

```
# traceroute www.microsoft.com
traceroute: Warning: www.microsoft.com has multiple addresses; using 207.46.230.220
traceroute to www.microsoft.akadns.net (207.46.230.220), 30 hops max, 40 byte packets
 1  208.44.95.1 (208.44.95.1)  2.517 ms  4.922 ms  5.987 ms
 2  63.144.65.170 (63.144.65.170)  10.981 ms  3.374 ms  3.249 ms
 3  chcg01-edge18.il.inet.qwest.net (65.113.85.229)  37.810 ms  37.505 ms  20.795 ms
 4  chcg01-core03.il.inet.qwest.net (205.171.20.21)  36.987 ms  32.320 ms  22.430 ms
 5  chcg01-brdr03.il.inet.qwest.net (205.171.20.142)  33.155 ms  32.859 ms  33.462 ms
 6  205.171.1.162 (205.171.1.162)  39.265 ms  20.482 ms  26.084 ms
 7  sl-bb24-chi-13-0.sprintlink.net (144.232.26.85)  26.681 ms  24.000 ms  28.975 ms
 8  sl-bb21-sea-10-0.sprintlink.net (144.232.20.30)  65.329 ms  69.694 ms  76.704 ms
 9  sl-bb21-tac-9-1.sprintlink.net (144.232.9.221)  65.659 ms  66.797 ms  74.408 ms
10  144.232.187.194 (144.232.187.194)  104.657 ms  89.958 ms  91.754 ms
11  207.46.154.1 (207.46.154.1)  89.197 ms  84.527 ms  81.629 ms
12  207.46.155.10 (207.46.155.10)  78.090 ms  91.550 ms  89.480 ms
13  * * *
.......
```

In this case, the Microsoft server cannot be found either because of multiple addresses or somewhere along the line a system or server cannot reply to the information request. At that point, one might think to try ping, in the Microsoft case, a ping does not reply, that is because somewhere on their network ICMP is most likely disabled.

19.5.3 netstat

Another problem that can crop up on a NetBSD system is routing table issues. These issues are not always the systems fault. The route(8) and netstat(1) commands can show information about routes and network connections (respectively).

The route command can be used to look at and modify routing tables while netstat can display information about network connections and routes. First, here is some output from route show:

```
# route show
Routing tables

Internet:
Destination      Gateway            Flags
default          208.44.95.1        UG
loopback         127.0.0.1          UG
localhost        127.0.0.1          UH
172.15.13.0      172.16.14.37       UG
172.16.0.0       link#2             U
172.16.14.8      0:80:d3:cc:2c:0    UH
172.16.14.10     link#2             UH
marie            0:10:83:f9:6f:2c   UH
172.16.14.37     0:5:32:8f:d2:35    UH
172.16.16.15     link#2             UH
loghost          8:0:20:a7:f0:75    UH
artemus          8:0:20:a8:d:7e     UH
```

```
ash              0:b0:d0:de:49:df   UH
208.44.95.0      link#1             U
208.44.95.1      0:4:27:3:94:20     UH
208.44.95.2      0:5:32:8f:d2:34    UH
208.44.95.25     0:c0:4f:10:79:92   UH

Internet6:
Destination      Gateway            Flags
default          localhost          UG
default          localhost          UG
localhost        localhost          UH
::127.0.0.0      localhost          UG
::224.0.0.0      localhost          UG
::255.0.0.0      localhost          UG
::ffff:0.0.0.0   localhost          UG
2002::           localhost          UG
2002:7f00::      localhost          UG
2002:e000::      localhost          UG
2002:ff00::      localhost          UG
fe80::           localhost          UG
fe80::%ex0       link#1             U
fe80::%ex1       link#2             U
fe80::%lo0       fe80::1%lo0        U
fec0::           localhost          UG
ff01::           localhost          U
ff02::%ex0       link#1             U
ff02::%ex1       link#2             U
ff02::%lo0       fe80::1%lo0        U
```

The flags section shows the status and whether or not it is a gateway. In this case we see U, H and G (U is up, H is host and G is gateway, see the man page for additional flags).

Now for some netstat output using the -r (routing) and -n (show network numbers) options:

```
Routing tables

Internet:
Destination        Gateway            Flags     Refs     Use    Mtu  Interface
default            208.44.95.1        UGS         0   330309   1500  ex0
127                127.0.0.1          UGRS        0        0  33228  lo0
127.0.0.1          127.0.0.1          UH          1     1624  33228  lo0
172.15.13/24       172.16.14.37       UGS         0        0   1500  ex1
172.16             link#2             UC         13        0   1500  ex1
...
Internet6:
Destination                   Gateway                   Flags     Refs     Use
  Mtu  Interface
::/104                        ::1                       UGRS        0        0
33228  lo0 =>
::/96                         ::1                       UGRS        0        0
```

The above output is a little more verbose. So, how can this help? Well, a good example is when routes between networks get changed while users are connected. I saw this happen several times when someone was rebooting routers all day long after each change. Several users called up saying they were getting kicked out and it was taking very long to log back in. As it turned out, the clients connecting to the system were redirected to another router (which took a very long route) to reconnect. I observed the M flag or Modified dynamically (by redirect) on their connections. I deleted the routes, had them reconnect and summarily followed up with the offending technician.

19.5.4 tcpdump

Last, and definitely not least is tcpdump(8), the network sniffer that can retrieve a lot of information. In this discussion, there will be some sample output and an explanation of some of the more useful options of tcpdump.

Following is a small snippet of tcpdump in action just as it starts:

```
# tcpdump
tcpdump: listening on ex0
14:07:29.920651 mail.ssh > 208.44.95.231.3551: P 2951836801:2951836845(44) ack 2
476972923 win 17520 <nop,nop,timestamp 1219259 128519450> [tos 0x10]
14:07:29.950594 12.125.61.34 >  208.44.95.16: ESP(spi=2548773187,seq=0x3e8c) (DF)
14:07:29.983117 smtp.somecorp.com.smtp > 208.44.95.30.42828: . ack 420285166 win
16500 (DF)
14:07:29.984406 208.44.95.30.42828 > smtp.somecorp.com.smtp: . 1:1376(1375) ack 0
 win 7431 (DF)
...
```

Given that the particular server is a mail server, what is shown makes perfect sense, however, the utility is very verbose, I prefer to initially run tcpdump with no options and send the text output into a file for later digestion like so:

```
# tcpdump > tcpdump.out
tcpdump: listening on ex0
```

So, what precisely in the mish mosh are we looking for? In short, anything that does not seem to fit, for example, messed up packet lengths (as in a lot of them) will show up as improper lens or malformed packets (basically garbage). If, however, we are looking for something specific, tcpdump may be able to help depending on the problem.

19.5.4.1 Specific tcpdump Usage

These are just examples of a few things one can do with tcpdump.

Look for duplicate IP addresses:

```
tcpdump -e host ip-address
```

For example:

```
tcpdump -e host 192.168.0.2
```

Routing Problems:

```
tcpdump icmp
```

There are plenty of third party tools available, however, NetBSD comes shipped with a good tool set for tracking down network level performance problems.

19.6 Accounting

The NetBSD system comes equipped with a great deal of performance monitors for active monitoring, but what about long term monitoring? Well, of course the output of a variety of commands can be sent to files and re-parsed later with a meaningful shell script or program. NetBSD does, by default, offer some extraordinarily powerful low level monitoring tools for the programmer, administrator or really astute hobbyist.

19.6.1 Accounting

While accounting gives system usage at an almost userland level, kernel profiling with gprof provides explicit system call usage.

Using the accounting tools can help figure out what possible performance problems may be lying in wait, such as increased usage of compilers or network services for example.

Starting accounting is actually fairly simple, as root, use the accton(8) command. The syntax to start accounting is: **accton filename**

Where accounting information is appended to filename, now, strangely enough, the lastcomm command which reads from an accounting output file, by default, looks in `/var/account/acct` so I tend to just use the default location, however, lastcomm can be told to look elsewhere.

To stop accounting, simply type accton with no arguments.

19.6.2 Reading Accounting Information

To read accounting information, there are two tools that can be used:

- lastcomm(1)
- sa(8)

19.6.2.1 lastcomm

The lastcomm command shows the last commands executed in order, like all of them. It can, however, select by user, here is some sample output:

```
$ lastcomm jrf
last       -       jrf      ttyp3      0.00 secs Tue Sep  3 14:39 (0:00:00.02)
man        -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:01:49.03)
sh         -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:01:49.03)
less       -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:01:49.03)
lastcomm   -       jrf      ttyp3      0.02 secs Tue Sep  3 14:38 (0:00:00.02)
stty       -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:00:00.02)
tset       -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:00:01.05)
```

```
hostname   -       jrf      ttyp3      0.00 secs Tue Sep  3 14:38 (0:00:00.02)
ls         -       jrf      ttyp0      0.00 secs Tue Sep  3 14:36 (0:00:00.00)
...
```

Pretty nice, the lastcomm command gets its information from the default location of /var/account/acct, however, using the -f option, another file may be specified.

As may seem obvious, the output of lastcomm could get a little heavy on large multi user systems. That is where sa comes into play.

19.6.2.2 sa

The sa command (meaning "print system accounting statistics") can be used to maintain information. It can also be used interactively to create reports. Following is the default output of sa:

```
$ sa
      77      18.62re       0.02cp       8avio       0k
       3       4.27re       0.01cp      45avio       0k   ispell
       2       0.68re       0.00cp      33avio       0k   mutt
       2       1.09re       0.00cp      23avio       0k   vi
      10       0.61re       0.00cp       7avio       0k   ***other
       2       0.01re       0.00cp      29avio       0k   exim
       4       0.00re       0.00cp       8avio       0k   lastcomm
       2       0.00re       0.00cp       3avio       0k   atrun
       3       0.03re       0.00cp       1avio       0k   cron*
       5       0.02re       0.00cp      10avio       0k   exim*
      10       3.98re       0.00cp       2avio       0k   less
      11       0.00re       0.00cp       0avio       0k   ls
       9       3.95re       0.00cp      12avio       0k   man
       2       0.00re       0.00cp       4avio       0k   sa
      12       3.97re       0.00cp       1avio       0k   sh
...
```

From left to right, total times called, real time in minutes, sum of user and system time, in minutes, Average number of I/O operations per execution, size, command name.

The sa command can also be used to create summary files or reports based on some options, for example, here is the output when specifying a sort by CPU-time average memory usage:

```
$ sa -k
      86      30.81re       0.02cp       8avio       0k
      10       0.61re       0.00cp       7avio       0k   ***other
       2       0.00re       0.00cp       3avio       0k   atrun
       3       0.03re       0.00cp       1avio       0k   cron*
       2       0.01re       0.00cp      29avio       0k   exim
       5       0.02re       0.00cp      10avio       0k   exim*
       3       4.27re       0.01cp      45avio       0k   ispell
       4       0.00re       0.00cp       8avio       0k   lastcomm
      12       8.04re       0.00cp       2avio       0k   less
      13       0.00re       0.00cp       0avio       0k   ls
      11       8.01re       0.00cp      12avio       0k   man
       2       0.68re       0.00cp      33avio       0k   mutt
       3       0.00re       0.00cp       4avio       0k   sa
```

```
      14       8.03re       0.00cp        1avio        0k   sh
       2       1.09re       0.00cp       23avio        0k   vi
```

The sa command is very helpful on larger systems.

19.6.3 How to Put Accounting to Use

Accounting reports, as was mentioned earlier, offer a way to help predict trends, for example, on a system that has cc and make being used more and more may indicate that in a few months some changes will need to be made to keep the system running at an optimum level. Another good example is web server usage. If it begins to gradually increase, again, some sort of action may need to be taken before it becomes a problem. Luckily, with accounting tools, said actions can be reasonably predicted and planned for ahead of time.

19.7 Kernel Profiling

Profiling a kernel is normally employed when the goal is to compare the difference of new changes in the kernel to a previous one or to track down some sort of low level performance problem. Two sets of data about profiled code behavior are recorded independently: function call frequency and time spent in each function.

19.7.1 Getting Started

First, take a look at both Section 19.9 and Chapter 34. The only difference in procedure for setting up a kernel with profiling enabled is when you run config add the -p option. The build area is `../compile/<KERNEL_NAME>.PROF` , for example, a GENERIC kernel would be `../compile/GENERIC.PROF`.

Following is a quick summary of how to compile a kernel with profiling enabled on the amd64 port, the assumptions are that the appropriate sources are available under `/usr/src` and the GENERIC configuration is being used, of course, that may not always be the situation:

1. **`cd /usr/src/sys/arch/amd64/conf`**
2. **`config -p GENERIC`**
3. **`cd ../compile/GENERIC.PROF`**
4. **`make depend && make`**
5. **`cp /netbsd /netbsd.old`**
6. **`cp netbsd /`**
7. **`reboot`**

Once the new kernel is in place and the system has rebooted, it is time to turn on the monitoring and start looking at results.

19.7.1.1 Using kgmon

To start kgmon:

```
$ kgmon -b
kgmon: kernel profiling is running.
```

Next, send the data into the file `gmon.out`:

```
$ kgmon -p
```

Now, it is time to make the output readable:

```
$ gprof /netbsd > gprof.out
```

Since gmon is looking for `gmon.out`, it should find it in the current working directory.

By just running kgmon alone, you may not get the information you need, however, if you are comparing the differences between two different kernels, then a known good baseline should be used. Note that it is generally a good idea to stress the subsystem if you know what it is both in the baseline and with the newer (or different) kernel.

19.7.2 Interpretation of kgmon Output

Now that kgmon can run, collect and parse information, it is time to actually look at some of that information. In this particular instance, a GENERIC kernel is running with profiling enabled for about an hour with only system processes and no adverse load, in the fault insertion section, the example will be large enough that even under a minimal load detection of the problem should be easy.

19.7.2.1 Flat Profile

The flat profile is a list of functions, the number of times they were called and how long it took (in seconds). Following is sample output from the quiet system:

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  ns/call  ns/call  name
 99.77    163.87   163.87                             idle
  0.03    163.92     0.05      219 228310.50 228354.34  _wdc_ata_bio_start
  0.02    163.96     0.04      219 182648.40 391184.96  wdc_ata_bio_intr
  0.01    163.98     0.02     3412  5861.66  6463.02  pmap_enter
  0.01    164.00     0.02      548 36496.35 36496.35  pmap_zero_page
  0.01    164.02     0.02                             Xspllower
  0.01    164.03     0.01   481968    20.75    20.75  gettick
  0.01    164.04     0.01     6695  1493.65  1493.65  VOP_LOCK
  0.01    164.05     0.01     3251  3075.98 21013.45  syscall_plain
...
```

As expected, idle was the highest in percentage, however, there were still some things going on, for example, a little further down there is the *vn_lock* function:

```
...
  0.00    164.14     0.00     6711     0.00     0.00  VOP_UNLOCK
  0.00    164.14     0.00     6677     0.00  1493.65  vn_lock
  0.00    164.14     0.00     6441     0.00     0.00  genfs_unlock
```

This is to be expected, since locking still has to take place, regardless.

19.7.2.2 Call Graph Profile

The call graph is an augmented version of the flat profile showing subsequent calls from the listed functions. First, here is some sample output:

```
                     Call graph (explanation follows)


granularity: each sample hit covers 4 byte(s) for 0.01% of 164.14 seconds

index % time    self  children    called     name
                                                 <spontaneous>
[1]     99.8  163.87    0.00                 idle [1]
-----------------------------------------------
                                                 <spontaneous>
[2]      0.1    0.01    0.08                 syscall1 [2]
                0.01    0.06    3251/3251        syscall_plain [7]
                0.00    0.01     414/1660        trap [9]
-----------------------------------------------
                0.00    0.09     219/219         Xintr14 [6]
[3]      0.1    0.00    0.09     219         pciide_compat_intr [3]
                0.00    0.09     219/219         wdcintr [5]
-----------------------------------------------
...
```

Now this can be a little confusing. The index number is mapped to from the trailing number on the end of the line, for example,

```
...
                0.00    0.01      85/85          dofilewrite [68]
[72]     0.0    0.00    0.01      85         soo_write [72]
                0.00    0.01      85/89          sosend [71]
...
```

Here we see that dofilewrite was called first, now we can look at the index number for 64 and see what was happening there:

```
...
                0.00    0.01     101/103         ffs_full_fsync <cycle 6> [58]
[64]     0.0    0.00    0.01     103         bawrite [64]
                0.00    0.01     103/105         VOP_BWRITE [60]
...
```

And so on, in this way, a "visual trace" can be established.

At the end of the call graph right after the terms section is an index by function name which can help map indexes as well.

19.7.3 Putting it to Use

In this example, I have modified an area of the kernel I know will create a problem that will be blatantly obvious.

Here is the top portion of the flat profile after running the system for about an hour with little interaction from users:

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  us/call  us/call  name
 93.97    139.13   139.13                             idle
  5.87    147.82     8.69       23 377826.09 377842.52  check_exec
  0.01    147.84     0.02      243    82.30    82.30  pmap_copy_page
  0.01    147.86     0.02      131   152.67   152.67  _wdc_ata_bio_start
  0.01    147.88     0.02      131   152.67   271.85  wdc_ata_bio_intr
  0.01    147.89     0.01     4428     2.26     2.66  uvn_findpage
  0.01    147.90     0.01     4145     2.41     2.41  uvm_pageactivate
  0.01    147.91     0.01     2473     4.04  3532.40  syscall_plain
  0.01    147.92     0.01     1717     5.82     5.82  i486_copyout
  0.01    147.93     0.01     1430     6.99    56.52  uvm_fault
  0.01    147.94     0.01     1309     7.64     7.64  pool_get
  0.01    147.95     0.01      673    14.86    38.43  genfs_getpages
  0.01    147.96     0.01      498    20.08    20.08  pmap_zero_page
  0.01    147.97     0.01      219    45.66    46.28  uvm_unmap_remove
  0.01    147.98     0.01      111    90.09    90.09  selscan
...
```

As is obvious, there is a large difference in performance. Right off the bat the idle time is noticeably less. The main difference here is that one particular function has a large time across the board with very few calls. That function is *check_exec*. While at first, this may not seem strange if a lot of commands had been executed, when compared to the flat profile of the first measurement, proportionally it does not seem right:

```
...
  0.00    164.14     0.00       37     0.00 62747.49  check_exec
...
```

The call in the first measurement is made 37 times and has a better performance. Obviously something in or around that function is wrong. To eliminate other functions, a look at the call graph can help, here is the first instance of *check_exec*

```
...
-----------------------------------------------
                0.00    8.69      23/23          syscall_plain [3]
[4]      5.9    0.00    8.69      23         sys_execve [4]
```

```
                8.69    0.00      23/23          check_exec [5]
                0.00    0.00      20/20          elf32_copyargs [67]
...
```

Notice how the time of 8.69 seems to affect the two previous functions. It is possible that there is something wrong with them, however, the next instance of *check_exec* seems to prove otherwise:

```
...
-----------------------------------------------
                8.69    0.00      23/23          sys_execve [4]
[5]      5.9    8.69    0.00      23         check_exec [5]
...
```

Now we can see that the problem, most likely, resides in *check_exec*. Of course, problems are not always this simple and in fact, here is the simpleton code that was inserted right after *check_exec* (the function is in `sys/kern/kern_exec.c`):

```
...
        /* A Cheap fault insertion */
        for (x = 0; x < 100000000; x++) {
                y = x;
        }
..
```

Not exactly glamorous, but enough to register a large change with profiling.

19.7.4 Summary

Kernel profiling can be enlightening for anyone and provides a much more refined method of hunting down performance problems that are not as easy to find using conventional means, it is also not nearly as hard as most people think, if you can compile a kernel, you can get profiling to work.

19.8 System Tuning

Now that monitoring and analysis tools have been addressed, it is time to look into some actual methods. In this section, tools and methods that can affect how the system performs that are applied without recompiling the kernel are addressed, the next section examines kernel tuning by recompiling.

19.8.1 Using sysctl

The sysctl utility can be used to look at and in some cases alter system parameters. There are so many parameters that can be viewed and changed they cannot all be shown here, however, for the first example here is a simple usage of sysctl to look at the system PATH environment variable:

```
$ sysctl user.cs_path
user.cs_path = /usr/bin:/bin:/usr/sbin:/sbin:/usr/pkg/bin:/usr/pkg/sbin:/usr/local/bin:/usr/
```

Fairly simple. Now something that is actually related to performance. As an example, let's say a system with many users is having file open issues, by examining and perhaps raising the kern.maxfiles parameter the problem may be fixed, but first, a look:

```
$ sysctl kern.maxfiles
kern.maxfiles = 1772
```

Now, to change it, as root with the -w option specified:

```
# sysctl -w kern.maxfiles=1972
kern.maxfiles: 1772 -> 1972
```

Note, when the system is rebooted, the old value will return, there are two cures for this, first, modify that parameter in the kernel and recompile, second (and simpler) add this line to `/etc/sysctl.conf`:

```
kern.maxfiles=1972
```

19.8.2 tmpfs & mfs

NetBSD's "ramdisk" implementations cache all data in the RAM, and if that is full, the swap space is used as backing store. NetBSD comes with two implementations, the traditional BSD memory-based file system "mfs" and the more modern "tmpfs". While the former can only grow in size, the latter can also shrink if space is no longer needed.

When to use and not to use a memory based filesystem can be hard on large multi user systems. In some cases, however, it makes pretty good sense, for example, on a development machine used by only one developer at a time, the obj directory might be a good place, or some of the tmp directories for builds. In a case like that, it makes sense on machines that have a fair amount of RAM on them. On the other side of the coin, if a system only has 16MB of RAM and `/var/tmp` is mfs-based, there could be severe applications issues that occur.

The GENERIC kernel has both tmpfs and mfs enabled by default. To use it on a particular directory first determine where the swap space is that you wish to use, in the example case, a quick look in `/etc/fstab` indicates that `/dev/wd0b` is the swap partition:

```
mail% cat /etc/fstab
/dev/wd0a / ffs rw 1 1
/dev/wd0b none swap sw 0 0
/kern /kern kernfs rw
```

This system is a mail server so I only want to use `/tmp` with tmpfs, also on this particular system I have linked `/tmp` to `/var/tmp` to save space (they are on the same drive). All I need to do is add the following entry:

```
/dev/wd0b /var/tmp tmpfs rw 0 0
```

If you want to use "mfs" instead of "tmpfs", put just that into the above place.

Now, a word of warning: make sure said directories are empty and nothing is using them when you mount the memory file system! After changing `/etc/fstab`, you can either run **mount -a** or reboot the system.

19.8.3 Journaling

Journaling is a mechanism which puts written data in a so-called "journal" first, and in a second step the data from the journal is written to disk. In the event of a system crash, data that was not written to disk but that is in the journal can be replayed, and will thus get the disk into a proper state. The main effect of this is that no file system check (fsck) is needed after a rough reboot.

Journaling can be enabled by adding "log" to the filesystem options in `/etc/fstab`. Here is an example which enables journaling for the root (`/`), `/var`, and `/usr` file systems:

```
/dev/wd0a /    ffs rw,log 1 1
/dev/wd0e /var ffs rw,log 1 2
/dev/wd0g /usr ffs rw,log 1 2
```

19.8.4 LFS

LFS, the log structured filesystem, writes data to disk in a way that is sometimes too aggressive and leads to congestion. To throttle writing, the following sysctls can be used:

```
vfs.sync.delay
vfs.sync.filedelay
vfs.sync.dirdelay
vfs.sync.metadelay
vfs.lfs.flushindir
vfs.lfs.clean_vnhead
vfs.lfs.dostats
vfs.lfs.pagetrip
vfs.lfs.stats.segsused
vfs.lfs.stats.psegwrites
vfs.lfs.stats.psyncwrites
vfs.lfs.stats.pcleanwrites
vfs.lfs.stats.blocktot
vfs.lfs.stats.cleanblocks
vfs.lfs.stats.ncheckpoints
vfs.lfs.stats.nwrites
vfs.lfs.stats.nsync_writes
vfs.lfs.stats.wait_exceeded
vfs.lfs.stats.write_exceeded
vfs.lfs.stats.flush_invoked
vfs.lfs.stats.vflush_invoked
vfs.lfs.stats.clean_inlocked
vfs.lfs.stats.clean_vnlocked
vfs.lfs.stats.segs_reclaimed
vfs.lfs.ignore_lazy_sync
```

Besides tuning those parameters, disabling write-back caching on wd(4) devices may be beneficial. See the dkctl(8) man page for details.

More is available in the NetBSD mailing list archives. See this (http://mail-index.NetBSD.org/tech-perform/2007/04/01/0000.html) and this (http://mail-index.NetBSD.org/tech-perform/2007/04/01/0001.html) mail.

19.9 Kernel Tuning

While many system parameters can be changed with sysctl, many improvements by using enhanced system software, layout of the system and managing services (moving them in and out of inetd for example) can be achieved as well. Tuning the kernel however will provide better performance, even if it appears to be marginal.

19.9.1 Preparing to Recompile a Kernel

First, get the kernel sources for the release as described in Chapter 32, reading Chapter 34 for more information on building the kernel is recommended. Note, this document can be used for -current tuning, however, a read of the Tracking -current (http://www.NetBSD.org/docs/current/) documentation should be done first, much of the information there is repeated here.

19.9.2 Configuring the Kernel

Configuring a kernel in NetBSD can be daunting. This is because of multiple line dependencies within the configuration file itself, however, there is a benefit to this method and that is, all it really takes is an ASCII editor to get a new kernel configured and some dmesg output. The kernel configuration file is under `src/sys/arch/ARCH/conf` where ARCH is your architecture (for example, on a SPARC it would be under `src/sys/arch/sparc/conf`).

After you have located your kernel config file, copy it and remove (comment out) all the entries you don't need. This is where dmesg(8) becomes your friend. A clean dmesg(8)-output will show all of the devices detected by the kernel at boot time. Using dmesg(8) output, the device options really needed can be determined.

19.9.2.1 Some example Configuration Items

In this example, an ftp server's kernel is being reconfigured to run with the bare minimum drivers and options and any other items that might make it run faster (again, not necessarily smaller, although it will be). The first thing to do is take a look at some of the main configuration items. So, in `/usr/src/sys/arch/amd64/conf` the GENERIC file is copied to FTP, then the file FTP edited.

At the start of the file there are a bunch of options beginning with maxusers, which will be left alone, however, on larger multi-user systems it might be help to crank that value up a bit. Next is CPU support, looking at the dmesg output this is seen:

```
cpu0: Intel Pentium II/Celeron (Deschutes) (686-class), 400.93 MHz
```

Indicating that only the options I686_CPU options needs to be used. In the next section, all options are left alone except the PIC_DELAY which is recommended unless it is an older machine. In this case it is enabled since the 686 is "relatively new."

Between the last section all the way down to compat options there really was no need to change anything on this particular system. In the compat section, however, there are several options that do not need to be enabled, again this is because this machine is strictly a FTP server, all compat options were turned off.

The next section is File systems, and again, for this server very few need to be on, the following were left on:

```
# File systems
file-system     FFS             # UFS
file-system     LFS             # log-structured file system
file-system     MFS             # memory file system
file-system     CD9660          # ISO 9660 + Rock Ridge file system
file-system     FDESC           # /dev/fd
file-system     KERNFS          # /kern
file-system     NULLFS          # loopback file system
file-system     PROCFS          # /proc
file-system     UMAPFS          # NULLFS + uid and gid remapping
...
options         SOFTDEP         # FFS soft updates support.
...
```

Next comes the network options section. The only options left on were:

```
options         INET            # IP + ICMP + TCP + UDP
options         INET6           # IPV6
options         IPFILTER_LOG    # ipmon(8) log support
```

IPFILTER_LOG is a nice one to have around since the server will be running ipf.

The next section is verbose messages for various subsystems, since this machine is already running and had no major problems, all of them are commented out.

19.9.2.2 Some Drivers

The configurable items in the config file are relatively few and easy to cover, however, device drivers are a different story. In the following examples, two drivers are examined and their associated “areas” in the file trimmed down. First, a small example: the cdrom, in dmesg, is the following lines:

```
...
cd0 at atapibus0 drive 0: <CD-540E, , 1.0A> type 5 cdrom removable
cd0: 32-bit data port
cd0: drive supports PIO mode 4, DMA mode 2, Ultra-DMA mode 2
pciide0: secondary channel interrupting at irq 15
cd0(pciide0:1:0): using PIO mode 4, Ultra-DMA mode 2 (using DMA data transfer
...
```

Now, it is time to track that section down in the configuration file. Notice that the "cd"-drive is on an atapibus and requires pciide support. The section that is of interest in this case is the kernel config’s "IDE and related devices" section. It is worth noting at this point, in and around the IDE section are also ISA, PCMCIA etc., on this machine in the dmesg(8) output there are no PCMCIA devices, so it stands to reason that all PCMCIA references can be removed. But first, the "cd" drive.

At the start of the IDE section is the following:

```
...
wd*     at atabus? drive ? flags 0x0000
...
atapibus* at atapi?
...
```

Well, it is pretty obvious that those lines need to be kept. Next is this:

```
...
# ATAPI devices
# flags have the same meaning as for IDE drives.
cd*     at atapibus? drive ? flags 0x0000       # ATAPI CD-ROM drives
sd*     at atapibus? drive ? flags 0x0000       # ATAPI disk drives
st*     at atapibus? drive ? flags 0x0000       # ATAPI tape drives
uk*     at atapibus? drive ? flags 0x0000       # ATAPI unknown
...
```

The only device type that was in the dmesg(8) output was the cd, the rest can be commented out.

The next example is slightly more difficult, network interfaces. This machine has two of them:

```
...
ex0 at pci0 dev 17 function 0: 3Com 3c905B-TX 10/100 Ethernet (rev. 0x64)
ex0: interrupting at irq 10
ex0: MAC address 00:50:04:83:ff:b7
UI 0x001018 model 0x0012 rev 0 at ex0 phy 24 not configured
ex1 at pci0 dev 19 function 0: 3Com 3c905B-TX 10/100 Ethernet (rev. 0x30)
ex1: interrupting at irq 11
ex1: MAC address 00:50:da:63:91:2e
exphy0 at ex1 phy 24: 3Com internal media interface
exphy0: 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
...
```

At first glance it may appear that there are in fact three devices, however, a closer look at this line:

```
exphy0 at ex1 phy 24: 3Com internal media interface
```

Reveals that it is only two physical cards, not unlike the cdrom, simply removing names that are not in dmesg will do the job. In the beginning of the network interfaces section is:

```
...
# Network Interfaces

# PCI network interfaces
an*     at pci? dev ? function ?        # Aironet PC4500/PC4800 (802.11)
bge*    at pci? dev ? function ?        # Broadcom 570x gigabit Ethernet
en*     at pci? dev ? function ?        # ENI/Adaptec ATM
ep*     at pci? dev ? function ?        # 3Com 3c59x
epic*   at pci? dev ? function ?        # SMC EPIC/100 Ethernet
esh*    at pci? dev ? function ?        # Essential HIPPI card
ex*     at pci? dev ? function ?        # 3Com 90x[BC]
...
```

There is the ex device. So all of the rest under the PCI section can be removed. Additionally, every single line all the way down to this one:

```
exphy*  at mii? phy ?                   # 3Com internal PHYs
```

can be commented out as well as the remaining.

19.9.2.3 Multi Pass

When I tune a kernel, I like to do it remotely in an X windows session, in one window the dmesg output, in the other the config file. It can sometimes take a few passes to rebuild a very trimmed kernel since it is easy to accidentally remove dependencies.

19.9.3 Building the New Kernel

Now it is time to build the kernel and put it in place. In the conf directory on the ftp server, the following command prepares the build:

```
$ config FTP
```

When it is done a message reminding me to make depend will display, next:

```
$ cd ../compile/FTP
$ make depend && make
```

When it is done, I backup the old kernel and drop the new one in place:

```
# cp /netbsd /netbsd.orig
# cp netbsd /
```

Now reboot. If the kernel cannot boot, stop the boot process when prompted and type **`boot netbsd.orig`** to boot from the previous kernel.

19.9.4 Shrinking the NetBSD kernel

When building a kernel for embedded systems, it's often necessary to modify the Kernel binary to reduce space or memory footprint.

19.9.4.1 Removing ELF sections and debug information

We already know how to remove Kernel support for drivers and options that you don't need, thus saving memory and space, but you can save some KiloBytes of space by removing debugging symbols and two ELF sections if you don't need them: `.comment` and `.ident`. They are used for storing RCS strings viewable with ident(1) and a gcc(1) version string. The following examples assume you have your `TOOLDIR` under `/usr/src/tooldir.NetBSD-2.0-i386` and the target architecture is `i386`.

```
$ /usr/src/tooldir.NetBSD-2.0-i386/bin/i386--netbsdelf-objdump -h /netbsd

/netbsd:     file format elf32-i386

Sections:
Idx Name          Size      VMA       LMA       File off  Algn
  0 .text         0057a374  c0100000  c0100000  00001000  2**4
                  CONTENTS, ALLOC, LOAD, READONLY, CODE
  1 .rodata       00131433  c067a380  c067a380  0057b380  2**5
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  2 .rodata.str1.1 00035ea0  c07ab7b3  c07ab7b3  006ac7b3  2**0
```

```
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  3 .rodata.str1.32 00059d13  c07e1660  c07e1660  006e2660  2**5
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  4 link_set_malloc_types 00000198  c083b374  c083b374  0073c374  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  5 link_set_domains 00000024  c083b50c  c083b50c  0073c50c  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  6 link_set_pools 00000158  c083b530  c083b530  0073c530  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  7 link_set_sysctl_funcs 000000f0  c083b688  c083b688  0073c688  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  8 link_set_vfsops 00000044  c083b778  c083b778  0073c778  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  9 link_set_dkwedge_methods 00000004  c083b7bc  c083b7bc  0073c7bc  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
 10 link_set_bufq_strats 0000000c  c083b7c0  c083b7c0  0073c7c0  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
 11 link_set_evcnts 00000030  c083b7cc  c083b7cc  0073c7cc  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
 12 .data         00048ae4  c083c800  c083c800  0073c800  2**5
                  CONTENTS, ALLOC, LOAD, DATA
 13 .bss          00058974  c0885300  c0885300  00785300  2**5
                  ALLOC
 14 .comment      0000cda0  00000000  00000000  00785300  2**0
                  CONTENTS, READONLY
 15 .ident        000119e4  00000000  00000000  007920a0  2**0
                  CONTENTS, READONLY
```

On the third column we can see the size of the sections in hexadecimal form. By summing `.comment` and `.ident` sizes we know how much we're going to save with their removal: around 120KB (= 52640 + 72164 = 0xcda0 + 0x119e4). To remove the sections and debugging symbols that may be present, we're going to use strip(1):

```
# cp /netbsd /netbsd.orig
# /usr/src/tooldir.NetBSD-2.0-i386/bin/i386--netbsdelf-strip -S -R .ident -R .comment /netbsd
# ls -l /netbsd /netbsd.orig
-rwxr-xr-x  1 root  wheel  8590668 Apr 30 15:56 netbsd
-rwxr-xr-x  1 root  wheel  8757547 Apr 30 15:56 netbsd.orig
```

Since we also removed debugging symbols, the total amount of disk space saved is around 160KB.

19.9.4.2 Compressing the Kernel

On some architectures, the bootloader can boot a compressed kernel. You can save several MegaBytes of disk space by using this method, but the bootloader will take longer to load the Kernel.

```
# cp /netbsd /netbsd.plain
# gzip -9 /netbsd
```

To see how much space we've saved:

```
$ ls -l /netbsd.plain /netbsd.gz
```

```
-rwxr-xr-x  1 root  wheel  8757547 Apr 29 18:05 /netbsd.plain
-rwxr-xr-x  1 root  wheel  3987769 Apr 29 18:05 /netbsd.gz
```

Note that you can only use gzip coding, by using gzip(1), bzip2 is not supported by the NetBSD bootloaders!

Chapter 20

NetBSD Veriexec subsystem

Veriexec is NetBSD's file integrity subsystem. It's kernel based, hence can provide some protection even in the case of a root compromise.

20.1 How it works

Veriexec works by loading a specification file, also called the **signatures file**, to the kernel. This file contains information about files Veriexec should monitor, as well as their digital fingerprint (along with the hashing algorithm used to produce this fingerprint), and various flags that will be discussed later.

At the moment, the following hashing algorithms are supported by Veriexec: **MD5**, **SHA1**, **SHA256**, **SHA384**, **SHA512**, and **RMD160**.

20.2 Signatures file

An entry in the Veriexec signatures file looks like this:

```
/path/to/file algorithm fingerprint flags
```

Where the first element, the path, must always be an absolute path. The algorithm is one of the algorithms listed above, and fingerprint is the ASCII fingerprint.

20.3 Generating fingerprints

You can generate ASCII fingerprints for each algorithm using the following tools:

Table 20-1. Veriexec fingerprints tools

Algorithm	Tool
MD5	`/usr/bin/cksum -a md5`
SHA1	`/usr/bin/cksum -a sha1`
SHA256	`/usr/bin/cksum -a sha256`
SHA384	`/usr/bin/cksum -a sha384`
SHA512	`/usr/bin/cksum -a sha512`
RMD160	`/usr/bin/cksum -a rmd160`

For example, to generate a MD5 fingerprint for `/bin/ls`:

```
% cksum -a md5 < /bin/ls
a8b525da46e758778564308ed9b1e493
```

And to generate a SHA512 fingerprint for `/bin/ps`:

```
% cksum -a sha512 < /bin/ps
381d4ad64fd47800897446a2026eca42151e03adeae158db5a34d12c529559113d928a9fef9a7c4615d257688d
```

Each entry may be associated with zero or more flags. Currently, these flags indicate how the file the entry is describing should be accessed. Note that this access type is enforced only in strict level 2 (IPS mode) and above.

The access types you can use are "DIRECT", "INDIRECT", and "FILE".

- **DIRECT** access means that the file is executed directly, and not invoked as an interpreter for some script, or opened with an editor. Usually, most programs you use will be accessed using this mode:

  ```
  % ls /tmp
  % cp ~/foo /tmp/bar
  % rm ~/foo
  ```

- **INDIRECT** access means that the file is executed indirectly, and is invoked to interpret a script. This happens usually when scripts have a #! magic as their first line. For example, if you have a script with the following as its first line:

  ```
  #!/bin/sh
  ```

  And you run it as:

  ```
  % ./script.sh
  ```

  Then `/bin/sh` will be executed indirectly -- it will be invoked to interpret the script.

- **FILE** entries refer to everything which is not (or should not) be an executable. This includes shared libraries, configuration files, etc.

  Some examples for Veriexec signature file entries:

  ```
  /bin/ls         MD5 dc2e14dc84bdefff4bf9777958c1b20b DIRECT
  /usr/bin/perl   MD5 914aa8aa47ebd79ccd7909a09ed61f81 INDIRECT
  /etc/pf.conf    MD5 950e1dd6fcb3f27df1bf6accf7029f7d FILE
  ```

Veriexec allows you to specify more than one way to access a file in an entry. For example, even though `/usr/bin/perl` is mostly used as an interpreter, it may be desired to be able to execute it directly, too:

```
/usr/bin/perl MD5 914aa8aa47ebd79ccd7909a09ed61f81 DIRECT, INDIRECT
```

Shell scripts using #! magic to be "executable" also require two access types: We need them to be "DIRECT" so we can execute them, and we need them to be "FILE" so that the kernel can feed their contents to the interpreter they define:

```
/usr/src/build.sh MD5 e80dbb4c047ecc1d84053174c1e9264a DIRECT, FILE
```

To make it easier to create signature files, and to make the signature files themselves more readable, Veriexec allows you to use the following aliases:

Table 20-2. Veriexec access type aliases

Alias	Expansion
PROGRAM	DIRECT
INTERPRETER	INDIRECT
SCRIPT	DIRECT, FILE
LIBRARY	FILE

After you have generated a signatures file, you should save it as `/etc/signatures`, and enable Veriexec in `rc.conf`:

```
veriexec=YES
```

20.4 Strict levels

Since different people might want to use Veriexec for different purposes, we also define four strict levels, ranging 0-3, and named “learning”, “IDS”, “IPS”, and “lockdown” modes.

In **strict level 0**, learning mode, Veriexec will act passively and simply warn about any anomalies. Combined with verbose level 1, running the system in this mode can help you fine-tune the signatures file. This is also the only strict level in which you can load new entries to the kernel.

Strict level 1, or IDS mode, will deny access to files with a fingerprint mismatch. This mode suits mostly to users who simply want to prevent access to files which might’ve been maliciously modified by an attacker.

Strict level 2, IPS mode, takes a step towards trying to protect the integrity of monitored files. In addition to preventing access to files with a fingerprint mismatch, it will also deny write access and prevent the removal of monitored files, and enforce the way monitored files are accessed. (as the signatures file specifies).

Lockdown mode (**strict level 3**) can be used in highly critical situations such as custom made special-purpose machines, or as a last line of defense after an attacker compromised the system and we want to prevent traces from being removed, so we can perform post-mortem analysis. It will prevent the creation of new files, and deny access to files not monitored by Veriexec.

It’s recommended to first run Veriexec in strict level 0 and verbose level 1 to fine-tune your signatures file, ensuring that desired applications run correctly, and only then raise the strict level (and lower the verbosity level). You can use `/etc/sysctl.conf` to auto raise the strict level to the desired level after a reboot:

```
kern.veriexec.strict=1
```

20.5 Veriexec and layered file systems

Veriexec can be used on NFS file systems on the client side and on layered file systems such as the union file system. The files residing on these file systems need only be specified in the `/etc/signatures` file and that the file systems be mounted prior to the fingerprints being loaded.

If you are going to use layered file systems then you must ensure that you include the fingerprint for files you want protected at every layer. If you fail to do this someone could overwrite a file protected by Veriexec by using a different layer in a layered file system stack. This limitation may be removed in later versions of NetBSD.

It's recommended that if you are not going to use layered file systems nor NFS then these features should be disabled in they kernel configuration. If you need to use layered file systems then you must follow the instructions in the previous paragraph and ensure that the files you want protected have fingerprints at all layers. Also you should raise securelevel to 2 after all mounts are done:

```
kern.securelevel=2
```

To prevent new layers being mounted which could compromise Veriexec's protection.

20.6 Kernel configuration

To use Veriexec, aside from creating a signatures file, you should enable (uncomment) it in your kernel's config file: (e.g. `/usr/src/sys/arch/i386/conf/GENERIC`):

```
pseudo-device veriexec
```

Then, you need to enable the hashing algorithms you wish to support:

```
options VERIFIED_EXEC_FP_MD5
options VERIFIED_EXEC_FP_SHA1
options VERIFIED_EXEC_FP_RMD160
options VERIFIED_EXEC_FP_SHA512
options VERIFIED_EXEC_FP_SHA384
options VERIFIED_EXEC_FP_SHA256
```

Depending on your operating system version and platform, these may already be enable. Once done, rebuild and reinstall your kernel, see Chapter 34 for further instructions.

If you do not have the Veriexec device `/dev/veriexec`, you can create it manually by running the following command:

```
# cd /dev
# sh MAKEDEV veriexec
```

Chapter 21

Bluetooth on NetBSD

21.1 Introduction

Bluetooth is a digital radio protocol used for short range and low power communications. NetBSD includes support for the Bluetooth protocol stack, and some integration of service profiles into the NetBSD device framework.

The lower layers of the Bluetooth protocol stack pertaining to actual radio links between devices are handled inside the Bluetooth Controller, which communicates with the Host computer using the "Host Controller Interface" (HCI) protocol which can be accessed via a raw packet BTPROTO_HCI socket interface.

Most of the Bluetooth protocols or services layer atop the "Link Layer Control and Adaptation Protocol" (L2CAP), which can be accessed via a BTPROTO_L2CAP socket interface. This provides sequential packet connections to remote devices, with up to 64k channels. When an L2CAP channel is opened, the protocol or service that is required is identified by a "Protocol/Service Multiplexer" (PSM) value.

Service Discovery in the Bluetooth environment is provided for by the sdp(3) library functions and the sdpd(8) daemon, which keeps a database of locally registered services and makes the information available to remote devices performing queries. The sdpquery(1) tool can be used to query local and remote service databases.

Security on Bluetooth links can be enabled by encryption and authentication options to btconfig(8) which apply to all baseband links that a controller makes, or encryption and authentication can be enabled for individual RFCOMM and L2CAP links as required. When authentication is requested, a PIN is presented by each side (generally entered by the operator, some limited input devices have a fixed PIN). The controller uses this PIN to generate a Link Key and reports this to the Host which may be asked to produce it to authenticate subsequent connections. On NetBSD, the bthcid(8) daemon is responsible for storing link keys and responding to Link Key Requests, and also provides an interface to allow unprivileged users to specify a PIN with a PIN client, such as btpin(1).

21.2 Supported Hardware

Because Bluetooth controllers normally use the standard HCI protocol as specified in the "Bluetooth 2.0 Core" documentation to communicate with the host, the NetBSD Bluetooth stack is compatible with most controllers, only requiring an interface driver:

- bcsp(4) provides a tty(4) line discipline to send and receive BlueCore Serial Protocol packets over a serial line as described in the "BlueCore Serial Protocol (BCSP)" specification.
- bt3c(4) provides an interface to the 3Com Bluetooth PC Card, model 3CRWB6096-A.

- btbc(4) provides support for the AnyCom BlueCard (LSE041, LSE039, LSE139) PCMCIA devices.
- btuart(4) provides a tty(4) line discipline to send and receive Bluetooth packets over a serial line as described in the “Bluetooth Host Controller Interface [Transport Layer] specification, Vol 4 part A”.
- sbt(4) provides support for Secure Digital IO Bluetooth adapters.
- ubt(4) interfaces to all USB Bluetooth controllers conforming to the “HCI USB Transport Layer” specification.

If the hardware is supported by the NetBSD Bluetooth stack, autoconfiguration messages will show up in the **dmesg** output, for example:

```
bt3c0 at pcmcia0 function 0: <3COM, 3CRWB60-A, Bluetooth PC Card>

ubt0 at uhub1 port 4 configuration 1 interface 0
ubt0: Cambridge Silicon Radio Bluetooth USB Adapter, rev 2.00/19.58, addr 4

ubt1 at uhub1 port 2 configuration 1 interface 0
ubt1: Broadcom Belkin Bluetooth Device, rev 1.10/0.01, addr 5
```

When support is not already compiled in, it can be added to the kernel configuration file for any platform that supports USB and/or PCMCIA (see Section 19.9), using the following declarations, as required:

```
# Bluetooth Controller and Device support

pseudo-device   bcsp                    # BlueCore Serial Protocol
pseudo-device   btuart                  # Bluetooth HCI UART

# Bluetooth PCMCIA Controllers
bt3c* at pcmcia? function ?              # 3Com 3CRWB6096-A
btbc* at pcmcia? function ?              # AnyCom BlueCard LSE041/039/139

# Bluetooth SDIO Controllers
sbt* at sdmmc?

# Bluetooth USB Controllers
ubt* at uhub? port ?

# Bluetooth Device Hub
bthub* at bcsp?
bthub* at bt3c?
bthub* at btbc?
bthub* at btuart?
bthub* at sbt?
bthub* at ubt?

# Bluetooth HID support
bthidev* at bthub?

# Bluetooth Mouse
btms* at bthidev? reportid ?
wsmouse* at btms? mux 0
```

```
# Bluetooth Keyboard
btkbd* at bthidev? reportid ?
wskbd* at btkbd? console ? mux 1

# Bluetooth Audio support
btsco* at bthub?
```

Some older USB Bluetooth dongles based on the Broadcom BCM2033 chip require firmware to be loaded before they can function, and these devices will be attached to ugen(4). Use the "sysutils/bcmfw" package from the NetBSD Package Collection, to load firmware and enable these.

21.3 System Configuration

To fully enable Bluetooth services on NetBSD, the following line should be added to the `/etc/rc.conf` file.

```
bluetooth=YES
```

and either reboot, or execute the following command:

```
# /etc/rc.d/bluetooth start
```

Configuration of Bluetooth controllers is done with the btconfig(8) program, and the above argument enables only basic functionality, see the manual page for other useful options. The extra options for btconfig on a given device, say utb0, can be set by adding a line for it to the `/etc/rc.conf` file.

```
btconfig_ubt0="name MyComputerName"
```

> **Important:** bthcid(8) *must* be running in order to make authenticated connections with remote devices, and authentication may be requested by either device.

21.4 Human Interface Devices

Support for "Human Interface Devices" (HIDs), which operate using the USB HID protocol over a pair of L2CAP channels is provided by the bthidev(4) driver. Currently, keyboards and mice are catered for, and attach to wscons(4) as normal.

21.4.1 Mice

Bluetooth Mice can be attached to the system with the btms(4) driver, using btdevctl(8).

First, you must discover the BDADDR of the device. This may be printed on the box, but the easiest way is to place the device into discoverable mode and perform a device inquiry with the appropriate controller:

```
% btconfig ubt0 inquiry
Device Discovery on ubt0 .... 1 response
  1: bdaddr 00:14:51:c1:b9:2d (unknown)
   : name "Mighty Mouse"
   : class: [0x002580] Peripheral Mouse <Limited Discoverable>
   : page scan rep mode 0x01
   : page scan period mode 0x02
   : page scan mode 0x00
   : clock offset 6944
```

For ease of use, you may want to add the address to the `/etc/bluetooth/hosts` file, so that you can refer to the mouse by alias:

```
# echo "00:14:51:c1:b9:2d mouse" >>/etc/bluetooth/hosts
```

Now, you can query the mouse, which will likely request authentication before it accepts connections. The fixed PIN should be listed in the documentation, though “0000” is often used. Set the PIN first using the btpin(1) program:

```
% btpin -d ubt0 -a mouse -p 0000
# btdevctl -d ubt0 -a mouse -s HID
local bdaddr: 00:08:1b:8d:ba:6d
remote bdaddr: 00:14:51:c1:b9:2d
link mode: auth
device type: bthidev
control psm: 0x0011
interrupt psm: 0x0013
Collection page=Generic_Desktop usage=Mouse
  Input id=2 size=1 count=1 page=Button usage=Button_1 Variable, logical range 0..1
  Input id=2 size=1 count=1 page=Button usage=Button_2 Variable, logical range 0..1
  Input id=2 size=1 count=1 page=Button usage=Button_3 Variable, logical range 0..1
  Input id=2 size=1 count=1 page=Button usage=Button_4 Variable, logical range 0..1
  Input id=2 size=4 count=1 page=0x0000 usage=0x0000 Const Variable, logical range 0..1
Collection page=Generic_Desktop usage=Pointer
  Input id=2 size=8 count=1 page=Generic_Desktop usage=X Variable Relative, logical range -1
  Input id=2 size=8 count=1 page=Generic_Desktop usage=Y Variable Relative, logical range -1
  Input id=2 size=8 count=1 page=Consumer usage=AC_Pan Variable Relative, logical range -127
  Input id=2 size=8 count=1 page=Generic_Desktop usage=Wheel Variable Relative, logical rang
End collection
  Input id=2 size=8 count=1 page=0x00ff usage=0x00c0 Variable, logical range -127..127
Feature id=71 size=8 count=1 page=0x0006 usage=0x0020 Variable NoPref Volatile, logical rang
End collection
```

This tells you that the mouse has responded to an SDP query, and the device capabilities are shown. Note that authentication is enabled by default for Bluetooth mice. You may now attach to the system:

```
# btdevctl -d ubt0 -a mouse -s HID -A
```

which should generate some messages on the system console:

```
bthidev0 at bthub0 remote-bdaddr 00:14:51:c1:b9:2d link-mode auth
btms0 at bthidev1 reportid 2: 4 buttons, W and Z dirs.
wsmouse1 at btms0 mux 0
bthidev1: reportid 71 not configured
bthidev1: connected
```

and the mouse should work.

The device capabilities are cached by btdevctl(8), and to reattach the mouse at system startup, place an entry in `/etc/bluetooth/btdevctl.conf`. The bthidev(4) driver will attempt to connect once, though mice will usually be sleeping and may require a tap on the shoulder to awaken, in which case they should initiate the connection to the host computer.

21.4.2 Keyboards

Bluetooth Keyboards can be attached to the system with the btkbd(4) driver, using btdevctl(8).

First, you must discover the BDADDR of the device. This may be printed on the box, but the easiest way is to place the device into discoverable mode and perform a device inquiry with the appropriate controller:

```
% btconfig ubt0 inquiry
Device Discovery on ubt0 .... 1 response
  1: bdaddr 00:0a:95:45:a4:a0 (unknown)
   : name "Apple Wireless Keyboard"
   : class: [0x002540] Peripheral Keyboard <Limited Discoverable>
   : page scan rep mode 0x01
   : page scan period mode 0x00
   : page scan mode 0x00
   : clock offset 18604
```

For ease of use, you may want to add the address to the `/etc/bluetooth/hosts` file, so that you can refer to the keyboard by alias:

```
# echo "00:0a:95:45:a4:a0 keyboard" >>/etc/bluetooth/hosts
```

Now, you can query the keyboard, which will likely request authentication before it accepts connections. The PIN will need to be entered on the keyboard, and we can generate a random PIN, using the btpin(1) program.

```
% btpin -d ubt0 -a keyboard -r -l 8
PIN: 18799632
# btdevctl -d ubt0 -a keyboard -s HID

    < ENTER PIN ON BLUETOOTH KEYBOARD NOW >

local bdaddr: 00:08:1b:8d:ba:6d
remote bdaddr: 00:0a:95:45:a4:a0
link mode: encrypt
```

```
device type: bthidev
control psm: 0x0011
interrupt psm: 0x0013
Collection page=Generic_Desktop usage=Keyboard
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_LeftControl Variable, logical range
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_LeftShift Variable, logical range 0
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_LeftAlt Variable, logical range 0..
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_Left_GUI Variable, logical range 0.
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_RightControl Variable, logical rang
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_RightShift Variable, logical range
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_RightAlt Variable, logical range 0.
  Input id=1 size=1 count=1 page=Keyboard usage=Keyboard_Right_GUI Variable, logical range 0
  Input id=1 size=8 count=1 page=0x0000 usage=0x0000 Const, logical range 0..1
 Output id=1 size=1 count=1 page=LEDs usage=Num_Lock Variable, logical range 0..1
 Output id=1 size=1 count=1 page=LEDs usage=Caps_Lock Variable, logical range 0..1
 Output id=1 size=1 count=1 page=LEDs usage=Scroll_Lock Variable, logical range 0..1
 Output id=1 size=1 count=1 page=LEDs usage=Compose Variable, logical range 0..1
 Output id=1 size=1 count=1 page=LEDs usage=Kana Variable, logical range 0..1
 Output id=1 size=3 count=1 page=0x0000 usage=0x0000 Const, logical range 0..1
  Input id=1 size=8 count=6 page=Keyboard usage=No_Event, logical range 0..255
  Input id=1 size=1 count=1 page=Consumer usage=Eject Variable Relative, logical range 0..1
  Input id=1 size=1 count=1 page=Consumer usage=Mute Variable Relative, logical range 0..1
  Input id=1 size=1 count=1 page=Consumer usage=Volume_Up Variable, logical range 0..1
  Input id=1 size=1 count=1 page=Consumer usage=Volume_Down Variable, logical range 0..1
  Input id=1 size=1 count=4 page=0x0000 usage=0x0000 Const, logical range 0..1
End collection
```

This tells you that the keyboard has responded to an SDP query, and the device capabilities are shown. Note that encryption is enabled by default, since encrypted connection support is mandatory for Bluetooth keyboards. You may now attach to the system:

```
# btdevctl -d ubt0 -a keyboard -s HID -A
```

which should generate some messages on the system console:

```
bthidev1 at bthub0 remote-bdaddr 00:0a:95:45:a4:a0 link-mode encrypt
btkbd0 at bthidev0 reportid 1
wskbd1 at btkbd0 mux 1
wskbd1: connecting to wsdisplay0
bthidev1: connected
```

and the keyboard should work.

The device capabilities are cached by btdevctl(8), and to reattach the keyboard at system startup, place an entry in `/etc/bluetooth/btdevctl.conf`. The bthidev(4) driver will attempt to connect once when attached, but if the keyboard is not available at that time, you may find that pressing a key will cause it to wake up and initiate a connection to the last paired host.

21.5 Personal Area Networking

Personal Area Networking services over Bluetooth are provided by the btpand(8) daemon which can assume all roles from the PAN profile and connects remote devices to the system through a tap(4) virtual Ethernet interface.

21.5.1 Personal Area Networking User

The "Personal Area Networking User" role is the client that accesses Network services on another device. For instance, in order to connect to the Internet via a smart phone with the NAP profile, make sure that the phone is discoverable, then:

```
% btconfig ubt0 inquiry
Device Discovery from device: ubt0 .... 1 response
  1: bdaddr 00:17:83:30:bd:5e (unknown)
   : name "HTC Touch"
   : class: [0x5a020c] Smart Phone <Networking> <Capturing> <Object Transfer>
 <Telephony>
   : page scan rep mode 0x01
   : clock offset 9769
   : rssi -42

# echo "00:17:83:30:bd:5e phone" >>/etc/bluetooth/hosts
```

You will see that the phone should have the <Networking> flag set in the Class of Device. Checking for the NAP service:

```
% sdpquery -a phone search NAP
ServiceRecordHandle: 0x00010000
ServiceClassIDList:
    Network Access Point
ProtocolDescriptorList:
    L2CAP (PSM 0x000f)
    BNEP (v1.0; IPv4, ARP, IPv6)
LanguageBaseAttributeIDList:
    en.UTF-8 base 0x0100
BluetoothProfileDescriptorList:
    Network Access Point, v1.0
ServiceName: "Network Access Point"
ServiceDescription: "Bluetooth NAP Service"
SecurityDescription: None
NetAccessType: 100Mb Ethernet
MaxNetAccessRate: 100000
```

reveals that the NAP service is available and that it provides IPv4, ARP and IPv6 protocols.

Most likely, the phone will request authentication before it allows connections to the NAP service, so before you make the first connection you may need to provide a PIN, which can be randomly generated. Then start btpand(8):

```
% btpin -d ubt0 -a phone -r -l 6
```

```
PIN: 862048
# btpand -d ubt0 -a phone -s NAP

    < ENTER PIN ON PHONE NOW >

Searching for NAP service at 00:17:83:30:bd:5e
Found PSM 15 for service NAP
Opening connection to service 0x1116 at 00:17:83:30:bd:5e
Using interface tap0 with addr 00:10:60:e1:50:3d
```

Finally, you will need to configure the tap(4) interface, but the phone should have a DHCP server so dhcpcd(8) will do that for you.

```
# dhcpcd tap0
```

Now you can surf the World Wide Web, but watch your data usage unless you have a comprehensive data plan.

21.6 Serial Connections

Serial connections over Bluetooth are provided for by the RFCOMM protocol, which provides up to 30 channels multiplexed over a single L2CAP channel. This streamed data protocol can be accessed using the BTPROTO_RFCOMM socket interface, or via the rfcomm_sppd(1) program.

For instance, you can make a serial connection to the "Dial Up Networking" (DUN) service of a mobile phone in order to connect to the Internet with PPP. First you should discover the BDADDR of the phone, and add this to your `/etc/bluetooth/hosts` for ease of use. Place the phone into Discoverable mode, and perform an inquiry from the appropriate controller:

```
% btconfig ubt0 inquiry
Device Discovery from device: ubt0 ..... 1 response
  1: bdaddr 00:16:bc:00:e8:48 (unknown)
   : name "Nokia 6103"
   : class: [0x520204] Cellular Phone <Networking> <Object Transfer> <Telephony>
   : page scan rep mode 0x01
   : page scan period mode 0x02
   : page scan mode 0x00
   : clock offset 30269

# echo "00:16:bc:00:e8:48 phone" >>/etc/bluetooth/hosts
```

Now, you can query the phone to confirm that it supports the DUN profile:

```
% sdpquery -d ubt0 -a phone search DUN
ServiceRecordHandle: 0x00010003
ServiceClassIDList:
    Dialup Networking
    Generic Networking
```

```
ProtocolDescriptorList:
    L2CAP
    RFCOMM (channel 1)
BrowseGroupList:
    Public Browse Root
LanguageBaseAttributeIDList:
    en.UTF-8 base 0x0100
BluetoothProfileDescriptorList:
    Dialup Networking, v1.0
ServiceName: "Dial-up networking"
```

Most likely, the phone will request authentication before it allows connections to the DUN service, so before you make the first connection you may need to provide a PIN, which can be randomly generated. You can use **rfcomm_sppd** in stdio mode to check that the connection is working ok, press `^C` to disconnect and return to the shell, for example:

```
% btpin -d ubt0 -a phone -r -l 6
PIN: 904046
% rfcomm_sppd -d ubt0 -a phone -s DUN

    < ENTER PIN ON PHONE NOW >

rfcomm_sppd[24635]: Starting on stdio...
at
OK
ati
Nokia

OK
ati3
Nokia 6103

OK
at&v
ACTIVE PROFILE:
E1 Q0 V1 X5 &C1 &D2 &S0 &Y0
+CMEE=0 +CSTA=129 +CBST=0,0,1 +CRLP=61,61,48,6 +CR=0 +CRC=0 +CLIP=0,2
+CLIR=0,2 +CSNS=0 +CVHU=1 +DS=0,0,2048,32 +DR=0 +ILRR=0
+CHSN=0,0,0,0 +CHSR=0 +CPBS="SM"
S00:000 S01:000 S02:043 S03:013 S04:010 S05:008 S07:060 S08:002
S10:100 S12:050 S25:000

OK
^C
rfcomm_sppd[24635]: Completed on stdio
```

To have pppd(8) connect to the DUN service of your phone automatically when making outbound connections, add the following line to the `/etc/ppp/options` file in place of the normal tty declaration:

```
pty "rfcomm_sppd -d ubt0 -a phone -s DUN -m encrypt"
```

21.7 Audio

Isochronous (SCO) Audio connections may be created on a baseband radio link using either the BTPROTO_SCO socket interface, or the btsco(4) audio device driver. While the specification says that up to three such links can be made between devices, the current Bluetooth stack can only handle one with any dignity.

> **Important:** When using SCO Audio with USB Bluetooth controllers, you will need to enable isochronous data, and calculate the MTU that the device will use, see ubt(4) and btconfig(8).

> **Note:** SCO Audio does not work properly with the bt3c(4) driver, use a USB controller for best results.

21.7.1 SCO Audio Headsets

Audio connections to Bluetooth Headsets are possible using the btsco(4) audio driver, and the bthset(1) program. First, you need to discover the BDADDR of the headset, and will probably wish to make an alias in your `/etc/bluetooth/hosts` file for ease of use. Place the headset into discoverable mode and perform an inquiry with the appropriate controller:

```
% btconfig ubt0 inquiry
Device Discovery from device: ubt0 ..... 1 response
 1: bdaddr 00:07:a4:23:10:83 (unknown)
  : name "JABRA 250"
  : class: [0x200404] Wearable Headset <Audio>
  : page scan rep mode 0x01
  : page scan period mode 0x00
  : page scan mode 0x00
  : clock offset 147

# echo "00:07:a4:23:10:83 headset" >>/etc/bluetooth/hosts
```

You will need to pair with the headset the first time you connect, the fixed PIN should be listed in the manual (often, “0000” is used). btdevctl(8) will query the device and attach the btsco(4) audio driver.

```
% btpin -d ubt0 -a headset -p 0000
# btdevctl -d ubt0 -a headset -s HSET -A
local bdaddr: 00:08:1b:8d:ba:6d
remote bdaddr: 00:07:a4:23:10:83
link mode: none
device type: btsco
mode: connect
channel: 1
```

which should generate some messages on the system console:

```
btsco0 at bthub0 remote-bdaddr 00:07:a4:23:10:83 channel 1
```

```
audio1 at btsco0: full duplex
```

In order to use the audio device, you will need to open a control connection with bthset(1) which conveys volume information to the mixer device.

```
% bthset -m /dev/mixer1 -v
Headset Info:
        mixer: /dev/mixer1
        laddr: 00:08:1b:8d:ba:6d
        raddr: 00:07:a4:23:10:83
        channel: 1
        vgs.dev: 0, vgm.dev: 1
```

and you should now be able to transfer 8khz samples to and from `/dev/audio1` using any program that supports audio, such as audioplay(1) or audiorecord(1). Adjusting the mixer values should work when playing though you may find that when opening a connection, the headset will reset the volume to the last known settings.

```
% audiorecord -d /dev/audio1 voice.au

        < TALK NONSENSE NOW >

^C
% audioplay -d /dev/audio voice.au

        < THATS REALLY WHAT YOU SOUND LIKE >

% audioplay -d /dev/audio1 voice.au

        < IN THE HEADSET >
```

The device capabilities are cached by btdevctl(8), and to reattach the btsco(4) driver at system startup, add an entry to `/etc/bluetooth/btdevctl.conf`.

21.7.2 SCO Audio Handsfree

Audio connections to Bluetooth mobile phones using the Handsfree profile are possible with the “comms/bthfp” program from the NetBSD Package Collection.

First, you need to discover the BDADDR of the phone, and will probably wish to make an alias in your `/etc/bluetooth/hosts` file for ease of use. Place the phone into discoverable mode and perform an inquiry with the appropriate controller:

```
% btconfig ubt0 inquiry
Device Discovery from device: ubt0 ..... 1 response
  1: bdaddr 00:16:bc:00:e8:48 (unknown)
   : name "Nokia 6103"
   : class: [0x520204] Cellular Phone <Networking;gt; <Object Transfer;gt; <Telephony;gt;
   : page scan rep mode 0x01
```

```
   : page scan period mode 0x02
   : page scan mode 0x00
   : clock offset 10131

# echo "00:16:bc:00:e8:48 phone" >>/etc/bluetooth/hosts
```

Now, you should be able to query the phone to confirm that it supports the Handsfree profile:

```
% sdpquery -d ubt0 -a phone search HF
ServiceRecordHandle: 0x00010006
ServiceClassIDList:
    Handsfree Audio Gateway
    Generic Audio
ProtocolDescriptorList:
    L2CAP
    RFCOMM (channel 13)
BrowseGroupList:
    Public Browse Root
LanguageBaseAttributeIDList:
    en.UTF-8 base 0x0100
BluetoothProfileDescriptorList:
    Handsfree, v1.5
ServiceName: "Voice Gateway"
Network: Ability to reject a call
SupportedFeatures:
    3 Way Calling
    Echo Cancellation/Noise Reduction
    Voice Recognition
    In-band Ring Tone
```

and you will be able to use the bthfp program to access the Handsfree profile. The first time you connect, you may need to use a PIN to pair with the phone, which can be generated randomly by btpin(1):

```
% btpin -d ubt0 -a phone -r -l 6
PIN: 349163
% bthfp -d ubt0 -a phone -v

      < ENTER PIN ON PHONE NOW >
Handsfree channel: 13
Press ? for commands
Connecting.. ok
< AT+BRSF=20
> +BRSF: 47
Features: [0x002f] <3 way calling> <EC/NR> <Voice Recognition> <In-band ringtone> <reject ab
> OK
< AT+CIND=?
> +CIND: ("call",(0,1)),("service",(0,1)),("call_setup",(0-3)),("callsetup",(0-3))
> OK
< AT+CIND?
> +CIND: 0,1,0,0
> OK
```

```
< AT+CMER=3,0,0,1
> OK
< AT+CLIP=1
> OK
Service Level established
```

When the phone rings, just press **a** to answer, and audio should be routed through the `/dev/audio` device. Note that you will need a microphone connected in order to speak to the remote party.

21.8 Object Exchange

NetBSD does not currently have any native OBEX capability, see the “comms/obexapp” or “comms/obexftp” packages from the NetBSD Package Collection.

21.9 Troubleshooting

When nothing seems to be happening, it may be useful to try the hcidump program from the “sysutils/netbt-hcidump” package in the NetBSD Package Collection. This has the capability to dump packets entering and leaving Bluetooth controllers on NetBSD, which is greatly helpful in pinpointing problems.

Chapter 22

Miscellaneous operations

This chapter collects various topics, in sparse order

22.1 Installing the boot manager

Sysinst, the NetBSD installation program usually installs the NetBSD boot manager on the hard disk. The boot manager can also be installed or reconfigured at a later time, if needed, with the **fdisk** command. For example:

```
# fdisk -B wd0
```

If NetBSD doesn't boot from the hard disk, you can boot it from the installation floppy and start the kernel on the hard disk. Insert the installation disk and, at the boot prompt, give the following command:

```
> boot wd0a:netbsd
```

This boots the kernel on the hard disk (use the correct device, for example sd0a for a SCSI disk).

> **Note:** Sometimes **fdisk -B** doesn't give the expected result (at least it happened to me), probably if you install/remove other operating systems. In this case, try running **fdisk -i** and then run again **fdisk** from NetBSD.

22.2 Deleting the disklabel

Though this is not an operation that you need to perform frequently, it can be useful to know how to do it in case of need. Please be sure to know exactly what you are doing before performing this kind of operation. For example:

```
# dd if=/dev/zero of=/dev/rwd0c bs=8k count=1
```

The previous command deletes the disklabel (not the MBR partition table). To completely delete the disk, the whole device `rwd0d` must be used. For example:

```
# dd if=/dev/zero of=/dev/rwd0d bs=8k
```

The commands above will only work as expected on the i386 and amd64 ports of NetBSD. On other ports, the whole device will end in c, not d (e.g. `rwd0c`).

22.3 Speaker

To output a sound from the speaker (for example at the end of a long script) the *spkr* driver can be used in the kernel config, which is mapped on `/dev/speaker`. For example:

```
echo 'BPBPBPBPBP' > /dev/speaker
```

Note: The *spkr* device is not enabled in the generic kernel; a customized kernel is needed.

22.4 Forgot root password?

If you forget root's password, not all is lost and you can still recover the system with the following steps: boot single user, mount / and change root's password. In detail:

1. Boot single user: when the boot prompt appears and the five seconds countdown starts, give the following command:

   ```
   > boot -s
   ```

2. At the following prompt

   ```
   Enter pathname of shell or RETURN for sh:
   ```

   press Enter.

3. Write the following commands:

   ```
   # fsck -y /
   # mount -u /
   # fsck -y /usr
   # mount /usr
   ```

4. Change root's password:

   ```
   # passwd root
   Changing local password for root.
   New password: (not echoed)
   Retype new password: (not echoed)
   #
   ```

5. Exit the shell to go to multiuser mode.

   ```
   # exit
   ```

If you get the error "Password file is busy", please see the section below.

22.5 Password file is busy?

If you try to modify a password and you get the mysterious message "Password file is busy", it probably means that the file `/etc/ptmp` has not been deleted from the system. This file is a temporary copy of the `/etc/master.passwd` file; check that you are not losing important information and then delete it:

```
# rm /etc/ptmp
```

Note: If the file `/etc/ptmp` exists you can also receive a warning message at system startup. For example:

```
root: password file may be incorrect - /etc/ptmp exists
```

22.6 Adding a new hard disk

This section describes how to add a new hard disk to an already working NetBSD system. In the following example a new SCSI controller and a new hard disk, connected to the controller, will be added. If you don't need to add a new controller, skip the relevant part and go to the hard disk configuration. The installation of an IDE hard disk is identical; only the device name will be different (`wd#` instead of `sd#`).

As always, before buying new hardware, consult the hardware compatibility list of NetBSD and make sure that the new device is supported by the system.

When the SCSI controller has been physically installed in the system and the new hard disk has been connected, it's time to restart the computer and check that the device is correctly detected, using the **dmesg** command. This is the sample output for an NCR-875 controller:

```
ncr0 at pci0 dev 15 function 0: ncr 53c875 fast20 wide scsi
ncr0: interrupting at irq 10
ncr0: minsync=12, maxsync=137, maxoffs=16, 128 dwords burst, large dma fifo
ncr0: single-ended, open drain IRQ driver, using on-chip SRAM
ncr0: restart (scsi reset).
scsibus0 at ncr0: 16 targets, 8 luns per target
sd0(ncr0:2:0): 20.0 MB/s (50 ns, offset 15)
sd0: 2063MB, 8188 cyl, 3 head, 172 sec, 512 bytes/sect x 4226725 sectors
```

If the device doesn't appear in the output, check that it is supported by the kernel that you are using; if necessary, compile a customized kernel (see Chapter 34).

Now the partitions can be created using the **fdisk** command. First, check the current status of the disk:

```
# fdisk sd0
NetBSD disklabel disk geometry:
cylinders: 8188 heads: 3 sectors/track: 172 (516 sectors/cylinder)

BIOS disk geometry:
cylinders: 524 heads: 128 sectors/track: 63 (8064 sectors/cylinder)

Partition table:
0: sysid 6 (Primary 'big' DOS, 16-bit FAT (> 32MB))
    start 63, size 4225473 (2063 MB), flag 0x0
        beg: cylinder    0, head   1, sector  1
        end: cylinder  523, head 127, sector 63
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
```

In this example the hard disk already contains a DOS partition, which will be deleted and replaced with a native NetBSD partition. The command **fdisk -u sd0** allows to modify interactively the partitions. The modified data will be written on the disk only before exiting and fdisk will request a confirmation before writing, so you can work relaxedly.

Disk geometries

The geometry of the disk reported by fdisk can appear confusing. Dmesg reports 4226725 sectors with 8188/3/172 for C/H/S, but 8188*3*172 gives 4225008 and not 4226725. What happens is that most modern disks don't have a fixed geometry and the number of sectors per track changes depending on the cylinder: the only interesting parameter is the number of sectors. The disk reports the C/H/S values but it's a fictitious geometry: the value 172 is the result of the total number of sectors (4226725) divided by 8188 and then by 3.

To make things more confusing, the BIOS uses yet another "fake" geometry (C/H/S 524/128/63) which gives a total of 4225536, a value which is a better approximation to the real one than 425008. To partition the disk we will use the BIOS geometry, to maintain compatibility with other operating systems, although we will lose some sectors (4226725 - 4225536 = 1189 sectors = 594 KB).

To create the BIOS partitions the command **fdisk -u** must be used; the result is the following:

```
Partition table:
0: sysid 169 (NetBSD)
    start 63, size 4225473 (2063 MB), flag 0x0
        beg: cylinder    0, head   1, sector  1
        end: cylinder  523, head 127, sector 63
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
```

Now it's time to create the disklabel for the NetBSD partition. The correct steps to do this are:

```
# disklabel sd0 > tempfile
# vi tempfile
# disklabel -R -r sd0 tempfile
```

If you try to create the disklabel directly with

```
# disklabel -e sd0
```

you get the following message

```
disklabel: ioctl DIOCWDINFO: No disk label on disk;
use "disklabel -I" to install initial label
```

because the disklabel does not yet exist on the disk.

Now we create some disklabel partitions, editing the `tempfile` as already explained. The result is:

```
#       size   offset    fstype [fsize bsize   cpg]
a:   2048004       63    4.2BSD   1024  8192    16 # (Cyl.   0*- 3969*)
```

```
c:  4226662       63   unused      0     0       # (Cyl.  0*- 8191*)
d:  4226725        0   unused      0     0       # (Cyl.  0 - 8191*)
e:  2178658  2048067   4.2BSD   1024  8192    16 # (Cyl.  3969*- 8191*)
```

> **Note:** When the disklabel has been created it is possible to optimize it studying the output of the command **newfs -N /dev/rsd0a**, which warns about the existence of unallocated sectors at the end of a disklabel partition. The values reported by newfs can be used to adjust the sizes of the partitions with an iterative process.

The final operation is the creation of the file systems for the newly defined partitions (*a* and *e*).

```
# newfs /dev/rsd0a
# newfs /dev/rsd0e
```

The disk is now ready for usage, and the two partitions can be mounted. For example:

```
# mount /dev/sd0a /mnt
```

If this succeeds, you may want to put an entry for the partition into `/etc/fstab`.

22.7 How to rebuild the devices in /dev

First shutdown to single user, partitions still mounted "rw" (read-write); You can do that by just typing **shutdown now** while you are in multi user mode, or reboot with the `-s` option and make `/` and `/dev` read-writable by doing.

```
# mount -u /
# mount -u /dev
```

Then:

```
# mkdir /newdev
# cd /newdev
# cp /dev/MAKEDEV* .
# sh ./MAKEDEV all
# cd /
# mv dev olddev
# mv newdev dev
# rm -r olddev
```

Or if you fetched all the sources in `/usr/src`:

```
# mkdir /newdev
# cd /newdev
# cp /usr/src/etc/MAKEDEV.local .
# ( cd /usr/src/etc ; make MAKEDEV )
# cp /usr/src/etc/obj*/MAKEDEV .
# sh ./MAKEDEV all
# cd /
# mv dev olddev; mv newdev dev
# rm -r olddev
```

You can determine $arch by

```
# uname -m
```

or

```
# sysctl hw.machine_arch
```

IV. Networking and related issues

Chapter 23

Introduction to TCP/IP Networking

23.1 Audience

This section explains various aspects of networking. It is intended to help people with little knowledge about networks to get started. It is divided into three big parts. We start by giving a general overview of how networking works and introduce the basic concepts. Then we go into details for setting up various types of networking in the second parts, and the third part of the networking section covers a number of "advanced" topics that go beyond the basic operation as introduced in the first two sections.

The reader is assumed to know about basic system administration tasks: how to become root, edit files, change permissions, stop processes, etc. See the other chapters of this NetBSD guide and, e.g., AeleenFrisch for further information on this topic. Besides that, you should know how to handle the utilities we're going to set up here, i.e., you should know how to use telnet, FTP, ... I will not explain the basic features of those utilities, please refer to the appropriate manual pages, the references listed or, of course, the other parts of this document instead.

This introduction to TCP/IP networking was written with the intention in mind to give starters a basic knowledge. If you really want to know what it's all about, read CraigHunt. This book does not only cover the basics, but goes on and explains all the concepts, services and how to set them up in detail. It's great, I love it! :-)

23.2 Supported Networking Protocols

There are several protocol suites supported by NetBSD, most of which were inherited from NetBSD's predecessor, 4.4BSD, and subsequently enhanced and improved. The first and most important one today is DARPA's Transmission Control Protocol/Internet Protocol (TCP/IP). Other protocol suites available in NetBSD include the Stream Control Transmission Protocol (SCTP), and Apple's AppleTalk protocol suite. They are only used in some special applications.

Today, TCP/IP is the most widespread protocol of the ones mentioned above. It is implemented on almost every hardware and operating system, and it is also the most-used protocol in heterogenous environments. So, if you just want to connect your computer running NetBSD to some other machine at home or you want to integrate it into your company's or university's network, TCP/IP is the right choice.

23.3 Supported Media

The TCP/IP protocol stack behaves the same regardless of the underlying media used, and NetBSD supports a wide range of these, among them are Ethernet (10/100Mb/1/10/40/100Gb), USB, serial line and FireWire (IEEE 1394).

23.3.1 Ethernet

Ethernet is the medium commonly used to build local area networks (LANs) of interconnected machines within a limited area such as an office, company or university campus. Ethernet is based on a bus structure to which many machines can connect to, and communication always happens between two nodes at a time. When two or more nodes want to talk at the same time, both will restart communication after some timeout. The technical term for this is CSMA/CD (Carrier Sense w/ Multiple Access and Collision Detection).

Initially, Ethernet hardware consisted of a thick (yellow) cable that machines tapped into using special connectors that poked through the cable's outer shielding. The successor of this was called 10base5, which used BNC-type connectors for tapping in special T-connectors and terminators on both ends of the bus. Today, ethernet is mostly used with twisted pair lines which are used in a collapsed bus system that are contained in switches or hubs. The twisted pair lines give this type of media its name - 10baseT for 10 Mbit/s networks, and 100baseT for 100 MBit/s ones. In switched environments there's also the distinction if communication between the node and the switch can happen in half- or in full duplex mode.

23.3.2 IEEE 802.11 (Wi-Fi)

IEEE 802.11 (commonly known as Wi-Fi) is the primary means by which mobile devices are connected over a Local Area Network.

IEEE 802.11 primarily operates over two radio bands, 2.4 GHz (modes b, g, and n), and 5 GHz (modes a, and ac). The 2.4 GHz band is typically more congested, but loses less performance through walls and other barriers.

The main protocol used for securing Wi-Fi connections is WPA (Wi-Fi Protected Access). In a typical configuration, this encrypts the connection between the access point and its clients with a password.

23.3.3 Serial Line

The disadvantage of a serial connection is that it's slower than other methods. NetBSD can use at most 115200 bit/s, making it a lot slower than e.g. Ethernet's minimum 10 Mbit/s.

There are two possible protocols to connect a host running NetBSD to another host using a serial line (possibly over a phone-line):

- Serial Line IP (SLIP)
- Point to Point Protocol (PPP)

The choice here depends on whether you use a dial-up connection through a modem or if you use a static connection (null-modem or leased line). If you dial up for your IP connection, it's wise to use PPP as it offers some possibilities to auto-negotiate IP-addresses and routes, which can be quite painful to do by hand. If you want to connect to another machine which is directly connected, use SLIP, as this is supported by about every operating system and more easy to set up with fixed addresses and routes.

PPP on a direct connection is a bit difficult to setup, as it's easy to timeout the initial handshake; with SLIP, there's no such initial handshake, i.e. you start up one side, and when the other site has its first packet, it will send it over the line.

RFC1331 and RFC1332 describe PPP and TCP/IP over PPP. SLIP is defined in RFC1055.

23.4 TCP/IP Address Format

TCP/IP uses 4-byte (32-bit) addresses in the current implementations (IPv4), also called IP-numbers (Internet-Protocol numbers), to address hosts.

TCP/IP allows any two machines to communicate directly. To permit this all hosts on a given network must have a unique IP address. To assure this, IP addresses are administrated by one central organisation, the InterNIC. They give certain ranges of addresses (network-addresses) directly to sites which want to participate in the internet or to internet-providers, which give the addresses to their customers.

If your university or company is connected to the Internet, it has (at least) one such network-address for its own use, usually not assigned by the InterNIC directly, but rather through an Internet Service Provider (ISP).

If you just want to run your private network at home, see below on how to "build" your own IP addresses. However, if you want to connect your machine to the (real :-) Internet, you should get an IP addresses from your local network-administrator or -provider.

IP addresses are usually written in "dotted quad"-notation - the four bytes are written down in decimal (most significant byte first), separated by dots. For example, 132.199.15.99 would be a valid address. Another way to write down IP-addresses would be as one 32-bit hex-word, e.g. 0x84c70f63. This is not as convenient as the dotted-quad, but quite useful at times, too. (See below!)

Being assigned a network means nothing else but setting some of the above-mentioned 32 address-bits to certain values. These bits that are used for identifying the network are called network-bits. The remaining bits can be used to address hosts on that network, therefore they are called host-bits. Figure 23-1 illustrates the separation.

Figure 23-1. IPv4-addresses are divided into more significant network- and less significant hostbits

n netbits	32−n hostbits

In the above example, the network-address is 132.199.0.0 (host-bits are set to 0 in network-addresses) and the host's address is 15.99 on that network.

How do you know that the host's address is 16 bit wide? Well, this is assigned by the provider from which you get your network-addresses. In the classless inter-domain routing (CIDR) used today, host fields are usually between as little as 2 to 16 bits wide, and the number of network-bits is written after the network address, separated by a "/", e.g. 132.199.0.0/16 tells that the network in question has 16 network-bits. When talking about the "size" of a network, it's usual to only talk about it as "/16", "/24", etc.

Before CIDR was used, there used to be four classes of networks. Each one starts with a certain bit-pattern identifying it. Here are the four classes:

- Class A starts with "0" as most significant bit. The next seven bits of a class A address identify the network, the remaining 24 bit can be used to address hosts. So, within one class A network there can be 2^{24} hosts. It's not very likely that you (or your university, or company, or whatever) will get a whole class A address.

  The CIDR notation for a class A network with its eight network bits is an "/8".
- Class B starts with "10" as most significant bits. The next 14 bits are used for the networks address and the remaining 16 bits can be used to address more than 65000 hosts. Class B addresses are very rarely given out today, they used to be common for companies and universities before IPv4 address space went scarce.

  The CIDR notation for a class B network with its 16 network bits is an "/16".

  Returning to our above example, you can see that 132.199.15.99 (or 0x84c70f63, which is more appropriate here!) is on a class B network, as 0x84... = **10**00... (base 2).

  Therefore, the address 132.199.15.99 can be split into an network-address of 132.199.0.0 and a host-address of 15.99.
- Class C is identified by the MSBs being "110", allowing only 256 (actually: only 254, see below) hosts on each of the 2^{21} possible class C networks. Class C addresses are usually found at (small) companies.

  The CIDR notation for a class C network with its 24 network bits is an "/24".
- There are also other addresses, starting with "111". Those are used for special purposes (e. g. multicast-addresses) and are not of interest here.

Please note that the bits which are used for identifying the network-class are part of the network-address.

When separating host-addresses from network-addresses, the "netmask" comes in handy. In this mask, all the network-bits are set to "1", the host-bits are "0". Thus, putting together IP-address and netmask with a logical AND-function, the network-address remains.

To continue our example, 255.255.0.0 is a possible netmask for 132.199.15.99. When applying this mask, the network-address 132.199.0.0 remains.

For addresses in CIDR notation, the number of network-bits given also says how many of the most significant bits of the address must be set to "1" to get the netmask for the corresponding network. For classful addressing, every network-class has a fixed default netmask assigned:

- Class A (/8): default-netmask: 255.0.0.0, first byte of address: 1-127
- Class B (/16): default-netmask: 255.255.0.0, first byte of address: 128-191
- Class C (/24): default-netmask: 255.255.255.0, first byte of address: 192-223

Another thing to mention here is the "broadcast-address". When sending to this address, *all* hosts on the corresponding network will receive the message sent. The broadcast address is characterized by having all host-bits set to "1".

Taking 132.199.15.99 with its netmask 255.255.0.0 again, the broadcast-address would result in 132.199.255.255.

You'll ask now: But what if I want a host's address to be all bits "0" or "1"? Well, this doesn't work, as network- and broadcast-address must be present! Because of this, a class B (/16) network can contain at most 2^{16}-2 hosts, a class C (/24) network can hold no more than 2^8-2 = 254 hosts.

Besides all those categories of addresses, there's the special IP-address 127.0.0.1 which always refers to the "local" host, i.e. if you talk to 127.0.0.1 you'll talk to yourself without starting any network-activity. This is sometimes useful to use services installed on your own machine or to play around if you don't have other hosts to put on your network.

Let's put together the things we've introduced in this section:

IP-address

: 32 bit-address, with network- and host-bits.

Network-address

: IP-address with all host bits set to "0".

Netmask

: 32-bit mask with "1" for network- and "0" for host-bits.

Broadcast

: IP-address with all host bits set "1".

localhost's address

: The local host's IP address is always 127.0.0.1.

23.5 Subnetting and Routing

After talking so much about netmasks, network-, host- and other addresses, I have to admit that this is not the whole truth.

Imagine the situation at your university, which usually has a class B (/16) address, allowing it to have up to 2^{16} ~= 65534 hosts on that net. Maybe it would be a nice thing to have all those hosts on one single network, but it's simply not possible due to limitations in the transport media commonly used today.

For example, when using thinwire ethernet, the maximum length of the cable is 185 meters. Even with repeaters in between, which refresh the signals, this is not enough to cover all the locations where machines are located. Besides that, there is a maximum number of 1024 hosts on one ethernet wire, and you'll lose quite a bit of performance if you go to this limit.

So, are you hosed now? Having an address which allows more than 60000 hosts, but being bound to media which allows far less than that limit?

Well, of course not! :-)

The idea is to divide the "big" class B net into several smaller networks, commonly called sub-networks or simply subnets. Those subnets are only allowed to have, say, 254 hosts on them (i.e. you divide one big class B network into several class C networks!).

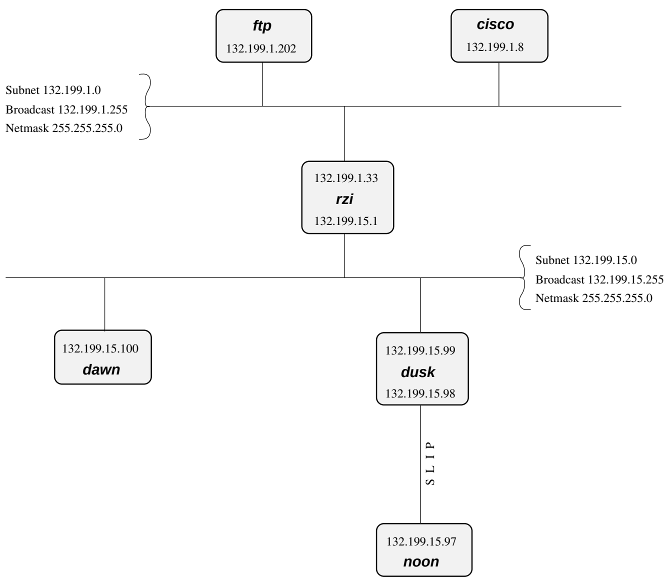
To do this, you adjust your netmask to have more network- and less host-bits on it. This is usually done on a byte-boundary, but you're not forced to do it there. So, commonly your netmask will not be 255.255.0.0 as supposed by a class B network, but it will be set to 255.255.255.0.

In CIDR notation, you now write a "/24" instead of the "/16" to show that 24 bits of the address are used for identifying the network and subnet, instead of the 16 that were used before.

This gives you one additional network-byte to assign to each (physical!) network. All the 254 hosts on that subnet can now talk directly to each other, and you can build 256 such class C nets. This should fit your needs.

To explain this better, let's continue our above example. Say our host 132.199.15.99 (I'll call him dusk from now; we'll talk about assigning hostnames later) has a netmask of 255.255.255.0 and thus is on the subnet 132.199.15.0/24. Let's furthermore introduce some more hosts so we have something to play around with, see Figure 23-2.

Figure 23-2. Our demo-network



In the above network, dusk can talk directly to dawn, as they are both on the same subnet. (There are other hosts attached to the 132.199.15.0/24-subnet but they are not of importance for us now)

But what if dusk wants to talk to a host on another subnet?

Well, the traffic will then go through one or more gateways (routers), which are attached to two subnets. Because of this, a router always has two different addresses, one for each of the subnets it is on. The router is functionally transparent, i.e. you don't have to address it to reach hosts on the "other" side. Instead, you address that host directly and the packets will be routed to it correctly.

Example. Let's say dusk wants to get some files from the local ftp-server. As dusk can't reach ftp directly (because it's on a different subnet), all its packets will be forwarded to its "defaultrouter" rzi (132.199.15.1), which knows where to forward the packets.

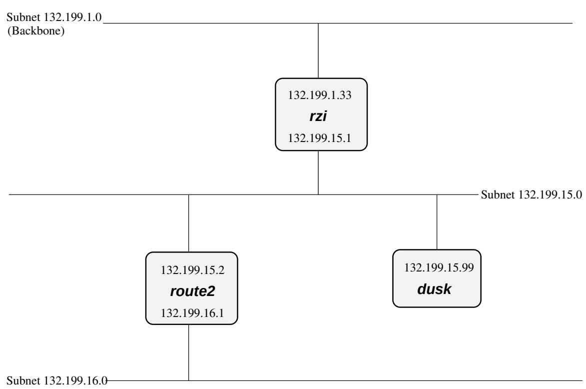
Dusk knows the address of its defaultrouter in its network (rzi, 132.199.15.1), and it will forward any packets to it which are not on the same subnet, i.e. it will forward all IP-packets in which the third address-byte isn't 15.

The (default)router then gives the packets to the appropriate host, as it's also on the FTP-server's network.

In this example, *all* packets are forwarded to the 132.199.1.0/24-network, simply because it's the network's backbone, the most important part of the network, which carries all the traffic that passes between several subnets. Almost all other networks besides 132.199.15.0/24 are attached to the backbone in a similar manner.

But what if we had hooked up another subnet to 132.199.15.0/24 instead of 132.199.1.0/24? Maybe something the situation displayed in Figure 23-3.

Figure 23-3. Attaching one subnet to another one



When we now want to reach a host which is located in the 132.199.16.0/24-subnet from dusk, it won't work routing it to rzi, but you'll have to send it directly to route2 (132.199.15.2). Dusk will have to know to forward those packets to route2 and send all the others to rzi.

When configuring dusk, you tell it to forward all packets for the 132.199.16.0/24-subnet to route2, and all others to rzi. Instead of specifying this default as 132.199.1.0/24, 132.199.2.0/24, etc., 0.0.0.0 can be used to set the default-route.

Returning to Figure 23-2, there's a similar problem when dawn wants to send to noon, which is connected to dusk via a serial line running. When looking at the IP-addresses, noon seems to be attached to the 132.199.15.0-network, but it isn't really. Instead, dusk is used as gateway, and dawn will have to send its packets to dusk, which will forward them to noon then. The way dusk is forced into accepting packets that aren't destined at it but for a different host (noon) instead is called "proxy arp".

The same goes when hosts from other subnets want to send to noon. They have to send their packets to dusk (possibly routed via rzi),

23.6 Name Service Concepts

In the previous sections, when we talked about hosts, we referred to them by their IP-addresses. This was necessary to introduce the different kinds of addresses. When talking about hosts in general, it's more convenient to give them "names", as we did when talking about routing.

Most applications don't care whether you give them an IP address or a hostname. However, they'll use IP addresses internally, and there are several methods for them to map hostnames to IP addresses, each one with its own way of configuration. In this section we'll introduce the idea behind each method, in the next chapter, we'll talk about the configuration-part.

The mapping from hostnames (and domainnames) to IP-addresses is done by a piece of software called the "resolver". This is not an extra service, but some library routines which are linked to every application using networking-calls. The resolver will then try to resolve (hence the name ;-) the hostnames you give into IP addresses. See RFC1034 and RFC1035 for details on the resolver.

Hostnames are usually up to 256 characters long, and contain letters, numbers and dashes ("-"); case is ignored.

Just as with networks and subnets, it's possible (and desirable) to group hosts into domains and subdomains. When getting your network-address, you usually also obtain a domainname by your provider. As with subnets, it's up to you to introduce subdomains. Other as with IP-addresses, (sub)domains are not directly related to (sub)nets; for example, one domain can contain hosts from several subnets.

Figure 23-2 shows this: Both subnets 132.199.1.0/24 and 132.199.15.0/24 (and others) are part of the subdomain "rz.uni-regensburg.de". The domain the University of Regensburg got from its IP-provider is "uni-regensburg.de" (".de" is for Deutschland, Germany), the subdomain "rz" is for Rechenzentrum, computing center.

Hostnames, subdomain- and domainnames are separated by dots ("."). It's also possible to use more than one stage of subdomains, although this is not very common. An example would be fox_in.socs.uts.edu.au.

A hostname which includes the (sub)domain is also called a fully qualified domain name (FQDN). For example, the IP-address 132.199.15.99 belongs to the host with the FQDN dusk.rz.uni-regensburg.de.

Further above I told you that the IP-address 127.0.0.1 always belongs to the local host, regardless what's the "real" IP-address of the host. Therefore, 127.0.0.1 is always mapped to the name "localhost".

The three different ways to translate hostnames into IP addresses are: `/etc/hosts`, the Domain Name Service (DNS) and the Network Information Service (NIS).

23.6.1 `/etc/hosts`

The first and simplest way to translate hostnames into IP-addresses is by using a table telling which IP address belongs to which hostname(s). This table is stored in the file `/etc/hosts` and has the following format:

```
IP-address        hostname [nickname [...]]
```

Lines starting with a hash mark ("`#`") are treated as comments. The other lines contain one IP-address and the corresponding hostname(s).

It's not possible for a hostname to belong to several IP addresses, even if I made you think so when talking about routing. rzi for example has really two distinct names for each of its two addresses: rzi and rzia (but please don't ask me which name belongs to which address!).

Giving a host several nicknames can be convenient if you want to specify your favorite host providing a special service with that name, as is commonly done with FTP-servers. The first (leftmost) name is usually the real (canonical) name of the host.

Besides giving nicknames, it's also convenient to give a host's full name (including domain) as its canonical name, and using only its hostname (without domain) as a nickname.

Important: There *must* be an entry mapping localhost to 127.0.0.1 in `/etc/hosts`!

23.6.2 Domain Name Service (DNS)

`/etc/hosts` bears an inherent problem, especially in big networks: when one host is added or one host's address changes, all the `/etc/hosts` files on all machines have to be changed! This is not only time-consuming, it's also very likely that there will be some errors and inconsistencies, leading to problems.

Another approach is to hold only one hostnames-table (-database) for a network, and make all the clients query that "nameserver". Updates will be made only on the nameserver.

This is the basic idea behind the Domain Name Service (DNS).

Usually, there's one nameserver for each domain (hence DNS), and every host (client) in that domain knows which domain it is in and which nameserver to query for its domain.

When the DNS gets a query about a host which is not in its domain, it will forward the query to a DNS which is either the DNS of the domain in question or knows which DNS to ask for the specified domain. If the DNS forwarded the query doesn't know how to handle it, it will forward that query again to a DNS one step higher. This is not ad infinitum, there are several "root"-servers, which know about any domain.

See Chapter 26 for details on DNS.

23.6.3 Network Information Service (NIS/YP)

Yellow Pages (YP) was invented by Sun Microsystems. The name has been changed into Network Information Service (NIS) because YP was already a trademark of the British telecom. So, when I'm talking about NIS you'll know what I mean. ;-)

There are quite some configuration files on a Unix-system, and often it's desired to maintain only one set of those files for a couple of hosts. Those hosts are grouped together in a NIS-domain (which has *nothing* to do with the domains built by using DNS!) and are usually contained in one workstation cluster.

Examples for the config-files shared among those hosts are `/etc/passwd`, `/etc/group` and - last but not least - `/etc/hosts`.

So, you can "abuse" NIS for getting a unique name-to-address-translation on all hosts throughout one (NIS-)domain.

There's only one drawback, which prevents NIS from actually being used for that translation: In contrast to the DNS, NIS provides no way to resolve hostnames which are not in the hosts-table. There's no hosts "one level up" which the NIS-server can query, and so the translation will fail! Suns NIS+ takes measures against that problem, but as NIS+ is only available on Solaris-systems, this is of little use for us now.

Don't get me wrong: NIS is a fine thing for managing e.g. user-information (`/etc/passwd`, ...) in workstation-clusters, it's simply not too useful for resolving hostnames.

23.6.4 Other

The name resolving methods described above are what's used commonly today to resolve hostnames into IP addresses, but they aren't the only ones. Basically, every database mechanism would do, but none is implemented in NetBSD. Let's have a quick look what you may encounter.

With NIS lacking hierarchy in data structures, NIS+ is intended to help out in that field. Tables can be setup in a way so that if a query cannot be answered by a domain's server, there can be another domain "above" that might be able to do so. E.g. you could choose to have a domain that lists all the hosts (users, groups, ...) that are valid in the whole company, one that defines the same for each division, etc. NIS+ is not used a lot today, even Sun went back to ship back NIS by default.

Last century, the X.500 standard was designed to accommodate both simple databases like `/etc/hosts` as well as complex, hierarchical systems as can be found e.g. in DNS today. X.500 wasn't really a success, mostly due to the fact that it tried to do too much at the same time. A cut-down version is available today as the Lightweight Directory Access Protocol (LDAP), which is becoming popular in the last years to manage data like users but also hosts and others in small to medium sized organisations.

23.7 IPv6

23.7.1 What good is IPv6?

When telling people to migrate from IPv4 to IPv6, the question you usually hear is "why?". There are actually a few good reasons to move to the new version:

- Bigger address space
- Support for mobile devices
- Built-in security

23.7.1.1 Bigger Address Space

The bigger address space that IPv6 offers is the most obvious enhancement it has over IPv4. While today's internet architecture is based on 32-bit wide addresses, the new version has 128 bit available for addressing. Thanks to the enlarged address space, work-arounds like NAT don't have to be used any more. This allows full, unconstrained IP connectivity for today's mobile phones and IoT devices.

23.7.1.2 Mobility

When mentioning mobile devices and IP, another important point to note is that some special protocol is needed to support mobility, and implementing this protocol - called "Mobile IP" - is one of the requirements for every IPv6 stack. Thus, if you have IPv6 going, you have support for roaming between different networks, with everyone being updated when you leave one network and enter the other one. Support for roaming is possible with IPv4 too, but there are a number of hoops that need to be jumped in order to get things working. With IPv6, there's no need for this, as support for mobility was one of the design requirements for IPv6. See RFC3024 for some more information on the issues that need to be addressed with Mobile IP on IPv4.

23.7.1.3 Security

Besides support for mobility, security was another requirement for the successor to today's Internet Protocol version. As a result, IPv6 protocol stacks are required to include IPsec. IPsec allows authentication, encryption and compression of any IP traffic. Unlike application level protocols like SSL or SSH, all IP traffic between two nodes can be handled, without adjusting any applications. The benefit of this is that all applications on a machine can benefit from encryption and authentication, and that policies can be set on a per-host (or even per-network) base, not per application/service. An introduction to IPsec with a roadmap to the documentation can be found in RFC2411, the core protocol is described in RFC2401.

23.7.2 Changes to IPv4

After giving a brief overview of all the important features of IPv6, we'll go into the details of the basics of IPv6 here. A brief understanding of how IPv4 works is assumed, and the changes in IPv6 will be highlighted. Starting with IPv6 addresses and how they're split up we'll go into the various types of addresses there are, what became of broadcasts, then after discussing the IP layer go into changes for name resolving and what's new in DNS for IPv6.

23.7.2.1 Addressing

An IPv4 address is a 32 bit value, that's usually written in "dotted quad" representation, where each "quad" represents a byte value between 0 and 255, for example:

127.0.0.1

This allows a theoretical number of 2^{32} or ~4 billion hosts to be connected on the internet today. Due to grouping, not all addresses are available today.

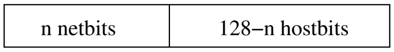
IPv6 addresses use 128 bit, which results in 2^{128} theoretically addressable hosts. This allows for a Really Big number of machines to addressed, and it sure fits all of today's requirements plus all those nifty PDAs and cell phones with IP phones in the near future without any sweat. When writing IPv6 addresses, they are usually divided into groups of 16 bits written as four hex digits, and the groups are separated by colons. An example is:

fe80::2a0:d2ff:fea5:e9f5

This shows a special thing - a number of consecutive zeros can be abbreviated by a single "::" once in the IPv6 address. The above address is thus equivalent to fe80:0:00:000:2a0:d2ff:fea5:e9f5 - leading zeros within groups can be omitted, and only one "::" can be used in an IPv6 address.

To make addresses manageable, they are split in two parts, which are the bits identifying the network a machine is on, and the bits that identify a machine on a (sub)network. The bits are known as netbits and hostbits, and in both IPv4 and IPv6, the netbits are the "left", most significant bits of an IP address, and the host bits are the "right", least significant bits, as shown in Figure 23-4.

Figure 23-4. IPv6-addresses are divided into more significant network- and less significant hostbits, too



In IPv4, the border is drawn with the aid of the netmask, which can be used to mask all net/host bits. Typical examples are 255.255.0.0 that uses 16 bit for addressing the network, and 16 bit for the machine, or 255.255.255.0 which takes another 8 bit to allow addressing 256 subnets on e.g. a class B net.

When addressing switched from classful addressing to CIDR routing, the borders between net and host bits stopped being on 8 bit boundaries, and as a result the netmasks started looking ugly and not really manageable. As a replacement, the number of network bits is used for a given address, to denote the border, e.g.

10.0.0.0/24

is the same as a netmask of 255.255.255.0 (24 1-bits). The same scheme is used in IPv6:

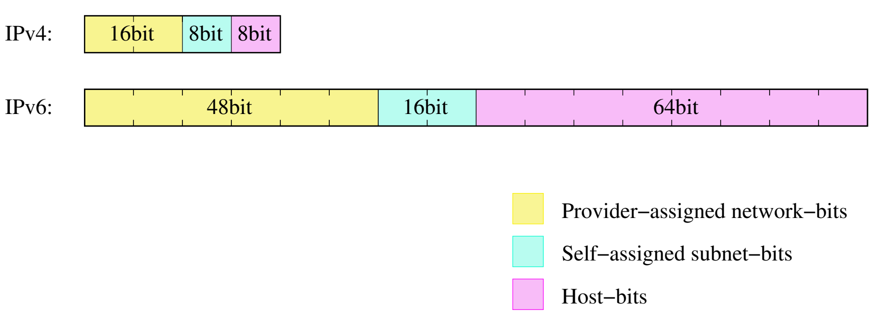
2001:638:a01:2::/64

tells us that the address used here has the first (leftmost) 64 bits used as the network address, and the last (rightmost) 64 bits are used to identify the machine on the network. The network bits are commonly referred to as (network) “prefix”, and the “prefixlen” here would be 64 bits.

Common addressing schemes found in IPv4 are the (old) class B and class C nets. With a class C network (/24), you get 24 bits assigned by your provider, and it leaves 8 bits to be assigned by you. If you want to add any subnetting to that, you end up with “uneven” netmasks that are a bit nifty to deal with. Easier for such cases are class B networks (/16), which only have 16 bits assigned by the provider, and that allow subnetting, i.e. splitting of the rightmost bits into two parts. One to address the on-site subnet, and one to address the hosts on that subnet. Usually, this is done on byte (8 bit) boundaries. Using a netmask of 255.255.255.0 (or a /24 prefix) allows flexible management even of bigger networks here. Of course there is the upper limit of 254 machines per subnet, and 256 subnets.

With 128 bits available for addressing in IPv6, the scheme commonly used is the same, only the fields are wider. Providers usually assign /48 networks, which leaves 16 bits for a subnetting and 64 hostbits.

Figure 23-5. IPv6-addresses have a similar structure to class B addresses



Now while the space for network and subnets here is pretty much ok, using 64 bits for addressing hosts seems like a waste. It’s unlikely that you will want to have several billion hosts on a single subnet, so what is the idea behind this?

The idea behind fixed width 64 bit wide host identifiers is that they aren't assigned manually as it's usually done for IPv4 nowadays. Instead, IPv6 host addresses are recommended (not mandatory!) to be built from so-called EUI64 addresses. EUI64 addresses are - as the name says - 64 bit wide, and derived from MAC addresses of the underlying network interface. E.g. for ethernet, the 6 byte (48 bit) MAC address is usually filled with the hex bits "fffe" in the middle and a bit is set to mark the address as unique (which is true for Ethernet), e.g. the MAC address

01:23:45:67:89:ab

results in the EUI64 address

03:23:45:ff:fe:67:89:ab

which again gives the host bits for the IPv6 address as

::0323:45ff:fe67:89ab

These host bits can now be used to automatically assign IPv6 addresses to hosts, which supports autoconfiguration of IPv6 hosts - all that's needed to get a complete IPv6 address is the first (net/subnet) bits, and IPv6 also offers a solution to assign them automatically.

When on a network of machines speaking IP, there's usually one router which acts as the gateway to outside networks. In IPv6 land, this router will send "router advertisement" information, which clients are expected to either receive during operation or to solicit upon system startup. The router advertisement information includes data on the router's address, and which address prefix it routes. With this information and the host-generated EUI64 address, an IPv6-host can calculate its IP address, and there is no need for manual address assignment. Of course routers still need some configuration.

The router advertisement information they create are part of the Neighbor Discovery Protocol (NDP, see RFC2461), which is the successor to IPv4's ARP protocol. In contrast to ARP, NDP does not only do lookup of IPv6 addresses for MAC addresses (the neighbor solicitation/advertisement part), but also does a similar service for routers and the prefixes they serve, which is used for autoconfiguration of IPv6 hosts as described in the previous paragraph.

23.7.2.2 Multiple Addresses

In IPv4, a host usually has one IP address per network interface or even per machine if the IP stack supports it. Only very rare applications like web servers result in machines having more than one IP address. In IPv6, this is different. For each interface, there is not only a globally unique IP address, but there are two other addresses that are of interest: The link local address, and the site local address. The link local address has a prefix of fe80::/64, and the host bits are built from the interface's EUI64 address. The link local address is used for contacting hosts and routers on the same network only, the addresses are not visible or reachable from different subnets. If wanted, there's the choice of either using global addresses (as assigned by a provider), or using site local addresses. Site local addresses are assigned the network address fec0::/10, and subnets and hosts can be addressed just as for provider-assigned networks. The only difference is, that the addresses will not be visible to outside machines, as these are on a different network, and their "site local" addresses are in a different physical net (if assigned at all). As with the 10/8 network in IPv4, site local addresses can be used, but don't have to. For IPv6 it's most common to have hosts assigned a link-local and a global IP address. Site local addresses are rather uncommon today, and are no substitute for globally unique addresses if global connectivity is required.

23.7.2.3 Multicasting

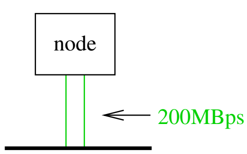
In IP land, there are three ways to talk to a host: unicast, broadcast and multicast. The most common one is by talking to it directly, using its unicast address. In IPv4, the unicast address is the “normal” IP address assigned to a single host, with all address bits assigned. The broadcast address used to address all hosts in the same IP subnet has the network bits set to the network address, and all host bits set to “1” (which can be easily done using the netmask and some bit operations). Multicast addresses are used to reach a number of hosts in the same multicast group, which can be machines spread over the whole internet. Machines must join multicast groups explicitly to participate, and there are special IPv4 addresses used for multicast addresses, allocated from the 224/8 subnet. Multicast isn’t used very much in IPv4, and only few applications like the MBone audio and video broadcast utilities use it.

In IPv6, unicast addresses are used the same as in IPv4, no surprise there - all the network and host bits are assigned to identify the target network and machine. Broadcasts are no longer available in IPv6 in the way they were in IPv4, this is where multicasting comes into play. Addresses in the ff::/8 network are reserved for multicast applications, and there are two special multicast addresses that supersede the broadcast addresses from IPv4. One is the “all routers” multicast address, the others is for “all hosts”. The addresses are specific to the subnet, i.e. a router connected to two different subnets can address all hosts/routers on any of the subnets it’s connected to. Addresses here are:

- ff0*X*::1 for all hosts and
- ff0*X*::2 for all routers,

where “*X*” is the scope ID of the link here, identifying the network. Usually this starts from “1” for the “node local” scope, “2” for the first link, etc. Note that it’s perfectly ok for two network interfaces to be attached to one link, thus resulting in double bandwidth:

Figure 23-6. Several interfaces attached to a link result in only one scope ID for the link



One use of the “all hosts” multicast is in the neighbor solicitation code of NDP, where any machine that wants to communicate with another machine sends out a request to the “all hosts” group, and the machine in question is expected to respond.

23.7.2.4 Name Resolving in IPv6

After talking a lot about addressing in IPv6, anyone still here will hope that there’s a proper way to abstract all these long & ugly IPv6 addresses with some nice hostnames as one can do in IPv4, and of course there is.

Hostname to IP address resolving in IPv4 is usually done in one of three ways: using a simple table in `/etc/hosts`, by using the Network Information Service (NIS, formerly YP) or via the Domain Name System (DNS).

As of this writing, NIS/NIS+ over IPv6 is currently only available on Solaris 8, for both database contents and transport, using a RPC extension.

Having a simple address<->name map like `/etc/hosts` is supported in all IPv6 stacks. With the KAME implementation used in NetBSD, `/etc/hosts` contains IPv6 addresses as well as IPv4 addresses. A simple example is the "localhost" entry in the default NetBSD installation:

```
127.0.0.1               localhost
::1                     localhost
```

For DNS, there are no fundamentally new concepts. IPv6 name resolving is done with AAAA records that - as the name implies - point to an entity that's four times the size of an A record. The AAAA record takes a hostname on the left side, just as A does, and on the right side there's an IPv6 address, e.g.

```
noon            IN      AAAA    3ffe:400:430:2:240:95ff:fe40:4385
```

For reverse resolving, IPv4 uses the in-addr.arpa zone, and below that it writes the bytes (in decimal) in reversed order, i.e. more significant bytes are more right. For IPv6 this is similar, only that hex digits representing 4 bits are used instead of decimal numbers, and the resource records are also under a different domain, ip6.int.

So to have the reverse resolving for the above host, you would put into your `/etc/named.conf` something like:

```
zone "0.3.4.0.0.0.4.0.e.f.f.3.IP6.INT" {
      type master;
      file "db.reverse";
};
```

and in the zone file db.reverse you put (besides the usual records like SOA and NS):

```
5.8.3.4.0.4.e.f.f.f.5.9.0.4.2.0.2.0.0.0 IN   PTR   noon.ipv6.example.com.
```

The address is reversed here, and written down one hex digit after the other, starting with the least significant (rightmost) one, separating the hex digits with dots, as usual in zone files.

One thing to note when setting up DNS for IPv6 is to take care of the DNS software version in use. BIND 8.x does understand AAAA records, but it does not offer name resolving via IPv6. You need BIND 9.x for that. Beyond that, BIND 9.x supports a number of resource records that are currently being discussed but not officially introduced yet. The most noticeable one here is the A6 record which allows easier provider/prefix changing.

To sum up, this section talked about the technical differences between IPv4 and IPv6 for addressing and name resolving. Some details like IP header options, QoS and flows were deliberately left out to not make this document more complex than necessary.

Chapter 24

Setting up TCP/IP on NetBSD in practice

24.1 Overview of the network configuration files

The following is a list of the files used to configure the network. The usage of these files, some of which have already been met the first chapters, will be described in the following sections.

`/etc/hosts`

Local hosts database file. Each line contains information regarding a known host and contains the internet address, the host's name and the aliases. Small networks can be configured using only the hosts file, without a *name server*. See hosts(5)

`/etc/resolv.conf`

This file specifies how the routines which provide access to the Internet Domain Name System should operate. Generally it contains the addresses of the DNS servers. See resolv.conf(5)

`/etc/sysctl.conf`

This file is used for configuring kernel settings, e.g. enabling packet forwarding on a gateway. See sysctl.conf(5).

`/etc/ifconfig.xxx`

This file is used for the automatic configuration of the network interfaces at boot, see ifconfig.if(5)

`/etc/npf.conf`

Contains firewall configuration for the NetBSD Packet Filter, see npf.conf(5) and `/usr/share/examples/npf`.

`/etc/dhcpcd.conf`

Contains configuration for a DHCP client. DHCP is used to automatically get IPv4 address assignments over Ethernet, but dhcpcd(8) is also used to for IPv6 Prefix Delegation and DHCPv6. See dhcpcd.conf(5) and `/usr/share/examples/dhcpcd`.

`/etc/dhcpd.conf`

Contains configuration for a DHCP server. DHCP is used to automatically assign IPv4 addresses to clients. See dhcpd.conf(5) and `/usr/share/examples/dhcpd`.

`/etc/mygate`

Contains the IP address of the IPv4 gateway. Used to configure a default route when not using DHCP. You can also set `defaultroute=""` in `/etc/rc.conf`.

`/etc/mygate6`

Contains the IP address of the IPv6 gateway. Used to configure a default route when not using autoconfiguration. You can also set `defaultroute6=""` in `/etc/rc.conf`.

`/etc/nsswitch.conf`

Name service switch configuration file. It controls how a process looks up various databases containing information regarding hosts, users, groups, etc. Specifically, this file defines the order to look up the databases. For example, the line:

```
hosts:    files dns mdnsd
```

specifies that the hosts database comes from two sources, *files* (the local `/etc/hosts` file) and *DNS*, (the Internet Domain Name System) and that the local files are searched before the DNS.

It is usually not necessary to modify this file except to enable Multicast DNS.

See nsswitch.conf(5).

`/etc/hostapd.conf`

Used to configure an IEEE 802.11 (Wi-Fi) wireless access point. See hostapd.conf(5) and `/usr/share/examples/hostapd`.

`/etc/wpa_supplicant.conf`

Used to configure an IEEE 802.11 (Wi-Fi) client. See wpa_supplicant.conf(5) and `/usr/share/examples/wpa_supplicant`.

24.2 Connecting to common LAN setups

In Local Area Networks that are centrally managed, one can expect Internet connectivity being available via some router, a DNS server being available, and most important, a DHCP server which hands out IP addresses to clients on request. To make a NetBSD client run in such an environment, it's usually enough to set

```
dhcpcd=YES
```

in `/etc/rc.conf`, and the IP address will be set automatically, `/etc/resolv.conf` will be created and routing setup to the default router.

24.2.1 Connecting using IEEE 802.11 (Wi-Fi)

WPA Supplicant allows connecting to Wi-Fi networks using a password, but also provides a consistent interface through which to connect to access points.

As well as having dhcpcd(8) running, on a system using Wi-Fi to connect to an access point, wpa_supplicant(8) must typically be enabled:

```
ifconfig_iwm0="up"
dhcpcd=YES
wpa_supplicant=YES
```

At runtime:

```
# ifconfig iwm0 up
# service dhcpcd start
# service wpa_supplicant start
```

In this case, our Wi-Fi interface is called `iwm0`. It is set to `up` with ifconfig(8). You can find a list of detected Wi-Fi interfaces with wlanctl(8):

```
# wlanctl -a
iwm0: mac 10:02:xx:xx:xx:xx bss 00:00:00:00:00:00
```

The following `/etc/wpa_supplicant.conf` configures NetBSD to automatically connect to two access points. More can also be added.

Example 24-1. `/etc/wpa_supplicant.conf`

```
# Allow wpa_cli(8) to configure wpa_supplicant
ctrl_interface=/var/run/wpa_supplicant
ctrl_interface_group=wheel
update_config=1

# Automatically connect to the unprotected network "metalab".
network={
 ssid="metalab"
 key_mgmt=NONE
 priority=100
}

# Automatically connect to the protected network "discord" using the password "XXX".
network={
        ssid="discord"
        psk="XXX"
}
```

After adding access points, reload wpa_supplicant(8)'s configuration:

```
# service wpa_supplicant reload
# service dhcpcd restart
```

You can use wpa_cli(8) to scan for networks once WPA supplicant is running:

```
# wpa_cli scan
# wpa_cli scan_results
Selected interface 'iwm0'
16:01:33.578: bssid / frequency / signal level / flags / ssid
xx:xx:xx:xx:xx:xx       5180    91      [WPA2-PSK-CCMP][ESS]    FRITZ!Box 1000 EZ
```

24.3 Manually creating a small LAN

This section describes how to configure a LAN *manually* in order to describe the basics of the networking stack. Usually, this configuration is automatic through dhcpcd(8), see Section 24.2

First, the network cards must be installed and connected to a switch or directly.

Next, check that the network cards are recognized by the kernel, studying the output of the **dmesg** command. In the following example the kernel recognized correctly an NE2000 clone:

```
...
ne0 at isa0 port 0x280-0x29f irq 9
ne0: NE2000 Ethernet
ne0: Ethernet address 00:c2:dd:c1:d1:21
...
```

The following command shows the network card's current configuration:

```
# ifconfig ne0
ne0: flags=8822<BROADCAST,NOTRAILERS,SIMPLEX,MULTICAST> mtu 1500
address: 00:50:ba:aa:a7:7f
media: Ethernet autoselect (10baseT)
inet6 fe80::250:baff:feaa:a77f%ne0 prefixlen 64 scopeid 0x1
```

The software configuration of the network card is very easy. The IP address "192.168.1.1" is assigned to the card.

```
# ifconfig ne0 inet 192.168.1.1 netmask 0xffffff00
```

Note that the networks 10.0.0.0/8 and 192.168.0.0/16 are reserved for private networks, which is what we're setting up here.

Repeating the previous command now gives a different result:

```
# ifconfig ne0
ne0: flags=8863<UP,BROADCAST,NOTRAILERS,RUNNING,SIMPLEX,MULTICAST> mtu 1500
address: 00:50:ba:aa:a7:7f
media: Ethernet autoselect (10baseT)
inet 192.168.1.1 netmask 0xffffff00 broadcast 192.168.1.255
inet6 fe80::250:baff:feaa:a77f%ne0 prefixlen 64 scopeid 0x1
```

The output of **ifconfig** has now changed: the IP address is now printed and there are two new flags, "UP" and "RUNNING" If the interface isn't "UP", it will not be used by the system to send packets.

The host was given the IP address 192.168.1.1, which belongs to the set of addresses reserved for internal networks which are not reachable from the Internet. The configuration is finished and must now be tested; if there is another active host on the network, a *ping* can be tried. For example, if 192.168.1.2 is the address of the active host:

```
# ping 192.168.1.2
PING ape (192.168.1.2): 56 data bytes
64 bytes from 192.168.1.2: icmp_seq=0 ttl=255 time=1.286 ms
64 bytes from 192.168.1.2: icmp_seq=1 ttl=255 time=0.649 ms
64 bytes from 192.168.1.2: icmp_seq=2 ttl=255 time=0.681 ms
64 bytes from 192.168.1.2: icmp_seq=3 ttl=255 time=0.656 ms
```

```
^C
----ape PING Statistics----
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.649/0.818/1.286/0.312 ms
```

With the current setup, at the next boot it will be necessary to repeat the configuration of the network card. In order to avoid repeating the card's configuration at each boot, add the following lines to `/etc/rc.conf`:

```
auto_ifconfig=yes
ifconfig_ne0="inet 192.168.1.1 netmask 0xffffff00"
```

In this example the variable `ifconfig_ne0` was set because the network card was recognized as *ne0* by the kernel; if you are using a different adapter, substitute the appropriate name in place of ne0.

At the next boot the network card will be configured automatically.

If you have a router that is connected to the internet, you can use it as default router, which will handle all your packets. To do so, set `defaultroute` to the router's IP address in `/etc/rc.conf`:

```
defaultroute=192.168.0.254
```

Be sure to use the default router's IP address instead of name, in case your DNS server is beyond the default router. In that case, the DNS server couldn't be reached to resolve the default router's hostname and vice versa, creating a chicken-and-egg problem.

To reach hosts on your local network, and assuming you really have very few hosts, adjust `/etc/hosts` to contain the addresses of all the hosts belonging to the internal network. For example:

Example 24-2. `/etc/hosts`

```
#
# Host Database
# This file should contain the addresses and aliases
# for local hosts that share this file.
# It is used only for "ifconfig" and other operations
# before the nameserver is started.
#
#
127.0.0.1             localhost
::1                   localhost
#
# RFC 1918 specifies that these networks are "internal".
# 10.0.0.0    10.255.255.255
# 172.16.0.0  172.31.255.255
# 192.168.0.0 192.168.255.255

192.168.1.1   ape.insetti.net ape
192.168.1.2   vespa.insetti.net vespa
192.168.1.0   insetti.net
```

To configure a machine as DNS client, you need to edit `/etc/resolv.conf`, and enter the DNS server's address, in addition to an optional domain name that will be appended to hosts with no domain, in order to create a FQDN for resolving. Assuming your DNS server's IP address is 192.168.1.2 and it is setup to serve for "home.net", put the following into `/etc/resolv.conf`:

```
# /etc/resolv.conf
domain home.net
nameserver 192.168.1.2
```

Summing up, to configure the network the following must be done: the network adapters must be installed and physically connected. Next they must be configured (with **ifconfig**) and, finally, the file `/etc/rc.conf` must be modified to configure the interface and possibly default router, and `/etc/resolv.conf` and `/etc/nsswitch.conf` should be adjusted if DNS should be used. This type of network management is sufficient for small networks without sophisticated needs.

24.4 Connecting to a home/office ISP with PPPoE

Many home/office ISPs use PPP (point to point protocol) to provide Internet access to their clients. NetBSD includes pppoe(4) (PPP over Ethernet) functionality that can be used to connect to a modem which communicates with the ISP, typically not using Ethernet, allowing NetBSD to be used as a gateway on small home and office networks.

We start by configuring the kernel for PPPoE use by bumping the tty queue size. This setting can be made permanent by editing `/etc/sysctl.conf`:

```
# sysctl -w kern.tty.qsize=32768
```

Now, create the interface with ifconfig(8):

```
# ifconfig pppoe0 create
# ifconfig inet 0.0.0.0 0.0.0.1 down
# ifconfig re0 up
# pppoectl -e re0 pppoe0
```

We are using our computer's `re0` interface to connect to our DSL modem.

Then, configure the PPPoE connection to use our ISP's provided username and password:

```
# pppoectl pppoe0 myauthproto=pap 'myauthname=XXX' 'myauthsecret=YYY' hisauthproto=none
```

We are now ready to test a first connection. Since something may be wrong, we will restrict retries for now:

```
# pppoectl pppoe0 max-auth-failure=1
# ifconfig pppoe0 up
# pppoectl -d pppoe0
pppoe0: state = session
 Session ID: 0x254f
 PADI retries: 0
 PADR retries: 0
```

This example output shows a working setup. The PPPoE session has been established and is still in use (state = session). We can now check the IP negotiation of PPP:

```
# ifconfig pppoe0
pppoe0: flags=8851<UP,POINTOPOINT,RUNNING,SIMPLEX,MULTICAST> mtu 1492
 inet 117.80.111.85 -> 118.5.113.169 netmask 0xff000000
```

We can make the configuration permanent by creating `/etc/ifconfig.pppoe0`:

Example 24-3. `/etc/ifconfig.pppoe0`

```
create
# Mark the physical interface used by this PPPoE interface up
! /sbin/ifconfig re0 up
# Let $int use re0 as its Ethernet interface
! /sbin/pppoectl -e re0 $int
# Configure authentication
! /sbin/pppoectl $int myauthproto=pap 'myauthname=XXX' 'myauthsecret=YYY' hisauthproto=none
# Configure the PPPoE interface itself. These addresses are magic
# meaning we don't care about either address and let the remote
# ppp choose them.
0.0.0.0 0.0.0.1 up
```

To automatically get a route(8) to the outside world, we use ifwatchd(8). Create the following scripts:

Example 24-4. `/etc/ppp/ip-up`

```
#!/bin/sh
/sbin/route add default $5
```

Example 24-5. `/etc/ppp/ip-down`

```
#!/bin/sh
/sbin/route delete default $5
```

And make them executable by root:

```
# chmod +x /etc/ppp/ip-up /etc/ppp/ip-down
```

Now, edit `/etc/rc.conf` to enable ifwatchd:

```
ifwatchd=YES
ifwatchd_flags="-u /etc/ppp/ip-up -d /etc/ppp/ip-down pppoe0"
```

And start the service:

```
# service ifwatchd start
```

24.4.1 Configuring a VLAN

A typical PPPoE connection requires a VLAN ID to be set on the external interface. On NetBSD this is accomplished by creating a vlan(4) interface:

```
# ifconfig vlan0 create
```

```
# ifconfig vlan0 vlan 6 vlanif pppoe0
```

Example 24-6. `/etc/ifconfig.vlan0`

```
create
vlan 6 vlanif pppoe0
```

To ensure that `vlan0` is created at the appropriate time, refer to Section 24.7.

24.4.2 Setting up MSS clamping

Some systems behind misconfigured firewalls try to use Path-MTU-Discovery, while their firewall blocks all ICMP messages. This is an illegal, but not uncommon configuration. Typically, remote servers with this configuration are outside of your control, but you might still need to connect to them, e.g. to do your online banking.

Without special care, such systems will not be able to send larger chunks of data to a system connected via PPPoE. But there is a workaround: pretend to not be able to handle large packets, by sending a small MSS (maximum segment size) option during initial TCP handshake.

For connections originating from your PPPoE connected system, this is accomplished by setting the sysctl(8) variable `net.inet.tcp.mss_ifmtu` to 1, i.e. by adding this to `/etc/sysctl.conf`:

```
# Obey interface MTUs when calculating MSS
net.inet.tcp.mss_ifmtu=1
```

For connections originating from systems behind your PPPoE router, you need to configure MSS clamping in your firewall, like in this example `/etc/npf.conf`:

```
procedure "norm4" {
 normalize: "random-id", "max-mss" 1440
}

procedure "norm6" {
 normalize: "random-id", "max-mss" 1420
}

group "external" on "pppoe0" {
 pass stateful out final family inet4 all apply "norm4"
 pass stateful out final family inet6 all apply "norm6"
}
```

For more information about configuring NPF, see Section 24.5

24.4.3 Obtaining IPv6 addresses via Prefix Delegation

To obtain an IPv6 address, the NetBSD kernel must be configured to accept IPv6 router advertisements with sysctl(8):

```
# sysctl -w net.inet6.ip6.accept_rtadv=1
```

This setting can be made permanent by editing `/etc/sysctl.conf`.

Many ISPs implement IPv6 over PPP via prefix delegation. Prefix Delegation can be configured with dhcpcd(8), for example with this `/etc/dhcpcd.conf`:

Example 24-7. `/etc/dhcpcd.conf`

```
duid
ipv6only
require dhcp_server_identifier
option interface_mtu
noipv6rs
slaac private
interface pppoe0
  option rapid_commit
  ipv6rs
  iaid 1
  ia_na 1
  ia_pd 2/::/64 re1/1
```

With this configuration, running rtadvd(8) on the `re1` interface should be enough to assign IPv6 addresses to clients.

If you still can't get IPv6 working, other things to try are to make sure `ipv6-icmpand` and `dhcpv6` can pass through your firewall.

24.5 Setting up an Internet gateway with NPF

npf(7) (NetBSD Packet Filter) is NetBSD's firewall. It can be used to protect a local network from the dangers of the wider Internet, and can also perform Network Address Translation (NAT) in order to make sure IPv4 packets reach the correct destination computer.

Some usage examples of NPF can be found in the subdirectory `/usr/share/examples/npf`. Look at the file `soho_gw-npf.conf` for an example of a configuration for a small home/office gateway.

In order to use NetBSD as a gateway, the packet forwarding sysctl(8) options must be enabled. You can add them to `/etc/sysctl.conf`.

```
# sysctl -w net.inet.ip.forwarding=1
net.inet.ip.forwarding = 1
# sysctl -w net.inet6.ip6.forwarding=1
net.inet6.ip6.forwarding = 1
```

And enable NPF in `/etc/rc.conf`:

```
npf=YES
```

The following configuration performs straightforward NAT, using `re0` as the external network and `re1` as the internal network interface. If you have multiple internal network interfaces, you might want to bridge them. See Section 24.6

Example 24-8. `/etc/npf.conf`

```
$ext_if = "re0"
$int_if = "re1"
$ext_addrs = { ifaddrs($ext_if) }
$localnet = { 192.168.0.0/24 }

# Allow pings.
alg "icmp"

# Perform IPv4 NAT.
map inet4($ext_if) dynamic $localnet -> inet4($ext_if)

group "external" on $ext_if {
 # Allow all outbound traffic
        pass stateful out all
 # Block all incoming traffic
 block in all
}

group "internal" on $int_if {
 # We trust the internal network.
 pass in final all
 pass out final all
}

group default {
 pass final on lo0 all
 block all
}
```

Usually, you will want to configure dhcpd(8) so clients are automatically assigned IP addresses in the correct range:

Example 24-9. `/etc/dhcpd.conf`

```
subnet 192.168.0.0 netmask 255.255.255.0 {
        option routers 192.168.0.1;
 option domain-name-servers 9.9.9.9;
        option subnet-mask 192.168.0.0;
        range 192.168.0.100 192.168.0.254;
        default-lease-time 604800; # default lease 7 days
}
```

24.6 Setting up a network bridge device

A bridge can be used to combine different physical networks into one logical network, i.e. connect them at layer 2 of the ISO-OSI model, not at layer 3, which is what a router would do. It can allow multiple network interfaces to be addressed as one. The NetBSD “bridge” driver provides bridge functionality on NetBSD systems.

24.6.1 Bridge example

In this example two physical networks are going to be combined in one logical network, 192.168.1.0, using a NetBSD bridge. The NetBSD machine which is going to act as bridge has two interfaces, ne0 and ne1, which are each connected to one physical network.

When the system is ready the bridge can be created, this can be done using the brconfig(8) command. First of a bridge interface has to be created. With the following ifconfig(8) command the `bridge0` interface will be created:

```
$ ifconfig bridge0 create
```

Please make sure that at this point both the ne0 and ne1 interfaces are up. The next step is to add the ne0 and ne1 interfaces to the bridge.

```
$ brconfig bridge0 add ne0 add ne1 up
```

This configuration can be automatically set up by creating an `/etc/ifconfig.interface` file, in this case `/etc/ifconfig.bridge0`, with the following contents:

```
create
!brconfig $int add ne0 add ne1 up
```

> **Note:** In NetBSD 10.0 and later, it will become necessary to use *vether* instead of *tap* as a bridge endpoint. *vether* is unavailable in previous releases.

After setting up the bridge the bridge configuration can be displayed using the **brconfig -a** command. Remember that if you want to give the bridge machine an IP address you can only allocate an IP address to one of the interfaces which are part of the bridge. A virtual tap(4) interface can also be created and configured as a bridge endpoint, e.g. in `/etc/ifconfig.tap0`:

Example 24-10. `/etc/ifconfig.tap0`

```
create
inet 192.168.0.1 netmask 255.255.255.0
up
!ifconfig bridge0 create
!brconfig bridge0 add $int add ne0 add ne1 up
```

24.7 Ensuring interfaces are initialized in the correct order

In our previous example Section 24.6, we created a bridge(4) and tap(4) that are dependent upon other networking interfaces to function. This can present a problem if rc(8) initializes them before the interfaces they depend upon. Fortunately, it is possible to force a specific initialization order in `/etc/rc.conf`:

```
auto_ifconfig=NO
net_interfaces="ne0 ne1 pppoe0 bridge0 tap0"
```

With these lines, `/etc/ifconfig.ne0` will be read first, and `/etc/ifconfig.tap0` last. The same applies if `ifconfig_ne0="up"` lines are used in `/etc/rc.conf` instead of dedicated configuration files.

24.8 Some useful commands

The following commands can be useful for diagnosing problems:

ifconfig(8)

Displays and can change the configuration of network intefaces.

ping(8)

Attempt to reach a host and measure latency.

netstat(1)

Displays active connections.

npfctl(8)

npfctl show displays the current firewall configuration, **npfctl validate filename** can be used to verify a configuration is correct before loading it.

route(8)

route show displays the routing tables, other commands can be used to manipulate them.

traceroute(8)

Shows the route followed by the packets to their destination.

sysstat(1)

sysstat ifstat can be used to monitor network interfaces.

tcpdump(8)

Can be used to monitor TCP/IP traffic.

Chapter 25

The Internet Super Server inetd

The "internet super server", or inetd(8), is available on all Unix(like) systems, providing many of the basic network services available. This chapter describes the relationship between the daemon and several of the config files in the `/etc/` directory.

25.1 Overview

In this document we will look at a simple definition of inetd(8), how several files that relate to inetd(8) work (not that these files are not related to other software), how to add a service to inetd(8) and some considerations both to use inetd(8) for a particular service and times when a service might be better off running outside of inetd(8).

25.2 What is inetd?

In traditional Unix scenarios, one server (daemon) process watches for connections on a particular port, and handles incoming requests. Now if a machine offers many services, many daemon processes would be needed, mostly running idle but still wasting resources like memory. The internet super server, inetd, is an approach to this problem. It listens on a number of ports, and when it receives a request it then determines which program to run to handle the request and starts an instance of that program.

Following is a very simple diagram to illustrate inetd(8):

```
 pop3  ------ |
              |
 ftpd -------  | INETD | ---- Internet / DMZ / Switch / Whatever . . .
              |
cvsupserver -  |
```

In the above diagram you can see the general idea. The inetd(8) process receives a request and then starts the appropriate server process. What inetd(8) is doing is software multiplexing. An important note here, regarding security: On many other UNIX-like systems, a package called tcpwrappers is used as a security enhancement for inetd(8). On NetBSD the tcpwrapper functionality is built into inetd(8) using libwrap.

25.3 Configuring inetd - `/etc/inetd.conf`

The operation of inetd(8) is controlled by its own config file, surprisingly named `/etc/inetd.conf`, see inetd.conf(5). The `inetd.conf` file basically provides enabling and mapping of services the systems administrator would like to have multiplexed through inetd(8), indicating which program should be started for incoming requests on which port.

inetd.conf(5) is an ascii file containing one service per line, and several fields per line. The basic field layout is:

```
service-name socket-type protocol wait/nowait user:group server-program arguments
```

service-name:

> The service name indicates the port inetd(8) should listen on. It is either a decimal number, or a name matching a service name given in `/etc/services`.

socket-type:

> The communications socket type, the different types are "stream" for a TCP stream, "dgram" for an UDP service, "raw" for a raw socket, "rdm" for reliably delivered message and "seqpacket" for a sequenced packet socket. The most common socket types are "stream" and "dgram".

protocol

> The protocol used, mostly "tcp", "tcp6", "udp" and "udp6" for stream-oriented services via the Transmission Control Protocol, or datagram-oriented services via the User Datagram Protocol. It is worth noting that "tcp" and "udp" mean they use the default (currently IPv4), "tcp4" specifically means communication via IPv4 only, and "tcp6" and "udp6" are IPv6-only. In addition to those, protocols based on Remote Procedure Calls (RPC) can be specified as either "rpc/tcp" or "rpc/udp".

wait/nowait

> This field tells inetd(8) if it should wait for a server program to return or to continue processing new connections immediately. Many connections to server processes require answers after data transfers are complete, where other types can keep transmitting on a connection continuously, the latter is a "nowait" and the former "wait". In most cases, this entry corresponds to the socket-type, for example a streaming connection would (most of the time) have a "nowait" value in this field.

user[:group]

> This field gives the user name and optionally a group name that the server process which inetd(8) starts up runs as.

server-program

> This field is the full path of the program that gets started.

program-arguments

> This field contains the argument vector argv[] of the program started, including the program name and additional arguments the systems administrator may need to specify for the server program that is started.

That is all a lot to digest and there are other things the systems administrator can do with some of the fields. Here is a sample line from an `inetd.conf` file:

```
ftp        stream  tcp    nowait  root   /usr/libexec/ftpd    ftpd -ll
```

From the left, the service-name is "ftp", socket-type is "stream", protocol is "tcp", inetd(8) won't wait for the server process to terminate ("nowait"), the process runs as user "root", path is `/usr/libexec/ftpd` and program name and arguments are "ftpd -ll". Notice in the last field, the program name is different from the service-name.

25.4 Services - `/etc/services`

The next file to consider is the service name data base that can be found in `/etc/services`. This file basically contains information mapping a service name to a port number. The format of the `/etc/services` file is:

```
service-name port-number/protocol-name [aliases]
```

"service-name" is the name of the service, "port-number" is the port number assigned to the service, "protocol-name" is either "tcp" or "udp", and if alias names for a port are needed, they can be added as "aliases", separated by white spaces. Comments may be added after a hash mark (#).

Let's take a look at the "ssh" entries as an example:

```
ssh             22/tcp           # Secure Shell
ssh             22/udp
```

As we can see, from the left, the service name is "ssh", the port number is "22", the protocols are both "tcp" and "udp". Notice that there is a separate entry for every protocol a service can use (even on the same port).

25.5 Protocols - `/etc/protocols`

Another file read by inetd(8) is `/etc/protocols`. This file has the information pertaining to DARPA Internet protocols. The format of the protocols name data base is:

```
protocol-name number [aliases]
```

where "protocol-name" describes the payload of an IP packet, e.g. "tcp" or "udp". "number" is the official protocol number assigned by IANA, and optional alias names can be added after that.

Let's look at the seventh entry in the `/etc/protocols` db as an example:

```
tcp     6       TCP             # transmission control protocol
```

Starting from the left, we see that the protocol name is "tcp", the number is "6" and the only aliases listed is "TCP", belonging to the Transmission Control Protocol as indicated by the comment in that line.

25.6 Remote Procedure Calls (RPC) - `/etc/rpc`

The rpc program number data base used by services with the "rpc" protocol type in inetd.conf(5) is kept in `/etc/rpc` and contains name mappings to rpc program numbers. The format of the file is:

```
server-name program-number aliases
```

For example, here is the nfs entry:

```
nfs             100003  nfsprog
```

25.7 Allowing and denying hosts - `/etc/hosts.{allow,deny}`

As mentioned above, NetBSD's inetd(8) has the tcpwrapper package built in via the libwrap library. As such, inetd(8) can allow or deny access to each service on a more fine-grained base than just allowing a service to everyone, or not enabling it at all. The access control is defined in the files `/etc/hosts.allow` and `/etc/hosts.deny`, see the hosts_access(5) manpage.

Each of the two files contains several lines that describe access restrictions for a certain server. Access is allowed if permission is given in `/etc/hosts.allow`. If the service is not listened in `/etc/hosts.allow` but in `/etc/hosts.deny`, it is denied. If a service is listed in neither file, it is allowed, giving standard inetd(8) behaviour.

Each line in `/etc/hosts.allow` and `/etc/hosts.deny` contains a service either by name (as given in the field for argv[0] in `/etc/inetd.conf`, e.g. "ftpd" instead of "ftp"), or the special service "ALL" which obviously applies to all services. Following the service name is - separated by a colon - a number of access restrictions, which can be hostnames, domains, single IP addresses, whole IP subnets or some other restrictions, please check hosts_access(5) for all the details.

An example configuration that is mostly open but denies access to services to a certain host and all machines from a certain domain would look like this:

```
# /etc/hostname.deny:
ALL: some.host.name, .some.domain
```

Another example that would be mostly closed, denying access to all but very few machines would need entries in both `/etc/hosts.allow` and `/etc/hosts.deny`. The entry for `/etc/hosts.deny` would be:

```
# /etc/hosts.deny
ALL: ALL
```

The entry to allow a few hosts would be put into `/etc/hosts.allow`:

```
# /etc/hosts.allow
ALL: friend.host.domain otherfriend.otherhost.otherdomain
```

25.8 Adding a Service

Many times a systems administrator will find that they need to add a service to their system that is not already in inetd(8) or they may wish to move a service to it because it does not get very much traffic. This is usually pretty simple, so as an example we will look at adding a version of POP3 on a NetBSD system.

In this case we have retrieved and installed the "cucipop" package, which can be found in `pkgsrc/mail/cucipop`. This server is pretty simple to use, the only oddities are different path locations. Since it is POP3 we know it is a stream oriented connection with "nowait". Running as "root" will be fine, the only item that is different is the location of the program and the name of the program itself.

So the first half of the new entry in `/etc/inetd.conf` looks like this:

```
pop3   stream  tcp     nowait  root
```

After installation, pkgsrc deposited cucipop in `/usr/pkg/sbin/cucipop`. So with the next field we have:

```
pop3   stream  tcp     nowait  root /usr/pkg/sbin/cucipop
```

Last, we want to use the Berkeley mailbox format, so our server program must be called with the `-Y` option. This leaves the entire entry looking like so:

```
pop3   stream  tcp     nowait  root /usr/pkg/sbin/cucipop cucipop -Y
```

We have added the service named "pop3" to `/etc/inetd.conf`. Next item to check is that the system can map the service name to a port number in `/etc/services`:

```
# grep ^pop3 /etc/services
pop3           110/tcp         # POP version 3
pop3           110/udp
pop3s          995/tcp                 # pop3 protocol over TLS/SSL (was spop3)
pop3s          995/udp                 # pop3 protocol over TLS/SSL (was spop3)
```

The "pop3" entries here are of interest, i.e. they are already contained in the `/etc/services` file shipped with NetBSD.

Now, to have inetd(8) use the new entry, we simply restart it using the rc script:

```
# sh /etc/rc.d/inetd restart
```

All done, in most cases, the software you are using has documentation that will specify the entry, in the off case it does not, sometimes it helps to try and find something similar to the server program you will be adding. A classic example of this is a MUD server which has built-in telnet. You can pretty much borrow the telnet entry and change parts where needed.

25.9 When to use or not to use inetd

The decision to add or move a service into or out of inetd(8) is usually based on server load. As an example, on most systems the telnet daemon does not require as many new connections as say a mail server. Most of the time the administrator has to feel out if a service should be moved.

A good example I have seen is mail services such as smtp and pop. I had setup a mail server in which pop3 was in inetd(8) and exim was running in standalone, I mistakenly assumed it would run fine since there was a low amount of users, namely myself and a diagnostic account. The server was also setup to act as a backup MX and relay in case another heavily used one went down. When I ran some tests I discovered a huge time lag for pop connections remotely. This was because of my steady fetching of mail and the diagnostic user constantly mailing diagnostics back and forth. In the end I had to move the pop3 service out of inetd(8).

The reason for moving the service is actually quite interesting. When a particular service becomes heavily used, of course, it causes a load on the system. In the case of a service that runs within the inetd(8) meta daemon the effects of a heavily loaded service can also harm other services that use inetd(8). If the multiplexor is getting too many requests for one particular service, it will begin to affect the performance of other services that use inetd(8). The fix, in a situation like that, is to make the offending service run outside of inetd(8) so the response time of both the service and inetd(8) will increase.

25.10 Other Resources

Following is some additional reading and information about topics covered in this document.

NetBSD manual pages:

- inetd(8) (//man.NetBSD.org/inetd.8)
- protocols(5) (//man.NetBSD.org/protocols.5)
- rpc(5) (//man.NetBSD.org/rpc.5)
- services(5) (//man.NetBSD.org/services.5)
- hosts_access(5) (//man.NetBSD.org/hosts_access.5)

Miscellaneous links:

- IANA: Protocol Numbers and Assignment Services (http://www.iana.org/numbers.htm)
- RFC1700: Assigned Numbers (http://www.isi.edu/in-notes/rfc1700.txt)

Chapter 26
The Domain Name System

Use of the Domain Name System has been discussed in previous chapters, without going into detail on the setup of the server providing the service. This chapter describes setting up a simple, small domain with one Domain Name System (DNS) nameserver on a NetBSD system. It includes a brief explanation and overview of the DNS; further information can be obtained from the DNS Resources Directory (DNSRD) at http://www.dns.net/dnsrd/.

26.1 DNS Background and Concepts

The DNS is a widely used *naming service* on the Internet and other TCP/IP networks. The network protocols, data and file formats, and other aspects of the DNS are Internet Standards, specified in a number of RFC documents, and described by a number of other reference and tutorial works. The DNS has a distributed, client-server architecture. There are reference implementations for the server and client, but these are not part of the standard. There are a number of additional implementations available for many platforms.

26.1.1 Naming Services

Naming services are used to provide a mapping between textual names and configuration data of some form. A *nameserver* maintains this mapping, and clients request the nameserver to *resolve* a name into its attached data.

The reader should have a good understanding of basic hosts to IP address mapping and IP address class specifications, see Section 23.6.

In the case of the DNS, the configuration data bound to a name is in the form of standard *Resource Records* (RR's). These textual names conform to certain structural conventions.

26.1.2 The DNS namespace

The DNS presents a hierarchical name space, much like a UNIX filesystem, pictured as an inverted tree with the *root* at the top.

```
TOP-LEVEL                        .org
                                  |
MID-LEVEL                     .diverge.org
                  ______________________|______________________
                 |                      |                      |
BOTTOM-LEVEL strider.diverge.org   samwise.diverge.org   wormtongue.diverge.org
```

The system can also be logically divided even further if one wishes at different points. The example shown above shows three nodes on the diverge.org domain, but we could even divide diverge.org into subdomains such as "strider.net1.diverge.org", "samwise.net2.diverge.org" and "wormtongue.net2.diverge.org"; in this case, 2 nodes reside in "net2.diverge.org" and one in "net1.diverge.org".

There are directories of names, some of which may be sub-directories of further names. These directories are sometimes called *zones*. There is provision for symbolic links, redirecting requests for information on one name to the records bound to another name. Each name recognised by the DNS is called a *Domain Name*, whether it represents information about a specific host, or a directory of subordinate Domain Names (or both, or something else).

Unlike most filesystem naming schemes, however, Domain Names are written with the innermost name on the left, and progressively higher-level domains to the right, all the way up to the root directory if necessary. The separator used when writing Domain Names is a period, ".".

Like filesystem pathnames, Domain Names can be written in an absolute or relative manner, though there are some differences in detail. For instance, there is no way to indirectly refer to the parent domain like with the UNIX `..` directory. Many (but not all) resolvers offer a search path facility, so that partially-specified names can be resolved relative to additional listed sub-domains other than the client's own domain. Names that are completely specified all the way to the root are called *Fully Qualified Domain Names* or *FQDN*s. A defining characteristic of an FQDN is that it is written with a terminating period. The same name, without the terminating period, may be considered relative to some other sub-domain. It is rare for this to occur without malicious intent, but in part because of this possibility, FQDNs are required as configuration parameters in some circumstances.

On the Internet, there are some established conventions for the names of the first few levels of the tree, at which point the hierarchy reaches the level of an individual organisation. This organisation is responsible for establishing and maintaining conventions further down the tree, within its own domain.

26.1.3 Resource Records

Resource Records for a domain are stored in a standardised format in an ASCII text file, often called a *zone file*. The following Resource Records are commonly used (a number of others are defined but not often used, or no longer used). In some cases, there may be multiple RR types associated with a name, and even multiple records of the same type.

Common DNS Resource Records

A: Address

This record contains the numerical IP address associated with the name.

CNAME: Canonical Name

This record contains the Canonical Name (an FQDN with an associated A record) of the host name to which this record is bound. This record type is used to provide name aliasing, by providing a link to another name with which other appropriate RR's are associated. If a name has a CNAME record bound to it, it is an alias, and no other RR's are permitted to be bound to the same name.

It is common for these records to be used to point to hosts providing a particular service, such as an FTP or HTTP server. If the service must be moved to another host, the alias can be changed, and the same name will reach the new host.

PTR: Pointer

This record contains a textual name. These records are bound to names built in a special way from numerical IP addresses, and are used to provide a reverse mapping from an IP address to a textual name. This is described in more detail in Section 26.1.8.

NS: Name Server

This record type is used to *delegate* a sub-tree of the Domain Name space to another nameserver. The record contains the FQDN of a DNS nameserver with information on the sub-domain, and is bound to the name of the sub-domain. In this manner, the hierarchical structure of the DNS is established. Delegation is described in more detail in Section 26.1.4.

MX: Mail eXchange

This record contains the FQDN for a host that will accept SMTP electronic mail for the named domain, together with a priority value used to select an MX host when relaying mail. It is used to indicate other servers that are willing to receive and spool mail for the domain if the primary MX is unreachable for a time. It is also used to direct email to a central server, if desired, rather than to each and every individual workstation.

HINFO: Host Information

Contains two strings, intended for use to describe the host hardware and operating system platform. There are defined strings to use for some systems, but their use is not enforced. Some sites, because of security considerations, do not publicise this information.

TXT: Text

A free-form text field, sometimes used as a comment field, sometimes overlaid with site-specific additional meaning to be interpreted by local conventions.

SOA: Start of Authority

This record is required to appear for each zone file. It lists the primary nameserver and the email address of the person responsible for the domain, together with default values for a number of fields associated with maintaining consistency across multiple servers and caching of the results of DNS queries.

26.1.4 Delegation

Using NS records, authority for portions of the DNS namespace below a certain point in the tree can be delegated, and further sub-parts below that delegated again. It is at this point that the distinction between a domain and a zone becomes important. Any name in the DNS is called a domain, and the term applies to that name and to any subordinate names below that one in the tree. The boundaries of a zone are narrower, and are defined by delegations. A zone starts with a delegation (or at the root), and encompasses all names in the domain below that point, excluding names below any subsequent delegations.

This distinction is important for implementation - a zone is a single administrative entity (with a single SOA record), and all data for the zone is referred to by a single file, called a *zone file*. A zone file may contain more than one period-separated level of the namespace tree, if desired, by including periods in the names in that zone file. In order to simplify administration and prevent overly-large zone files, it is quite legal for a DNS server to delegate to itself, splitting the domain into several zones kept on the same server.

26.1.5 Delegation to multiple servers

For redundancy, it is common (and often administratively required) that there be more than one nameserver providing information on a zone. It is also common that at least one of these servers be located at some distance (in terms of network topology) from the others, so that knowledge of that zone does not become unavailable in case of connectivity failure. Each nameserver will be listed in an NS record bound to the name of the zone, stored in the parent zone on the server responsible for the parent domain. In this way, those searching the name hierarchy from the top down can contact any one of the servers to continue narrowing their search. This is occasionally called *walking the tree*.

There are a number of nameservers on the Internet which are called *root nameservers*. These servers provide information on the very top levels of the domain namespace tree. These servers are special in that their addresses must be pre-configured into nameservers as a place to start finding other servers. Isolated networks that cannot access these servers may need to provide their own root nameservers.

26.1.6 Secondaries, Caching, and the SOA record

In order to maintain consistency between these servers, one is usually configured as the *primary* server, and all administrative changes are made on this server. The other servers are configured as *secondaries*, and transfer the contents of the zone from the primary. This operational model is not required, and if external considerations require it, multiple primaries can be used instead, but consistency must then be maintained by other means. DNS servers that store Resource Records for a zone, whether they be primary or secondary servers, are said to be *authoritative* for the zone. A DNS server can be authoritative for several zones.

When nameservers receive responses to queries, they can *cache* the results. This has a significant beneficial impact on the speed of queries, the query load on high-level nameservers, and network utilisation. It is also a major contributor to the memory usage of the nameserver process.

There are a number of parameters that are important to maintaining consistency amongst the secondaries and caches. The values for these parameters for a particular domain zone file are stored in the SOA record. These fields are:

Fields of the SOA Record

Serial

> A serial number for the zone file. This should be incremented any time the data in the domain is changed. When a secondary wants to check if its data is up-to-date, it checks the serial number on the primary's SOA record.

Refresh

A time, in seconds, specifying how often the secondary should check the serial number on the primary, and start a new transfer if the primary has newer data.

Retry

If a secondary fails to connect to the primary when the refresh time has elapsed (for example, if the host is down), this value specifies, in seconds, how often the connection should be retried.

Expire

If the retries fail to reach the primary within this number of seconds, the secondary destroys its copies of the zone data file(s), and stops answering requests for the domain. This stops very old and potentially inaccurate data from remaining in circulation.

TTL

This field specifies a time, in seconds, that the resource records in this zone should remain valid in the caches of other nameservers. If the data is volatile, this value should be short. TTL is a commonly-used acronym, that stands for "Time To Live".

26.1.7 Name Resolution

DNS clients are configured with the addresses of DNS servers. Usually, these are servers which are authoritative for the domain of which they are a member. All requests for name resolution start with a request to one of these local servers. DNS queries can be of two forms:

- A *recursive* query asks the nameserver to resolve a name completely, and return the result. If the request cannot be satisfied directly, the nameserver looks in its configuration and caches for a server higher up the domain tree which may have more information. In the worst case, this will be a list of pre-configured servers for the root domain. These addresses are returned in a response called a *referral*. The local nameserver must then send its request to one of these servers.
- Normally, this will be an *iterative* query, which asks the second nameserver to either respond with an authoritative reply, or with the addresses of nameservers (NS records) listed in its tables or caches as authoritative for the relevant zone. The local nameserver then makes iterative queries, walking the tree downwards until an authoritative answer is found (either positive or negative) and returned to the client.

In some configurations, such as when firewalls prevent direct IP communications between DNS clients and external nameservers, or when a site is connected to the rest of the world via a slow link, a nameserver can be configured with information about a *forwarder*. This is an external nameserver to which the local nameserver should make requests as a client would, asking the external nameserver to perform the full recursive name lookup, and return the result in a single query (which can then be cached), rather than reply with referrals.

26.1.8 Reverse Resolution

The DNS provides resolution from a textual name to a resource record, such as an A record with an IP address. It does not provide a means, other than exhaustive search, to match in the opposite direction;

there is no mechanism to ask which name is bound to a particular RR.

For many RR types, this is of no real consequence, however it is often useful to identify by name the host which owns a particular IP address. Rather than complicate the design and implementation of the DNS database engine by providing matching functions in both directions, the DNS utilises the existing mechanisms and creates a special namespace, populated with PTR records, for IP address to name resolution. Resolving in this manner is often called *reverse resolution*, despite the inaccurate implications of the term.

The manner in which this is achieved is as follows:

- A normal domain name is reserved and defined to be for the purpose of mapping IP addresses. The domain name used is "in-addr.arpa." which shows the historical origins of the Internet in the US Government's Defence Advanced Research Projects Agency's funding program.
- This domain is then subdivided and delegated according to the structure of IP addresses. IP addresses are often written in *decimal dotted quad notation*, where each octet of the 4-octet long address is written in decimal, separated by dots. IP address ranges are usually delegated with more and more of the left-most parts of the address in common as the delegation gets smaller. Thus, to allow delegation of the reverse lookup domain to be done easily, this is turned around when used with the hierarchical DNS namespace, which places higher level domains on the right of the name.
- Each byte of the IP address is written, as an ASCII text representation of the number expressed in decimal, with the octets in reverse order, separated by dots and appended with the in-addr.arpa. domain name. For example, to determine the hostname of a network device with IP address 11.22.33.44, this algorithm would produce the string "44.33.22.11.in-addr.arpa." which is a legal, structured Domain Name. A normal nameservice query would then be sent to the nameserver asking for a PTR record bound to the generated name.
- The PTR record, if found, will contain the FQDN of a host.

One consequence of this is that it is possible for mismatch to occur. Resolving a name into an A record, and then resolving the name built from the address in that A record to a PTR record, may not result in a PTR record which contains the original name. There is no restriction within the DNS that the "reverse" mapping must coincide with the "forward" mapping. This is a useful feature in some circumstances, particularly when it is required that more than one name has an A record bound to it which contains the same IP address.

While there is no such restriction within the DNS, some application server programs or network libraries will reject connections from hosts that do not satisfy the following test:

- the state information included with an incoming connection includes the IP address of the source of the request.
- a PTR lookup is done to obtain an FQDN of the host making the connection
- an A lookup is then done on the returned name, and the connection rejected if the source IP address is not listed amongst the A records that get returned.

This is done as a security precaution, to help detect and prevent malicious sites impersonating other sites by configuring their own PTR records to return the names of hosts belonging to another organisation.

26.2 The DNS Files

Now let's look at actually setting up a small DNS enabled network. We will continue to use the examples mentioned in Chapter 24, i.e. we assume that:

- Our IP networking is working correctly
- We have IPNAT working correctly
- Currently all hosts use the ISP for DNS

Our Name Server will be the "strider" host which also runs IPNAT, and our two clients use "strider" as a gateway. It is not really relevant as to what type of interface is on "strider", but for argument's sake we will say a 56k dial up connection.

So, before going any further, let's look at our `/etc/hosts` file on "strider" before we have made the alterations to use DNS.

Example 26-1. strider's `/etc/hosts` file

```
127.0.0.1       localhost
192.168.1.1     strider
192.168.1.2     samwise sam
192.168.1.3     wormtongue worm
```

This is not exactly a huge network, but it is worth noting that the same rules apply for larger networks as we discuss in the context of this section.

The other assumption we want to make is that the domain we want to set up is `diverge.org`, and that the domain is only known on our internal network, and not worldwide. Proper registration of the nameserver's IP address as primary would be needed in addition to a static IP. These are mostly administrative issues which are left out here.

The NetBSD operating system provides a set of config files for you to use for setting up DNS. Along with a default `/etc/named.conf`, the following files are stored in the `/etc/namedb` directory:

- `localhost`
- `127`
- `loopback.v6`
- `root.cache`

You will see modified versions of these files in this section, and I strongly suggest making a backup copy of the original files for reference purposes.

> **Note:** The examples in this chapter refer to BIND major version 8, however, it should be noted that format of the name database and other config files are almost 100% compatible between version. The only difference I noticed was that the "$TTL" information was not required.

26.2.1 /etc/named.conf

The first file we want to look at is `/etc/named.conf`. This file is the config file for bind (hence the catchy name). Setting up system like the one we are doing is relatively simple. First, here is what mine looks like:

```
options {
        directory "/etc/namedb";
        allow-transfer { 192.168.1.0/24; };
        allow-query { 192.168.1.0/24; };
        listen-on port 53 { 192.168.1.1; };
};

zone "localhost" {
   type master;
   notify no;
   file "localhost";
};

zone "127.IN-ADDR.ARPA" {
   type master;
   notify no;
   file "127";
};

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.int" {
   type master;
   file "loopback.v6";
};

zone "diverge.org" {
   type master;
   notify no;
   file "diverge.org";
};

zone "1.168.192.in-addr.arpa" {
   type master;
   notify no;
   file "1.168.192";
};

zone "." in {
   type hint;
   file "root.cache";
};
```

Note that in my `named.conf` the root (".") section is last, that is because there is another domain called diverge.org on the internet (I happen to own it) so I want the resolver to look out on the internet last. This is not normally the case on most systems.

Another very important thing to remember here is that if you have an internal setup, in other words no live internet connection and/or no need to do root server lookups, comment out the root (".") zone. It may cause lookup problems if a particular client decides it wants to reference a domain on the internet, which our server couldn't resolve itself.

Looks like a pretty big mess, upon closer examination it is revealed that many of the lines in each section are somewhat redundant. So we should only have to explain them a few times.

Let's go through the sections of `named.conf`:

26.2.1.1 options

This section defines some global parameters, most noticeable is the location of the DNS tables, on this particular system, they will be put in `/etc/namedb` as indicated by the "directory" option.

Following are the rest of the params:

allow-transfer

> This option lists which remote DNS servers acting as secondaries are allowed to do zone transfers, i.e. are allowed to read all DNS data at once. For privacy reasons, this should be restricted to secondary DNS servers only.

allow-query

> This option defines hosts from what network may query this name server at all. Restricting queries only to the local network (192.168.1.0/24) prevents queries arriving on the DNS server's external interface, and prevent possible privacy issues.

listen-on port

> This option defined the port and associated IP addresses this server will run named(8) on. Again, the "external" interface is not listened here, to prevent queries getting received from "outside".

The rest of the `named.conf` file consists of "zone"s. A zone is an area that can have items to resolve attached, e.g. a domain can have hostnames attached to resolve into IP addresses, and a reverse-zone can have IP addresses attached that get resolved back into hostnames. Each zone has a file associated with it, and a table within that file for resolving that particular zone. As is readily apparent, their format in `named.conf` is strikingly similar, so I will highlight just one of their records:

26.2.1.2 zone "diverge.org"

type

> The type of a zone is usually of type "master" in all cases except for the root zone "." and for zones that a secondary (backup) service is provided - the type obviously is "secondary" in the latter case.

notify

> Do you want to send out notifications to secondaries when your zone changes? Obviously not in this setup, so this is set to "no".

file

> This option sets the filename in our `/etc/namedb` directory where records about this particular zone may be found. For the "diverge.org" zone, the file `/etc/namedb/diverge.org` is used.

26.2.2 `/etc/namedb/localhost`

For the most part, the zone files look quite similar, however, each one does have some unique properties. Here is what the `localhost` file looks like:

Example 26-2. `localhost`

```
 1|$TTL    3600
 2|@              IN SOA  strider.diverge.org. root.diverge.org. (
 3|                        1       ; Serial
 4|                        8H      ; Refresh
 5|                        2H      ; Retry
 6|                        1W      ; Expire
 7|                        1D)     ; Minimum TTL
 8|              IN NS   localhost.
 9|localhost.     IN      A       127.0.0.1
10|               IN      AAAA    ::1
```

Line by line:

Line 1:

This is the Time To Live for lookups, which defines how long other DNS servers will cache that value before discarding it. This value is generally the same in all the files.

Line 2:

This line is generally the same in all zone files except `root.cache`. It defines a so-called "Start Of Authority" (SOA) header, which contains some basic information about a zone. Of specific interest on this line are "strider.diverge.org." and "root.diverge.org." (note the trailing dots!). Obviously one is the name of this server and the other is the contact for this DNS server, in most cases root seems a little ambiguous, it is preferred that a regular email account be used for the contact information, with the "@" replaced by a "." (for example, mine would be "jrf.diverge.org.").

Line 3:

This line is the serial number identifying the "version" of the zone's data set (file). The serial number should be incremented each time there is a change to the file, the usual format is to either start with a value of "1" and increase it for every change, or use a value of "YYYYMMDDNN" to encode year (YYYY), month (MM), day (DD) and change within one day (NN) in the serial number.

Line 4:

This is the refresh rate of the server, in this file it is set to once every 8 hours.

Line 5:

The retry rate.

Line 6:

Lookup expiry.

Line 7:

The minimum Time To Live.

Line 8:

This is the Nameserver line, which uses a "NS" resource record to show that "localhost" is the only DNS server handing out data for this zone (which is "@", which indicates the zone name used in the `named.conf` file, i.e. "diverge.org") is, well, "localhost".

Line 9:

This is the localhost entry, which uses an "A" resource record to indicate that the name "localhost" should be resolved into the IP-address 127.0.0.1 for IPv4 queries (which specifically ask for the "A" record).

Line 10:

This line is the IPv6 entry, which returns ::1 when someone asks for an IPv6-address (by specifically asking for the AAAA record) of "localhost.".

26.2.3 `/etc/namedb/zone.127.0.0`

This is the reverse lookup file (or zone) to resolve the special IP address 127.0.0.1 back to "localhost":

```
 1| $TTL    3600
 2| @              IN SOA  strider.diverge.org. root.diverge.org. (
 3|                        1       ; Serial
 4|                        8H      ; Refresh
 5|                        2H      ; Retry
 6|                        1W      ; Expire
 7|                        1D)     ; Minimum TTL
 8|                 IN NS   localhost.
 9| 1.0.0           IN PTR  localhost.
```

In this file, all of the lines are the same as the localhost zonefile with exception of line 9, this is the reverse lookup (PTR) record. The zone used here is "@" again, which got set to the value given in `named.conf`, i.e. "127.in-addr.arpa". This is a special "domain" which is used to do reverse-lookup of IP addresses back into hostnames. For it to work, the four bytes of the IPv4 address are reserved, and the domain "in-addr.arpa" attached, so to resolve the IP address "127.0.0.1", the PTR record of "1.0.0.127.in-addr.arpa" is queried, which is what is defined in that line.

26.2.4 `/etc/namedb/diverge.org`

This zone file is populated by records for all of our hosts. Here is what it looks like:

```
$TTL    3600
@              IN SOA  strider.diverge.org. root.diverge.org. (
                        1       ; serial
                        8H      ; refresh
                        2H      ; retry
                        1W      ; expire
```

```
 7|                         1D )    ; minimum seconds
 8|                 IN NS   strider.diverge.org.
 9|                 IN MX   10 strider.diverge.org.   ; primary mail server
10|                 IN MX   20 samwise.diverge.org.   ; secondary mail server
11| strider         IN A     192.168.1.1
12| samwise         IN A     192.168.1.2
13| www             IN CNAME samwise.diverge.org.
14| worm            IN A     192.168.1.3
```

There is a lot of new stuff here, so let's just look over each line that is new here:

Line 9

This line shows our mail exchanger (MX), in this case it is "strider". The number that precedes "strider.diverge.org." is the priority number, the lower the number their higher the priority. The way we are setup here is if "strider" cannot handle the mail, then "samwise" will.

Line 11

CNAME stands for canonical name, or an alias for an existing hostname, which must have an A record. So we have aliased the following:

www.diverge.org to samwise.diverge.org

The rest of the records are simply mappings of IP address to a full name (A records).

26.2.5 `/etc/namedb/1.168.192`

This zone file is the reverse file for all of the host records, to map their IP numbers we use on our private network back into hostnames. The format is similar to that of the "localhost" version with the obvious exception being the addresses are different via the different zone given in the `named.conf` file, i.e. "0.168.192.in-addr.arpa" here:

```
$TTL    3600
@              IN SOA  strider.diverge.org. root.diverge.org. (
                     1       ; serial
                     8H      ; refresh
                     2H      ; retry
                     1W      ; expire
                     1D )    ; minimum seconds
               IN NS   strider.diverge.org.
1              IN PTR  strider.diverge.org.
2              IN PTR  samwise.diverge.org.
3              IN PTR  worm.diverge.org.
```

26.2.6 `/etc/namedb/root.cache`

This file contains a list of root name servers for your server to query when it gets requests outside of its own domain that it cannot answer itself. Here are first few lines of a root zone file:

```
;
```

```
;       This file holds the information on root name servers needed to
;       initialize cache of Internet domain name servers
;       (e.g. reference this file in the "cache  .  <file>"
;       configuration file of BIND domain name servers).
;
;       This file is made available by InterNIC
;       under anonymous FTP as
;           file                /domain/db.cache
;           on server           FTP.INTERNIC.NET
;       -OR-                    RS.INTERNIC.NET
;
;       last update:    Jan 29, 2004
;       related version of root zone:   2004012900
;
;
; formerly NS.INTERNIC.NET
;
.                        3600000  IN  NS    A.ROOT-SERVERS.NET.
A.ROOT-SERVERS.NET.      3600000      A     198.41.0.4
;
; formerly NS1.ISI.EDU
;
.                        3600000      NS    B.ROOT-SERVERS.NET.
B.ROOT-SERVERS.NET.      3600000      A     192.228.79.201
;
; formerly C.PSI.NET
;
.                        3600000      NS    C.ROOT-SERVERS.NET.
C.ROOT-SERVERS.NET.      3600000      A     192.33.4.12
;
...
```

This file can be obtained from ISC at http://www.isc.org/ and usually comes with a distribution of BIND. A `root.cache` file is included in the NetBSD operating system's "etc" set.

This section has described the most important files and settings for a DNS server. Please see the BIND documentation in `/usr/src/dist/bind/doc/bog` and named.conf(5) for more information.

26.3 Using DNS

In this section we will look at how to get DNS going and setup "strider" to use its own DNS services.

Setting up named to start automatically is quite simple. In `/etc/rc.conf` simply set `named=yes`. Additional options can be specified in `named_flags`, for example, I like to use `-g nogroup -u nobody`, so a non-root account runs the "named" process.

In addition to being able to startup "named" at boot time, it can also be controlled with the **ndc** command. In a nutshell the **ndc** command can stop, start or restart the named server process. It can also do a great many other things. Before use, it has to be setup to communicate with the "named" process, see the rndc(8) and named.conf(5) man pages for more details on setting up communication channels between "ndc" and the "named" process.

Next we want to point "strider" to itself for lookups. We have two simple steps, first, decide on our resolution order. On a network this small, it is likely that each host has a copy of the hosts table, so we can get away with using `/etc/hosts` first, and then DNS. However, on larger networks it is much easier to use DNS. Either way, the file where order of name services used for resolution is determined is `/etc/nsswitch.conf` Here is part of a typical `nsswitch.conf`:

```
. . .
group_compat:   nis
hosts:          files dns
netgroup:       files [notfound=return] nis
. . .
```

The line we are interested in is the "hosts" line. "files" means the system uses the `/etc/hosts` file first to determine ip to name translation, and if it can't find an entry, it will try DNS.

The next file to look at is `/etc/resolv.conf`, which is used to configure DNS lookups ("resolution") on the client side. The format is pretty self explanatory but we will go over it anyway:

```
domain diverge.org
search diverge.org
nameserver 192.168.1.1
```

In a nutshell this file is telling the resolver that this machine belongs to the "diverge.org" domain, which means that lookups that contain only a hostname without a "." gets this domain appended to build a FQDN. If that lookup doesn't succeed, the domains in the "search" line are tried next. Finally, the "nameserver" line gives the IP addresses of one or more DNS servers that should be used to resolve DNS queries.

To test our nameserver we can use several commands, for example:

```
# host sam
sam.diverge.org has address 192.168.1.2
```

As can be seen, the domain was appended automatically here, using the value from `/etc/resolv.conf`. Here is another example, the output of running **host www.yahoo.com**:

```
$ host www.yahoo.com
www.yahoo.com is an alias for www.yahoo.akadns.net.
www.yahoo.akadns.net has address 68.142.226.38
www.yahoo.akadns.net has address 68.142.226.39
www.yahoo.akadns.net has address 68.142.226.46
www.yahoo.akadns.net has address 68.142.226.50
www.yahoo.akadns.net has address 68.142.226.51
www.yahoo.akadns.net has address 68.142.226.54
www.yahoo.akadns.net has address 68.142.226.55
www.yahoo.akadns.net has address 68.142.226.32
```

Other commands for debugging DNS besides host(1) are nslookup(8) and dig(1). Note that ping(8) is *not* useful for debugging DNS, as it will use whatever is configured in `/etc/nsswitch.conf` to do the name-lookup.

At this point the server is configured properly. The procedure for setting up the client hosts are easier, you only need to setup `/etc/nsswitch.conf` and `/etc/resolv.conf` to the same values as on the server.

26.4 Setting up a caching only name server

A caching only name server has no local zones; all the queries it receives are forwarded to the root servers and the replies are accumulated in the local cache. The next time the query is performed the answer will be faster because the data is already in the server's cache. Since this type of server doesn't handle local zones, to resolve the names of the local hosts it will still be necessary to use the already known `/etc/hosts` file.

Since NetBSD supplies defaults for all the files needed by a caching only server, it only needs to be enabled and started and is immediately ready for use! To enable named, put `named=yes` into `/etc/rc.conf`, and tell the system to use it adding the following line to the `/etc/resolv.conf` file:

```
# cat /etc/resolv.conf
nameserver 127.0.0.1
```

Now we can start named:

```
# sh /etc/rc.d/named restart
```

26.4.1 Testing the server

Now that the server is running we can test it using the nslookup(8) program:

```
$ nslookup
Default server: localhost
Address: 127.0.0.1

>
```

Let's try to resolve a host name, for example "www.NetBSD.org":

```
> www.NetBSD.org
Server:  localhost
Address:  127.0.0.1

Name:    www.NetBSD.org
Address:  204.152.190.12
```

If you repeat the query a second time, the result is slightly different:

```
> www.NetBSD.org
Server:  localhost
Address:  127.0.0.1

Non-authoritative answer:
Name:    www.NetBSD.org
Address:  204.152.190.12
```

As you've probably noticed, the address is the same, but the message "Non-authoritative answer" has appeared. This message indicates that the answer is not coming from an authoritative server for the domain NetBSD.org but from the cache of our own server.

The results of this first test confirm that the server is working correctly.

We can also try the host(1) and dig(1) commands, which give the following result.

```
$ host www.NetBSD.org
www.NetBSD.org has address 204.152.190.12
$
$ dig www.NetBSD.org

; <<>> DiG 8.3 <<>> www.NetBSD.org
;; res options: init recurs defnam dnsrch
;; got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 19409
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 5, ADDITIONAL: 0
;; QUERY SECTION:
;;      www.NetBSD.org, type = A, class = IN

;; ANSWER SECTION:
www.NetBSD.org.         23h32m54s IN A  204.152.190.12

;; AUTHORITY SECTION:
NetBSD.org.             23h32m54s IN NS  uucp-gw-1.pa.dec.com.
NetBSD.org.             23h32m54s IN NS  uucp-gw-2.pa.dec.com.
NetBSD.org.             23h32m54s IN NS  ns.NetBSD.org.
NetBSD.org.             23h32m54s IN NS  adns1.berkeley.edu.
NetBSD.org.             23h32m54s IN NS  adns2.berkeley.edu.

;; Total query time: 14 msec
;; FROM: miyu to SERVER: 127.0.0.1
;; WHEN: Thu Nov 25 22:59:36 2004
;; MSG SIZE  sent: 32  rcvd: 175
```

As you can see dig(1) gives quite a bit of output, the expected answer can be found in the "ANSWER SECTION". The other data given may be of interest when debugging DNS problems.

Chapter 27
Mail and news

This chapter explains how to set up NetBSD to use mail and news. Only a simple but very common setup is described: the configuration of a host connected to the Internet with a modem through a provider. You can think of this chapter as the continuation of Chapter 24, assuming a similar network configuration. Even this “simple” setup proves to be difficult if you don’t know where to start or if you’ve only read introductory or technical documentation. A general description of mail and news configuration is beyond the scope of this guide; please read a good Unix Administration book (some very good ones are listed on the NetBSD site).

This chapter also briefly describes the configuration (but not the usage) of two popular applications, mutt for mail and tin for news. The usage is not described because they are easy to use and well documented. Obviously, both mutt and tin are not mandatory choices: many other similar applications exist but I think that they are a good starting point because they are widely used, simple, work well and don’t use too much disk space and memory. Both are console mode programs; if you prefer graphics applications there are also many choices for X.

In short, the programs required for the configuration described in this chapter are:

- postfix
- fetchmail
- mutt
- tin

Only postfix is installed with the base system; you can install the other programs from the NetBSD package collection, pkgsrc.

> **Note:** Because sendmail is widely popular and several programs like fetchmail are designed to be used with it, postfix includes a command line wrapper that accepts sendmail’s commands line syntax but works with postfix. See sendmail(1) for more details.

Before continuing, remember that none of the programs presented in this chapter is mandatory: there are other applications performing similar tasks and many users prefer them. You’ll find different opinions reading the mailing lists. You can also use different strategies for sending and receiving mail: the one explained here is only a starting point; once you understand how it works you’ll probably want to modify it to suit your needs or to adopt a different method altogether.

At the opposite extreme of the example presented here, there is the usage of an application like Mozilla, which does everything and frees you from the need of configuring many components: with Mozilla you can browse the Internet, send and receive mail and read news. Besides, the setup is very simple. There is a price to pay, though: Mozilla is a “closed” program that will not cooperate easily with other standard Unix utilities.

Another possibility is to use emacs to read mail and news. Emacs needs no introduction to Unix users but, in case you don't know, it is an extensible editor (although calling emacs an editor is somewhat reductive) which becomes a complete work environment, and can be used to read mail, news and to perform many operations. For many people emacs is the only environment that they need and they use it for all their work. The configuration of emacs for mail and news is described in the emacs manual.

In the rest of this chapter we will deal with a host connected to the Internet through a PPP connection via serial modem to a provider.

- the local host's name is "ape" and the internal network is "insetti.net", which means that the FQDN (Fully Qualified Domain Name) is "ape.insetti.net".
- the user's login name on ape is "carlo".
- the provider's name is BigNet.
- the provider's mail server is "mail.bignet.it".
- the provider's news server is "news.bignet.it".
- the user's ("carlo") account at the provider is "alan" with the password "pZY9o".

First some basic terminology:

MUA (mail user agent)

: a program to read and write mail. For example: mutt, elm and pine but also the simple mail application installed with the base system.

MTA (mail transfer agent)

: a program that transfers mail between two host but also locally (on the same host). The MTA decides the path that the mail will follow to get to the destination. On other BSD systems (but not only) the standard MTA is sendmail, other examples are qmail, exim and Microsoft Exchange.

MDA (mail delivery agent)

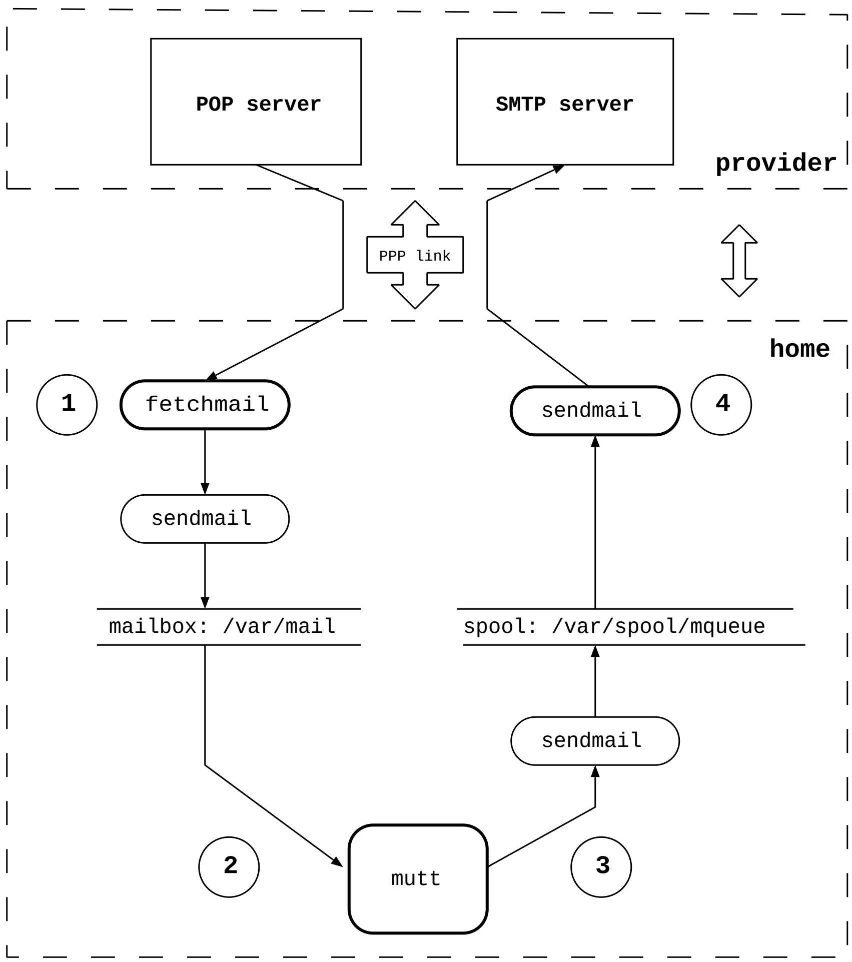
: a program, usually used by the MTA, that delivers the mail; for example, it physically puts the messages in the recipient's mailbox. For example, postfix uses one or more MDAs to deliver mail, and procmail is another well-known MDA.

Figure 27-1 depicts the mail system that we want to set up. Between the local network (or the single host) and the provider there is a modem PPP connection. The "bubbles" with the thick border (postfix, fetchmail, mutt) are the programs launched manually by the user; the remaining bubbles are the programs that are launched automatically. The circled numbers refer to the logical steps of the mail cycle:

1. In step (1) mail is downloaded from the provider's POP server using fetchmail, which hands messages off to postfix's sendmail wrapper to put the messages in the user's mailbox.
2. In step (2) the user launches mutt (or another MUA) to read mail, reply and write new messages.
3. In step (3) the user "sends" the mail from within mutt. Messages are accumulated in the spool area.
4. In step (4) the user calls postfix's sendmail wrapper to transfer the messages to the provider's SMTP server, that will deliver them to the final destination (possibly through other mail servers). The provider's SMTP server acts as a *relay* for our mail.

The connection with the provider must be up only during steps (1) and (4); for the remaining steps it is not needed.

Figure 27-1. Structure of the mail system



27.1 postfix

When an MTA must deliver a local message, it is delivered directly. If the message is intended for a different domain, the MTA must find out the address of the mail server for that domain. Postfix uses the DNS service (described in Chapter 26) to find a mail exchanger handling mail for the given domain, and delivers the message to that mail server then.

Postfix is controlled by a set of configuration files and databases, of which `/etc/postfix/main.cf` and `/etc/postfix/master.cf` are the most important.

The first problem to be solved is that the local network we are dealing with is an internal network, i.e. not directly accessible from the Internet. This means that the names used internally have no meaning on the Internet; in short, “ape.insetti.net” cannot be reached by an external host: no one will be able to reply to a mail sent with this return address (many mail systems will even reject the message as spam prevention as it comes from an unknown host). The true address, the one visible from everybody, is assigned by the provider and, therefore, it is necessary to convert the local address “carlo@ape.insetti.net” to the real address “alan@bignet.it”. Postfix, if correctly configured, will take care of this when it transfers the messages.

You’ll probably also want to configure postfix in order to send the e-mails to the provider’s mail server, using it as a *relay*. In the configuration described in this chapter, postfix does not directly contact the recipient’s mail server (as previously described) but relays all its mail to the provider’s mail server.

> **Note:** The provider’s mail server acts as a *relay*, which means that it delivers mail which is not destined to its own domain, to another mail server. It acts as an intermediary between two servers.

Since the connection with the provider is not always active, it is not necessary to start postfix as a daemon in `/etc/rc.conf`: you can disable it with the line “`postfix=NO`”. As a consequence it will be necessary to launch postfix manually when you want to transfer mail to the provider. Local mail is delivered correctly even if postfix is not active as a daemon.

Let’s start configuring postfix.

27.1.1 Configuration of generic mapping

This type of configuration uses a new file `/etc/postfix/generic` which contains the hostname mapping used by postfix to rewrite the internal hostnames.

The first step is therefore to write the mapping file:

```
carlo@ape.insetti.net   alan@bignet.it
root@ape.insetti.net   alan@bignet.it
news@ape.insetti.net   alan@bignet.it
```

These entries will map the mail sent from the users given on the left side into the globally valid email addresses given on the right, making it appear as if the mail was really sent from that address.

For the sake of efficiency, `generic` must be transformed into a binary file with the following command:

```
# postmap /etc/postfix/generic
```

Now it’s time to create the prototype configuration file which we’ll use to create the postfix configuration file.

```
# vi /etc/postfix/main.cf
```

For the sake of simplicity, we’ll only show the variables you need to change:

```
relayhost = mail.bignet.it
smtp_generic_maps = hash:/etc/postfix/generic
```

This configuration tells postfix to rewrite the addresses of type “ape.insetti.net” using the real names found in the `/etc/postfix/generic` file. It also says that mail should be sent to the “mail.bignet.it” server. The meaning of the options is described in detail in postconf(5).

The last step is to reload the configuration. You can do that easily with:

```
# /etc/rc.d/postfix reload
postfix/postfix-script: refreshing the Postfix mail system
```

Now everything is ready to start sending mail.

27.1.2 Testing the configuration

Postfix is finally configured and ready to work, but before sending real mail it is better to do some simple tests. First let's try sending a local e-mail with the following command (postfix's sendmail wrapper):

```
$ sendmail carlo
Subject: test

Hello world
.
```

Please follow exactly the example above: leave a blank line after Subject: and end the message with a line containing only one dot. Now you should be able to read the message with your mail client and verify that the From: field has been correctly rewritten.

```
From: alan@bignet.it
```

27.1.3 Using an alternative MTA

```
$ ls -l /usr/sbin/sendmail
lrwxr-xr-x  1 root  wheel  21 Nov  1 01:14 /usr/sbin/sendmail@ -> /usr/sbin/mailwrapper
```

The purpose of mailwrapper is to allow the usage of an alternative MTA instead of postfix (for example, sendmail). If you plan to use a different mailer I suggest that you read the mailwrapper(8) and the mailer.conf(5) manpages, which are very clear.

27.2 fetchmail

If someone sends me mail, it is received and stored by the provider, and not automatically transferred to the local hosts; therefore it is necessary to download it. Fetchmail is a very popular program that downloads mail from a remote mail server (using e.g. the Post Office Protocol, POP) and forwards it to the local system for delivery (usually using postfix's sendmail wrapper). It is powerful yet easy to use and configure: after installation, the file `~/.fetchmailrc` must be created and the program is ready to run (`~/.fetchmailrc` contains a password so appropriate permissions on the file are required).

This is an example `.fetchmailrc`:

```
poll mail.bignet.it
protocol POP3
username alan there with password pZY9o is carlo here
flush
mda "/usr/sbin/sendmail -oem %T"
```

The last line ("mda ...") is used only if postfix is not active as daemon on the system. Please note that the POP-mail server indicated in this file (mail.bignet.it) is only used to retrieve mails, and that it is not necessary the same as the mail relay used by postfix to send out mails.

After setting up the `.fetchmailrc` file, the following command can be used to download and deliver mail to the local system:

```
$ fetchmail
```

The messages can now be read with mutt.

27.3 Reading and writing mail with mutt

Mutt is one of the most popular mail programs: it is "lightweight", easy to use and has lots of features. The man page mutt is very bare bones; the real documentation is in `/usr/pkg/share/doc/mutt/`, in particular `manual.txt`.

Mutt's configuration is defined by the `~/.muttrc` file. The easiest way to create it is to copy mutt's example muttrc file (usually `/usr/pkg/share/examples/mutt/sample.muttrc`) to the home directory and modify it. The following example shows how to achieve some results:

- Save a copy of sent mail.
- Define a directory and two files for incoming and outgoing mail saved by mutt (in this example the directory is `~/Mail` and the files are `incoming` and `outgoing`).
- Define some colors.
- Define an alias.

```
set copy=yes
set edit_headers
set folder="~/Mail"
unset force_name
set mbox="~/Mail/incoming"
set record="~/Mail/outgoing"
unset save_name

bind pager <up> previous-page
bind pager <down> next-page

color normal white black
color hdrdefault blue black
color indicator white blue
color markers red black
color quoted cyan black
color status white blue
color error red white
color underline yellow black

mono quoted standout
mono hdrdefault underline
mono indicator underline
```

```
mono status bold

alias pippo Pippo Verdi <pippo.verdi@pluto.net>
```

To start mutt:

```
$ mutt
```

Please note that mutt supports color, but this depends on the terminal settings. Under X you can use "xterm-color", for example:

```
$ env TERM=xterm-color mutt
```

27.4 Strategy for receiving mail

This section describes a simple method for receiving and reading mail. The connection to the provider is activated only for the time required to download the messages; mail is then read offline.

1. Activate the connection to the provider.
2. Run **fetchmail**.
3. Deactivate the connection.
4. Read mail with mutt.

27.5 Strategy for sending mail

When mail has been written and “sent” with mutt, the messages must be transferred to the provider with postfix. Mail is sent from mutt with the **y** command, but this does not really send it; the messages are enqueued in the spool area; if postfix is not active as a daemon it is necessary to start it manually or the messages will remain on the hard disk. The necessary steps are:

1. Write mail with mutt, send it and exit mutt. You can check if and what messages are in the postfix mail queue using the mailq(1) program.
2. Activate the connection with the provider.
3. If your provider requires you to do "SMTP-after-POP", i.e. it first wants to make sure to know who you are before you are allowed to send mail (and no spam), you need to run **fetchmail** again first.
4. Write the command **/usr/sbin/postfix flush** to transfer the queued messages to the provider.
5. Deactivate the connection when the queue is empty.

27.6 Advanced mail tools

When you start using mail, you won’t probably have very sophisticated requirements and the already described standard configuration will satisfy all your needs. But for many users the number of daily messages will increase with time and a more rational organization of the mail storage will become necessary, for example subdividing mail in different mail boxes organized by topic. If, for example, you subscribe to a mailing list, you will likely receive many messages every day and you will want to keep them separate from the rest of your mail. You will soon find that you are spending too much time every day repeating the same manual operations to organize your mail boxes.

Why repeat the same operations manually when you can have a program perform them automatically for you? There are numerous tools that you can add to your mail system to increase its flexibility and automatically process your messages. Amongst the most known and used there are:

- procmail, an advanced mail delivery agent and general purpose mail filter for local mail, which automatically processes incoming mail using user defined rulesets. It integrates smoothly with sendmail/postfix.
- spamassassin or spamprobe, to help fight spam.
- metamail, a tool to process attachments.
- formail, a mail formatter.

In the remaining part of this section a sample configuration for procmail will be presented for a very common case: delivering automatically to a user defined mailbox all the messages coming from a mailing list. The configuration of postfix will be modified in order to call procmail directly (procmail will be the *local mailer* used by sendmail). and a custom configuration file for procmail will be created.

First, procmail must be installed using the package system (`mail/procmail`) or **pkg_add**.

Next, the configuration of postfix must be changed, in order to use procmail as local mailer:

```
mailbox_command = /usr/pkg/bin/procmail
```

The line defines the path of the procmail program (you can see where procmail is installed with the command **which procmail**).

The last step is the creation of the procmail configuration file, containing the recipes for mail delivery.

Let’s say that, for example, you subscribed to a mailing list on roses whose address is “roses@flowers.org” and that every message from the list contains the following line in the header:

```
Delivered-To: roses@flowers.org
```

Assuming you want to automatically sort all mails going over that list into the local mail folder "roses_list", the procmail configuration file (`.procmailrc`) looks like this:

```
PATH=/bin:/usr/bin:/usr/pkg/bin
MAILDIR=$HOME/Mail
LOGFILE=$MAILDIR/from

:0
* ^Delivered-To: roses@flowers.org
roses_list
```

The previous file contains only one rule, beginning with the line containing “:0”. The following line identifies all messages containing the string “Delivered-To: roses@flowers.org” and the last line says that the selected messages must go to the `roses_list` mailbox (which you should have created in

$MAILDIR). The remaining messages will be delivered to the default mailbox. Note that $MAILDIR is the same directory that you have configured with mutt:

```
set folder="~/Mail"
```

Of course the mailing list is only an example; procmail is a very versatile tool which can be used to filter mail based on many criteria. As usual, refer to the man pages for more details: procmail(1), procmailrc(5), and procmailex(5) (this last one contains many examples of configuration files).

27.7 News with tin

The word *news* indicates the set of messages posted to the USENET newsgroups, a service available on the Internet. Each newsgroup contains articles related to a specific topic. Reading a newsgroup is different than reading a mailing list: when you subscribe to a mailing list you receive the articles by mail and you read them with a standard mail program like mutt, which you use also to send replies. News, instead, are read directly from a news server with a dedicated program called *newsreader* like, for example, tin. With tin you can subscribe to the newsgroups that you're interested in and follow the *threads*. A thread is a sequence of articles which all derive from an article that we could call “original”. In short, a message is sent to the group, someone answers, other people answer to those who answered in the first place and so on, creating a tree like structure of messages and replies: without a newsreader it is impossible to understand the correct sequence of messages.

After the installation of tin (from the package collection as usual) the only thing left to do is to write the name of the NNTP server in the file `/usr/pkg/etc/nntp/server`, which you may need to create first. For example:

```
news.bignet.it
```

Once this has been done, the program can be started with the command **tin**. On the screen something similar to the following example will be displayed:

```
$ tin
Connecting to news.bignet.it...
news.bignet.it InterNetNews NNRP server INN 1.7.2 08-Dec-1997 ready (posting ok).
Reading groups from active file...
Checking for new groups...
Reading attributes file...
Reading newsgroups file...
Creating newsrc file...
Autosubscribing groups...
Reading newsrc file...
```

Be patient when you connect for the first time, because tin downloads an immense list of newsgroups to which you can subscribe and this takes several minutes. When the download is finished, the program's main screen is displayed; usually no groups are displayed; to see the list of groups press **y**. To subscribe to a group, move on the group's name and press **y**.

Once that you have subscribed to some newsgroups you can start tin more quickly with the command **tin -Q**. The search for new groups is disabled (`-q`), only active groups are searched (`-n`) and newsgroup description are not loaded (`-d`): it will not be possible to use the **y** (yank) command in tin. When tin is started with this option it can't tell if a newsgroup is moderated or not.

Note that if you are connecting from an internal network (like in our example), when you send ("post") a message the address at the beginning of the message will be wrong (because it is the internal address). To solve the problem, use the option “mail_address” in the tin configuration file (`~/.tin/tinrc`) or set the REPLYTO environment variable.

Chapter 28

Introduction to the Common Address Redundancy Protocol (CARP)

See Section D.3.3 for the license of this chapter.

CARP is the Common Address Redundancy Protocol. Its primary purpose is to allow multiple hosts on the same network segment to share an IP address. CARP is a secure, free alternative to the Virtual Router Redundancy Protocol (http://www.ietf.org/rfc/rfc3768.txt) and the Hot Standby Router Protocol (http://www.ietf.org/rfc/rfc2281.txt).

CARP works by allowing a group of hosts on the same network segment to share an IP address. This group of hosts is referred to as a "redundancy group". The redundancy group is assigned an IP address that is shared amongst the group members. Within the group, one host is designated the "master" and the rest as "backups". The master host is the one that currently "holds" the shared IP; it responds to any traffic or ARP requests directed towards it. Each host may belong to more than one redundancy group at a time.

One common use for CARP is to create a group of redundant firewalls. The virtual IP that is assigned to the redundancy group is configured on client machines as the default gateway. In the event that the master firewall suffers a failure or is taken offline, the IP will move to one of the backup firewalls and service will continue unaffected.

While highly redundant and fault-tolerant hardware minimizes the need for CARP, it doesn't erase it. There's no hardware fault tolerance that's capable of helping if someone knocks out a power cord, or if your system administrator types reboot in the wrong window. CARP also makes it easier to make the patch and reboot cycle transparent to users, and easier to test a software or hardware upgrade--if it doesn't work, you can fall back to your spare until fixed.

There are, however, situations in which CARP won't help. CARP's design does require that the members of a group be on the same physical subnet with a static IP address, although with the introduction of the carpdev directive, there is no more need for IP addresses on the physical interfaces. Similarly, services that require a constant connection to the server (such as SSH or IRC) will not be transparently transferred to the other system--though in this case, CARP can help with minimizing downtime. CARP by itself does not synchronize data between applications, for example, manually duplicating data between boxes with rsync, or whatever is appropriate for your application.

CARP supports both IPv4 and IPv6.

28.1 CARP Operation

The master host in the group sends regular advertisements to the local network so that the backup hosts know it's still alive. If the backup hosts don't hear an advertisement from the master for a set period of time, then one of them will take over the duties of master (whichever backup host has the lowest configured advbase and advskew values). It's possible for multiple CARP groups to exist on the same network segment. CARP advertisements contain the Virtual Host ID which allows group members to identify which redundancy group the advertisement belongs to.

In order to prevent a malicious user on the network segment from spoofing CARP advertisements, each group can be configured with a password. Each CARP packet sent to the group is then protected by an SHA1 HMAC.

28.2 Configuring CARP

Each redundancy group is represented by a carp(4) virtual network interface. As such, CARP is configured using ifconfig(8) The follow options are available:

`carpN`

The name of the carp(4) virtual interface where N is a integer that represents the interface's number (e.g. carp0).

`vhid`

The Virtual Host ID. This is a unique number that is used to identify the redundancy group to other nodes on the network. Acceptable values are from 1 to 255. This allows for multiple redundancy groups to exist on the same network.

`password`

The authentication password to use when talking to other CARP-enabled hosts in this redundancy group. This must be the same on all members of the redundancy group.

`carpdev`

This optional parameter specifies the physical network interface that belongs to this redundancy group. By default, CARP will try to determine which interface to use by looking for a physical interface that is in the same subnet as the ipaddress and mask combination given to the carp(4) interface.

`advbase`

This optional parameter specifies how often, in seconds, to advertise that we're a member of the redundancy group. The default is 1 second. Acceptable values are from 1 to 255.

`advskew`

This optional parameter specifies how much to skew the advbase when sending CARP advertisements. By manipulating advbase, the master CARP host can be chosen. The higher the number, the less preferred the host will be when choosing a master. The default is 0. Acceptable values are from 1 to 254.

state

Force a carp(4) interface into a certain state. Valid states are init, backup, and master

ipaddress

This is the shared IP address assigned to the redundancy group. This address does not have to be in the same subnet as the IP address on the physical interface (if present). This address needs to be the same on all hosts in the group, however.

mask

The subnet mask of the shared IP.

Further CARP behaviour can be controlled via sysctl(8)

net.inet.carp.allow

Accept incoming CARP packets or not. Default is 1 (yes).

net.inet.carp.preempt

Allow hosts within a redundancy group that have a better advbase and advskew to preempt the master. In addition, this option also enables failing over all interfaces in the event that one interface goes down. If one physical CARP-enabled interface goes down, CARP will change advskew to 240 on all other CARP-enabled interfaces, in essence, failing itself over. This option is 0 (disabled) by default.

net.inet.carp.log

Log bad CARP packets. Default is 0 (disabled).

net.inet.carp.arpbalance

Load balance traffic across multiple redundancy group hosts. Default is 0 (disabled). See carp(4) for more information.

28.3 Enabling CARP Support

CARP support is not enabled by default.

To use carp(4) you need a kernel with support for the `carp` pseudo-device. Make sure the following line is in your kernel configuration file:

```
pseudo-device   carp  # CARP
```

After configuring the `carp` pseudo-device in your kernel configuration, you must recompile your kernel and reboot to enable carp(4) support.

28.4 CARP Example

An example CARP configuration:

```
# sysctl -w net.inet.carp.allow=1
# ifconfig carp0 create
# ifconfig carp0 vhid 1 pass lanpasswd \
     carpdev em0 advskew 100 10.0.0.1 255.255.255.0
```

This sets up the following:

- Enables receipt of CARP packets (this is the default setting)
- Creates a carp(4) interface.
- Configures carp0 for virtual host #1, enables a password(lanpasswd), sets em0 as the interface belonging to the group, and makes this host a backup due to the advskew of 100 (assuming of course that the master is set up with an advskew less than 100). The shared IP assigned to this group is 10.0.0.1/255.255.255.0.

Running ifconfig on carp0 shows the status of the interface:

```
# ifconfig carp0
carp0: flags=8802<UP,BROADCAST,SIMPLEX,MULTICAST> mtu 1500
     carp: BACKUP carpdev em0 vhid 1 advbase 1 advskew 100
     inet 10.0.0.1 netmask 0xffffff00 broadcast 10.0.0.255
```

28.5 Advanced CARP configuration

The following example creates a cluster of two highly-available, redundant firewalls. The following diagram presents what we're trying to achieve:

```
      +----| WAN/Internet |----+
      |                        |
   em1|                        |em1
   +-----+                  +-----+
   | fw1 |                  | fw2 |
   +-----+                  +-----+
   em0|                        |em0
      |                        |
   ---+-------Shared LAN-------+---
```

Both firewalls are connected to the LAN on em0 and to a WAN/Internet connection on em1. IP addresses are as follows:

- Firewall 1 (fw1) em0: 172.16.0.1
- Firewall 1 (fw1) em1: 192.0.2.1
- Firewall 2 (fw2) em0: 172.16.0.2

- Firewall 2 (fw2) em1: 192.0.2.2

The IP addresses we wish to share between the redundancy groups:

- WAN/Internet Shared IP: 192.0.2.100
- LAN Shared IP: 172.16.0.100

The network policy is that Firewall 1 (fw1) will be the preferred master.

The following configuration is for Firewall 1 (fw1):

```
#Enable preemption and group interface failover
# sysctl -w net.inet.carp.preempt=1


#Configure CARP on the LAN side
# ifconfig carp0 create
# ifconfig carp0 vhid 1 pass lanpasswd carpdev em0 \
     172.16.0.100 255.255.255.0


#Configure CARP on the WAN side
# ifconfig carp1 create
# ifconfig carp1 vhid 2 pass wanpasswd carpdev em1 \
     192.0.2.100 255.255.255.0
```

As mentioned before, our policy is for Firewall 1 to be the preferred master. When configuring Firewall 2 we make the `advskew` a higher value since it's less preferred to be the master.

The following configuration is for Firewall 2 (fw2):

```
#Enable preemption and group interface failover
# sysctl -w net.inet.carp.preempt=1


#Configure CARP on the LAN side
# ifconfig carp0 create
# ifconfig carp0 vhid 1 pass lanpasswd carpdev em0 \
     advskew 128 172.16.0.100 255.255.255.0


#Configure CARP on the WAN side
# ifconfig carp1 create
# ifconfig carp1 vhid 2 pass wanpasswd carpdev em1 \
     advskew 128 192.0.2.100 255.255.255.0
```

28.6 Forcing Failover of the Master

There can be times when it's necessary to failover or demote the master node on purpose. Examples include taking the master node down for maintenance or when troubleshooting a problem. The objective here is to gracefully fail over traffic to one of the backup hosts so that users do not notice any impact.

To failover, shut down the carp(4) interface on the master node. This will cause the master to advertise itself with an "infinite" advbase and advskew. The backup host(s) will see this and immediately take over the role of master.

```
# ifconfig carp0 down
```

Chapter 29

Network services

29.1 The *Network File System* (NFS)

Now that the network is working it is possible to share files and directories over the network using the Network File System (NFS). From the point of view of file sharing, the computer which gives access to its files and directories is called the *server*, and the computer using these files and directories is the *client*. A computer can be client and server at the same time.

- The server must enable the rpcbind, mountd lockd statd and `nfs_server` daemons in `/etc/rc.conf`:

  ```
  rpcbind=yes
  mountd=yes
  nfs_server=yes
  lockd=yes
  statd=yes
  ```

- The client must enable the rpcbind, lockd statd and `nfs_client` daemons in `/etc/rc.conf`:

  ```
  rpcbind=yes
  nfs_client=yes
  lockd=yes
  statd=yes
  ```

- The server must list the exported directories in `/etc/exports` and then run the command **kill -HUP ‘cat /var/run/mountd.pid** (**hup mountd** may work too!).

A client host can access a remote directory through NFS if:

- The server host exports the directory to the client. The list of filesystems a NFS server exports can be checked with the **showmount -e** command, see showmount(8):

  ```
  # showmount -e 192.168.1.2
  Exports list on 192.168.1.2:
  /home                              host1 host2 host3
  ```

- The client host mounts the remote directory with the command **mount 192.168.1.2:/home /home**

The **mount** command has a rich set of options for remote directories which are not very intuitive (to say the least).

29.1.1 NFS setup example

The scenario described here is the following: five client machines (cli1, ..., cli5) share some directories on a server (buzz.toys.org). Some of the directories exported by the server are reserved for a specific client, the other directories are common for all client machines. All the clients boot from the server and must mount the directories.

The directories exported from the server are:

`/export/cli?/root`

  the five root directories for the five client machines. Each client has its own root directory.

`/export/cli?/swap`

  Five swap directories for the five swap machines.

`/export/common/usr`

  `/usr` directory; common for all client hosts.

`/usr/src`

  Common `/usr/src` directory for all client machines.

The following file systems exist on the server

```
/dev/ra0a on /
/dev/ra0f on /usr
/dev/ra1a on /usr/src
/dev/ra2a on /export
```

Each client needs the following file systems

```
buzz:/export/cli?/root   on /
buzz:/export/common/usr  on /usr
buzz:/usr/src            on /usr/src
```

The server configuration is the following:

```
# /etc/exports
/usr/src  -network 192.168.1.0 -mask 255.255.255.0
/export   -alldirs -maproot=root -network 192.168.1.0 -mask 255.255.255.0
```

On the client machines `/etc/fstab` contains:

```
buzz:/export/cliX/root  /        nfs rw
buzz:/export/common/usr /usr     nfs ro,nodev,nosuid
buzz:/usr/src           /usr/src nfs rw,nodev,nosuid
```

Each client machine has its number substituted to the "*X*" character in the first line of the previous example.

29.1.2 Setting up NFS automounting for `/net` with amd(8)

29.1.2.1 Introduction

The problem with NFS (and other) mounts is, that you usually have to be root to make them, which can be rather inconvenient for users. Using amd(8) you can set up a certain directory (Commonly `/net`), under which one can make any NFS-mount as a normal user, as long as the filesystem about to be accessed is actually exported by the NFS server.

To check if a certain server exports a filesystem, and which ones, use the **showmount**-command with the `-e` (export) switch:

```
$ showmount -e wuarchive.wustl.edu
Exports list on wuarchive.wustl.edu:
/export/home                      onc.wustl.edu
/export/local                     onc.wustl.edu
/export/adm/log                   onc.wustl.edu
/usr                              onc.wustl.edu
/                                 onc.wustl.edu
/archive                          Everyone
```

If you then want to mount a directory to access anything below it (for example `/archive/systems/unix/NetBSD`), just change into that directory:

```
$ cd /net/wuarchive.wustl.edu/archive/systems/unix/NetBSD
```

The filesystem will be mounted (by **amd**), and you can a access any files just as if the directory was mounted by the superuser of your system.

29.1.2.2 Actual setup

You can set up such a `/net` directory with the following steps (including basic **amd** configuration):

1. in `/etc/rc.conf`, set the following variable:

   ```
   amd=yes
   ```

2. **mkdir /amd**
3. **mkdir /net**
4. Taking `/usr/share/examples/amd/amd.conf`, put the following into `/etc/amd.conf`:

   ```
   [ /net ]
   map_name =              /etc/amd/net
   map_type =              file
   ```

5. Taking `/usr/share/examples/amd/net` as example, put the following into `/etc/amd/net`:

   ```
   /defaults       type:=host;rhost:=${key};fs:=${autodir}/${rhost}/root
   *             host==${key};type:=link;fs:=/                           \
                 host!=${key};opts:=ro,soft,intr,nodev,nosuid,noconn
   ```

6. Reboot, or (re)start **amd** by hand:

   ```
   # sh /etc/rc.d/amd restart
   ```

29.2 The *Network Time Protocol* (NTP)

It is not unusual to find that the system clock is wrong, often by several minutes: for some strange reason it seems that computer clocks are not very accurate. The problem gets worse if you administer many networked hosts: keeping the clocks in sync can easily become a nightmare. To solve this problem, the NTP protocol (version 3) comes to our aid: this protocol can be used to synchronize the clocks of a network of workstations using one or more NTP servers.

Thanks to the NTP protocol it is possible to adjust the clock of a single workstation but also to synchronize an entire network. The NTP protocol is quite complex, defining a hierarchical master-slave structure of servers divided in strata: the top of the hierarchy is occupied by stratum 1 servers, connected to an external clock (ex. a radio clock) to guarantee a high level of accuracy. Underneath, stratum 2 servers synchronize their clocks with stratum 1, and so on. The accuracy decreases as we proceed towards lower levels. This hierarchical structure avoids the congestion which could be caused by having all hosts refer to the same (few) stratum 1 servers. If, for example, you want to synchronize a network, you don't connect all the hosts to the same public stratum 1 server. Instead, you create a local server which connects to the main server and the remaining hosts synchronize their clocks with the local server.

Fortunately, to use the NTP tools you don't need to understand the details of the protocol and of its implementation (if you are interested, refer to RFC 1305) and you only need to know how to configure and start some programs. The base system of NetBSD already contains the necessary tools to utilize this protocol (and other time related protocols, as we'll see), derived from the xntp implementation. This section describes a simple method to always have a correct system time.

First, it is necessary to find the address of the public NTP servers to use as a reference; a detailed listing can be found at http://support.ntp.org/bin/view/Servers/WebHome. As an example, for Italy the three stratum 1 servers tempo.cstv.to.cnr.it, ntp1.inrim.it, and ntp2.inrim.it can be used.

Next, to adjust the system clock give the following command as root:

```
# ntpdate -b ntp1.inrim.it ntp2.inrim.it
```

(substitute the names of the servers in the example with the ones that you are actually using. Option `-b` tells **ntpdate** to set the system time with the settimeofday system call, instead of slewing it with adjtime (the default). This option is suggested when the difference between the local time and the correct time can be considerable.

As you've seen, ntpdate is not difficult to use. The next step is to start it automatically, in order to always have the correct system time. If you have a permanent connection to the Internet, you can start the program at boot with the following line of `/etc/rc.conf`:

```
ntpdate=YES       ntpdate_hosts="ntp1.inrim.it"
```

The name of the NTP server to use is specified in the `ntpdate_hosts` variable; if you leave this field empty, the boot script will try to extract the name from the `/etc/ntp.conf` file.

If you don't have a permanent Internet connection (ex. you have a dial-up modem connection through an ISP) you can start ntpdate from the `ip-up` script, as explained in Chapter 24. In this case add the following line to the `ip-up` script:

```
/usr/sbin/ntpdate -s -b ntp1.inrim.it
```

(the path is mandatory or the script will probably not find the executable). Option `-s` diverts logging output from the standard output (this is the default) to the system syslog(3) facility, which means that the messages from ntpdate will usually end up in `/var/log/messages`.

Besides ntpdate there are other useful NTP commands. It is also possible to turn one of the local hosts into an NTP server for the remaining hosts of the network. The local server will synchronize its clock with a public server. For this type of configuration you must use the **ntpd** daemon and create the `/etc/ntp.conf` configuration file. For example:

```
server ntp1.inrim.it
    server ntp2.inrim.it
```

ntpd can be started too from `rc.conf`, using the relevant option:

```
ntpd=YES
```

NTP is not your only option if you want to synchronize your network: you can also use the timed daemon or the rdate(8) command as well. timed was developed for 4.3BSD.

Timed too uses a master-slave hierarchy: when started on a host, timed asks the network time to a master and adjusts the local clock accordingly. A mixed structure, using both timed and ntpd can be used. One of the local hosts gets the correct time from a public NTP server and is the timed master for the remaining hosts of network, which become its clients and synchronize their clocks using timed. This means that the local server must run both NTP and timed; care must be taken that they don't interfere with each other (timed must be started with the `-F hostname` option so that it doesn't try to adjust the local clock).

Finally, rdate(8) can be used to synchronize once against a given host, much like ntpdate(8). The host in question must have the "time" service (port 37) enabled in `/etc/inetd.conf`.

V. Virtualization and emulation

Chapter 30

Using virtualization: QEMU and NVMM

A virtual machine is a virtual computer (the "guest") running inside another computer (the "host"). Virtual machines are useful for testing, running different operating systems, isolating parts of a system, and more.

nvmm(4) (NetBSD Virtual Machine Monitor) is NetBSD's native hypervisor. In regular usage, it's used as an "accelerator" for the QEMU virtual machine software. It will make virtual machines on your NetBSD host run faster by taking advantage of CPU virtualization extensions. Currently, a CPU that supports AMD SVM or Intel VMX is required, but more backends for other architectures may be added in the future. QEMU can also be used without an accelerator, with significantly reduced performance.

Other hypervisors supported by NetBSD include Intel HAXM (https://github.com/intel/haxm) (also used with QEMU), and Xen (https://wiki.NetBSD.org/ports/xen/howto/), which has quite a different design.

When running modern operating systems as VM guests, you will generally want to use para-virtualized I/O, rather than having QEMU emulate real hardware devices. On NetBSD, this is supported with the virtio(4) drivers.

30.1. Enabling the NetBSD Virtual Machine Monitor

> **Note:** Many computers (especially laptops) have hardware virtualization capabilities disabled by default. You may need to enable the necessary features from the firmware at boot.
>
> Before loading the NVMM module, make sure the modules in `/stand` are correct and up-to-date for the version of the NetBSD kernel you are using.

The NetBSD Virtual Machine Monitor isn't active by default. It must be activated by loading the `nvmm` module with modload(8):

```
# modload nvmm
```

Verify NVMM is loaded with modstat(8):

```
# modstat | grep nvmm
nvmm                          misc      filesys  -         0        - -
```

You can load the module automatically at boot time by adding this line to `/etc/modules.conf`:

```
nvmm
```

Loading NVMM at boot time will also allow the system to run with a secmodel_securelevel(9) of 1, which prevents loading modules after boot. However, since NVMM blocks things like suspend, you may wish to unload it:

```
# modunload nvmm
```

By default the `/dev/nvmm` device is owned by the `root` user. You probably want to run virtual machines as a non-root user for security reasons, so set the owner of the `/dev/nvmm` device to something reasonable:

```
# chown nia:wheel /dev/nvmm
```

On a machine containing lots of untrusted VMs, you may wish to create a dedicated user or group for them with useradd(8) and groupadd(8).

You can see NVMM's current status with nvmmctl(8):

```
$ nvmmctl identify
nvmm: Kernel API version 2
nvmm: State size 1008
nvmm: Max machines 128
nvmm: Max VCPUs per machine 256
nvmm: Max RAM per machine 128G
nvmm: Arch Mach conf 0
nvmm: Arch VCPU conf 0x3<CPUID,TPR>
nvmm: Guest FPU states 0x3<x87,SSE>
```

30.2. Using QEMU with NVMM

QEMU is a CPU emulator and virtual machine that can use NVMM as an accelerator. It isn't included with NetBSD by default. However, it is available in pkgsrc as `emulators/qemu`, and can be installed with **pkgin**:

```
# pkgin install qemu
```

30.2.1. Starting QEMU with acceleration

This command starts a VM in an X11 window with NVMM acceleration, the same CPU type as the host machine, two CPU cores, and one gigabyte of memory:

```
$ qemu-system-x86_64 -accel nvmm
        -cpu max -smp cpus=2 -m 1G \
        -display sdl,gl=on \
        -cdrom NetBSD-9.1-amd64.iso
```

The guest system will be much slower without acceleration as every CPU instruction will have to be emulated.

You should also be able to see the virtual machine running with nvmmctl(8):

```
$ nvmmctl list
```

```
Machine ID VCPUs RAM  Owner PID Creation Time
---------- ----- ---- --------- ------------------------
0          2     147M 10982     Sat May  8 10:09:59 2021
```

30.2.2. Creating a virtual disk

Generally, you will want to create a virtual drive to contain your virtual machine on the host. We'll want to create a `qcow2` image because it provides better performance and is more versatile than a raw image:

```
$ qemu-img create -f qcow2 netbsd.qcow2 16G
```

A VirtIO block device provides the best performance. Add the following arguments to `qemu-system-x86_64` to use it:

```
-drive file=netbsd.qcow2,if=none,id=hd0 \
-device virtio-blk-pci,drive=hd0
```

Older operating systems may not have VirtIO drivers, in which case you can use a normal emulated disk:

```
-hda netbsd.qcow2
```

30.2.3. Adding entropy to the guest

Operating systems require a good source of randomness for system security, cryptography, and so on. In a VM, this is ideally provided by the host machine, which has greater access to the underlying hardware. You can easily attach a VirtIO random number generator device with the following arguments to QEMU:

```
-object rng-random,filename=/dev/urandom,id=viornd0 \
-device virtio-rng-pci,rng=viornd0
```

This requires no extra configuration on the host machine.

Entropy is generally required for secure communications. For more information on entropy, refer to entropy(7).

30.2.4. Using networking

The simplest way to set up networking with QEMU is so-called "user networking". This will mean raw socket operations like ping(8) won't work, but normal TCP/IP protocols like HTTP/FTP/etc will work. Another way is with bridged networking, see Section 30.3.

The most performant device type is `virtio-net-pci`:

```
-netdev user,id=vioif0 -device virtio-net-pci,netdev=vioif0
```

To use older guest operating systems that don't support VirtIO, Intel Gigabit Ethernet is a good choice:

```
-netdev user,id=wm0 -device e1000,netdev=wm0
```

Or an AMD PCnet card, for very old guest operating systems:

```
-netdev user,id=pcn0 -device pcnet,netdev=pcn0
```

30.2.5. Using audio

On a NetBSD host, the following QEMU arguments may be used to enable audio:

```
-audiodev oss,id=oss,out.dev=/dev/audio,in.dev=/dev/audio \
-device ac97,audiodev=oss
```

`ac97` is the classic standardized sound driver for x86 systems.

You may wish to change the `/dev/audioX` device being used, see Chapter 10.

You may need to adjust things further to get smooth playback, see Section 30.4.3.

30.2.6. Using graphics (or no graphics)

These arguments will create an X11 window with OpenGL enabled (for smooth scaling if the window is resized), using a VMware-compatible VGA device, and an USB mouse:

```
-display sdl,gl=on -vga vmware \
-usb -device usb-mouse,bus=usb-bus.0
```

There is a VMware video driver included with X11 on NetBSD, so the display will automatically configure when startx(1) runs and can be adjusted with xrandr(1).

A VNC display will allow remote access from a VNC client like `net/tigervnc`, useful when running QEMU with `--daemonize` on a server:

```
-display vnc=unix:/home/nia/.qemu-myvm-vnc -vga vmware
-usb -device usb-mouse,bus=usb-bus.0
```

A simpler option is a `curses` display, preferable for systems that don’t need more than text output in a terminal:

```
-display curses
```

For more information on configuring X11, see Chapter 9.

For more information on securely configuring VNC, see QEMU’s online documentation on VNC (https://qemu.readthedocs.io/en/latest/system/vnc-security.html).

30.3. Configuring bridged networking on a NetBSD host

While QEMU user networking is easy to use and doesn’t require root privileges, it’s generally slower than bridged networking using a tap(4) device, and doesn’t allow the use of diagnostic tools like ping(8) inside the guest.

To configure bridged networking on a NetBSD host, you must first make note of your host machine's primary network interace. Find the one with an address assigned and a route to the outside world with ifconfig(8).

In this example, the host machine's primary interface is `wm0`. All of these commands run on the host machine.

Create a virtual tap(4) interface:

```
# ifconfig tap0 create
# ifconfig tap0 descr "NetBSD VM" up
```

Create a bridge(4) connecting the actual interface and the virtual interface:

```
# ifconfig bridge0 create
# ifconfig bridge0 descr "LAN VM bridge" up
# brconfig bridge0 add tap0 add wm0
```

Configure NetBSD to do this all at boot time by editing `/etc/ifconfig.tap0`:

```
create
descr "NetBSD VM" up
! ifconfig bridge0 create
! ifconfig bridge0 descr "LAN VM bridge" up
! brconfig bridge0 add tap0 add wm0
```

You can now pass the arguments to QEMU to run with bridged networking:

```
-netdev tap,id=tap0,ifname=tap0,script=no -device virtio-net-pci,netdev=tap0
```

For more information on NetBSD network configuration, see Chapter 24.

30.4. Notes on using NetBSD as a guest

30.4.1. Unclean VM shutdown, data recovery, and fsck

AVOID UNCLEAN SHUTDOWNS! This means pressing Ctrl+C or killing the virtual machine. In QEMU, the disks will rarely be synced, and data loss will almost certainly occur.

You may wish to add the `log,noatime` mount options in `/etc/fstab` next to `rw` to speed up fsck(8). You can also enable the `sync` option, but this will significantly decrease performance.

Always shut down NetBSD safely using the shutdown(8) command and make backups.

30.4.2. NetBSD VMs lacking IPv6

QEMU's networking will sometimes configure an invalid IPv6 route on IPv4-only configurations, meaning programs like the NetBSD packaging tools will prefer IPv6 and spend a long time timing out before succeeding.

Work around this by editing `/etc/rc.conf` to prefer IPv4 addresses:

```
ip6addrctl=YES
ip6addrctl_policy="ipv4_prefer"
```

30.4.3. Smooth audio playback and latency in VMs

Virtual machines cannot generally provide the same smooth playback at low latency that real hardware provides. For smooth playback, you may need to increase NetBSD's audio latency inside the VM:

```
$ sysctl -w hw.audio0.blk_ms=100
```

To set this automatically automatically at boot time, add it to `/etc/sysctl.conf`.

You can test audio output in the VM. Ensure that audiocfg(1) plays a continuous beep for each channel:

```
$ audiocfg test 0
```

30.4.4. Changing the console resolution in an x86 VM

> **Note:** On physical hardware where the display resolution is already set properly by the kernel, doing this will disable graphical acceleration.

If you want to increase the size of the x86 console, enter the following at the NetBSD boot prompt:

```
> vesa 1024x768x32
```

This setting can be made permanent in `/boot.cfg`.

Chapter 31

Linux emulation

The NetBSD port for amd64, i386, alpha, mac68k, macppc, and many others can execute a great number of native Linux programs, using the Linux emulation layer. Generally, when you think about emulation you imagine something slow and inefficient because, often, emulations must reproduce hardware instructions and even architectures (usually from old machines) in software. In the case of the Linux emulation this is radically different: it is only a thin software layer, mostly for system calls which are already very similar between the two systems. The application code itself is processed at the full speed of your CPU, so you don't get a degraded performance with the Linux emulation and the feeling is exactly the same as for native NetBSD applications.

31.1 Emulation setup

The installation of the Linux emulation is described in the compat_linux(8) man page; using the package system only two steps are needed.

31.1.1 Configuring the kernel

If you use a GENERIC kernel you don't need to do anything because Linux compatibility is already enabled.

If you use a customized kernel, check that the following options are enabled:

```
option COMPAT_LINUX
option EXEC_ELF32
```

or the following options if you are going to use 64-bit ELF binaries:

```
option COMPAT_LINUX
option EXEC_ELF64
```

when you have compiled a kernel with the previous options you can start installing the necessary software.

31.1.2 Installing the Linux libraries

Usually, applications are linked against shared libraries, and for Linux applications, Linux shared libraries are needed. You can get the shared libraries from any Linux distribution, provided it's not too old, but the suggested method is to use the package system to install the provided libraries from openSUSE.

All Linux binaries exist entirely within the separate root directories inside `/emul/linux` and `/emul/linux32`. The kernel will always search these paths first when looking for shared objects required by Linux programs.

A number of useful Linux shared object binaries is provided by pkgsrc, for running both 64-bit and 32-bit applications. The absolute minimum required to run dynamically linked Linux applications are are provided by the `suse131_base` and `suse131_32_base` packages (or, if using binary packages `suse_base-13` and `suse32_base-13`). Many other libraries are also provided as separate packages.

Some packages in pkgsrc are provided as Linux binaries and will also install all the required SUSE dependencies when installed. However, this is uncommon. One such package is `adoptopenjdk11-bin`.

It is possible to examine which libraries are required by a Linux program with readelf(1):

```
$ readelf -d ./runner
Dynamic section at offset 0x3a2e94 contains 40 entries:
  Tag        Type      Name/Value
 0x00000001 (NEEDED) Shared library: [libstdc++.so.6]
 0x00000001 (NEEDED) Shared library: [libz.so.1]
 0x00000001 (NEEDED) Shared library: [libXxf86vm.so.1]
 0x00000001 (NEEDED) Shared library: [libGL.so.1]
 0x00000001 (NEEDED) Shared library: [libopenal.so.1]
 0x00000001 (NEEDED) Shared library: [libm.so.6]
 0x00000001 (NEEDED) Shared library: [librt.so.1]
 0x00000001 (NEEDED) Shared library: [libpthread.so.0]
 0x00000001 (NEEDED) Shared library: [libdl.so.2]
 0x00000001 (NEEDED) Shared library: [libcrypto.so.1.0.0]
 0x00000001 (NEEDED) Shared library: [libXext.so.6]
 0x00000001 (NEEDED) Shared library: [libX11.so.6]
 0x00000001 (NEEDED) Shared library: [libXrandr.so.2]
 0x00000001 (NEEDED) Shared library: [libGLU.so.1]
 0x00000001 (NEEDED) Shared library: [libssl.so.1.0.0]
 0x00000001 (NEEDED) Shared library: [libgcc_s.so.1]
 0x00000001 (NEEDED) Shared library: [libc.so.6]
```

For example, an application which requires `libcrypto.so.1.0.0`, `libXext.so.6`, and `libGL.so.1` will require `openssl`, `x11`, and `glx`, in addition to the `base` SUSE package.

31.1.3 Running Linux programs

Once the correct libraries are installed, no special steps are required to run a Linux program - simply type the command (if you acquired it as a non-pkgsrc download, include the full path on the filesystem). The kernel will detect it is a Linux executable and run it in the correct translation mode.

31.2 Directory structure

If we examine the outcome of the installation of the Linux libraries and programs we find that `/emul/linux` is a symbolic link pointing to `/usr/pkg/emul/linux`, where the following directories have been created:

bin/
dev/
etc/
lib/
lib64/
proc/
sbin/
usr/
var/

> **Note:** Please always refer to `/emul/linux` and not to `/usr/pkg/emul/linux`. The latter is an implementation detail and may change in the future.

How much space is required for the Linux emulation software? On one system we got the following figure:

```
# cd /usr/pkg/emul
# du -k /emul/linux/
...
399658  /emul/linux/
```

31.3 Using Linux browser plugins

Linux plugins for Mozilla-based browsers can be used on native NetBSD Firefox builds through nspluginwrapper, a wrapper that translates between the native browser and a foreign plugin. At the moment, nspluginwrapper only works reliably on Mozilla-based browsers that link against GTK2+ (GTK1+ is not supported). nspluginwrapper can be installed through pkgsrc:

```
# cd /usr/pkgsrc/www/nspluginwrapper
# make install
```

Plugins can then be installed in two steps: first, the plugin has to be installed on the system (e.g. through pkgsrc). After that the plugin should be registered with the **nspluginwrapper** by the users who want to use that plugin.

In this short example we will have a look at installing the Macromedia Flash plugin. We can fullfill the first step by installing the Flash plugin through pkgsrc:

```
# cd /usr/pkgsrc/multimedia/ns-flash
# make install
```

After that an unprivileged user can register the Flash plugin:

```
$ nspluginwrapper -i /usr/pkg/lib/netscape/plugins/libflashplayer.so
```

The plugin should then be registered correctly. You can check this by using the `-l` option of **nspluginwrapper** (**nspluginwrapper -l**). If the plugin is listed, you can restart Firefox, and verify that the plugin was installed by entering *about:plugins* in the location bar.

31.4 Further reading

The following articles may be of interest for further understanding Linux (and other) emulation:

Bibliography

Implementing Linux emulation on NetBSD (https://www.linux.com/news/implementing-linux-emulation-netbsd/) , Peter Seebach, May 2004.

VI. Building the system

Chapter 32

Obtaining the sources

To read the NetBSD sources from your local disk or to build the system, you need to download the NetBSD sources. This chapter explains a number of different ways to obtain the NetBSD sources, although the preferred method is to download the tarballs and then update via cvs(1).

32.1 Preparing directories

Traditionally, the NetBSD kernel and userland sources are placed in `/usr/src`. This directory is not present by default in the NetBSD installation and you will need to create it first. As it is in a system directory, you will need root access to create the directory and make sure your normal user account can write to it. For demonstration purposes, it is assumed that the non-root login is *carlo*. Please replace it with a valid login name on your system:

```
$ su
Password: ********
# mkdir /usr/src
# chown <carlo> /usr/src
```

If you want the sources to the X Window System, you should prepare `/usr/xsrc` as well:

```
# mkdir /usr/xsrc
# chown <carlo> /usr/xsrc
```

> **Note:** Please note that for the subsequent steps, root access is neither needed nor recommended, so this preparation step should be done first. All CVS operations can (and should) be done as normal user, so relinquish your root privileges:
>
> ```
> # exit
> $
> ```

32.2 Terminology

Before starting to fetch or download the required files, you may want to know the definitions of “Formal releases”, “Maintenance branches” and other related terms. That information is available under the NetBSD release glossary and graphs (http://www.NetBSD.org/releases/release-map.html).

32.3 Downloading tarballs

It is sometimes faster to begin by downloading a source tarball. You can download tarballs (see tar(1)) from ftp.NetBSD.org (or any other mirror) for a number of releases or branches. These tarballs include the `CVS` directories, so you can continue to update your source tree using cvs(1), as explained in the CVS section.

Note that source tarballs for stable branches are only updated every three days.

32.3.1 Downloading sources for a NetBSD release

The source files to a release do not change after the release has been made.

The tarballs for the sources of a specific release are available under `/pub/NetBSD/NetBSD-<RELEASE-NUMBER>/source/sets/` on ftp.NetBSD.org (or a mirror), where `<RELEASE-NUMBER>` is the release you want to fetch (for example, 9.3).

To fetch the sources of a NetBSD release using tarballs, simply do:

```
$ ftp -i ftp://ftp.NetBSD.org/pub/NetBSD/NetBSD-9.3/source/sets/
Trying 2001:470:a085:999::21:21 ...
Connected to ftp.NetBSD.org.
220 ftp.NetBSD.org FTP server (NetBSD-ftpd 20180428) ready.
331 Guest login ok, type your name as password.
[...]
250 CWD command successful.
ftp> mget *.tgz
local: gnusrc.tgz remote: gnusrc.tgz
229 Entering Extended Passive Mode (|||61968|)
150 Opening BINARY mode data connection for 'gnusrc.tgz' (152604808 bytes).
[...]
ftp> quit
221-
221 Thank you for using the FTP service on ftp.NetBSD.org.
```

You should now have 5 files:

```
$ ls *.tgz
gnusrc.tgz      sharesrc.tgz    src.tgz         syssrc.tgz      xsrc.tgz
```

You now must extract them all:

```
$ for file in *.tgz
> do
> tar -xzf $file -C /
> done
```

32.3.2 Downloading sources for a NetBSD stable branch

```
$ ftp -i ftp://ftp.NetBSD.org/pub/NetBSD/NetBSD-release-9/tar_files/src/
Trying 2001:470:a085:999::21:21 ...
Connected to ftp.NetBSD.org.
```

```
220 ftp.NetBSD.org FTP server (NetBSD-ftpd 20180428) ready.
331 Guest login ok, type your name as password.
[...]
250 CWD command successful.
ftp> mget *.tar.gz
local: bin.tar.gz remote: bin.tar.gz
229 Entering Extended Passive Mode (|||56011|)
150 Opening BINARY mode data connection for 'bin.tar.gz' (996075 bytes).
[...]
ftp> quit
221-
    Data traffic for this session was 429024351 bytes in 25 files.
    Total traffic for this session was 429035139 bytes in 26 transfers.
221 Thank you for using the FTP service on ftp.NetBSD.org.
```

You should now have 25 files:

```
$ ls *.tar.gz
bin.tar.gz          doc.tar.gz          libexec.tar.gz      tools.tar.gz
common.tar.gz       etc.tar.gz          regress.tar.gz      top-level.tar.gz
compat.tar.gz       external.tar.gz     rescue.tar.gz       usr.bin.tar.gz
config.tar.gz       extsrc.tar.gz       sbin.tar.gz         usr.sbin.tar.gz
crypto.tar.gz       games.tar.gz        share.tar.gz
dist.tar.gz         include.tar.gz      sys.tar.gz
distrib.tar.gz      lib.tar.gz          tests.tar.gz
```

You now must extract them all:

```
$ for file in *.tar.gz
> do
> tar -xzf $file -C /usr
> done
```

32.3.3 Downloading sources for a NetBSD-current development branch

To download the NetBSD-current tarballs, located under `/pub/NetBSD/NetBSD-current/tar_files/src`, just follow the same steps as in Section 32.3.2, but using this path.

You may also want to fetch the X Window System sources, available under: `/pub/NetBSD/NetBSD-current/tar_files/xsrc`.

32.4 Fetching by CVS

CVS (Concurrent Versions System) can be used to fetch the NetBSD source tree or to keep the NetBSD source tree up to date with respect to changes made to the NetBSD sources. There are two main source modules available through cvs(1), “src” and “xsrc”.

The list of currently maintained branches is available under `src/doc/BRANCHES` (see the “Status” entry on the “Release branches” section).

> **Caution!:** Be sure to take care in selecting the correct and desired branch tag so you don't accidentally *downgrade* your source tree.

Before you can do an initial (full) checkout of the NetBSD sources via *anonymous CVS*, you must set the `CVSROOT` environment variable, which tells cvs(1) where to fetch the files from:

```
$ export CVSROOT="anoncvs@anoncvs.NetBSD.org:/cvsroot"
```

Make sure that the environment variable `CVS_RSH` is set to "ssh".

```
$ export CVS_RSH="ssh"
```

In the examples below, we use the `-P` option, which tells CVS to prune empty directories.

32.4.1 Fetching a NetBSD release

The source files to a release do not change after the release has been made.

To get the NetBSD (kernel and userland) sources for a specific release, run the following command after setting `CVSROOT` as shown above:

```
$ cd /usr
$ cvs checkout -r <TAG> -P src
```

Where *<TAG>* is the release tag to be checked out, e.g., "netbsd-9-3-RELEASE". If you want to fetch a later patchlevel, you would use, e.g., "netbsd-9-3-RELEASE".

For example, in order to fetch the sources for NetBSD 9.3, you would use the "netbsd-9-3-RELEASE" tag:

```
$ cvs checkout -r netbsd-9-3-RELEASE -P src
```

To fetch the X Window System source, just "checkout" the "xsrc" module. For example:

```
$ cvs checkout -r netbsd-9-3-RELEASE -P xsrc
```

32.4.2 Fetching a NetBSD stable branch

NetBSD stable branches are a flavor of "Maintenance branches". Please consult the Section 32.2.

If you want to follow a stable branch, just pass the branch name to the cvs(1) `-r` option.

For example, if you want to fetch the most recent version of "netbsd-9", you just need to use that tag:

```
$ cd /usr
$ cvs checkout -r netbsd-9 -P src
```

And for the "xsrc" module:

```
$ cvs checkout -r netbsd-9 -P xsrc
```

If you have checked out sources from a stable branch in `/usr/src` and want to update them to get the latest security and bug fixes, run:

```
$ cd /usr/src
$ cvs update -dP
```

The same applies to the “xsrc” module, but in that case you will have to change your working directory to `/usr/xsrc` first.

32.4.3 Fetching the NetBSD-current development branch

To obtain the NetBSD-current source just omit “`-r <BRANCH>`” and replace it with “`-A`”:

```
$ cd /usr
$ cvs checkout -A -P src
```

The “xsrc” module is obtained the same way:

```
$ cd /usr
$ cvs checkout -A -P xsrc
```

To update your NetBSD-current source tree, add the `-A` flag:

```
$ cd /usr/src
$ cvs update -A -dP
```

The same applies to the “xsrc” module, but in that case you will have to change your working directory to `/usr/xsrc` first.

32.4.4 Saving some cvs(1) options

If you find yourself typing the same options to CVS over and over again, you may want to make those options the default by adding them to `.cvsrc` in your home directory. In the following example, **cvs update** will add any missing newly-added directories to your tree, as well as delete any newly-empty directories. Also shown are examples of how to make **cvs rdiff** and **cvs diff** use the unified diff(1) format. The final line in the example causes CVS to be a bit more quiet in its operation.

Example 32-1. `.cvsrc`

```
update  -dP
rdiff   -u
diff    -u
cvs     -q
```

Chapter 33

Crosscompiling NetBSD with `build.sh`

NetBSD uses a framework, `build.sh`, to build both the operating system's kernel and the whole userland for either the same platform as the host machine, or for a different platform, using cross-compilation. `build.sh` will take care of creating all the tools required to build NetBSD for a given platform, and make them available ready to use for development work.

In this chapter, we will show how to use `build.sh` to first create a toolchain, including compiler, assembler, linker and so on, then use it to cross-compile a NetBSD kernel and userspace for AArch64 on an AMD64 host machine. While native kernel builds are covered in Chapter 34, using the `build.sh` script is generally preferred for building the entire of NetBSD.

Before starting, we have placed the sources in a subdirectory of our user's home directory: `/home/nia/cvs/src`. While `/usr/src` is the traditional location for NetBSD sources, as described in Chapter 32, we would like to build the operating system as an unprivileged (non-root) user.

A more detailed description of the `build.sh` framework can be found in Luke Mewburn and Matthew Green's paper (http://www.mewburn.net/luke/papers/build.sh.pdf) and their presentation (http://www.mewburn.net/luke/talks/bsdcon-2003/index.html) from BSDCon 2003 as well as in `/usr/src/BUILDING`.

33.1 Building the toolchain

The first step to do cross-development is to get all the necessary tools available. In NetBSD terminology, this is called the "toolchain", and it includes BSD-compatible make(1), C/C++ compilers, linker, assembler, config(8), as well as a fair number of tools that are only required when crosscompiling a full NetBSD release, which we won't cover here.

The command to create the toolchain is quite simple, using NetBSD's `src/build.sh` script. Please note that all the commands here can be run as normal (non-root) user:

```
$ cd /home/nia/cvs/src
$ ./build.sh -U -O ~/obj -j2 -m evbarm -a aarch64 tools
```

- The "-U" option indicates we are doing an unprivileged build, as a non-root user, typically with the source code located somewhere other than `/usr/src`
- The "-O" option specifies the directory to use for compiled object files.
- The "-j2" option specifies the number of parallel builds to run. You may wish to set this to the number of CPU cores on your host system.

- The "-m evbarm -a aarch64" options indicate we are building for a machine type of *evbarm* with a CPU type of *aarch64*. You can list the available machines and CPU types:

```
$ ./build.sh list-arch
```

If the tools have been built previously and they only need to be updated, then the update option "-u" can be used to only rebuild tools that have changed:

```
$ ./build.sh -U -u -O ~/obj -j2 -m evbarm -a aarch64 tools
```

When the tools are built, information about them and several environment variables is printed out:

```
===> Tools built to /home/nia/obj/tooldir.NetBSD-9.99.81-amd64
===> build.sh ended:      Sun Apr 18 12:10:58 CEST 2021
===> Summary of results:
         build.sh command:    ./build.sh -U -u -O /home/nia/obj -j2 -m evbarm -a aarch64 toc
         build.sh started:    Sun Apr 18 11:17:46 CEST 2021
         NetBSD version:      9.99.81
         MACHINE:             evbarm
         MACHINE_ARCH:        aarch64
         Build platform:      NetBSD 9.99.81 amd64
         HOST_SH:             /bin/sh
         No $TOOLDIR/bin/nbmake, needs building.
         Bootstrapping nbmake
         MAKECONF file:       /etc/mk.conf
         TOOLDIR path:        /home/nia/obj/tooldir.NetBSD-9.99.81-amd64
         DESTDIR path:        /home/nia/obj/destdir.evbarm
         RELEASEDIR path:     /home/nia/obj/releasedir
         Created /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbmake
         Updated makewrapper: /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbmake-evbarm
         Tools built to /home/nia/obj/tooldir.NetBSD-9.99.81-amd64
         build.sh ended:      Sun Apr 18 12:10:58 CEST 2021
```

During the build, object directories are used consistently, i.e. special directories are kept that keep the platform-specific object files and compile results. In our example, they will be kept in directories named "obj.evbarm" as we build for AArch64 as target platform.

The toolchain itself is part of this, but as it's hosted and compiled for an amd64 system, it will get placed in its own directory indicating where to cross-build from. Here's where our toolchain is located:

```
$ pwd
/home/nia/cvs/src
$ ls -d ~/obj/tooldir*
/home/nia/obj/tooldir.NetBSD-9.99.81-amd64
```

So, the general rule of thumb is for a given "host" and "target" system combination, the cross-compiler will be placed in the "tooldir.host" directory by default. A full list of all tools created for cross-compiling the whole NetBSD operating system includes:

```
$ ls ~/obj/tooldir.NetBSD-9.99.81-amd64/bin
aarch64--netbsd-addr2line    nbconfig                     nbmkcsmapper
aarch64--netbsd-ar           nbcrunchgen                  nbmkdep
aarch64--netbsd-as           nbctags                      nbmkesdb
aarch64--netbsd-c++          nbctfconvert                 nbmklocale
```

```
aarch64--netbsd-c++filt      nbctfmerge              nbmknod
aarch64--netbsd-cpp          nbcvslatest             nbmktemp
aarch64--netbsd-dbsym        nbdb                    nbmkubootimage
aarch64--netbsd-elfedit      nbdisklabel             nbmsgc
aarch64--netbsd-fdisk        nbdtc                   nbmtree
aarch64--netbsd-g++          nbeqn                   nbnroff
aarch64--netbsd-gcc          nbfile                  nbpax
aarch64--netbsd-gcc-9.3.0    nbgenassym              nbpaxctl
aarch64--netbsd-gcc-ar       nbgencat                nbperf
aarch64--netbsd-gcc-nm       nbgmake                 nbpic
aarch64--netbsd-gcc-ranlib   nbgpt                   nbpwd_mkdb
aarch64--netbsd-gcov         nbgrep                  nbrefer
aarch64--netbsd-gcov-dump    nbgroff                 nbrpcgen
aarch64--netbsd-gcov-tool    nbhexdump               nbsed
aarch64--netbsd-install      nbhost-mkdep            nbslc
aarch64--netbsd-ld           nbindxbib               nbsoelim
aarch64--netbsd-ld.bfd       nbinstall-info          nbsortinfo
aarch64--netbsd-mdsetimage   nbinstallboot           nbstat
aarch64--netbsd-nm           nbjoin                  nbstrfile
aarch64--netbsd-objcopy      nblex                   nbsunlabel
aarch64--netbsd-objdump      nbllvm-tblgen           nbtbl
aarch64--netbsd-ranlib       nblorder                nbtexi2dvi
aarch64--netbsd-readelf      nbm4                    nbtexi2pdf
aarch64--netbsd-size         nbmake                  nbtexindex
aarch64--netbsd-strings      nbmake-evbarm           nbtic
aarch64--netbsd-strip        nbmakefs                nbtsort
nbasn1_compile               nbmakeinfo              nbuudecode
nbawk                        nbmakekeys              nbxz
nbcap_mkdb                   nbmakestrs              nbyacc
nbcat                        nbmakewhatis            nbzic
nbcksum                      nbmandoc
nbcompile_et                 nbmenuc
```

As you can see, most of the tools that are available native on NetBSD are present with some program prefix to identify the target platform for tools that are specific to a certain target platform.

One important tool that should be pointed out here is "nbmake-evbarm". This is a shell wrapper for a BSD compatible make(1) command that’s setup to use all the right commands from the cross-compilation toolchain. Using this wrapper instead of /usr/bin/make allows crosscompiling programs that were written using the NetBSD Makefile infrastructure (see src/share/mk). We will use this make(1) wrapper in a second to cross compile the kernel!

33.2 Configuring the kernel manually

Now that we have a working toolchain available, the "usual" steps for building a kernel are needed - create a kernel config file, run config(1), then build. As the config(1) program used to create header files and Makefile for a kernel build is platform specific, we need to use the "nbconfig" program that’s part of our new toolchain. That aside, the procedure is just as like compiling a "native" NetBSD kernel. Commands involved here are:

```
$ cd /home/nia/cvs/src/sys/arch/evbarm/conf
```

```
$ cp GENERIC64 MYKERNEL
$ vi MYKERNEL
$ /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbconfig MYKERNEL
```

That's all. This command has created a directory `../compile/MYKERNEL` with a number of header files defining information about devices to compile into the kernel, a Makefile that is setup to build all the needed files for the kernel, and link them together.

33.3 Building the kernel manually

We have all the files and tools available to crosscompile our AArch64-based kernel from our Intel-based host system, so let's get to it! After changing in the directory created in the previous step, we need to use the toolchain's `nbmake-evbarm` shell wrapper, which just calls make(1) with all the necessary settings for crosscompiling for an AArch64 platform:

```
$ cd ../compile/MYKERNEL/
$ /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbmake-evbarm depend
$ /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbmake-evbarm
```

This will churn away a bit, then spit out a kernel:

```
...
   text    data     bss     dec     hex filename
11131832        3627920 1738912 16498664         fbbfe8 netbsd
...
$ ls -lh netbsd
-rwxr-xr-x  1 nia  wheel   16M Apr 18 12:46 netbsd
$ file netbsd
netbsd: ELF 64-bit LSB executable, ARM aarch64, version 1 (SYSV), statically linked, for Net
```

Note: Since we are building for AArch64, a few other kernel images in different formats were built, including `netbsd.img` and `netbsd.bin` for the U-Boot `/boot` partition. On systems with more standard boot procedures, you only need to worry about `netbsd`.

Now the kernel in the file `netbsd` can be transferred to a machine (via scp, rsync, etc.) and booted.

After configuring and crosscompiling the kernel, the next logical step is to crosscompile the whole system, and bring it into a distribution-ready format. Before doing so, an alternative approach to crosscompiling a kernel will be shown in the next section, using the `build.sh` script to do configuration and crosscompilation of the kernel in one step.

33.4 Building the kernel with build.sh

A cross compiled kernel can be done manually as described in the previous sections, or by the easier method of using `build.sh`, which will be shown here.

Preparation of the kernel config file is the same as described above:

```
$ cd /home/nia/cvs/src/sys/arch/evbarm/conf
```

```
$ cp GENERIC64 MYKERNEL
$ vi MYKERNEL
```

Then edit *MYKERNEL* and once finished, all that needs to be done is to use `build.sh` to build the kernel (it will also configure it, running the steps shown above):

```
$ cd /home/nia/cvs/src
$ ./build.sh -U -u -j2 -O ~/obj -m evbarm -a aarch64 kernel=MYKERNEL
```

Notice that update ("-u") was specified, the tools are already built, there is no reason to rebuild all of the tools. Once the kernel is built, `build.sh` will print its location, along with other information:

```
...
===> Summary of results:
         build.sh command:    ./build.sh -O /home/nia/obj -U -u -j2 -m evbarm -a aarch64 ker
         build.sh started:    Sun Apr 18 12:25:16 CEST 2021
         NetBSD version:      9.99.81
         MACHINE:             evbarm
         MACHINE_ARCH:        aarch64
         Build platform:      NetBSD 9.99.81 amd64
         HOST_SH:             /bin/sh
         MAKECONF file:       /etc/mk.conf
         TOOLDIR path:        /home/nia/obj/tooldir.NetBSD-9.99.81-amd64
         DESTDIR path:        /home/nia/obj/destdir.evbarm
         RELEASEDIR path:     /home/nia/obj/releasedir
         Updated makewrapper: /home/nia/obj/tooldir.NetBSD-9.99.81-amd64/bin/nbmake-evbarm
         Building kernel without building new tools
         Building kernel:     MYKERNEL
         Build directory:     /home/nia/obj/sys/arch/evbarm/compile/MYKERNEL
         Kernels built from MYKERNEL:
          /home/nia/obj/sys/arch/evbarm/compile/MYKERNEL/netbsd
         build.sh ended:      Sun Apr 18 12:46:26 CEST 2021
===> .
```

The path to the kernel built is of interest here:
`/home/nia/obj/sys/arch/evbarm/compile/MYKERNEL/netbsd`, it can be used the same way as described above.

33.5 Building the userland

By now it is probably becoming clear that the toolchain actually works in stages. First the toolchain is built, then a kernel. Since `build.sh` will attempt to rebuild the tools at every invocation, using “update” saves time. It is probably also clear that outside of a few options, the `build.sh` semantics are basically `build.sh` *command*. So, it stands to reason that building the whole userland and/or a release is a matter of using the right commands.

It should be no surprise that building and creating a release would look like the following:

```
$ ./build.sh -U -u -j2 -O ~/obj -m evbarm -a aarch64 release
```

These commands will compile the full NetBSD userland and put it into the destination object directory, and then build a release from it in a release subdirectory.

33.6 Building the X Window System

The NetBSD project has its own copy of the X Window System's which contains changes to make X function well on as many of the platforms supported by NetBSD as possible. Due to this, it is desirable to use the X Window System version available from and for NetBSD, which can also be crosscompiled much like the kernel and base system. To do so, the "xsrc" sources must be checked out from CVS into just as "src" and "pkgsrc" were as described in Chapter 32.

After this, X can be crosscompiled for the target platform by adding the `-x` switch to build.sh, e.g. when creating a full release:

```
$ ./build.sh -U -u -O ~/obj -j2 -x -X /home/nia/cvs/xsrc -m evbarm -a aarch64 release
```

The `-x` option automatically sets the variable to build X11, and `-X` points to the directory containing the X11 sources.

33.7 Changing build behaviour

The build system has a lot of variables that can be used to direct things like where certain files go, what (if any) tools are used and so on. A look in `src/BUILDING` covers most of them. In this section some examples of changing default settings are given, each following its own ways.

33.7.1 Changing the Destination Directory

Many people like to track NetBSD-current and perform cross compiles of architectures that they use. The logic for this is simple, sometimes a new feature or device becomes available and someone may wish to use it. By keeping track of changes and building every now and again, one can be assured that these architectures can build their own release.

It is reasonable to assume that if one is tracking and building for more than one architecture, they might want to keep the builds in a different location than the default. There are two ways to go about this, either use a script to set the new DESTDIR, or simply do so interactively. In any case, it can be set the same way as any other variable (depending on your shell of course).

For sh(1), or ksh(1), this is:

```
$ export DESTDIR=/usr/builds/evbarm-aarch64
```

For csh(1), the command is:

```
$ setenv DESTDIR /usr/builds/evbarm-aarch64
```

Simple enough. When the build is run, the binaries and files will be sent to `/usr/builds`.

33.7.2 Static Builds

The NetBSD toolchain builds and links against shared libraries by default. Many users still prefer to be able to link statically. Sometimes a small system can be created without having shared libraries, which is a good example of doing a full static build. If a particular build machine will always need one environment variable set in a particular way, then it is easiest to simply add the changed setting to `/etc/mk.conf`.

To make sure a build box always builds statically, simply add the following line to `/etc/mk.conf`:

```
LDSTATIC=-static
```

33.7.3 Using `build.sh` options

Besides variables in environment and `/etc/mk.conf`, the build process can be influenced by a number of switches to the `build.sh` script itself, as we have already seen when forcing unprivileged (non-root) builds, selecting the target architecture or preventing deletion of old files before the build. All these options can be listed by running **build.sh -h**:

```
$ cd /home/nia/cvs/src
$ build.sh -h

Usage: build.sh [-EhnoPRrUuxy] [-a arch] [-B buildid] [-C cdextras]
                [-c compiler] [-D dest] [-j njob] [-M obj] [-m mach]
                [-N noisy] [-O obj] [-R release] [-S seed] [-T tools]
                [-V var=[value]] [-w wrapper] [-X x11src] [-Y extsrcsrc]
                [-Z var]
                operation [...]

 Build operations (all imply "obj" and "tools"):
    build               Run "make build".
    distribution        Run "make distribution" (includes DESTDIR/etc/ files).
    release             Run "make release" (includes kernels & distrib media).

 Other operations:
    help                Show this message and exit.
    makewrapper         Create nbmake-${MACHINE} wrapper and nbmake.
                        Always performed.
    cleandir            Run "make cleandir".  [Default unless -u is used]
    dtb                 Build devicetree blobs.
    obj                 Run "make obj".  [Default unless -o is used]
    tools               Build and install tools.
    install=idir        Run "make installworld" to 'idir' to install all sets
                        except 'etc'.  Useful after "distribution" or "release"
    kernel=conf         Build kernel with config file 'conf'
    kernel.gdb=conf     Build kernel (including netbsd.gdb) with config
                        file 'conf'
    releasekernel=conf  Install kernel built by kernel=conf to RELEASEDIR.
    kernels             Build all kernels
    installmodules=idir Run "make installmodules" to 'idir' to install all
                        kernel modules.
    modules             Build kernel modules.
```

```
    rumptest            Do a linktest for rump (for developers).
    sets                Create binary sets in
                        RELEASEDIR/RELEASEMACHINEDIR/binary/sets.
                        DESTDIR should be populated beforehand.
    distsets            Same as "distribution sets".
    sourcesets          Create source sets in RELEASEDIR/source/sets.
    syspkgs             Create syspkgs in
                        RELEASEDIR/RELEASEMACHINEDIR/binary/syspkgs.
    iso-image           Create CD-ROM image in RELEASEDIR/images.
    iso-image-source    Create CD-ROM image with source in RELEASEDIR/images.
    live-image          Create bootable live image in
                        RELEASEDIR/RELEASEMACHINEDIR/installation/liveimage.
    install-image       Create bootable installation image in
                        RELEASEDIR/RELEASEMACHINEDIR/installation/installimage.
    disk-image=target   Create bootable disk image in
                        RELEASEDIR/RELEASEMACHINEDIR/binary/gzimg/target.img.gz.
    params              Display various make(1) parameters.
    list-arch           Display a list of valid MACHINE/MACHINE_ARCH values,
                        and exit.  The list may be narrowed by passing glob
                        patterns or exact values in MACHINE or MACHINE_ARCH.

 Options:
    -a arch        Set MACHINE_ARCH to arch.  [Default: deduced from MACHINE]
    -B buildid     Set BUILDID to buildid.
    -C cdextras    Append cdextras to CDEXTRA variable for inclusion on CD-ROM.
    -c compiler    Select compiler:
                       clang
                       gcc
                   [Default: gcc]
    -D dest        Set DESTDIR to dest.  [Default: destdir.MACHINE]
    -E             Set "expert" mode; disables various safety checks.
                   Should not be used without expert knowledge of the build
                   system.
    -h             Print this help message.
    -j njob        Run up to njob jobs in parallel; see make(1) -j.
    -M obj         Set obj root directory to obj; sets MAKEOBJDIRPREFIX.
                   Unsets MAKEOBJDIR.
    -m mach        Set MACHINE to mach.  Some mach values are actually
                   aliases that set MACHINE/MACHINE_ARCH pairs.
                   [Default: deduced from the host system if the host
                   OS is NetBSD]
    -N noisy       Set the noisyness (MAKEVERBOSE) level of the build:
                       0   Minimal output ("quiet")
                       1   Describe what is occurring
                       2   Describe what is occurring and echo the actual
                           command
                       3   Ignore the effect of the "@" prefix in make commands
                       4   Trace shell commands using the shell's -x flag
                   [Default: 2]
    -n             Show commands that would be executed, but do not execute them.
    -O obj         Set obj root directory to obj; sets a MAKEOBJDIR pattern.
                   Unsets MAKEOBJDIRPREFIX.
    -o             Set MKOBJDIRS=no; do not create objdirs at start of build.
```

```
-P              Set MKREPRO and MKREPRO_TIMESTAMP to the latest source
                CVS timestamp for reproducible builds.
-R release      Set RELEASEDIR to release.  [Default: releasedir]
-r              Remove contents of TOOLDIR and DESTDIR before building.
-S seed         Set BUILDSEED to seed.  [Default: NetBSD-majorversion]
-T tools        Set TOOLDIR to tools.  If unset, and TOOLDIR is not set in
                the environment, nbmake will be (re)built
                unconditionally.
-U              Set MKUNPRIVED=yes; build without requiring root privileges,
                install from an UNPRIVED build with proper file permissions.
-u              Set MKUPDATE=yes; do not run "make cleandir" first.
                Without this, everything is rebuilt, including the tools.
-V var=[value]  Set variable `var' to `value'.
-w wrapper      Create nbmake script as wrapper.
                [Default: ${TOOLDIR}/bin/nbmake-${MACHINE}]
-X x11src       Set X11SRCDIR to x11src.  [Default: /usr/xsrc]
-x              Set MKX11=yes; build X11 from X11SRCDIR
-Y extsrcsrc    Set EXTSRCSRCDIR to extsrcsrc.  [Default: /usr/extsrc]
-y              Set MKEXTSRC=yes; build extsrc from EXTSRCSRCDIR
-Z var          Unset ("zap") variable `var'.
```

As can be seen, a number of switches can be set to change the standard build behaviour. A number of them has already been introduced, others can be set as appropriate.

33.7.4 make(1) variables used during build

Several variables control the behaviour of NetBSD builds. Unless otherwise specified, these variables may be set in either the process environment or in the make(1) configuration file specified by `MAKECONF`. For a definitive list of these options, see `BUILDING` and `share/mk/bsd.README` files in the toplevel source directory.

BUILDID

Identifier for the build. The identifier will be appended to object directory names, and can be consulted in the make(1) configuration file in order to set additional build parameters, such as compiler flags.

DESTDIR

Directory to contain the built NetBSD system. If set, special options are passed to the compilation tools to prevent their default use of the host system's `/usr/include`, `/usr/lib`, and so forth. This pathname should not end with a slash (/) character (For installation into the system's root directory, set `DESTDIR` to an empty string). The directory must reside on a filesystem which supports long filenames and hard links.

Defaults to an empty string if `USETOOLS` is "yes"; unset otherwise. Note: `build.sh` will provide a default (destdir.MACHINE in the top-level `.OBJDIR`) unless run in "expert" mode.

EXTERNAL_TOOLCHAIN

If defined by the user, points to the root of an external toolchain (e.g. `/usr/local/gnu`). This enables the cross-build framework even when default toolchain is not available (see `TOOLCHAIN_MISSING` below).

Default: Unset

MAKEVERBOSE

The verbosity of build messages. Supported values:

0	No descriptive messages are shown.
1	Descriptive messages are shown.
2	Descriptive messages are shown (prefixed with a '#') and command output is not suppressed.

Default: 2

MKCATPAGES

Can be set to “yes” or “no”. Indicates whether preformatted plaintext manual pages will be created during a build.

Default: “yes”

MKDOC

Can be set to “yes” or “no”. Indicates whether system documentation destined for `DESTDIR/usr/share/doc` will be installed during a build.

Default: “yes”

MKHOSTOBJ

Can be set to “yes” or “no”. If set to “yes”, then for programs intended to be run on the compile host, the name, release and architecture of the host operating system will be suffixed to the name of the object directory created by “make obj”. This allows for multiple host systems to compile NetBSD for a single target. If set to “no”, then programs built to be run on the compile host will use the same object directory names as programs built to be run on the target.

Default: “no”

MKINFO

Can be set to “yes” or “no”. Indicates whether GNU info files, used for the documentation of most of the compilation tools, will be created and installed during a build.

Default: “yes”

MKLINT

Can be set to “yes” or “no”. Indicates whether lint(1) will be run against portions of the NetBSD source code during the build, and whether lint libraries will be installed into `DESTDIR/usr/libdata/lint`

Default: “yes”

MKMAN

Can be set to “yes” or “no”. Indicates whether manual pages will be installed during a build.

Default: “yes”

MKNLS

Can be set to “yes” or “no”. Indicates whether Native Language System locale zone files will be compiled and installed during a build.

Default: “yes”

MKOBJ

Can be set to “yes” or “no”. Indicates whether object directories will be created when running “make obj”. If set to “no”, then all built files will be located inside the regular source tree.

Default: “yes”

MKPIC

Can be set to “yes” or “no”. Indicates whether shared objects and libraries will be created and installed during a build. If set to “no”, the entire build will be statically linked.

Default: Platform dependent. As of this writing, all platforms except sh3 default to “yes”

MKPICINSTALL

Can be set to “yes” or “no”. Indicates whether the ar(1) format libraries (`lib*_pic.a`), used to generate shared libraries, are installed during a build.

Default: “yes”

MKPROFILE

Can be set to “yes” or “no”. Indicates whether profiled libraries (`lib*_p.a`) will be built and installed during a build.

Default: “yes”; however, some platforms turn off `MKPROFILE` by default at times due to toolchain problems with profiled code.

MKSHARE

Can be set to “yes” or “no”. Indicates whether files destined to reside in `DESTDIR/usr/share` will be built and installed during a build. If set to “no”, then all of `MKCATPAGES`, `MKDOC`, `MKINFO`, `MKMAN` and `MKNLS` will be set to “no” unconditionally.

Default: “yes”

MKTTINTERP

Can be set to “yes” or “no”. For X builds, decides if the TrueType bytecode interpreter is turned on. See freetype.org (http://freetype.org/patents.html) for details.

Default: “no”

MKUNPRIVED

Can be set to “yes” or “no”. Indicates whether an unprivileged install will occur. The user, group, permissions and file flags will not be set on the installed items; instead the information will be appended to a file called `METALOG` in `DESTDIR`. The contents of `METALOG` are used during the generation of the distribution tar files to ensure that the appropriate file ownership is stored.

Default: “no”

MKUPDATE

Can be set to “yes” or “no”. Indicates whether all install operations intended to write to `DESTDIR` will compare file timestamps before installing, and skip the install phase if the destination files are up-to-date. This also has implications on full builds (See below).

Default: “no”

MKLLVM

Can be set to “yes” or “no”. Indicates whether Clang should be built and installed as the host compiler.

Default: “no”

MKX11

Can be set to “yes” or “no”. Indicates whether X11 is built from `X11SRCDIR`.

Default: “yes”

TOOLDIR

Directory to hold the host tools, once built. This directory should be unique to a given host system and NetBSD source tree. (However, multiple targets may share the same `TOOLDIR`; the target-dependent files have unique names). If unset, a default based on the uname(1) information of the host platform will be created in the `.OBJDIR` of `src`.

Default: Unset.

USETOOLS

Indicates whether the tools specified by `TOOLDIR` should be used as part of a build in progress. Must be set to “yes” if cross-compiling.

yes	Use the tools from `TOOLDIR`.
no	Do not use the tools from `TOOLNAME`, but refuse to build native compilation tool components that are version-specific for that tool.
never	Do not use the tools from `TOOLNAME`, even when building native tool components. This is similar to the traditional NetBSD build method, but does not verify that the compilation tools in use are up-to-date enough in order to build the tree successfully. This may cause build or runtime problems when building the whole NetBSD source tree.

Default: “yes” if building all or part of a whole NetBSD source tree (detected automatically); “no” otherwise (to preserve traditional semantics of the `bsd.*.mk` make(1) include files).

X11SRCDIR

Directory containing the X11 source.

Default: “usr/xsrc”

The following variables only affect the top level `Makefile` and do not affect manually building subtrees of the NetBSD source code.

INSTALLWORLDDIR

Location for the “make installworld” target to install to.

Default: “/”

MKOBJDIRS

Can be set to “yes” or “no”. Indicates whether object directories will be created automatically (via a “make obj” pass) at the start of a build.

Default: “no”

MKUPDATE

Can be set to “yes” or “no”. If set, then addition to the effects described for `MKUPDATE=yes` above, this implies the effect of `NOCLEANDIR` (i.e., “make cleandir” is avoided).

Default: “no”

NOCLEANDIR

If set, avoids the “make cleandir” phase of a full build. This has the effect of allowing only changed files in a source tree to recompiled. This can speed up builds when updating only a few files in the tree.

Default: Unset

NODISTRIBDIRS

If set, avoids the “make distrib-dirs” of a full build. This skips running mtree(8) on `DESTDIR`, useful on systems where building as an unprivileged user, or where it is known that the system wide mtree files have not changed.

Default: Unset

NOINCLUDES

If set, avoids the “make includes” phase of a full build. This has the effect of preventing make(1) from thinking that some programs are out-of-date simply because system include files have changed. However, this option should not be trusted when updating the entire NetBSD source tree arbitrarily; it is suggested to use `MKUPDATE=yes` in that case.

Default: Unset

RELEASEDIR

If set, specifies the directory to which a release(7) layout will be written at the end of a “make release”.

Default: Unset

TOOLCHAIN_MISSING

Set to “yes” on platforms for which there is no working in-tree toolchain, or if you need/wish using native system toolchain (i.e. non-cross tools available via your shell search path).

Default: depends on target platform; on platforms with in-tree toolchain is set to “no”.

Chapter 34

Compiling the kernel

There are several reasons you might want to compile a NetBSD kernel:

- you can install bug-fixes, security updates, or new functionality by rebuilding the kernel from updated sources.
- by removing unused device drivers and kernel sub-systems from your configuration, you can dramatically reduce kernel size and, therefore, memory usage and attack surface. Care must be taken when doing this, since it can result in an unusable system. Always back up old working kernels.
- you can access additional features by enabling kernel options or sub-systems, some of which are experimental or disabled by default.
- you can get a deeper knowledge of the system.

34.1 Requirements and procedure

To recompile the kernel you must have installed the compiler set (`comp.tgz`).

The basic steps to an updated or customised kernel then are:

1. Install or update the kernel sources
2. Create or modify the kernel configuration file
3. Building the kernel from the configuration file, either manually or using **build.sh**
4. Install the kernel

34.2 Installing the kernel sources

> You can get the kernel sources from AnonCVS (see Chapter 32), or from the `syssrc.tgz` tarball that is located in the `source/sets/` directory of the release that you are using.

If you chose to use AnonCVS to fetch the entire source tree, be patient, the operation can last many minutes, because the repository contains thousands of files.

If you have a source tarball, you can extract it as root:

```
# cd /
# tar zxf /path/to/syssrc.tgz
```

Even if you used the tarball from the release, you may wish to use AnonCVS to update the sources with changes that have been applied since the release. This might be especially relevant if you are updating the kernel to include the fix for a specific bug, including a vulnerability described in a NetBSD Security Advisory. You might want to get the latest sources on the relevant release or critical updates branch for your version, or Security Advisories will usually contain information on the dates or revisions of the files containing the specific fixes concerned. See Section 32.4 for more details on the CVS commands used to update sources from these branches.

Once you have the sources available, you can create a custom kernel: this is not as difficult as you might think. In fact, a new kernel can be created in a few steps which will be described in the following sections.

34.3 Creating the kernel configuration file

> **Note:** The directories described in this section are amd64 specific. Users of other architectures must substitute the appropriate directories, see the subdirectories of `src/sys/arch` for a list.

The kernel configuration file defines the type, the number and the characteristics of the devices supported by the kernel as well as several kernel configuration options. For the amd64 port, kernel configuration files are located in the `/usr/src/sys/arch/amd64/conf` directory.

Please note that the names of the kernel configuration files are historically in all uppercase, so they are easy to distinguish from other files in that directory:

```
$ cd /usr/src/sys/arch/amd64/conf/
$ ls
ALL                 INSTALL             XEN3_DOM0           kern.ldscript.kaslr
CVS                 INSTALL_XEN3_DOMU   XEN3_DOMU           majors.amd64
GENERIC             MODULAR             files.amd64         std.amd64
GENERIC_KASLR       Makefile.amd64      kern.ldscript       std.xen
GENERIC_USERMODE    NOCOMPAT            kern.ldscript.Xen
```

The easiest way to create a new file is to copy an existing one and modify it. Usually the best choice on most platforms is the GENERIC configuration, as it contains most drivers and options. In the configuration file there are comments describing the options; a more detailed description is found in the options(4) man page. So, the usual procedure is:

```
$ cp GENERIC MYKERNEL
$ vi MYKERNEL
```

The modification of a kernel configuration file basically involves three operations:

1. support for hardware devices is included/excluded in the kernel (for example, SCSI support can be removed if it is not needed.)
2. support for kernel features is enabled/disabled (for example, enable NFS client support, enable Linux compatibility, ...)
3. tuning kernel parameters.

Lines beginning with “#” are comments; lines are disabled by commenting them and enabled by removing the comment character. It is better to comment lines instead of deleting them; it is always possible uncomment them later.

The output of the dmesg(8) command can be used to determine which lines can be disabled. For each line of the type:

```
XXX at YYY
```

both *XXX* and *YYY* must be active in the kernel configuration file. You’ll probably have to experiment a bit before achieving a minimal configuration but on a desktop system without SCSI and PCMCIA you can halve the kernel size.

You could also examine the options in the configuration file and disable the ones that you don’t need. Each option has a short comment describing it, which is normally sufficient to understand what the option does. Many options have a longer and more detailed description in the options(4) man page.

34.4 Building the kernel manually

Based on your kernel configuration file, either one of the standard configurations or your customised configuration, a new kernel must be built.

These steps can either be performed manually, or using the **build.sh** command that was introduced in section Chapter 33. This section will give instructions on how to build a native kernel using manual steps, the following section Section 34.5 describes how to use **build.sh** to do the same.

- Configure the kernel
- Generate dependencies
- Compile the kernel

34.4.1 Configuring the kernel manually

When you’ve finished modifying the kernel configuration file (which we’ll call `MYKERNEL`), you should issue the following command:

```
$ config MYKERNEL
```

If `MYKERNEL` contains no errors, the config(1) program will create the necessary files for the compilation of the kernel, otherwise it will be necessary to correct the errors before running config(1) again.

> **Notes for cross-compiling:** As the config(1) program used to create header files and Makefile for a kernel build is platform specific, it is necessary to use the **nbconfig** program that’s part of a newly created toolchain (created for example with
>
> ```
> /usr/src/build.sh -m sparc64 tools
> ```
>
>). That aside, the procedure is just as like compiling a "native" NetBSD kernel. The command is for example:
>
> ```
> % /usr/src/tooldir.NetBSD-9.0-amd64/bin/nbconfig MYKERNEL
> ```

This command has created a directory `../compile/MYKERNEL` with a number of header files defining information about devices to compile into the kernel, a Makefile that is setup to build all the needed files for the kernel, and link them together.

34.4.2 Generating dependencies and recompiling manually

Dependencies generation and kernel compilation is performed by the following commands:

```
$ cd ../compile/MYKERNEL
$ make depend
$ make
```

It can happen that the compilation stops with errors; there can be a variety of reasons but the most common cause is an error in the configuration file which didn't get caught by config(1). Sometimes the failure is caused by a hardware problem (often faulty RAM chips): the compilation puts a higher stress on the system than most applications do. Another typical error is the following: option B, active, requires option A which is not active. A full compilation of the kernel can last from some minutes to several hours, depending on the hardware.

The result of a successful make command is the `netbsd` file in the compile directory, ready to be installed.

Notes for cross-compiling: For crosscompiling a sparc64 kernel, it is necessary to use the crosscompiler toolchain's `nbmake-sparc64` shell wrapper, which calls make(1) with all the necessary settings for crosscompiling for a sparc64 platform:

```
% cd ../compile/MYKERNEL/
% /usr/src/tooldir.NetBSD-9.0-amd64/bin/nbmake-sparc64 depend
% /usr/src/tooldir.NetBSD-9.0-amd64/bin/nbmake-sparc64
```

This will churn away a bit, then spit out a kernel:

```
...
text    data     bss     dec     hex filename
5016899  163728  628752 5809379  58a4e3 netbsd
% ls -l netbsd
-rwxr-xr-x  1 feyrer  666  5874663 Dec  2 23:17 netbsd
% file netbsd
netbsd: ELF 64-bit MSB executable, SPARC V9, version 1 (SYSV), statically linked, not stripped
```

Now the kernel in the file `netbsd` can either be transferred to an UltraSPARC machine (via NFS, FTP, scp, etc.) and booted from a possible harddisk, or directly from the cross-development machine using NFS.

34.5 Building the kernel using `build.sh`

After creating and possibly editing the kernel config file, the manual steps of configuring the kernel, generating dependencies and recompiling can also be done using the `src/build.sh` script, all in one go:

```
$ cd /usr/src
$ ./build.sh kernel=MYKERNEL
```

This will perform the same steps as above, with one small difference: before compiling, all old object files will be removed, to start with a fresh build. This is usually overkill, and it's fine to keep the old file and only rebuild the ones whose dependencies have changed. To do this, add the `-u` option to `build.sh`:

```
$ cd /usr/src
$ ./build.sh -u kernel=MYKERNEL
```

At the end of its job, `build.sh` will print out the location where the new compiled kernel can be found. It can then be installed.

34.6 Installing the new kernel

Whichever method was used to produce the new kernel file, it must now be installed. The new kernel file should be copied to the root directory, after saving the previous version.

```
# mv /netbsd /netbsd.old
# mv netbsd /
```

Customization can considerably reduce the kernel's size. In the following example `netbsd.old` is the install kernel and `netbsd` is the new kernel.

```
-rwxr-xr-x  3 root  wheel  3523098 Dec 10 00:13 /netbsd
-rwxr-xr-x  3 root  wheel  7566271 Dec 10 00:13 /netbsd.old
```

The new kernel is activated after rebooting:

```
# shutdown -r now
```

34.7 If something went wrong

When the computer is restarted it can happen that the new kernel doesn't work as expected or even doesn't boot at all. Don't worry: if this happens, just reboot with the previously saved kernel and remove the new one (it is better to reboot "single user"):

- Reboot the machine
- Press the space bar at the boot prompt during the 5 seconds countdown

  ```
  boot:
  ```

- Type

  ```
  > boot netbsd.old -s
  ```

- Now issue the following commands to restore the previous version of the kernel:

  ```
  # fsck /
  # mount /
  # mv netbsd.old netbsd
  ```

```
# reboot
```

This will give you back the working system you started with, and you can revise your custom kernel config file to resolve the problem. In general, it's wise to start with a GENERIC kernel first, and then make gradual changes.

Chapter 35

Updating an existing system from sources

A common mechanism for upgrading a NetBSD system to a newer version is by rebuilding the system from sources and installing the results. This works both for stable releases such as NetBSD 9.3 and for NetBSD-current. In particular, if you are running a stable NetBSD release in a production environment, you are encouraged to perform this procedure regularly in order to incorporate any security fixes that have been applied to the branch since its release.

There are a variety of ways of achieving the goal of rebuilding NetBSD from source, and this chapter will guide you through the variety of options that are available. The chapter starts by showing first what the manual procedure looks like, and proceeds to describe some of automation tools that simplify the process.

> **Note:** *Please remember to check src/UPDATING (http://cvsweb.NetBSD.org/bsdweb.cgi/src/UPDATING) for the latest changes and special instructions that may be involved in upgrading the system.*

35.1 Manual build and update procedure

Most of the following steps can be done as ordinary user. Only the installation of a new kernel and the userland will require root privileges. Although `/usr` is choosen as the working directory in the following examples, the procedure can also take place in a user's home directory. Ordinary users have normally not the permissions to make changes in `/usr`, but this can be changed by root.

Having up-to-date sources is a prerequisite for the following steps. Section 32.4 informs about the ways to retrieve or update the sources for a release, stable or current branch (using CVS).

Please always refer to the output of **build.sh -h** and the files `UPDATING` and `BUILDING` for details - it's worth it, there are *many* options that can be set on the command line or in `/etc/mk.conf`

35.1.1 Building a new userland

The first step is to build the userland:

```
$ cd /usr/src
$ ./build.sh -O ../obj -T ../tools -U distribution
```

35.1.2 Building a new kernel

The next step will build the kernel:

```
$ cd /usr/src
$ ./build.sh -O ../obj -T ../tools -U kernel=<KERNEL>
```

35.1.3 Installing the kernel and userland

Installing the new kernel, rebooting (to ensure that the new kernel works) and installing the new userland are the final steps of the updating procedure:

```
$ cd /usr/src
$ su
# mv /netbsd /netbsd.old
# mv /usr/obj/sys/arch/<ARCH>/compile/<KERNEL>/netbsd /
# shutdown -r now
 ...
$ cd /usr/src
$ su
# ./build.sh -O ../obj -T ../tools -U install=/
```

If the new kernel `netbsd` does not boot successfully, you can fall back on booting the `netbsd.old` kernel.

35.1.4 Updating the system configuration files

Updating your system's configuration files is done in two steps. First, postinstall(8) is used to check and fix things that can be easily automated. Afterwards, etcupdate(8) is used to merge the remaining configuration file changes.

```
# /usr/sbin/postinstall -s /usr/src check
# /usr/sbin/postinstall -s /usr/src fix
# /usr/sbin/etcupdate -s /usr/src
```

Optionally reboot to ensure all running services are using the new binaries:

```
# shutdown -r now
```

35.1.5 Summary

1. From the root of the source tree:

   ```
   $ cd /usr/src
   ```

2. Build the userland:

   ```
   $ ./build.sh -O ../obj -T ../tools -U -u distribution
   ```

3. Build the kernel:

```
$ ./build.sh -O ../obj -T ../tools -U -u kernel=GENERIC
```

4. Install the kernel:

```
$ cd ../obj/sys/arch/<ARCH>/compile/GENERIC
$ su
# mv /netbsd /netbsd.old
# cp netbsd /netbsd
```

5. Reboot into the new kernel:

```
# shutdown -r now
```

6. Install the new userland:

```
$ cd /usr/src
$ su
# ./build.sh -O ../obj -T ../tools -U install=/
```

7. Update the system and configuration files;:

```
#  /usr/sbin/etcupdate -s /usr/src
```

Note: In the procedure above, the `-u` option indicates an update process, and that a make clean operation should not be run before starting the build. This is useful when doing an update from a previous build and/or a fresh build. The `-U` option allows the entire build by a non-root user followed with an install by root.

35.2 Using sysinst

It is also possible to use `sysinst` to install a freshly built system. The steps are as follows:

1. Build a complete release:

```
$ ./build.sh -O ../obj -T ../tools -U -u -x release
```

2. The resulting install sets will be in the `/usr/obj/releasedir/` directory.
3. Copy the install kernel to the root directory of your NetBSD system, reboot from it, and upgrade with `sysinst` (see Chapter 4).

35.3 Using sysbuild and sysupgrade

The sysbuild and sysupgrade tools (currently available in `pkgsrc/sysutils/sysbuild` and `pkgsrc/sysutils/sysupgrade` respectively) automate the full process of rebuilding NetBSD from sources (*including the retrieval of the sources from a CVS repository*) and installing the results with minimal effort.

Both of these tools have configuration files to determine how to build a release and how to install it. Among other things, these specify the CVS repository to use, what architecture to build for, where to place the build files and what steps to perform during an upgrade. The files can be found in

/usr/pkg/etc/sysbuild/default.conf and /usr/pkg/etc/sysupgrade.conf. The default configuration of both tools should let you get started with minimal effort.

In their simplest form, you can do a full NetBSD build and upgrade your system to it by running these commands:

```
# sysbuild build
# sysupgrade auto ~/sysbuild/release/$(uname -m)
```

And that's all that it takes. These invocations will do the following:

1. Download the source trees from CVS into /usr/src and /usr/xsrc. The latter is only fetched if your system has X11. And, if you already have the sources in your system, this will only update them to the newest version.
2. Build a new release into ~/sysbuild/<machine>/. This per-machine directory will include subdirectories like obj, destdir, etc. The build results will be left in ~/sysbuild/release/<machine>/.
3. Install a new kernel and unpack the new sets using the just-built release files.
4. Run both etcupdate and postinstall to aid you in merging new configuration changes into your system.

For more details, please see the included sysbuild(1) and sysupgrade(8) manual pages, as well as the comments in the referenced configuration files.

35.3.1 Tweak: Building as non-root

The commands above depict the most basic and simple invocation of the tools using the *default configuration files*. One drawback is that you require root access during the build of the source tree so that sysbuild can upgrade the source trees under /usr/src and /usr/xsrc. It is recommended that you avoid building as root once you are familiar with the procedure, and this section show what is needed to do so with sysbuild.

In order to build as non-root, you can either choose to store your source trees out of /usr (easiest) or give permissions to your user to modify the trees under /usr (good if you want to share the source tree with more than one user).

If you want to store the source trees under your home directory, which is convenient for development purposes, simply edit /usr/pkg/etc/sysbuild.conf and add these settings:

```
SRCDIR="${HOME}/sysbuild/src"
[ ! -f /etc/mtree/set.xbase ] || XSRCDIR="${HOME}/sysbuild/xsrc"
```

Once this is done, the "sysbuild build" invocation show above should just work under your unprivileged user. The upgrade procedure then becomes:

```
$ sysbuild build
... become root ...
# sysupgrade auto ~/sysbuild/release/$(uname -m)
```

The other alternative, in case you want to maintain your source trees in the locations described by hier(7), is to do the following as root:

```
# mkdir -p /usr/src /usr/xsrc
# chown -R <your-user>:wsrc /usr/src /usr/xsrc
... and optionally add <your-user> to wsrc in /etc/group ...
```

After this, the default configuration file of sysbuild will let you place the files in these locations and let you do unprivileged builds.

35.3.2 Tweak: Setting up nightly builds

The `pkgsrc/sysutils/sysbuild-user` package can be used to configure and maintain an unprivileged system user to perform periodic (e.g. nightly) builds from source. This can come in very handy to closely track NetBSD-current.

The installed user is appropriately named sysbuild, and is configured by default to run a full system build overnight. The results are left in `/home/sysbuild/release/<machine>/`, which is the convenient default of sysupgrade's release directory. Any build failures will be reported to you by email.

The behavior of sysbuild for this unprivileged user is configured in `/home/sysbuild/default.conf`.

You can interact with sysbuild under this unprivileged user by running commands of the form:

```
# su - sysbuild /usr/pkg/bin/sysbuild ...
```

35.4 More details about the updating of configuration and startup files

`etcupdate` is a script to help users compare, merge and install new configuration and startup files (files found in the etc.tgz distribution set) in /dev, /etc and /root after performing an operating system upgrade. The upgrade of the operating system could have been performed either by compiling sources or by extracting the distribution binaries.

35.4.1 Using etcupdate with source files

In case where the sources are in /usr/src the following command should be enough:

```
# etcupdate
```

But what if your NetBSD sources are in an alternative location, such as in `/home/jdoe/netbsd/src`? Don't worry, tell etcupdate the location of your source tree with -s srcdir and it will work just fine:

```
# etcupdate -s /home/jdoe/netbsd/src
```

35.4.2 Using etcupdate with binary distribution sets

Sometimes it's not convenient to have the sources around but you still want to update the configuration and startup files. The solution is to feed etc.tgz (or xetc.tgz) to etcupdate via the -s tgzfile switch.

```
# etcupdate -s /some/where/etc.tgz
```

35.4.3 Using `etcmanage` instead of `etcupdate`

The `etcmanage` perl script (available from pkgsrc/sysutils/etcmanage (http://pkgsrc.se/sysutils/etcmanage) or as binary package) is an alternative to `etcupdate`. It should be used in the following way, in combination with postinstall(8):

```
# /usr/pkg/bin/etcmanage
# /usr/sbin/postinstall
```

Chapter 36

Building NetBSD installation media

36.1 Creating standard installation images with build.sh

For some architectures, you can build a disk or ISO image that boots into an installer. This is accomplished by running `./build.sh` with the targets `install-image` (for an USB stick) or `iso-image` (for a DVD or CD):

```
$ ./build.sh -U -u -j2 -m amd64 -O ~/obj tools
$ ./build.sh -U -u -j2 -m amd64 -O ~/obj release
$ ./build.sh -U -u -j2 -m amd64 -O ~/obj install-image
```

Many other `./build.sh` targets are available, see Chapter 33.

36.2 Creating custom live disk images

Sometimes you may want to create your own customized pre-installed ("live") images instead of using the precompiled images, for e.g. mass deployment on embedded systems. This section outlines the steps to do so.

1. You must build a release of NetBSD so there are binaries to fill the image. See Chapter 33 for instructions.
2. You must write or pick a sh(1) script from `src/distrib/utils/embedded/conf`. Examine the default configurations, and if necessary, customize one to your needs. The scripts can alter and add to the system configuration files.
3. Run the utility:

   ```
   $ export MKDTB=no
   $ ./distrib/utils/embedded/mkimage -D obj/destdir.amd64 -K sys/arch/amd64/compile/obj/GENERIC/netb
   ```

   - In this case, we are building an image for the **amd64.conf** configuration, so we specify **-h amd64**.
   - We want to include the X11 sets, so we specify **-x**.
   - We need to specify the device type of the root filesystem with e.g. **-r sd**. Typically, this is ld(4) for SD/MMC devices, and sd(4) for USB sticks.
   - We specify MKDTB=no in the environment to avoid building device tree blobs, which are only used on ARM and MIPS.

4. Make any final additions to the image. This can include installing packages with pkg_add(1), etc. We mount the image as a virtual disk using vndconfig(8):

```
# vndconfig vnd0 ./example-amd64-image.img
# mount /dev/vnd0a /mnt
# pkg_add -P /mnt -K /usr/pkg/pkgdb -v darkstat-3.0.719.tgz
# umount /mnt
```

5. Write the image to your live media:

```
# dd if=example-amd64-image.img ibs=1m | progress dd of=/dev/rsd0 obs=1m
```

Appendix A.
Information

A.1 Where to get this document

This document is currently available in the following formats:

- HTML (http://www.NetBSD.org/docs/guide/en/index.html)
- PDF (http://www.NetBSD.org/docs/guide/download/netbsd-en.pdf)
- gzip'd PostScript (http://www.NetBSD.org/docs/guide/download/netbsd-en.ps.gz)

In addition, this guide is also sold on occasion in printed form at tradeshows and exhibitions, with all profits being donated to the NetBSD Foundation. On demand printing may at some point be available as well. If you are interested in obtaining a printed and bound copy of this document, please contact <`www@NetBSD.org`>.

A.2 Guide history

This guide was born as a collection of sparse notes that Federico Lupi, the original author of the NetBSD Guide, wrote mostly for himself. When he realized that they could be useful to other NetBSD users he started collecting them and created the first version of the guide using the groff formatter. In order to "easily" get a wider variety of output formats (e.g. HTML and PostScript/PDF), he made the "mistake" of moving to SGML/DocBook, which is the current format of the sources. Maintainership was picked up by the NetBSD project and its developers later, and the format was changed to XML/DocBook later due to better tools and slightly more knowhow on customisations.

The following open source tools were used to write and format the guide:

- the vi editor which ships with NetBSD (nvi).
- the libxslt parser from GNOME for transforming XML/DocBook into HTML.
- the TeX system from the NetBSD packages collection. TeX is used as a backend to produce the PS and PDF formats.
- the tgif program for drawing the figures.
- the gimp and xv programs for converting between image formats and making small modifications to the figures.

Many thanks to all the people involved in the development of these great tools.

Appendix B.

Contributing to the NetBSD guide

There is an interest for both introductory and advanced documentation on NetBSD: this is probably a sign of the increased popularity of this operating system and of a growing user base. It is therefore important to keep adding new material to this guide and improving the existing text.

Whatever your level of expertise with NetBSD, you can contribute to the development of this guide. This appendix explains how, and what you should know before you start.

If you are a beginner and you found this guide helpful, please send your comments and suggestions to <`www@NetBSD.org`>. For example, if you tried something described here and it didn't work for you, or if you think that something is not clearly explained, or if you have an idea for a new chapter, etc: this type of feedback is very useful.

If you are an intermediate or advanced user, please consider contributing new material to the guide: you could write a new chapter or improve an existing one.

Whatever you choose to do, don't start working before having contacted us, in order to avoid duplicating efforts.

B.1 Sending contributions

If you want to contribute some material to the guide you have several options, depending on the amount of text you want to write. If you just want to send a small fix, the easiest way to get it into the guide is to send it to <`www@NetBSD.org`> via e-mail. If you plan to write a substantial amount of text, such as a section or a chapter, you can choose among many formats:

- XML/DocBook; this is the preferred format. If you choose to use this format, please get the guide sources and use them as a template for the indentation and text layout, in order to keep the formatting consistent.
- text; if the formatting is kept simple, it is not difficult to convert text to XML format.
- other formats are also accepted if you really can't use any of the previous ones.

B.2 XML/DocBook template

For the guide I use a formatting style similar to a program. The following is a template:

```
<chapter id="chap-xxxxx">
  <title>This is the title of the chapter</title>
```

```
  <para>
    This is the text of a paragraph.  This is the text of a paragraph.
    This is the text of a paragraph.  This is the text of a paragraph.
    This is the text of a paragraph.
  </para>

  <!-- ============================================================== -->

  <sect1>
    <title>This is the title of a sect1</title>

    <para>
      This is the text of a paragraph.  This is the text of a paragraph.
      This is the text of a paragraph.  This is the text of a paragraph.
      This is the text of a paragraph.
    </para>

    <!-- ........................................................ -->

    <sect2>
      <title>This is the title of a sect2</title>

      <para>
 A sect2 is nested inside a sect1.
      </para>
    </sect2>

  </sect1>

  <!-- ============================================================== -->

  <sect1>
    <title>This is the title of another sect1</title>

    <para>
      An itemized list:
      <itemizedlist>
 <listitem>
   <para>
     text
   </para>
 </listitem>
 <listitem>
   <para>
     text
   </para>
 </listitem>
      </itemizedlist>
    </para>

  </sect1>
</chapter>
```

The defaults are:

- two spaces for each level of indentation
- lines not longer than 72 characters.
- use separator lines (comments) between sect1/sect2.

Appendix C.

Getting started with XML/DocBook

This appendix describes the installation of the tools needed to produce a formatted version of the NetBSD guide. Besides that it contains instructions that describe how to build the guide.

C.1 What is XML/DocBook

XML (eXtensible Markup Language) is a language which is used to define other languages based on markups, i.e. with XML you can define the grammar (i.e. the valid constructs) of markup languages. HTML, for example, can be defined using XML. If you are a programmer, think of XML like the BNF (Backus-Naur Form): a tool used to define grammars.

DocBook is a markup template defined using XML; DocBook lists the valid tags that can be used in a DocBook document and how they can be combined together. If you are a programmer, think of DocBook as the grammar of a language specified with the BNF. For example, it says that the tags:

```
<para> ... </para>
```

define a paragraph, and that a <para> can be inside a <sect1> but that a <sect1> cannot be inside a <para>.

Therefore, when you write a document, you write a document in DocBook and not in XML: in this respect DocBook is the counterpart of HTML (although the markup is richer and a few concepts are different).

The DocBook specification (i.e. the list of tags and rules) is called a DTD (Document Type Definition).

In short, a DTD defines how your source documents look like but it gives no indication about the format of your final (compiled) documents. A further step is required: the DocBook sources must be converted to some other representation like, for example, HTML or PDF. This step is performed by a tool like Jade, which applies the DSSSL transforms to the source document. DSSSL (Document Style Semantics and Specification Language) is a format used to define the *stylesheets* necessary to perform the conversion from DocBook to other formats. The build structure for the guide also supports the XSL (Extensible Stylesheet Language) stylesheet language. The **xsltproc** program is used for transforming XML with XSL stylesheets.

C.2 Installing the necessary tools

All the tools that are needed to generate the guide in various formats can be installed through the *netbsd-www*, *netbsd-doc*, and *netbsd-doc-print* meta-packages. Together the *netbsd-doc* and *netbsd-www* packages install everything that is needed to generate the HTML version of the guide. To be able to generate printable formats, such as Postscript and PDF, install the *netbsd-doc-print* meta-package.

Supposing that a current pkgsrc tree is installed at `/usr/pkgsrc`, you can install all these meta-packages with:

```
$ cd /usr/pkgsrc/meta-pkgs/netbsd-www
$ make install
$ cd /usr/pkgsrc/meta-pkgs/netbsd-doc
$ make install
$ cd /usr/pkgsrc/meta-pkgs/netbsd-doc-print
$ make install
```

C.3 Using the tools

This section provides an overview of how the guide can be compiled from XML to any of the following target formats: *html*, *html-split*, *ascii*, *ps*, and *pdf*. Creating all formats is the default. To produce any of the above output formats, run **make** with the format(s) as argument.

Let's look at a few examples.

Before looking at the output generated in any of the above-mentioned formats, integrity of the XML structure has to be ensured. This can be done by running **make lint**:

```
$ cd htdocs/docs/guide/en
$ make lint
```

Fix any errors you may get. When working on the contents of the guide, you may want to produce the HTML version to have a look at it for proofreading:

```
$ cd htdocs/docs/guide/en
$ make html-split
```

After this, please update the Postscript and PDF versions of the guide too. The command for this is:

```
$ cd htdocs/docs/guide/en
$ make pdf
```

Before you commit the generated files, please make sure that you commit the XML files first, then re-generate all formats, i.e. the procedure would be something like:

```
$ cd htdocs/docs/guide/en
$ cvs commit *.xml
$
$ make lint
$ make
$ make install-doc
$
$ cd ..
$ cvs commit en download
```

When running **make** with no argument, all formats will be re-generated. This is the default way to build the guide for the NetBSD.org website.

C.4 Links

The official DocBook home page (http://www.oasis-open.org/docbook/) is where you can find the definitive documentation on DocBook. You can also read online or download a copy of the book DocBook: The Definitive Guide (http://www.oasis-open.org/docbook/documentation/reference/) by Norman Walsh and Leonard Muellner.

For DSSSL start looking at http://nwalsh.com.

XSL is described at http://www.w3.org/Style/XSL/.

Jade/OpenJade sources and info can be found on the OpenJade Home Page (http://openjade.sourceforge.net/).

If you want to produce Postscript and PDF documents from your DocBook source, look at the home page of JadeTex (http://sourceforge.net/projects/jadetex/).

Appendix D.
Acknowledgements

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Appendix E.
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