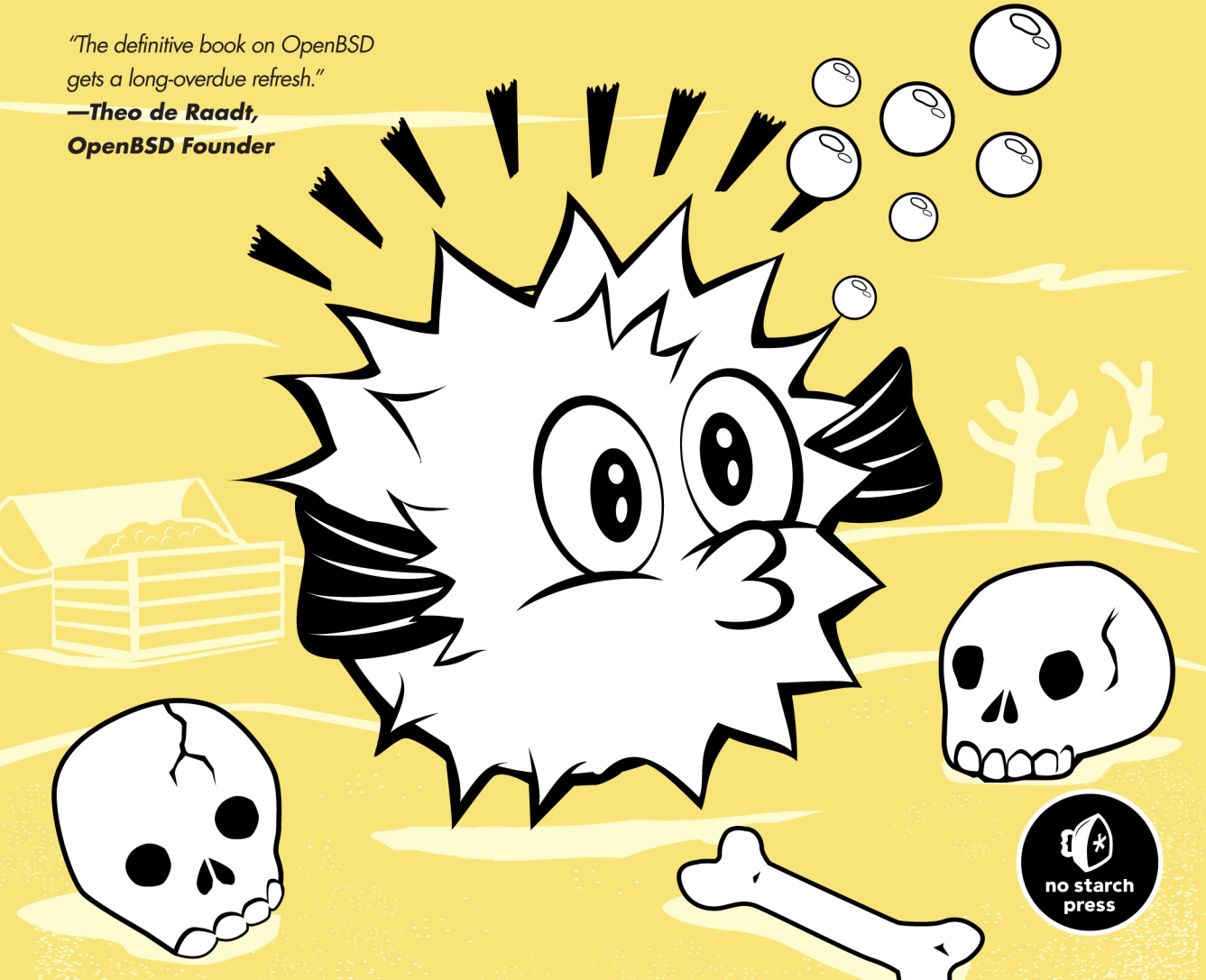
2ND EDITION

# ABSOLUTE OPENBSD

UNIX FOR THE PRACTICAL PARANOID

MICHAEL W. LUCAS

*"The definitive book on OpenBSD gets a long-overdue refresh."*
***—Theo de Raadt, OpenBSD Founder***



no starch press

## ADVANCE PRAISE FOR *ABSOLUTE OPENBSD, 2ND EDITION*

"Michael W. Lucas's books are good enough to raise national productivity statistics. Every copy of OpenBSD should be bundled with this book."
—RICHARD BEJTLICH, CSO OF MANDIANT, TAOSECURITY BLOGGER, AND AUTHOR OF *THE PRACTICE OF NETWORK SECURITY MONITORING*

"After 13 years of using OpenBSD, I learned something new and useful!"
—PETER HESSLER, OPENBSD JOURNAL (UNDEADLY.ORG)

"The OpenBSD world, myself included, has been waiting for an update to *Absolute OpenBSD* for years. Michael W. Lucas tackles OpenBSD topics in ways that are bound to inspire the learner and warm the hearts of Unix greybeards."
—PETER N.M. HANSTEEN, AUTHOR OF *THE BOOK OF PF*

"Michael W. Lucas is a layperson's tutor, sitting next to you in front of an OpenBSD box and working through the same issues the average sysadmin does."
—GEORGE ROSAMOND, FOUNDING MEMBER OF THE NYC*BSD USER GROUP

"Whether you are an experienced OpenBSD user seeking a functional desk reference or a new OpenBSD user seeking to gain the knowledge necessary to become an expert, then *Absolute OpenBSD* is the book you have to have."
—CHRIS SANDERS, AUTHOR OF *PRACTICAL PACKET ANALYSIS*

"The second edition of *Absolute OpenBSD* delivers an updated tour of OpenBSD with great attention to detail and zero hand-waving. Mr. Lucas and No Starch Press have once again demonstrated exemplary respect and loyalty to OpenBSD and the BSD community."
—MICHAEL DEXTER, CALLFORTESTING.ORG

# ABSOLUTE OPENBSD

## 2ND EDITION

### Unix for the Practical Paranoid

by Michael W. Lucas

no starch press

San Francisco

Printed in USA

First printing

17 16 15 14 13 1 2 3 4 5 6 7 8 9

ISBN-10: 1-59327-476-9
ISBN-13: 978-1-59327-476-4

Publisher: William Pollock
Production Editor: Alison Law
Cover Illustration: Charlie Wylie
Interior Design: Octopod Studios
Developmental Editor: William Pollock
Technical Reviewer: Peter N.M. Hansteen
Copyeditor: Marilyn Smith
Compositor: Susan Glinert Stevens
Proofreader: Elaine Merrill
Indexer: Nancy Guenther

For information on distribution, translations, or bulk sales, please contact No Starch Press, Inc. directly:

No Starch Press, Inc.
38 Ringold Street, San Francisco, CA 94103
phone: 415.863.9900; fax: 415.863.9950; info@nostarch.com; www.nostarch.com

*Library of Congress has cataloged the first edition as follows:*

```
Lucas, Michael W., 1967-
        Absolute OpenBSD: UNIX for the practical paranoid / Michael W. Lucas.
        p. cm.
Includes index.
        ISBN: 1-886411-99-9
1. OpenBSD (Electronic resource). 2. Operating systems (Computers) 3. UNIX (Computer file) I. Title.
        QA76.9.063L835 2003
        005.4'32--dc21
                                                        2003000473
```

For Liz

## About the Author

Michael W. Lucas is a network/security engineer who keeps getting stuck with the problems nobody else wants to touch. He's been using BSD since the days it came from Berkeley, and today uses OpenBSD for mission-critical infrastructure. You can find Lucas roaming around Detroit, Michigan, or teaching tutorials at tech conferences. He's the author of the critically acclaimed *Absolute FreeBSD*, *Network Flow Analysis*, *Cisco Routers for the Desperate*, and *PGP & GPG*, all from No Starch Press.

Find his website and blog at *http://www.michaelwlucas.com/*, or follow @mwlauthor on Twitter.

## About the Technical Reviewer

Peter N.M. Hansteen is a consultant, sysadmin, and writer from Bergen, Norway. During recent years he has been a frequent lecturer and tutor with emphasis on OpenBSD and FreeBSD, as well as the author of several articles and *The Book of PF* (No Starch Press, 2010). He writes about OpenBSD and rants about other IT topics at *http://bsdly.blogspot.com/*.

# BRIEF CONTENTS

# CONTENTS IN DETAIL

# FOREWORD

I got my OpenBSD account as a developer in 2002, more than 10 years ago. Over this time, quite a number of OpenBSD-related books have been published. Some were actually good, but many were not and were full of factual errors. I kept asking myself (and others) why these authors never approached us for fact-checking before publishing.

I have known Michael for a long time as well—many, many years. Both of us frequently visit BSD-related conferences, and we often end up having a beer together, which is always fun. I did read the first edition of *Absolute OpenBSD* when it was published, a long time ago, and quite frankly, I don't remember anything from it. That's a good thing in this case, because I would have remembered if it had been bad. I have recommended it as an introduction to OpenBSD a couple of times.

So when Michael approached me asking whether I would be willing to fact-check the second edition of *Absolute OpenBSD* and provide feedback, I happily agreed.

I have done the reading on airplanes almost exclusively, and one day when I had to fly to Helsinki, I had no chapters left to read. That ended quite badly, with a WWII bomb leading to Frankfurt Airport being closed for a while, the aircraft I was supposed to fly in being identified as defective, and, of course, bad weather causing massive delays. While that was coincidence, of course, the rumor was out that I couldn't fly without a chapter from Michael.

Now that I am long done with reviewing, I have survived many flights without chapters to read over, but *Absolute OpenBSD* made long hours up in the sky much more enjoyable for me. Michael has a writing style that I really like—snatchy, funny, and still precise and to the point. Don't skip the footnotes!

In the end, I contributed only a tiny share to this book, but I enjoyed doing so a lot. I hope you enjoy reading it as much.

Henning Brauer
OpenBSD PF developer

# ACKNOWLEDGMENTS

The world has changed in the 10 years since the first edition of *Absolute OpenBSD* came out. I used to have hair, for one thing. In 2003 OpenBSD was somewhere on the edge of open source software, known mainly for an uncompromising, fanatical view of computing security and correctness. So uncompromising that other open source projects didn't want to work with it. But a funny thing happened in the following decade: The uncompromising fanatics turned out to be right. More than once I've heard "That's fixed in the latest Linux, and in OpenBSD 3.2." OpenBSD code trickled into other BSDs, Linux, and even some commercial operating systems. Apple and BlackBerry products include the OpenBSD packet filter. Lots of BSDs support the OpenBSD wireless utilities. And everyone runs OpenSSH. So, the first people I have to thank are those who wrote all this code. It's one thing to give a gift to the world, but when everybody and their pet orangutan has posted their code online, it's another thing when your code is picked up and used dang near everywhere. Well done, guys.

I specifically want to thank Peter Hansteen and Henning Brauer. Henning read the early drafts of this book and pointed out innumerable errors and opportunities for improvement. Peter, the official tech reviewer, had the job of double-checking all the facts and finding what I'd broken when trying to incorporate Henning's suggestions. While all the OpenBSD folks were friendly and open, these two sank deep into this book and didn't come up for air until it was done. When you see either of them, please buy them a beer. They've earned it.

As always, No Starch Press does a great job producing books. Their indefatigable quest for making everything both correct and pleasing has made this book more than I thought it would be—as usual. Someday I'll consider that excellence routine and, as a result, will be much less impressed when they retain their high standards. But the day their quest for perfection bores me has not yet come.

iXsystems provided me with hardware for testing this book. The way to really test an operating system is to push it to its limits. The only way to really find those limits is to exceed them. Preferably as greatly as possible. I used and abused that poor server, folded and spindled and mutilated it, and the blasted thing still ran. (The machine did finally fail, mind you, when I ripped out the hard drives as it was running. That's probably considered cheating, but I had to test the software RAID chapter.) I greatly appreciate iX's support. When iXsystems says their hardware runs BSD, they mean that they've actually used it. In production. For real work. Not just my puny little website and blog.

My blog readers and Twitter followers made researching this book much easier than it could have been. When I throw out a question, someone knows the answer. I try to reward them by throwing out facts, tutorials, observations, and random ranting as well as questions. Check *http://www.michaelwlucas.com/* for links to these and more.

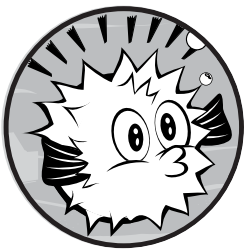
I considered dropping the haiku from this edition, but overwhelming reader feedback demanded that I not only retain them, but include more and better ones. As an experiment, I solicited haiku on my blog and used some in this book. Ludovic Simpson wrote the haiku for Chapter 7; Justin Sherrill, Chapter 12; and the relentless Josh Grosse, Chapters 1, 3, and 16. As a reward, each of them gets their name on the page you're reading right now. Here's your moment of glory, guys. Enjoy it before it—whoops, it's gone. Sorry.

I wanted this book to come out in 2010. Life happened. It happens. Then life kept happening, apparently with malice aforethought, for four years. My fans waited. The publisher waited. The OpenBSD folks waited. And my long-suffering wife has waited—specifically, for me to quit grumbling that I had to take time away from the crisis du jour and finish this dang book.

Thanks to everyone for your patience and support. There's a certain rightness in having this second edition come out almost exactly ten years to the day after the first edition. But six years would have done nicely, too.

Thanks, everyone.

# INTRODUCTION



I asked a psychiatric nurse practitioner about paranoia, and was told that "paranoiais the feeling that people are after you." A medical dictionary would give you a slightly different definition, but this one is actually terribly useful for any system administrator. It's not that everyone on the Internet is trying to attack you, but there's always *someone* who wants to break into your system. Even if you think you have nothing of value, someone wants to own your computer. And you won't realize the value of what you have until someone else has it. That's just human nature.

If you're not paranoid on the Internet, you're in trouble.

That's where OpenBSD comes in.

This book is an introduction to the OpenBSD operating system. OpenBSD is a member of the BSD family of operating systems. It is widely regarded as the most secure operating system available anywhere, under any licensing terms. It's widely used by Internet service providers, embedded systems

manufacturers, and anyone who needs security and stability. If you're an experienced Unix system administrator who wants to add OpenBSD to your repertoire, this book is for you.

When you finish this book, you should be comfortable working with OpenBSD. You will understand how to configure, troubleshoot, and upgrade computers running OpenBSD and have a basic understanding of OpenBSD's software, security, and network management features.

## What Is Security?

We bandy the word *security* around a whole lot, so it's worth taking a moment to talk about security itself. We all have a vague idea of what it means. "Security" means your stuff is safe, and other folks can't get it. That's fine, as far as it goes, but it doesn't go far enough. In information technology, security has three parts:

**Confidentiality**
: This means that secret data should remain secret. Your private information must not get into the public eye. That Eastern European kiddie porn syndicate should not get your credit card number.

**Integrity**
: This means that data on the system should not be changed without authorization. Your records should remain intact. That intruder should not change the shipping address on an order, making your staff ship a crate of really expensive stuff to an abandoned warehouse in Detroit.

**Availability**
: This means that the system keeps running. If your business depends on your website, losing the website means losing business. Someone who can take your website down can starve your company. And all kinds of people are willing to shut you down, either to compete or just for laughs.

Having been a system administrator for longer than some of you have been alive, I have a less formal idea of security. Security means eliminating bad days caused by computer problems. Spending a day getting a piece of software to compile is not a bad day. Is it an annoying day? Sure, but it's not *bad*. A day when I need to get intruders out of my systems is bad. A day when I have a meeting due to computer intrusions is bad. A day when I realize that I cannot trust any computer on the network, and I must reinstall every blasted piece of gear I own, is really bad.[1]

While OpenBSD cannot change the fact that some of my servers are old enough to leave elementary school, it can fix the software aspects of security.

1. I still have bad days due to people, mind you, but I largely solve them by other means. Don't ask about the mounds of dirt in my backyard.

## What Is BSD?

In the 1970s, AT&T needed a lot of specialized, custom-written computer software to run its business. The company was forbidden to compete in the computer industry, so it could not sell this software. Instead, AT&T licensed its software and the related source code to universities for nominal sums. Universities saved money by using this software instead of commercial equivalents with pricey licenses, and university students got access to this nifty technology and could learn how everything worked. In return, AT&T got exposure, some pocket change, and a generation of computer scientists who had cut their teeth on AT&T technology. Everyone got something out of the deal.

The best-known software distributed under this plan was UNIX.

Compared with modern operating systems, the original UNIX had a lot of problems. Thousands of students had access to its source code, however, and hundreds of teachers needed interesting projects for their students. If a program behaved oddly, or the operating system itself had a problem, the people who lived with the system had the tools and the motivation to fix it. Their efforts quickly improved UNIX and created many features we now take for granted. Students added the ability to control running processes, also known as *job control*. The UNIX S51K filesystem made system administrators wail and gnash their teeth, so they replaced it with the Fast File System (FFS), which introduced a whole host of features that have crept into every modern filesystem. Over the years, many small, useful programs were added to UNIX, and entire subsystems were replaced.

The Computer Science Research Group (CSRG) at the University of California, Berkeley, acted as a central clearinghouse for UNIX code improvements from 1979 to 1994. The group collected changes from other universities, evaluated them, packaged them, and distributed the compilation for free to anyone with a valid AT&T UNIX license. The CSRG also contracted with the Defense Advanced Research Projects Agency (DARPA) to implement various features in UNIX, such as TCP/IP. The resulting software collection came to be known as the Berkeley Software Distribution, or BSD. Users took the CSRG's software, improved it further, and fed their improvements back into the CSRG. Today, we consider this a fairly standard way to run an open source project, but in 1979, it was revolutionary.

Fifteen years of work is a lifetime in software development. For comparison, Microsoft went from Windows 95 to Windows 7 in 15 years. The CSRG members collected so many enhancements and improvements to UNIX that they replaced almost all of the original UNIX with code created by the CSRG and its contributors. You had to look hard to find any original AT&T code.

Eventually, the CSRG's funding ebbed, and it became clear that the BSD project would end. After some political wrangling within the University of California, in 1992, the BSD code was released to the general public under what became known as the *BSD license*.

### The BSD License

BSD code is available for anyone to use under what is probably the most permissive license in the history of software development. The license can be summarized as follows:

- Don't claim you wrote this.
- Don't blame us if it breaks.
- Don't use our name to promote your product.

Taken as a whole, this means that you can do almost anything you want with BSD code. (The original BSD license did require that users be notified if a software product included BSD-licensed code, but that requirement was later dropped.) You don't even need to share any changes with the original authors! People could take BSD and include it in proprietary, open source, or free products.

Instead of a restrictive *copyright*, or the more permissive but still restricted *copyleft*, the BSD license is sometimes referred to as *copycenter*, as in "take this down to the copy center and run off a few for yourself." Not surprisingly, companies such as Sun Microsystems jumped right on BSD. It was free, it worked, and plenty of new graduates had experience with the technology. One company, BSDi, was formed specifically to take advantage of BSD Unix.

### AT&T vs. the World

Back in AT&T-land, UNIX development continued. AT&T took parts of the BSD Unix distribution and integrated them with official UNIX, and then relicensed the results back to the universities that provided those improvements. This worked well for everyone until the US government broke up AT&T, and the resulting companies were permitted to compete in the computer software business.

AT&T had one particularly valuable software property: a high-end operating system that had been extensively debugged by thousands of people and had powerful features, such as a variety of small but mighty commands, a modern filesystem, job control, and TCP/IP. AT&T started a subsidiary, Unix Systems Laboratories (USL), which happily started selling UNIX to enterprises and charging very high fees for it, all the while maintaining the university relationship that had given it such an advanced operating system in the first place.

The University of California, Berkeley's public release of the BSD code met with great displeasure from USL. Almost immediately, USL sued the university and the software companies that had taken advantage of BSD. The University of California claimed that the CSRG had compiled BSD from thousands of third-party contributors unrelated to AT&T, and that it was the CSRG's intellectual property to dispose of as it saw fit. Oddly enough, the lawsuit promoted BSD to thousands of people who never would have heard of it otherwise, spawning open source BSD variants such as 386BSD, FreeBSD, and NetBSD.

In 1994, after two years of legal wrangling, the University of California lawyers proved that the majority of AT&T UNIX was actually taken from BSD, rather than the other way around. To add insult to injury, AT&T had violated the BSD license by stripping the CSRG copyright from the files it had appropriated

Only about a half-dozen files remained as the source of contention. Bruised and broken in court, USL donated some of those files to BSD while retaining others as proprietary information. BSD 4.4-Lite was released, containing everything except the proprietary files. Due to those missing files, BSD 4.4-Lite was the only formal operating system release ever that was known to not be usable or even compilable as delivered. Everyone knew this, and bought it anyway—a historic feat that modern vendors probably wish they could replicate.

A subsequent update, BSD 4.4-Lite2, is the grandfather of OpenBSD, as well as all other BSD code in use today, such as that in FreeBSD, NetBSD, and Mac OS X.

## The Birth of OpenBSD

Theo de Raadt was a NetBSD developer. After many strong, broad, and long-running disagreements with other NetBSD team members on how the project should be run, he went out on his own and founded the OpenBSD Project, attracting like-minded developers. The OpenBSD team quickly established an identity as a security-focused group, and it is now one of the best-known BSD descendants.

The OpenBSD team developers have introduced several ideas into the open source operating system world that are now taken for granted, such as public read-only access to the CVS repository and commit logs. They've also created several pieces of software that have become industry standards across many operating systems, such as `sudo` and the ubiquitous OpenSSH.

Today, many major companies rely on OpenBSD as a reliable, secure operating system with fanatical attention to security, correctness, usability, and freedom. OpenBSD runs on many different sorts of hardware, including the standard 32-bit and 64-bit "Intel PC" (i386 and amd64), Apple's PowerPC Macintoshes (macppc), Sparc (sparc and sparc64), and obscure platforms such as the Sharp Zaurus PDA, the Lemote Yeeloong, and antediluvian VAXes. OpenBSD puts almost all of its effort into security features, security debugging, and code correctness, and has demonstrated in the process that correct code has a much lower failure rate, and hence greater security. OpenBSD strives to be the ultimate secure operating system.

The OpenBSD team continually improves the operating system. New features are added only once they meet the team's code and documentation standards. Even if new software is added before it is feature-complete, it is expected to have full documentation and correct code.

## The OpenBSD Community

OpenBSD is more than just a collection of bits. It's a community of users, developers, and contributors, with a single central dictator—er, coordinator. And this community can be a bit of a shock for anyone who doesn't know what to expect.

How can individuals scattered all over the world create, maintain, and develop an operating system, let alone build a community? Almost all discussion occurs through email and online chat. The process is slower than talking face-to-face, but it's the only cost-effective way for a large group of people in every time zone to communicate in a reasonable fashion. Email and chat also offer written records of discussions. If you want to participate in OpenBSD development, you must be comfortable with email. (There are OpenBSD-dedicated web forums, but they're outside the main community.)

The OpenBSD community has four tiers: users, contributors, committers, and the coordinator.

### *OpenBSD Users*

Many open source operating systems put a lot of effort into growing their user base, evangelizing, and bringing new people into the Unix fold. OpenBSD does not.

Most open source Unix-like operating system groups do a lot of pro-Unix advocacy. Again, OpenBSD does not.

The communities surrounding other operating systems actively encourage new users and try to make newbies feel welcome. OpenBSD specifically and deliberately does not.

The OpenBSD community is not trying to be the most popular operating system—just the best at it what it does. The developers know exactly who their target market is: themselves. If you can use their work, that's great. If not, go away until you can.

The OpenBSD community generally expects newcomers to be advanced computer users. The members have written extensive OpenBSD documentation, and expect newcomers to be willing to read it. They're not interested in coddling new Unix users and, if pressed, will say so—often bluntly and forcefully. They will not hold your hand. They will not develop new features to please users. OpenBSD exists to meet the needs of the developers, and while others are welcome to ride along, the needs of the passengers do not steer the project.

### *OpenBSD Contributors*

Contributors are OpenBSD users who have the skills necessary to add features to the operating system, fix problems, write documentation, or accurately report problems. Problems range from typographical errors in the documentation to system crashes. Almost anyone can be a contributor. In fact, the community has even accepted problem reports from me, and resolved them within hours.

Every OpenBSD feature is present because some contributor took the time to write the code for it. Contributors who submit careful, correct fixes, or who provide useful problem reports, are welcome in the OpenBSD community. And if a contributor submits enough fixes of sufficient quality, he might be offered the role of committer.

### OpenBSD Committers

Committers have write access to the main OpenBSD source code repository. They can make whatever changes they deem necessary for their OpenBSD projects, but are answerable to each other and to the project coordinator. Most committers are skilled programmers who work on OpenBSD during their own time.

While being a committer seems glamorous, the role carries a lot of responsibility. If a committer breaks the operating system or changes something so that it conflicts with OpenBSD's driving "vision," he must fix it. Committers try to avoid breaking things, and frequently make their work available on websites and mailing lists before it's integrated into the main OpenBSD source code collection, allowing interested people to preview, test, and double-check their work.

Many committers have very specific coordination roles within OpenBSD. For example, quite a few hardware architectures have a point man for issues that affect that hardware, the compiler has a maintainer, and so on. These committers have earned that position of trust in the community.

### OpenBSD Coordinator

Theo de Raadt started OpenBSD in 1995 and still coordinates the project. He is the final word on how the system should work, what is included in the system, and who gets direct access to the repository. He resolves all disputes that contributors and committers cannot resolve among themselves. Theo takes whatever actions necessary to keep the OpenBSD Project running smoothly. If something should ever happen to Theo, the project does have plans for replacing him.

Building the OpenBSD organization around a central benevolent dictator avoids a lot of the management problems other large open source projects have.

If you decide to work on OpenBSD, you must accept Theo's decisions as final. A contributor who doesn't accept the project's leader won't remain with the community for long. Theo might have a big stick, but as he is the acknowledged project leader, he doesn't need to use it nearly as often as you might think.

## OpenBSD's Strengths

What makes OpenBSD OpenBSD? Why bother with yet another Unix-like operating system when there are so many out there, several closely related to OpenBSD? What makes this operating system worth a computer, let alone worthy of protecting your company's assets?

### Portability

OpenBSD is designed to run on a wide variety of popular processors and hardware platforms, including Intel-compatible (both 32-bit and 64-bit), Alpha, Macintosh (both PowerPC and Intel systems), and almost anything from Sun. It runs on tiny devices such as the Sharp Zaurus, hefty Hewlett-Packard HP 9000 systems, certain Silicon Graphics workstations, and whatever else grabs the developers' attention. The OpenBSD team wants to support as many interesting hardware architectures as it has the hardware and skills to maintain, so more are added regularly, and chances are most computers you encounter can run OpenBSD.

That said, when a hardware platform becomes too obscure, OpenBSD stops supporting it. A few MIPS systems, 68K Macintosh hardware, and Amiga systems are examples of systems that run older versions of OpenBSD but are not supported by new releases.

### Power

As a matter of legacy, OpenBSD will run on hardware that has been obsolete for decades because the hardware was in popular use when OpenBSD started, and the developers try to maintain compatibility and performance when possible. This includes platforms such as the VAX and Alpha, which were considered powerful in the 1980s and 1990s. While someone running OpenBSD on a dual-core 64-bit system might not notice a programming change in OpenBSD that increases the amount of CPU time needed to process network packets, people running OpenBSD on VAX systems will quickly notice that same change.

Of course, some performance-impacting changes cannot be avoided. For example, systems must support IPv6 in the very near future, and I suspect that decades-old hardware will struggle to keep up. OpenBSD cannot turn back the clock, but it will leave every scrap of computing power possible for your applications. And after all, that's what's important—people use applications, not operating systems. This focus on performance means that a system running OpenBSD with a 1GB disk and a 486 CPU can still support real applications, such as a DNS or web server.

### Documentation

Many free software projects are satisfied when they release code. Some think that they go above and beyond by including a help function in the program itself, available by typing some command-line flag. Others really go wild and offer a grammatically incorrect and technically vague manual page.

The OpenBSD community expects the documentation to be both complete and accurate. The manual pages for system and library calls are extensive, even when compared to other BSDs, and include discussions on usage and security.

Documentation errors are considered serious bugs, and are treated as harshly as any other serious bug. This might sound extreme, but in its own internal audits, the OpenBSD team has found any number of instances

where programmers used a library interface exactly as recommended in the manual page, but errors in the manual page made the usage dangerous or insecure. Documentation is important.

### Free

In the spirit of the original BSD license, OpenBSD is free for use in any way, by anyone, for any purpose. You can use it with any tool you like, on any computer.

Most of today's free software is licensed under terms that require software distributors to return any changes to the project's owner, but OpenBSD doesn't even carry that requirement. You can use OpenBSD in your proprietary system, ship that system everywhere in the world, and not pay the developers a dime.

OpenBSD is perhaps the freest of the free operating systems. Like every other free Unix-like operating system, the source code inherited from BSD originally contained a wide variety of programs that shipped under conditional licenses. Some were free for noncommercial use. Some were free if you changed the name once you changed the code. Others had a variety of obscure licensing terms, such as indemnifying a third party against lawsuits. These programs have either been relicensed (with the permission of the original author) or ripped out and replaced with free alternatives.

The word *freedom* has been given a lot of different twists by people in the programming community. Some believe that software is free if you can download it and use it. Some believe that software is only free if the end user gets the source code. The OpenBSD idea of freedom is that its code can be used for any purpose, by anyone.

Consider this: During a discussion on an OpenBSD mailing list regarding licensing terms,[2] Theo de Raadt said:

> We know what a free license should say.
> It should say
>  Copyright foo
>  I give up my rights and permit others to:
>  distribute
>  sell
>  give
>  modify
>  use
>  I retain the right to be known as the author/owner
> When it says something else, ask this:
>  - is it 100% guaranteed fluff which cannot ever affect anyone?
>  - is it giving away even more rights (the author right)?
> If not, then it must be giving someone more rights, or by the
> same token—taking more rights away from someone else!
> Then it is _less_ free than our requirements state!

2. This is from October 24, 2002, on the openbsd-misc mailing list. It's more than a decade old, but still pretty much says it all.

The OpenBSD team works hard to ensure that every line of code it supports is licensed in this manner.

**NOTE** *The source code tree does include code under different licenses, such as the GNU C compiler* `gcc`*, binutils, and so on. OpenBSD* runs *fine without them—you just can't* compile *OpenBSD without them.*

This is pretty straightforward. OpenBSD is a gift. You're free to use it or not. As with any gift, you can do whatever you want with it. But you're not free to bug the developers for features or support.

### Correctness

Every skilled programmer knows that programs written correctly are more reliable, predictable, and secure. However, many free software producers are satisfied if their code compiles and simply seems to work, and quite a few commercial software companies don't give their programmers time to write their code correctly.

OpenBSD developers strive to implement solutions correctly. They make it a strict rule to write programs in a reliable and secure manner, following best current programming practices. And exposing the code to "weird" environments such as ancient VAXes is part of the discipline; OpenBSD developers insist that some subtle bugs (and a few less subtle ones) have been pinpointed only during testing on one of OpenBSD's less mainstream architectures. Fixing those bugs benefits all users, of course.

OpenBSD implementations follow UNIX standards, such as the Portable Operating System Interface (POSIX) and the American National Standards Institute (ANSI), but they are less concerned about extensions to these standards created by third parties. For example, many Linux extensions do not appear in OpenBSD. When those extensions are added to standards, the OpenBSD team will add them.

OpenBSD code has been repeatedly audited for correctness through a lot of hard work. Anyone who tries to introduce incorrect code will be turned away—generally politely, and often with constructive criticism, but turned away nonetheless. And that brings us to OpenBSD's most well-known claim to fame.

### Security

OpenBSD strives to be the most secure operating system in the world. While it can reasonably make that claim today, maintaining that position requires constant effort. Intruders constantly try new ways to penetrate computers, which means that today's feature might be tomorrow's security problem. As OpenBSD developers learn of new classes of programming errors and security holes, they scan the entire source tree for that type of problem and make fixes before anyone even knows how these issues *might* be exploited.

Additionally, OpenBSD takes advantage of any security features offered by hardware. For example, AMD's 64-bit Intel-compatible CPUs can mark a page of memory as either executable or writable, but not both. (Intel later copied this feature.) This alleviates many buffer overflow attacks, but the operating system must use this facility. OpenBSD supported this feature in 2003, shortly after the hardware was released. In fact, OpenBSD generally supports all hardware security features offered on a platform.

The history of computing shows that users cannot be expected to patch or maintain their own systems. Systems must be secure against existing and future attacks out of the box. OpenBSD's goal is to eliminate problems before they exist.

## OpenBSD and Your Security

Even though OpenBSD is tightly secured, intruders still break into OpenBSD systems. This might seem contradictory, but in truth, it means that the person running the computer didn't understand computer security.

OpenBSD has many integrated security features, but you cannot assume that these features secure everything running on the system. That's just not possible. No operating system can defend itself against operator error. An operating system can protect itself from software problems to a limited extent, but ultimately, the responsibility for security is the administrator's.

Consider a web server—even OpenBSD's integrated Apache server—running on OpenBSD. OpenBSD provides the web server with a stable, reliable platform, and will provide services as the web server requests, within the limits assigned by the system administrator. If the system administrator has configured the web server correctly, a web server failure will not endanger the operating system. If the system administrator configures the web server to run with unlimited privileges, the web server can inflict almost unrestricted damage on the underlying system.

Or consider a less extreme case. The web server might be configured correctly, but suppose you install insecure forum software. An intruder can break into the forum and edit its data—maybe grab the username and password the forum software uses to access the local database. If that account information matches a system-level username and password, the intruder might be able to leverage them to gain access to the system. Or perhaps he can use that username and password to get administrator-level access to the database and penetrate other applications. What if those applications have elevated privileges?

Only careful, consistent, thoughtful work by a system administrator can prevent intrusions. Throughout this book, we'll discuss some basic security precautions you should take when installing and running software. We'll also discuss the advanced security features OpenBSD offers in order to protect itself.

## OpenBSD's Uses

Where does OpenBSD fit into your computing strategy? That ultimately depends on your strategy and your needs. OpenBSD can be used anywhere you need a solid, reliable, and secure system. I recommend OpenBSD for any of three different roles: a desktop, a server, or network management.

### *Desktop*

If you need a powerful desktop system with all the features you would expect from a complete Unix-like workstation, OpenBSD will do nicely. Graphic interfaces, office suites, web browsers, and other desktop software are available in the ports collection, OpenBSD also supports a variety of development tools, application environments, network servers, and other features that programmers and web developers need. If you're a network administrator, you'll find that OpenBSD supports packet sniffers, traffic analyzers, and all the other programs you rely on.

### *Server*

If you're serving web pages, handling email, providing Lightweight Directory Access Protocol (LDAP) or database services, or offering any other sort of network service to clients, OpenBSD can help you. It's a cheap and reliable platform. Once it's set up, it just works. And, of course, it's secure, which you cannot underestimate on the Internet.

### *Network Management*

OpenBSD makes an excellent firewall, bridge, or traffic shaper. You can use it to support intrusion detection software, web proxies, and traffic monitors. The integrated packet-filtering firewall and supporting software provides state-of-the-art network connection management and control, and can strip out many dangerous types of traffic before it reaches your servers. And its load-balancer features are competitive, with many commercial offerings that cost thousands of dollars more.

## About This Book

This book is written for experienced Unix users or system administrators who want to add OpenBSD to their repertoire. I assume you're familiar with basic commands, such as `tail(1)`, `chmod(1)`, `ping(8)`, and so on, and that you know why each command in this list includes a number in parentheses after the name. We'll discuss many programs that you might already be familiar with, but that might be slightly different in OpenBSD.

For maximum benefit, you should install OpenBSD on a dedicated machine. OpenBSD can coexist with other operating systems or run in a virtual machine, but if you're going to use OpenBSD in a production environment, you should run it on its own.

Many people believe that OpenBSD is not the easiest Unix-like operating system, or the easiest version of BSD, or even the easiest open source BSD. OpenBSD doesn't have handy wizards that walk you through each stage of the configuration process, although it does has a few menu-driven front ends. Once you're familiar with how the system works, though, such wizards would only get in the way.

To truly understand OpenBSD, you must be willing to learn, experiment, and spend time accumulating understanding. Much of this knowledge can be directly applied to other versions of BSD, other Unix-like operating systems, and even completely foreign operating systems, such as Microsoft's Windows.

## Contents Overview

While this book is designed to be read from front to back, here's a brief description of each chapter, in case you would rather skip around randomly.

**Chapter 1: Getting Additional Support** Discusses the OpenBSD documentation available both in the installed system and on the Web. You need to understand what you're getting into before installing OpenBSD.

**Chapter 2: Installation Preparations** Discusses installation on a standard amd64 (also known as the 64-bit Intel-compatible) system. Making some decisions before you install OpenBSD will ensure that you don't need to reinstall it later.

**Chapter 3: Installation Walk-Through** Carries you through every step of a real OpenBSD installation. The OpenBSD installer assumes a certain level of knowledge about computer hardware and OpenBSD that you might not yet possess. This walk-through will guide you through the rough spots.

**Chapter 4: Post-Install Setup** Discusses the basic steps you should take after installing OpenBSD to make your system secure, stable, and usable.

**Chapter 5: The Boot Process** Covers system startup. Different situations require different startup methods, and we'll cover them all. We'll also discuss how OpenBSD starts its component software.

**Chapter 6: User Management** Discusses how to add, remove, and restrict OpenBSD user accounts.

**Chapter 7: Root, and How to Avoid It** Discusses controlling user privileges and permissions. OpenBSD includes powerful tools such as classes and limits, as well as the privilege management tool `sudo(8)`.

**Chapter 8: Disks and Filesystems** Covers disk management with the standard OpenBSD filesystems.

**Chapter 9: More Filesystems** Covers advanced filesystem topics such as the Network File System (NFS), working with disk images, software RAID, and encrypted disks.

**Chapter 10: Securing Your System** Considers how to maintain security using tools such as file flags, securelevels, OpenBSD security announcements, and some basic cryptographic tools.

**Chapter 11: Overview of TCP/IP** Reviews the basics of TCP/IP versions 4 and 6, and covers some of OpenBSD's tools for examining and troubleshooting the network.

**Chapter 12: Connecting to the Network** Takes you through configuring OpenBSD's network stack for Ethernet, trunks, and virtual local area networks (VLANs).

**Chapter 13: Software Management** Describes OpenBSD's add-on software tools. You'll learn how to install precompiled software, compile your own software, and verify and remove software.

**Chapter 14: Everything /etc** Describes each major file in */etc* that isn't covered elsewhere, and discusses how you might want to use those files.

**Chapter 15: System Maintenance** Covers the various ways OpenBSD maintains itself and how you can make those processes fit your environment and workflow.

**Chapter 16: Network Servers** Covers configuring software integrated with OpenBSD. You'll learn about the system logger and log file management, the DHCP server, the web server, and more.

**Chapter 17: Desktop OpenBSD** Covers software useful to OpenBSD as a desktop, such as the window manager `cwm(1)` and Xenocara. This chapter includes coverage of important software that makes using OpenBSD with a desktop easier, such as SSH keys and `tmux`.

**Chapter 18: Kernel Configuration** Discusses the various tools available to configure a standard kernel. Unlike many other free Unix-like operating systems, OpenBSD does not expect or require the system administrator to compile a kernel. You can tune the standard kernels without recompiling.

**Chapter 19: Building Custom Kernels** Discusses how to recompile a kernel in those rare instances when you must.

**Chapter 20: Upgrading** Covers how to upgrade OpenBSD, either from a snapshot or from source.

**Chapter 21: Packet Filtering** Documents OpenBSD's integrated packet-filtering engine, PF. It includes discussions of real-world situations and how to handle them.

**Chapter 22: Advanced PF** Introduces things that the packet filter can do beyond just filtering packets.

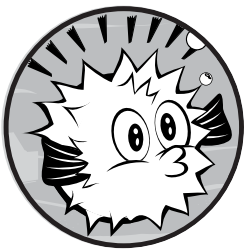
**Chapter 23: Customizing OpenBSD** Includes tidbits that didn't fit anywhere else but are not large enough topics to merit their own chapters. This includes diskless OpenBSD, building bootable USB installation media, and making custom OpenBSD installation sets.

This book won't cover everything OpenBSD can do, but it will get your feet firmly under the table. To learn the rest, you'll need to access OpenBSD's information resources, which is the subject of the first chapter.

# 1

# GETTING ADDITIONAL HELP

*Mailing lists are rough;*
*homework is mandatory.*
*Love it or leave it.*



You've bought this book, so you now possess all the information you will ever need about OpenBSD. You hold in your hands the ultimate repository of all OpenBSD wisdom and acumen, and once you complete it, you will be lord and master of all that OpenBSD offers. Right?

Sorry, no. No one book can possibly contain everything there is to know about OpenBSD. UNIX is pushing 40 years old, and BSD operating systems have been around for more than 30 years. OpenBSD itself is over 15 years old, and is built on decades of tradition, knowledge, and community development. You won't master it with any single book. You might master it with a room full of books and a few years of study, if you stop wasting time on trivialities like having a family and avoiding scurvy.

The OpenBSD community maintains a wide variety of information sources. Some, such as the manual, are integrated with the OpenBSD operating system. The OpenBSD team maintains additional resources, such as the main OpenBSD website and the official OpenBSD mailing lists. Users and devotees maintain additional websites, mailing lists, and

documentation. The flood of information can overwhelm experienced users and intimidate new users so badly that they don't even try to sort through it. That's why this chapter will take your hand and lead you through some of the other resources available.[1]

## OpenBSD's Support Model

If you've worked with only commercial UNIX, you might find OpenBSD's support structure a little surprising. There is no toll-free number to call and no vendor to guide you. No, you may not speak to the manager of the support team. There isn't one. The management is you.

Many commercial operating systems conceal their inner workings, and the only access you get is through the programs, application programming interfaces (APIs), and application binary interfaces (ABIs) they provide. If you want to learn more about how your operating system works, you can't (unless you reverse-engineer it). When something breaks, you either live with it or pay the vendor to solve the problem.

OpenBSD, on the other hand, is completely open. You can view the source code, the compiler, and the resulting binaries. You have the official manual and a whole bunch of ancillary documentation. You have access to the developers' logs—logs that describe every change ever made to every part of the system—through the same tools the developers use. You can back out of changes, understand the motivation behind the changes, and even contact the people who have most recently worked on a component you're interested in and ask them what they were thinking. You can add your own features. In other words, you have the opportunity to understand OpenBSD in exquisite, excruciating detail.

If you want to learn about OpenBSD, you must jump from eating what you're served to reading the cookbook and creating your own meals. If you're willing to learn using the information provided, you will develop skills, and you'll probably even make some friends in the OpenBSD community along the way. If you want to use OpenBSD and don't have the time or inclination to learn, invest in a commercial support contract. Many companies and consultants around the world support OpenBSD. The OpenBSD website lists dozens.

If you don't want to learn and don't want to buy a support contract, then OpenBSD is simply not for you.

## The Code Is Fine. What's Wrong with You?

Systems administrators rarely have trouble with OpenBSD itself; the software runs, and it runs well. Most problems arise from their own understanding, or lack thereof.

When a program behaves unexpectedly, the problem is usually a gap in your expectations or understanding, and the OpenBSD community expects

1. Yes, the first chapter in this book is about getting help outside the book. I am aware of the irony; you don't need to tell me.

that you will work to improve your own knowledge so that you can make the system meet your needs. Other people make OpenBSD work correctly, and you can, too.

That said, you may still find that a problem is quite real, but you can't be certain that it was caused by OpenBSD itself until you understand correct behavior—not just how you think the system works, but how it really does work. The problem could be an OpenBSD bug, bad hardware, or an errant third-party tool. To correctly identify bugs, you must learn how the system should behave and why.

For example, before writing the first edition of this book. I had never used an OpenBSD machine to display a serial console. All of my Unix-like boxes had connections to a rusty old terminal server. Most people don't have that many serial consoles, and they want to use a null modem cable between two OpenBSD machines and have each serve as the terminal for the others' console. (We'll cover serial consoles in Chapter 5.) From reading the manual page (discussed in the next section), this common configuration seemed simple enough: Attach the cables, configure one machine to dump its console to the serial port, become root on the display machine, and enter `tip tty00`. The other machine's console should have appeared in the terminal window, but that didn't happen.

The next question is, "What's wrong?" It might have been an OpenBSD bug, a hardware failure, or a gap in my comprehension. Swapping systems around demonstrated that the command worked on other OpenBSD machines, just not my particular test box. Further tests with a serial mouse and modem showed that the serial port on the test machine was bad.

Had the serial port been in working order, I might have actually found an OpenBSD bug, but probably not.

## Sources of Information

OpenBSD provides information through three primary channels: manual (man) pages, websites, and mailing lists. To understand why your system behaves in a particular way in your environment, you might need to check all three.

### *Man Pages*

Man pages are the original format for presenting documentation on Unix-like systems. While man pages have a reputation for being obtuse, difficult to read, or incomplete, the OpenBSD team expects its man pages to be readable, correct, and complete.

When man pages were first created, the average system administrator was a C programmer. As a result, man pages were written by programmers for programmers. The OpenBSD developers are programmers and consider man pages the final word in OpenBSD documentation. Even documentation errors are considered serious bugs and are dealt with as quickly as possible. Man pages should be your first line of attack in learning how OpenBSD works.

That said, a man page is *not* a tutorial. The manual explains how things work, not what to type to achieve particular effects. You must be able to assemble the knowledge offered by the man page into the tool that you need. If you want tutorials, read articles on third-party websites, the FAQ, and this book. If you find a tutorial that tells you how to do exactly what you want, read the relevant man pages along with the tutorial. Just remember that anyone can write a tutorial, and there's no guarantee of any particular tutorial's effectiveness or security.

### Manual Sections

The OpenBSD manual has nine sections, and each man page appears in only one section. These sections are sometimes called *volumes*, a name from the days when the manual was small enough to print and distribute. Each section covers a single topic. The sections are as follows:

1: General commands
2: System calls and error numbers
3: C libraries
3p: Perl libraries
4: Device drivers
5: File formats
6: Games
7: Miscellaneous
8: System maintenance and management commands
9: Kernel internals

Man pages often appear with the section number in parentheses after the command, such as `ping(8)` or `ed(1)`. This gives you the name of the command (`ping`) and the section where the command is documented (8, on system maintenance). Almost every part of OpenBSD has a man page.

### Viewing Man Pages

View man pages with `man(1)`. If you know the section number, enter it before the program name, but the section number isn't mandatory. For example, to see the man page for the standard network utility `ping(8)`, enter this:

```
$ man ping
```

You'll get something like this in response.

```
PING(8)                 OpenBSD System Manager's Manual                 PING(8)

NAME
     ping - send ICMP ECHO_REQUEST packets to network hosts
```

```
SYNOPSIS
     ping [-DdEefLnqRrv] [-c count] [-I ifaddr] [-i wait] [-l preload]
          [-p pattern] [-s packetsize] [-T tos] [-t ttl] [-V rtable]
          [-w maxwait] host

DESCRIPTION
     ping uses the ICMP protocol's mandatory ECHO_REQUEST datagram to elicit
     an ICMP ECHO_REPLY from a host or gateway. ECHO_REQUEST datagrams
     (``pings'') have an IP and ICMP header, followed by a "struct timeval"
     and then an arbitrary number of "pad" bytes used to fill out the
     packet. The options are as follows:

     -c count
             Stop sending after count ECHO_REQUEST packets have been sent. If
             count is 0, send an unlimited number of packets.

     -D      Set the Don't Fragment bit.
...
```

You can learn more than you ever wanted to know about the lowly troubleshooting tool `ping` just by reading this document. If you need more information, look at the other man pages referenced by `ping(8)`. Read enough pages, and you'll develop an in-depth understanding of OpenBSD.

Once you're in a man page, pressing the spacebar or PGDN takes you forward one full screen. If you don't want to go that far, press ENTER or the down arrow to scroll down one line. Typing **B** or pressing PGUP takes you back one screen. To search within a man page, type **/** followed by the word you're searching for, and then press ENTER. You'll jump to the first appearance of the search term. Subsequently, typing **N** takes you to the next occurrence of the word.

**NOTE** *The man page navigation discussed here assumes that you're using the default BSD pager, `more(1)`. If you're using a different pager, use that pager's syntax. If you know enough about Unix-like systems that you've already set your preferred default pager, you can probably skip this part of the book.*

### Finding Man Pages

New users often say that they would be happy to read the man pages, if they could find the right ones. You can perform basic keyword searches on the manual with `apropos(1)` and `whatis(1)`. The command `apropos` searches for any man page name or description that includes the word you specify. The command `whatis` does the same search, but matches only whole words. For example, if you're interested in the vi text editor, you might try the following:

```
$ apropos vi
...
vmware (4) - VMware SVGA video driver
```

```
voodoo (4) - Voodoo video driver
wsudl (4) - video driver for DisplayLink USB display devices
xcmsdb (1) - Device Color Characterization utility for X Color Management
System
...
```

On my system, this generates 686 entries, most of which have nothing to do with `vi(1)`. The random selection of entries shown here includes device drivers and user utilities, but no text editors. If you examine them closely, you'll see that the letters *vi* appear in each of them, encapsulated within words like ***vi****deo* or *de****vi****ce*. Depending on what you're looking for, `apropos` can offer you far too much information.

Try a similar search with `whatis`:

```
$ whatis vi
ex, vi, view (1) - text editors
```

Matching only whole words can be more useful. Experiment with `apropos` and `whatis` until you're comfortable with them, and you should be able to find just about any topic you like.

### Overlapping Man Page Names

Some man pages have a name in common with a man page in another section. For example, suppose someone mentions `sysctl` and you want to learn about it, so you search the man pages.

```
$ whatis sysctl
sysctl (3) - get or set system information
sysctl (8) - get or set kernel state
sysctl.conf (5) - sysctl variables to set at system startup
```

We have a *sysctl.conf* file and two different man pages called `sysctl`. Manual section 3 is for C libraries. If you're just learning about `sysctl`, you might find this man page intimidating.

By default, `man` displays the first matching page it finds. It searches commands first, then games, then programming libraries, then add-on programs such as Perl. You can change this search order in */etc/man.conf* (see Chapter 14).

In this situation, manual section 3 is before manual section 8. Without specifying a section number, you'll read about the programming interface. To see the man page for the system administrator command `sysctl`, you must run `man 8 sysctl`.

### Man Page Contents

Manual authors try to arrange their content meaningfully, although meaningful varies depending on what it documents. A man page for a common

user command will probably be much easier to understand than a man page for a kernel-programming interface. Even so, most man pages are divided into sections. Some of the common sections include the following:

- NAME tells you the names of a program or utility. Some programs have multiple names; for example, the `vi(1)` text editor is also available as `view(1)` or `ex(1)`. The man page lists all of these names.
- SYNOPSIS lists the possible command-line options and their arguments, or gives examples for how programmers can call a library or interface. Once you've read the man page and used the command a few times, the synopsis might be enough to remind you of what you need.
- DESCRIPTION contains a brief synopsis of the program or feature. You'll also find detailed discussions of the command-line options.
- BUGS describes known failure conditions and weird behavior, and generally discusses when a feature doesn't work as you might expect. Always look at the BUGS section; it can save you a lot of time. I've frequently had a problem with a command only to find that the behavior, and sometimes a work-around, is listed here. Honesty is a wonderful thing in computing products.
- SEE ALSO is traditionally the last section in a man page. OpenBSD is an interrelated whole, and every command has ties to other commands. In an ideal world, you would read every man page and be able to hold an integrated image of the system in your head. Because most of us can't do this, this section directs you to related man pages.

#### Man Pages on the Web

The man pages are also available on *http://www.OpenBSD.org/* and its various online mirrors. One of the interesting things about the web-based man pages is that you can look at them for both previous releases and for other architectures. Do you want to know if there's a difference between the `sysctl` command for i386 and Loongson hardware? The web versions will let you compare two different man pages. (You can also do this with the integrated manual, but the web version makes it easier.)

### *The OpenBSD Website*

The OpenBSD website (*http://www.OpenBSD.org/*) contains a lot of information—from administration, installation, and management to where to find hardware. The front page links you to a general discussion about OpenBSD's goals and support, where you can get OpenBSD, available resources, and ways you can support OpenBSD. Project members keep the website updated. If you have an OpenBSD problem or question, check this website first.

### Mirrors

Many people across the world mirror the OpenBSD website. The main website is quite heavily accessed, and mirrors will often respond more quickly. You'll see links at the bottom of the main website. I recommend you pick and bookmark an official mirror that responds quickly for you. The mirror sites are generally underused and hence faster than the official site.

### The OpenBSD FAQ

The OpenBSD FAQ is OpenBSD's repository of answers to frequently asked questions. While much of the information in the FAQ duplicates the man pages, the FAQ presents this information in a question-and-answer format that's often easier to understand.

Unlike many other FAQs, the OpenBSD FAQ includes extensive tutorials. For example, Chapter 4 of the FAQ contains the full, detailed installation process. If you're having a problem, or want to know how some major part of OpenBSD works, check the FAQ first!

### Non-Project Websites

Many people maintain websites dedicated to OpenBSD content, related to OpenBSD, or generally useful to OpenBSD users. Any time you have a problem or are trying to understand something, your search engine might lead you to articles on these sites. Read third-party documentation carefully and skeptically, however. Tutorials and articles outside the OpenBSD Project might contain erroneous information, violate OpenBSD's best practices, or work only in the author's particular environment.[2]

The only third-party website I can unconditionally recommend is *http://www.undeadly.org/*, an OpenBSD news aggregator. When a website posts worthwhile OpenBSD-related content, the *undeadly.org* maintainers link to it.

If you want a web forum to discuss OpenBSD, you might try DaemonForums (*http://www.daemonforums.org/*). DaemonForums has discussion groups for all of the major BSD variants, including OpenBSD.

## OpenBSD Mailing Lists

The OpenBSD Project primarily communicates through mailing lists. All mailing lists are accessible to the public, but some welcome new users more than others. Many hardware platforms have dedicated mailing lists, but they welcome only platform-specific discussions and specifically reject problem reports. The OpenBSD website contains a complete list of mailing lists. Here, I'll cover only the mailing lists useful to average users.

***announce@OpenBSD.org***
: This low-volume, moderated list includes only important OpenBSD news. This list receives at least one message every six months, when a new version of OpenBSD comes out.

2. Of course, this doesn't apply to anything on my blog. Everything I post is the one word of truth.

***security-announce@OpenBSD.org***
: When the OpenBSD team learns of an OpenBSD security flaw, it posts a bulletin to this list. If you are running an OpenBSD machine on the Internet, you *must* subscribe to this list. I'll say more about *security-announce* in Chapter 10.

***misc@OpenBSD.org***
: This list contains general OpenBSD discussions. While this is the "miscellaneous" list, it still has strict rules, and the community firmly enforces its etiquette. I'll cover how to usefully post to an OpenBSD mailing list in "Using Mailing Lists" on page 11.

***tech@OpenBSD.org***
: This list is for in-depth technical discussions, such as code reviews and protocol analysis. If you want to know what the OpenBSD folks are working on, read this list. It's not for support requests. As a good rule of thumb, if your email doesn't include a code diff, don't send it to this list.

***advocacy@OpenBSD.org***
: This list is for promoting OpenBSD. If you want to talk about OpenBSD's inherent awesomeness in a nontechnical manner, use this list.

You'll find other lists that might interest you, such as *www@* (discussions about the website) and *ports@* (discussing the OpenBSD ports system, which we'll cover in Chapter 13), but those lists require more OpenBSD expertise than most beginners have.

The easiest way to access the mailing lists is the web interface at *http://lists.OpenBSD.org/*. The OpenBSD team manages its mailing lists with Majordomo (*http://www.greatcircle.com/majordomo/*). If you're familiar with that package, you can access the mailing lists at *majordomo@OpenBSD.org*.

### Unofficial Mailing Lists

You can find a fairly complete list of all OpenBSD-related mailing lists hosted by third parties at *http://www.OpenBSD.org/mail.html*. This includes lists in languages other than English.

One unofficial list, run by an OpenBSD developer, is the PF mailing list, for users of the OpenBSD packet filter. This list is for all PF packet filter users, not only OpenBSD, but OpenBSD users dominate the list. If you want to learn more about PF, subscribe to this list. You can find more at *http://www.benzedrine.cx/*.

### Read-Only Mailing Lists

So *misc@OpenBSD.org* looks like the mailing list for you, and you subscribe. If you race ahead and ask all your questions, you'll immediately accomplish a couple things: You'll alienate the community, and you'll be told to shut up and go away; you certainly won't make friends. That's mainly because the mailing lists exist to be read more than posted to.

Unless you're in a truly unique situation or really on the bleeding edge of OpenBSD development, more likely than not, someone has struggled with your problem previously. That person probably got an answer, and that answer probably hasn't changed. The quickest and least intrusive way to answer your question is to find that previous message. That's where the mailing list archives come in.

Your favorite search engine has already indexed the OpenBSD mailing list. Always ask the search engine your question before going anywhere near the mailing lists. If you've looked around and found that your question is truly unique, send a message to the mailing list. But when you're first starting out, you're better off treating the OpenBSD mailing lists as read-only.

## Using OpenBSD Problem-Solving Resources

Let's pick a common question and use the OpenBSD resources to solve it, without resorting to sending mail. One of the things OpenBSD is known for is its support for cryptography in hardware. How does that work, and what does OpenBSD do to support it? Here's how I would search for information on this topic from each information source the OpenBSD Project provides.

### *Using the OpenBSD Website*

Look at *http://www.OpenBSD.org/* and you'll see a link to Crypto. This takes you to the Cryptography page, which covers OpenBSD's cryptography support. It includes algorithms and discusses how the team has integrated OpenSSL into hardware cryptographic accelerators. Read, learn, and enjoy.

### *Using Man Pages*

Let's try running `apropos cryptography`:

```
$ apropos cryptography
RSA_public_encrypt, RSA_private_decrypt (3) - RSA public key cryptography
```

This man page isn't terribly useful as a general overview, and `whatis cryptography` doesn't return anything.

Cryptography is often referred to as *crypto*. `apropos crypto` gives too many results. `whatis crypto` gives more reasonable results:

```
$ whatis crypto
crypto (3) - OpenSSL cryptographic library
crypto (4) - hardware crypto access driver
crypto (9) - API for cryptographic services in the kernel
```

This is a fairly short list, and all the entries look promising. Manual section 3 is for programmer interfaces, section 4 is for device drivers,

and section 9 is for the kernel. If you're specifically looking for hardware cryptographic accelerators, section 4 should jump out at you, but start wherever you feel most comfortable.

### Using Internet Searches

Go to your favorite search engine and search for "OpenBSD crypto hardware support." On the day I wrote this, the first result led me to the official page on the OpenBSD website. The second hit was a paper on the OpenBSD cryptographic framework. You'll find old articles, archived mailing list discussions, man pages, tutorials, and innumerable blog posts. You'll probably need to add the model number of a particular cryptographic accelerator card to reduce the results to a manageable number.

### Using Mailing Lists

If the mailing list archives, a web search, the OpenBSD FAQ, the OpenBSD website, the integrated manual, and other assorted resources do not answer your question, you can ask for help. A variety of highly knowledgeable and very skilled computing professionals read the OpenBSD mailing lists. Many of these people enjoy working with OpenBSD and want to help intelligent new users. In their minds, "intelligent" equates to "not asking a question that has been asked before."

Have another look at all the ways we gathered information on OpenBSD's cryptographic hardware accelerator support in the previous section. Information about most other topics is just as readily available. People who take the time to read and answer questions on the OpenBSD mailing lists have already spent considerable time and energy creating this content and ensuring its accuracy. Now imagine their reaction when someone asks about cryptographic accelerator support on the public mailing list. Most OpenBSD experts will assume any of the following:

- The person wants their hand held.
- The person is unwilling to read the documentation.
- The person has nothing but contempt for the OpenBSD developers.
- The person has the intelligence of a brick.

Most OpenBSD experts would conclude that the person asking the question simply isn't ready to run OpenBSD. At best, the questioner will be ignored. At worst, some experienced OpenBSD person who wrote all this documentation will take offense at his hard work being so thoroughly discounted and flame the questioner badly enough that his monitor will need three months in the Mayo Clinic burn unit.

Keep this in mind before you send an email. Have you really checked everywhere for an answer? Are there any other search terms you haven't tried? Performing a few extra searches with different keywords is much faster than composing a useful email, and there's an excellent chance you'll find the answer to your question.

If you're familiar with other free Unix-like operating systems, OpenBSD's mailing lists might give you a bit of a culture shock. OpenBSD users are advanced computer users almost by definition. If an experienced systems administrator tries to debug a piece of software, that administrator is expected to know enough to ask the responsible party. If you go to a Linux forum, you'll find people discussing server and client programs, desktop environments, and dang near any other piece of software that runs on that platform. Those forums are manned by volunteers dedicated to providing around-the-clock support and extreme efforts to help their operating system conquer the world.

The OpenBSD folks don't care if they take over the world or not. They don't really care if you use their software. If other people can get use out of it, that's great. If not, oh well. They will happily assist you with OpenBSD-specific problems, but they don't really care about your database issues or your website. If you're having trouble porting your preferred window manager to OpenBSD because of some subtle bug in OpenBSD's `libc`, the OpenBSD people would love to talk to you. If you can't configure your window manager the way you like, then you should talk to the window manager support group instead.

### Creating a Good Help Request

Before you send an email, think carefully about the problem you're trying to solve. What question should you actually be asking? Define the issue as narrowly as possible. Suppose you cannot connect to a virtual private network (VPN) server with OpenBSD's IPsec client. Is the problem that you can't actually reach the IPsec server? Does the connection work when you turn off your OpenBSD firewall, but return when you re-enable filtering? Does `isakmpd(8)` crash and leave a core file every time you try to start the VPN? Each of these is a very different problem. Including the precise problem in your email will get you a better reception.

The first paragraph of your email should state your problem briefly and succinctly. If your first paragraph doesn't contain enough to interest people, they'll probably delete the email before getting to anything relevant.

After that important first paragraph, gather any and all information related to the problem. Include this information in your email. This should include the following:

- The version of OpenBSD you are running
- Your hardware platform
- Any error output (be sure to check */var/log/messages* as well as your terminal)
- The contents of */var/run/dmesg.boot*
- A complete but narrow problem description

Give your email message an appropriate subject. A subject like "Problem with OpenBSD" will get ignored. A subject like "Reproducible isakmpd

crash on newest OpenBSD snapshot" will immediately attract attention. Many OpenBSD people decide which messages to read based entirely on the subject line. Moderately advanced email-reading programs allow the recipient to delete an entire thread of discussion based on the subject line or message headers.

### How to Be Ignored

Many senior OpenBSD users use a text-based email reader such as Mutt (although quite a few do use more graphic email readers, mind you.) Text-based email programs are very powerful programs for handling thousands of emails a day, but they show only text, and they do not display HTML messages well. If you are using a graphic mail client such as Mozilla Thunderbird or Microsoft Outlook, wrap your text at 72 columns. Sending mail in pure HTML or without readable line wrapping invites experienced recipients to discard it unread.

This might seem harsh, and it's definitely different from mailing lists run by other open source operating systems. But most email clients are not suited to handle thousands of messages in a day, scattered across dozens of mailing lists, with several parallel discussion threads each, in a manner accessible to the human mind. I receive thousands of email messages a day, and I know many OpenBSD developers get—and process—even more. We simply cannot cope without mail tools that address our problems. HTML support is not nearly as necessary as the ability to manage, present, and process a large number of messages in a sensible manner.

On a similar note, most email attachments are unnecessary (and several of the OpenBSD mailing lists will unceremoniously strip them from incoming messages). You do not need to PGP sign your email, and those business card attachments just demonstrate that you really shouldn't be running OpenBSD. If you include a signature in your email, it should be no longer than four lines. Long ASCII art signatures, even really nifty ones featuring the OpenBSD blowfish, are right out.

It's easy to let frustration turn a simple request into a rabid demand for immediate assistance. Remember to be polite; the people who receive your message might decide to help you, but they're under no obligation to do so. If you want someone to be obliged to help you, buy a support contract.

### Sending Your Email

Before sending your email, double-check your search engine. Are you *sure* this hasn't been asked before?

Send all of your information and your narrow, specific, documented question about the OpenBSD core system to *misc@OpenBSD.org*. Yes, OpenBSD has many other mailing lists, and some of them might look more appropriate for your problem, but people who post to them are almost always told to go ask on *misc@* instead. People on *misc@* might refer you to another mailing list, but it's much better to post a message to a specific list if that message starts with "So-and-so on *misc@* recommended that I ask this here."

If you have a narrow, specific, well-documented question about a piece of add-on software (or package, as discussed in Chapter 13), you can send it to *ports@OpenBSD.org* instead.

### Responding to Email

The response you receive might be a brief note with a URL, or even just the words "man such-and-such." If that's what you get, that's where you need to go. Remember that you're asking because you don't understand something, and these responses tell you where to learn the answer to your question. Don't just email back asking someone to hold your hand.

If you don't understand the reference you're given, treat that as another problem. Narrow down the source of your confusion. Man pages and tutorials are not perfect, and some parts might seem mutually exclusive or contradictory if you don't fully comprehend them.

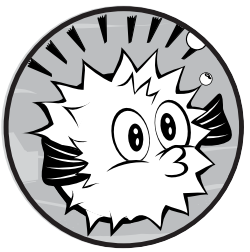
Finally, follow through. If you're asked for more information, provide it. If you don't know how to provide it, treat that as another problem. Go back to the beginning of this chapter and try to figure it out. If you develop a reputation as someone who doesn't follow up on requests for more information, you won't even get a first reply.

Now let's get ready to actually install OpenBSD.

# 2

## INSTALLATION PREPARATIONS

*I am script kiddie.*
*Windows is warm and tasty;*
*blowfish goes down hard.*



It's not enough to install OpenBSD and get the machine running; you want a *successful* installation. A successful installation means that the system is configured to perform the job you intend it to do. A developer's laptop has very different requirements than those of a dedicated firewall, which might look very different from a web server. Proper planning will make your OpenBSD installation quick, easy, and successful. We'll spend a great deal of time on installation planning. Once you understand what you're doing, the actual installation process is pretty simple. Many of the problems people have with OpenBSD come from not understanding their many choices.

The guidelines in this chapter cover most situations, but the final word on installing OpenBSD is the install document included in the release. For example, before installing OpenBSD on an i386 system, read *i386/INSTALL.i386* for your release.

## OpenBSD Hardware

OpenBSD supports a wide variety of different hardware architectures. Some platforms, such as i386 and amd64, have extensive support, and their web pages and release notes list pages and pages of supported hardware. Others, such as SGI, support only very specific hardware models.

OpenBSD's currently supported hardware platforms include i386 (standard PC), amd64 (64-bit PC-style hardware), sparc64 (Sun-style hardware), SGI (Silicon Graphics), and others. It also supports old platforms such as the VAX and tiny computers like the Zaurus. The platforms that I find interesting include the following:

**i386** the Intel-compatible computer that has been popular for the past couple of decades

**amd64** AMD's 64-bit extensions to the 32-bit i386, copied by Intel as EM64T, and sometimes called x64, x86_64, or x86-64 (this hardware can run both the 32-bit i386 and 64-bit amd64 versions of OpenBSD)

**sparc64** 64-bit Sun UltraSPARC and compatibles

**macppc** PowerPC-based Macintosh computers, from the iMac up until Apple switched to amd64 hardware

**Zaurus** Sharp Zaurus personal digital assistants (PDAs)

This chapter covers installing on the i386 and amd64 platforms. These are the standard 32-bit and 64-bit PC systems available from most vendors, and are what you're most likely to find on the secretary's desk while he is at lunch. They're architecturally close and install in exactly the same way.

Old systems can run OpenBSD quite well. I've run OpenBSD/i386 quite nicely on a 166 MHz processor with 128MB of memory. You probably have some old system lying around that's perfectly adequate for learning OpenBSD.

In this book, I assume that your equipment is PCI bus or newer. I do not cover EISA hardware, or ISA other than the onboard chips in modern hardware. If you have an EISA SCSI card or network interface card (NIC) that still works, OpenBSD probably supports it. I assume that you still have the original hardware configuration floppy and remember how to set the IRQ and interrupt to match that assumed by the OpenBSD kernel. If you don't, recycle that card and buy something built this millennium.

Note that the hardware must be in working condition. If your old Pentium machine kept crashing because its RAM is bad, using OpenBSD won't fix that problem. Also, OpenBSD will be most useful if the hardware meets certain minimum levels. I make recommendations based on my own experience, but again, the documentation gives the current and definitive requirements.

You can find a full list of supported hardware platforms at *http://www.OpenBSD.org/plat.html*. This page links to a page for each hardware platform, where you can get details on support for that hardware.

### Supported Hardware

The good news is that OpenBSD supports most hardware. The bad news is that it doesn't support everything. Generally speaking, OpenBSD supports the most common nonproprietary hardware. It might not support the very newest hardware, as the OpenBSD team doesn't get much access to hardware before it's released. Hardware that's a few months old has better support than bleeding-edge gear.

To verify if OpenBSD supports your hardware, read the release notes for your platform or just give it a try.

### Proprietary Hardware, Blobs, and Firmware

Some hardware vendors want to keep the inner workings of their equipment secret so that competitors can't copy their designs. They hide their hardware designs in two common ways: proprietary hardware and binary object device drivers.

Some vendors will not provide documentation for their hardware. The vendor expects that the user will use the vendor-provided driver, and they provide drivers only for the most widely used commodity operating systems (such as Windows) or for a specific target market (Apple). Without documentation, writing device drivers is tedious and difficult. Some hardware can be supported well without complete documentation, but much cannot. For example, OpenBSD's sparc64 platform didn't support newer Sparc processors for several years, until Sun released documentation.

Some vendors don't want to provide documentation, but do want users of open source operating systems to buy their hardware. These vendors provide drivers for their hardware in the form of binary objects, or *blobs*. This might sound reasonable at first, but the operating system must load these blobs into the kernel. The OpenBSD team has several objections to this. First, the code is not available for audit. If the blob has a security issue, or has some subtle interaction with the kernel that destabilizes the system, there's no way for the developers to resolve the problem. The blob might only be inefficient or wasteful, but it could negatively impact other kernel subsystems or even include backdoors. Lastly, OpenBSD's philosophy requires that all code be covered under a strict BSD license. In-kernel blobs are not free, and so OpenBSD will not support them.

Note that blobs are not the same as *firmware*. Firmware is a binary object a piece of hardware needs in order to run, and is loaded into the hardware itself, rather than into the operating system. You'll find firmware in almost every computer component: CPUs, motherboards, NICs, disk controllers, and so on. Firmware is never loaded into the kernel; the kernel loads the firmware into the card. The OpenBSD team considers this acceptable. The firmware lets the hardware provide its documented interface to the operating system, and if it wasn't on the disk, it would be on the hardware itself.

Generally speaking, if OpenBSD developers have a piece of hardware, documentation for that hardware, and any use for the hardware, they will probably implement support for it. If not, that hardware won't work. In most cases, unsupported proprietary or blob-driven hardware can be replaced with more effective (and less expensive) open hardware.

### Processors

Processor brand is irrelevant. OpenBSD doesn't care if it's running on a CPU from Intel, AMD, Cyrix, or any other Intel-compatible processor. OpenBSD probes the CPU on boot and uses whatever chip features it recognizes. I've run very effective multimegabit firewalls on 486-class processors, but you'll be happiest with a 1 GHz or faster processor.

OpenBSD's multiprocessor support is not as broad as some other operating systems, however. The OpenBSD kernel mostly runs with the Big Giant Lock method, so the kernel can run on only one processor at a time. (Some small chunks of the kernel are not under the Big Giant Lock.) In practical terms, this means that the OpenBSD kernel won't make effective use of more than two processors or cores.

Does this mean you shouldn't use OpenBSD on your dual-eight-core-processor server? That depends on your expected server load. User processes scale well as long as they don't go into the kernel. Most web log analysis software, for example, runs almost entirely in user space, and you run massively parallel analysis jobs that scale quite well with the number of processors. Tasks such as forwarding packets, however, pass through the kernel. The hardware you need depends entirely on your expected workload.

### Memory (RAM)

Memory is good. The more memory you have, the happier you will be. Adding RAM accelerates your system more than any other generic improvement. You should have at least 256MB of RAM, and preferably at least 512MB. If you can get a couple of gigabytes in your system, OpenBSD will take full advantage of that memory.

If you keep adding memory, you will hit a point where your system has all the memory it needs, and more memory won't further improve performance. This could be as low as 128MB for a small firewall, a couple of gigabytes for a desktop machine, or more for a large database server.

Most weird crashes and inexplicable, irreproducible problems can be traced back to bad memory, so be certain that the memory you are using is good. Memory is a common failure point in an old machine.

### Hard Drives

The smallest new hard drive you can buy today will run OpenBSD with vast amounts of space to spare. On older systems, I recommend at least 40GB of disk space—not because OpenBSD won't fit in less, but because you'll want room for additional files and software. The smaller your disk, the

more closely you'll need to monitor its use. It's easy to fill a small disk when building a desktop environment from source, and disks are cheap these days. If you're running a small firewall from a flash drive, I recommend at least 512MB.[1]

### Virtualization

Many people run new operating systems in a virtual environment while they become accustomed to those systems. Some companies even have firm policies mandating that all systems be run as virtual servers. OpenBSD runs fine in common virtual environments, and even has specific device drivers for virtualization systems such as VMware.

The hardware requirements for running OpenBSD on a virtual server are similar to the requirements for running OpenBSD on real hardware. Note that no operating system running in a virtual environment is as secure as that same operating system running on real hardware. Virtual environments do not precisely replicate real hardware. Emulated CPUs have their own new and interesting bugs, virtual NICs have unique errors, and so on. Additionally, the environment providing the virtual server is itself an operating system. An intruder can attack that underlying operating system, and once an intruder controls the virtualization server, clients running on that machine are much more vulnerable. No operating system can protect itself against its hardware. You must consider this risk when planning OpenBSD's role in your environment.

For learning about OpenBSD, however, a virtual environment is perfectly adequate. I run OpenBSD machines in VirtualBox, on ESXi, and on Linux's KVM hypervisor without difficulty.

### Multiple Operating Systems

For many years, I ran multiple operating systems on a single computer. I remember being thrilled by my new 6GB hard drive because I could run FreeBSD, OpenBSD, Windows, and Linux on one computer with plenty of space for each operating system. This was the only way to run multiple operating systems on a single desktop, but advances in virtualization technology have made this approach obsolete.

Rather than carefully dividing your desktop hard disk to run multiple operating systems and hoping that some proprietary disk-partitioning program won't munch its neighbor, I recommend running one operating system that supports a virtualization server and running your secondary operating systems as guests. OpenBSD supports running virtual guests with `qemu`.

## Getting OpenBSD

Once you have hardware, you need OpenBSD. You can get OpenBSD on CD and over the Internet.

1. Yes, that's megabytes—you know, the unit below gigabytes. Yes, megabytes can apply to disks.

### Official CDs

Why would you buy an official CD in the 21st century?

The OpenBSD project is funded largely by sales of official CDs, along with related books, clothing, and so on. You can download a disk image from the Internet and burn your own installation disk, but purchasing an official set helps improve OpenBSD. The OpenBSD team tries to make the official CD sets interesting pieces in and of themselves, and usually packages them in some sort of geek-themed art. To get an official CD, go to the OpenBSD website and look for the Getting OpenBSD link. You can also find a whole bunch of OpenBSD-related merchandise.

You can download installation images from the Internet, but they're not the same as the official CD set. The downloaded disk images don't contain any packages, lack the fancy physical packaging, and work on only one hardware architecture. You cannot download the images used for the official disks.

The main OpenBSD distribution point is in Canada, which increases delivery costs for those living on other continents. The OpenBSD website lists a variety of resellers that offer official OpenBSD CDs. Pick a vendor in your country and save on customs duties. If that option isn't available to you, you can at least pick a vendor on your same continent and save on shipping.

### Internet Downloads

The other OpenBSD installation methods require network access, either to download a complete image or to download files during the installation. Start by selecting an OpenBSD mirror site close to you. You can find a full list of mirrors at *http://www.OpenBSD.org/ftp.html*.

You can install the operating system files from an ISO image, FTP, HTTP, rsync, or even the Andrew File System (AFS) or Network File System (NFS) on some platforms. We will break the task into two parts: getting the target system to boot and getting the operating system files on the machine.

### Mirror Site Layout

All of the OpenBSD mirrors contain files and directories much like these:

***5.1, 5.2, 5.3, and 5.4*** The numbered directories contain OpenBSD releases. Most mirrors contain the last four releases. This particular server contains OpenBSD releases 5.1, 5.2, 5.3, and 5.4.

***Changelogs*** This directory contains collated OpenBSD Concurrent Version System (CVS) logs for those interested in OpenBSD's development. The casual user would probably find the web-based CVS browser more useful.

***distfiles*** This directory contains the files for building third-party software included in the OpenBSD ports collection (see Chapter 13). Not all mirror sites carry this very large directory.

***doc*** This directory contains the OpenBSD FAQ and the PF FAQ, as well as translated and obsolete versions of the documentation.

***ftplist*** This file documents the official FTP and HTTP installation mirrors. When you install via FTP or HTTP, the installer grabs this file to allow you to choose a mirror site close to you.

***OpenBGPD*, *OpenNTPD*, and *OpenSSH*** These three directories contain software that originated in the OpenBSD Project, but has been ported to other operating systems. *OpenBGPD* and *OpenNTPD* are newer projects aimed at creating OpenBSD-style Border Gateway Protocol (BGP) and Network Time Protocol (NTP) daemons. *OpenSSH* is the most widely deployed Secure Shell (SSH) client and server in the world, and is ported to all major operating systems.

***patches*** This directory contains patches for each earlier OpenBSD release. These patches address critical security and stability issues.

***snapshots*** This directory contains recent experimental OpenBSD versions, snapshots of development between releases. If you want an early preview of the next version of OpenBSD, install a snapshot. These are works in progress; the developers provide them so that users can help test new code and catch any bugs before a release. If you want to be helpful, use a snapshot, but be warned: A snapshot might work beautifully, or it might savage your hardware and subtly corrupt your data. See Chapter 20 for more information about snapshots.

***songs*** Each version of OpenBSD includes a song written for the release. The *songs* directory contains each of these soundtracks.

***timestamp*** This file contains the time this mirror was last updated.

***tools*** This directory contains add-on tools useful for the OpenBSD Project's internal workings.

### Release Directories

Look within any given release directory on an OpenBSD FTP site or on a CD, and you'll see the following:

- A directory for each architecture OpenBSD supports: *amd64*, *i386*, *sparc64*, and so on (on the CD, these directories are scattered among different disks as space permits)
- A *packages* directory containing precompiled software for this release (see Chapter 13)
- A *ports.tar.gz* file containing the compressed ports tree (see Chapter 13)
- A *src.tar.gz* file containing the operating system source code (see Chapter 20)
- A *sys.tar.gz* file containing the OpenBSD kernel source code (see Chapter 19)

- A *xenocara.tar.gz* file containing the OpenBSD version of the X Window System (see Chapter 19)
- A *tools* directory with software to help installation
- Several documents such as the release announcement (*ANNOUNCEMENT*), the basic instructions (*README*), and notes on OpenBSD's support for third-party software and different hardware

Look through your CD or the mirror site and find the directory for your hardware architecture. The architecture directories contain fairly similar files for every hardware platform.

First, find the installation instructions for your hardware. These are named *INSTALL* followed by the platform name (such as *INSTALL.i386*, *INSTALL.amd64*, and so on). Always read the installation instructions for your platform. While I've made every effort for accuracy in this book, OpenBSD continually changes, and the install document for your release is the last word on installation instructions.

### Boot Media

The OpenBSD boot media varies by hardware platform, and each hardware item has its own boot media requirements. You can't expect to boot a Zaurus or a VAX from a CD.

To easily boot the OpenBSD installer on i386 or amd64 hardware, use either a floppy disk or a CD (I usually recommend the latter). You can boot the installer from a USB disk, but the standard method requires bootstrapping from an OpenBSD machine, and nonstandard methods vary widely depending on available equipment.

If you cannot boot from a CD, use a floppy disk. OpenBSD provides one amd64 floppy image and three different i386 floppy disk images. If you're booting i386 from a floppy, I suggest downloading all floppy images.

If you cannot boot using either method, you must use the Preboot eXecution Environment (PXE) diskless booting method, as described in Chapter 23. This method works well but requires a bit more preparation.

### Choosing Install Media

The boot disk can format your hard drive, configure your network, and copy installation files to disk. Boot media don't include those installation files, however. Installation files for i386 and amd64 machines come on an ISO image and over the network via FTP or HTTP.

If you intend to install this release on multiple OpenBSD machines, you might download the CD image that includes the installation files. It's much larger than the boot-only installer ISO image, however, so downloading it will require some sort of broadband connection.

If you're doing a single OpenBSD installation, or you don't have a CD drive, I recommend an HTTP installation. If you install from a reasonably close mirror site and have sufficient bandwidth, OpenBSD installs from

HTTP quickly and reliably, and uses only about half as much bandwidth as downloading the installation ISO image. If you prefer, you can install from FTP as well.

Advanced users can install OpenBSD via the PXE method, as mentioned in the previous section and covered in detail in Chapter 23.

### Local Installation Servers

One reason CDs are so popular is that you need to download files from the Internet only once, but can reuse your downloads to install OpenBSD on many machines. But CDs are physically fragile, and not every machine has a CD drive. If you want to install OpenBSD on several machines without using up bandwidth for each installation, download all of the installation files for your architecture. If you copy these files to a local FTP or web server, you can install OpenBSD on any number of machines from these files. To install from the local FTP server, you'll need a username and password for the FTP server.

To help save the OpenBSD Project on bandwidth costs, download only the directories for the architectures you need. If you know exactly what you want to install, download just those file sets. You might have no respect for your own bandwidth, but please respect others' bandwidth.

## File Sets

The release directory for each architecture contains several compressed files with names like *comp52.tgz*, *base52.tgz*, and so on. These *file sets* contain compressed OpenBSD installation files. By choosing to install particular file sets, you can pick how much functionality your OpenBSD system will have out of the box. For example, the documentation is kept in a separate distribution set. If you have documentation elsewhere, you might choose to not install it on a particular system. Also, intruders often make use of compilers, so you might not want them on a system you want to protect. But if this is your experimental "learning OpenBSD" machine, install everything.

Each file set has a name and a version number. For example, one distribution set of OpenBSD in release 5.2 is *base52.tgz*. These are the base files of release 5.2. In the next release, this same file set will be called *base53.tgz*.

All architectures include all file sets, unless otherwise noted in the architecture's release notes. If this is your first OpenBSD installation, take a moment to decide which distribution sets you need. If at all possible, install them all on your test machine. You can always trim them down later for dedicated-purpose machines.

The following file sets are available:

***bsd*, *bsd.mp*, and *bsd.rd***

These file sets contain only OpenBSD kernels. The kernel is the heart of the operating system, containing the device drivers and basic system functions. Without a kernel, the system will not boot. The *bsd* kernel is for single-processor machines, while the *bsd.mp* kernel supports multiple

processors. The *bsd.rd* kernel contains the OpenBSD installer, basic userland utilities, and the live system kernel. You can run only one kernel at a time.

***baseXX.tgz***
This contains OpenBSD's core programs—all the things that make OpenBSD Unix-like. The contents of */bin*, */sbin*, */usr/bin*, and */usr/sbin*; the system libraries; and all the miscellaneous programs you expect to find on a minimal Unix-like system are in this file set. You must install this file set.

***etcXX.tgz***
You might guess that this file set contains the files from */etc*, but it also contains other required files and directories, such as */var/log* and the root user's home directory. You must install this file set.

***manXX.tgz***
If you need the man pages for the programs in the base and *etc* file sets, install this distribution set. The man pages for other sets are installed with their respective file sets.

***compXX.tgz***
This file set contains C and C++ compilers, the assembler, libraries, tools, manuals, and the toolchain for each. You need this file set to develop or compile software, or use the ports collection (see Chapter 13). You do not need this file set if you plan to use only precompiled software packages. At roughly 60MB, it is the largest file set for most platforms, but it's trivial compared to the size of modern hard disks. You might choose to not install it on a secure machine.

***gameXX.tgz***
This file set contains several simple games, based on games originally distributed in BSD 4.4. Some of these, such as *fortune(1)*, are considered UNIX classics, and old farts won't be happy unless they're installed. Others, such as */usr/games/wargames*, assume that you're familiar with early 1980s films. You don't need the games file set (unless you want to see what passed for "computer games" back when I was in high school).

***xbaseXX.tgz***
This contains the core of Xenocara, the OpenBSD version of the X Window System. If you want to use X, you need this. Although you might not have a console or monitor on this computer, remember that X allows programs on this server to display remotely.

Most OpenBSD packages assume that you have installed this file set. If you find that a package crashes with errors about missing X libraries, you need this file set.

***xetcXX.tgz***
: This contains the X configuration files. If you're using X for more than its libraries, you need this file set.

***xfontXX.tgz***
: This contains X fonts. If you plan to use X on this machine's console, install this file set.

***xservXX.tgz***
: This file set contains all the X video card drivers. If you plan to use X on this machine's console, install this file set.

***xshareXX.tgz***
: This contains the X documentation. If you plan to use X on this machine's console, install this file set.

## Partitioning

*Partitions* are logical subsections of a hard drive. OpenBSD can handle different partitions with their own unique privileges. You might make some partitions read-only so that files on them cannot be added, moved, or changed.

OpenBSD might refuse to run programs on a specified partition, and it knows that device nodes should appear only on certain partitions. User files should not have `setuid` or `setgid` permissions, so the operating system won't recognize those privileges on files on the user data partition. While many operating systems support these sorts of privilege controls, OpenBSD uses them by default.

The most difficult part of installing OpenBSD is partitioning. When you don't know how partitions work, choosing partitioning can be troublesome.

If you're familiar with other Unix-like operating systems (such as some distributions of Linux), you might be accustomed to using a single large root partition and putting everything on it. This is a bad idea for several reasons. OpenBSD uses partitions as a security tool. A single large partition eliminates per-partition security and privileges. With your log files safely contained on one partition, a process or user gone amok cannot fill your entire drive. While it could fill a partition, you could still create and edit files on other partitions, giving you the flexibility you need to address the problem.

Unlike many installers that have fancy menus and graphic tools, OpenBSD's installer expects you to know how to use low-level disk management tools such as `disklabel(8)`. Unlike with those operating systems, however, OpenBSD can be installed in a much wider variety of ways on a wider variety of systems, all with a single installer.

If this is your first OpenBSD installation, use the default partitioning offered by the installer. OpenBSD will provide all its standard partitions, but adjust their sizes based on the size of your disk. The discussion here is based on a standard i386 installation on a fairly small disk.

If you've previously installed OpenBSD and you're installing it on a special-purpose machine, you might want special partitioning. In that case, get a piece of paper and a pencil, and write down the size of your hard disk, each partition you need, and each partition's desired size. Your special-purpose OpenBSD machine should almost certainly have all the same partitions as a default installation, but their sizes will differ. A web server has very different disk space requirements than a desktop machine, which in turn has different requirements than those of a firewall.

If you have a large disk, leave some space unallocated. Having partitions the size you need accelerates filesystem integrity checks; `fsck(8)` doesn't spend cycles integrity-checking unused disk space. On solid-state disks, unused space gives wear-leveling algorithms more cells to play with, increasing the life span of the disk and decreasing the odds of failure. It's better to have spare disk space you never need than to need disk space you don't have.

## Standard OpenBSD Partitions

The standard OpenBSD partitions are / (root), swap space, */tmp*, */var*, */usr*, */usr/X11R6*, */usr/local*, */usr/src*, */usr/obj*, and */home*. If you create a custom layout and don't include one of these partitions, the installer will put files that go into that partition into either your root or */usr* partition, quickly filling them. If you want to create a partition after installation, you must find space on your disk for it. Unless you left unallocated space on your disk, you're better off reinstalling the whole system.

### Root Partition

The root partition holds the main OpenBSD configuration files and the most essential software needed to get the computer into single-user mode and on the network. Your system needs fast access to the root filesystem, so if you have multiple disks, put the root partition on the fastest (or smallest) one.

The root partition is the only one whose placement on disk is vitally important. Over the years, i386 systems have been repeatedly expanded to surpass their own limits—they're based on an architecture that could originally handle only up to 640KB of RAM, after all! All modern operating system kernels work around these limits in a manner mostly transparent to users, but when the system is first booting, you're trapped within the hardware's limits.

Many old i386 systems have limits on hard drive size. They only recognize 128GB drives, 2TB drives, or some other number. The hardware BIOS cannot access anything beyond that limit. If you're using a computer that has a 128GB limit on hard drive size, and you put the kernel somewhere beyond the first 128GB of disk space, the computer will be unable to find the kernel

and thus unable to boot the system. Check your hardware manual before you get started. If the manual refers to a disk size limit, your entire root partition must fit within that limit.

If you violate this limit, your system will probably appear to work. The second you change the file */bsd*, however, it's likely that your computer will refuse to boot. Save yourself much pain by putting the root partition first on the disk, and making sure it's small enough to fit within the hardware's limits.

### Swap Space

Swap space is used for virtual memory. When your computer runs low on RAM, it starts to move information that has been sitting idle in memory into swap space. When the computer needs that information, it's loaded from virtual memory into real memory. This isn't necessarily bad for performance. Many programs spend the vast majority of their time executing only a small fraction of their code. OpenBSD is pretty good about figuring out which sections of memory can be moved into swap space and which are used too frequently to be swapped. If things go well, your computer will almost never need swap space.

OpenBSD also uses swap space during system failures. If the kernel panics, the computer writes the contents of system memory to the swap partition. This means that the swap partition must be, at its smallest, slightly larger than the amount of physical RAM in the system.

How much swap space do you need? The short answer is, "It depends on the system." OpenBSD defaults to allocating twice as much swap space as you have physical RAM. This isn't a bad rule, as long as you understand it's very general. A swap space three or four times the size of your physical memory won't hurt. If your computer uses more swap space than that, it's overloaded and will perform poorly.

If you find yourself using swap space often, consider increasing your physical memory instead. RAM is cheap.

Also consider future upgrades. If your system has 2GB of RAM when you install OpenBSD, but you intend to increase that to 8GB, assigning 16GB of swap space is a good idea. Adding a swap partition later is difficult, unless you leave unallocated disk space when you install the software. (Note that, while you can swap to a file, OpenBSD can write only crash dumps to an actual swap partition.)

### /tmp Directory

The */tmp* directory is temporary space for all users on the system. Space requirements for */tmp* are generally a matter of opinion—after all, you can always use a chunk of space in your */home* directory for scratch space. Automated software installers frequently extract files into */tmp*. I usually recommend at least 3GB in */tmp*, but I do horrible things to my temp space. Many people use a */tmp* directory of 256MB or 512MB and get along just fine.

### /var Partition

The */var* partition contains frequently changing data, such as logs, databases, mail spools, temporary run files, websites, and so on. OpenBSD allocates about 5GB to */var* by default. This should be plenty for an educational installation. If you're building a web, database, or logging server, however, */var* should get the majority of your disk space. If you're on a really tiny system, you could use as little as 10MB for */var*.

### /usr Partition

The */usr* partition holds the operating system programs, compilers, libraries, and add-on programs. The majority of */usr* changes only when you upgrade your system. OpenBSD assigns */usr* 2GB by default, which is more than sufficient, even on a desktop system.

### /usr/X11R6 Partition

The */usr/X11R6* partition contains the X Window System programs and documentation. OpenBSD does package software linked against the X Window System, and a lot of software you might expect to find on servers (such as ImageMagick) requires X libraries.

If you are not going to install any X software, and plan to build all your own software without X, you don't need this partition. If you're in doubt, or if this is your first installation, keep this partition.

### /usr/local Partition

The */usr/local* partition contains add-on OpenBSD software, usually from packages (see Chapter 13). This can be much larger than the */usr* partition containing the core OpenBSD software. OpenBSD allocates 5GB of disk space to */usr/local* by default, and I've never needed more than that.

### /usr/src Partition

The */usr/src* partition is dedicated to the OpenBSD source code. On a dedicated-purpose machine that doesn't have a compiler, such as a firewall or a secure web server, you probably don't need a local copy of the source code. If you don't plan to upgrade this machine from source code, and you don't plan to use the source code as a reference on the local machine, you don't need this partition. If you're in doubt, keep it.

### /usr/obj Partition

The */usr/obj* partition is where OpenBSD builds new versions of the operating system and Xenocara. The files in here are temporary; once you've installed a new OpenBSD version, you don't need these files any longer. Creating a new filesystem is faster than erasing the individual files in this kind of filesystem, so */usr/obj* is configured as its own partition.

If you don't intend to build a new OpenBSD from source code, you don't need */usr/obj*. If you find that you do need this partition later, you can either create it from unused space or mount it via NFS.

#### /home Partition

The */home* partition can be described as "everything else." User directories go into */home*, as well as any random data that's meant for users. The family MP3 and photo collections should go in */home*, as well as your personal source code, email, and anything else you want to keep.

### *Creating Other Partitions*

OpenBSD supports up to 16 partitions per disk. If you want other partitions, you can create them using the installer. Does your company have a policy that all add-on software must go in */opt* or */usr/companyname*? Fine, create that partition. The OpenBSD standards are not a straitjacket, but rather a starting point. You own the system. Make it behave according to your needs.

## Partition Filesystems

The words *filesystem* and *partition* are often used interchangeably. They are closely related, but two different things. A filesystem is a method of allocating and tracking files that are on a partition. You can back up and restore a filesystem, but if a partition is damaged, you're in much worse trouble.

OpenBSD uses the standard Fast File System (FFS) by default. FFS has been around for decades, and is both well debugged and well understood. Unfortunately, with its default settings, it can handle partitions only up to slightly less than 1TB in size. Modern disks make partitions of that size common.

If a partition is 1TB or more in size, the installer automagically formats it with FFS version 2 (FFS2). In Chapter 8, we'll cover how to adjust your filesystems to exactly fit your needs.

## Multiple Hard Drives

Disk input/output is usually the slowest part of a computer. If you have more than one hard drive, you can use those drives to accelerate your system performance.

First, make sure that each drive is on its own port. SCSI and SATA drives usually accommodate one drive per port (unless you specifically use a port multiplier), but IDE drives usually attach two devices per port. Each port has a maximum throughput. It does no good to attach two fast drives to one port, as the drives compete for the one port's throughput.

In general, when you have multiple drives, you want to split the read and write activity between the drives. I usually put the data I'm serving on

one disk and the important system files on another. If I'm building a database server, I might dedicate one disk to swap space and */var*, while assigning all other partitions to the other disk.

Split your swap space between the drives. Be sure that at least one partition is large enough to hold the contents of your physical RAM, so that OpenBSD can do a crash dump if needed. OpenBSD cannot split a crash dump between two different swap partitions.

If you're a more experienced OpenBSD user, you can use multiple hard drives to create a redundant disk with software RAID. We'll cover how to do that in Chapter 9.

If your second drive is much slower than your main system drive, don't bother using it. A computer runs only as fast as its slowest component, so adding that old IDE drive to your SATA system will drag down the whole machine. Not only will its presence degrade performance for the whole system, but it's also probably much older than your main drive and far more likely to fail.

## Understanding Partitions

As a historical accident, i386 and amd64 systems have two different types of partitions. OpenBSD refers to the first as *MBR partitions* and the second as *disklabel partitions* (or just *partitions*).

### MBR Partitions

MBR partitions, also known as *primary partitions*, are universally understood by operating systems that run on i386 hardware. Every hard drive has four MBR partitions. In most cases, only one partition has any space allocated to it; the other three partitions have zero size. If you want to install multiple operating systems on a single disk, then each operating system needs its own MBR partition.

Most operating systems manage MBR partitions with a program called *fdisk*. It's not the same program, mind you—OpenBSD's `fdisk(8)` is not the same as Microsoft's Fdisk, which is different from the program for Linux, FreeBSD, OpenSolaris, and so on. Any operating system's fdisk can see MBR partitions that belong to other operating systems, and while they might not recognize what's on the MBR partition, they will recognize that space has been allocated for *something* and will warn you about overwriting it. Unfortunately, not all fdisk programs play nicely with each other. Do not partition disks for one operating system with another operating system's tools.[2]

With the advent of cheap virtualization, installing multiple operating systems on a single disk is no longer advisable. Assign each disk a single MBR partition that fills the entire disk, and give the other three MBR partitions zero size. You will see an example of how to do this in Chapter 3.

2. I'm assured by OpenBSD developers that any fdisk should suffice for any operating system. Having been repeatedly savaged by buggy fdisk programs, I find myself unable to give you carte blanche to try this.

### Disklabel Partitions

BSD did not originate on i386 hardware; it had its own disk-partitioning system, based on labeling the disk's partitions. When BSD was ported to i386, the disklabel was nailed up inside an MBR partition. When someone speaks of "partitions" in OpenBSD, they almost certainly mean disklabel partitions.

One disklabel can support 16 partitions. If you need more than 16 partitions, you must create a second MBR partition and add more disklabels. I would suggest that if you need more than 16 partitions on a single disk, you took a wrong turn somewhere in your decision-making process. Step back and reassess what you want to accomplish and how you're going about it.

Foreign operating systems do not recognize OpenBSD disklabels. BSD-based operating systems might appear to understand them, but the disklabel formats used on the various BSD-derived systems have diverged in the past 20 years. Use only OpenBSD disk tools to manage OpenBSD partitions.

## Understanding Disklabels

The OpenBSD installer expects you to understand disklabels. You can avoid learning about disklabels by blindly accepting the default partitioning OpenBSD offers, but that won't take you very far. Disklabels might look intimidating to the new user and require some basic math, but they aren't that difficult once you walk through them slowly. You need to understand disk geometry first.

### Sectors and Lies

Once upon a time, disk drives had clearly defined geometry. Each disk was actually round, and it spun inside the hard drive. The manufacturer divided each disk into tiny sections, called *sectors*. Each sector had a number, with sector 0 at the beginning of the disk and the sectors numbered sequentially until the end of the disk. Sectors were gathered into rings, or *tracks*. Stacks of tracks were aggregated into *cylinders*. Each disk drive had a number of *heads*—data-reading devices that read information from the disk as the disk spun beneath them. Taken as a whole, sectors, tracks, and cylinders described the disk *geometry*.

This all seems simple enough, but today you can't actually count on disk sectors to actually map to anything useful. Over the years, both hard drive manufacturers and operating systems have set and broken limits. This applies to all aspects of machine design, from the 640KB memory limit to the 504MB disk limit. Hard drive manufacturers avoided these limits by tricking the system BIOS and/or the operating system.

If you're a hard drive manufacturer making a hard drive with 126 sectors per track, but the most popular operating system can accept only 63 sectors per track, you have a problem. The easy solution is to teach your hard drive to lie. If you claim you have half as many sectors per track

but twice as many platters, the numbers still add up, and you can still provide unique sector numbers. Every hard drive manufacturer chooses to lie in a slightly different way. The most obvious examples are flash drives (which still report cylinders, sectors, and tracks, even though they're not round and don't spin[3]) and hardware RAID (which reports the same information about several disks as if they were one). If you read about the history of hard drives, you'll discover all sorts of interesting lies.

By the time disk geometry information reaches the operating system, it has been through one or more translations. Reach into your head, find the button that says "Accept What You're Told," and press it as you repeat the following: Disks are divided into sequentially numbered sectors. Partitions fill a number of consecutive sectors. Sectors are grouped into cylinders, based on the number of heads in the drive. Partitions end on cylinder boundaries.

### Sectors and Disklabels

The installer will display your disk's disklabel. (You can also see the disklabel once the system is installed and running, as discussed in Chapter 8.)

We'll look at the disk's physical information first. While the physical information doesn't usually directly impact the installation, you need to know how to read it if something goes wrong.

```
❶ # /dev/rsd0c:
❷ type: SCSI
❸ disk: SCSI disk
❹ label: DSA2CW120G3
❺ duid: adb697598fa0a010
  flags:
❻ bytes/sector: 512
  sectors/track: 63
  tracks/cylinder: 255
  sectors/cylinder: 16065
  cylinders: 14593
❼ total sectors: 234441648
❽ boundstart: 64
❾ boundend: 234436545
  drivedata: 0
```

Except for the device unique identifier (DUID), you cannot change any of these entries without changing the underlying hardware.

The first entry is the device name, `/dev/rsd0c` ❶. The leading `/dev` means that this is a device node. The `rsd0c` is the disk name. `sd` means that this drive uses the `sd(4)` device driver, and the `0` means that this is the first drive OpenBSD found and attached. (This is usually, but not always, BIOS drive 0.) The leading `r` means that we're addressing the disk in raw mode, while the tailing `c` means that we're examining disklabel partition *c*. Disklabel

3. Yes, you can make flash drives spin. But a flash drive doing 5400 RPM has a whole set of problems beyond the scope of normal systems administration.

partition *c* always matches the entire MBR partition containing this disklabel. Almost any disk that isn't explicitly IDE will probably show up as a SCSI disk.

The `type` ❷ is a general label describing the disk's physical interface. Any IDE disk will show up as ESDI (Enhanced Small Device Interface), while SCSI, SAS, SATA, and almost every other type of disk has type SCSI.

The `disk` field ❸ shows what sort of disk is attached to this interface. Here, it shows a SCSI disk, but we knew that already from the type.

The `label` ❹ displays the manufacturer's name and/or the drive model number. In the case of virtualized servers, this shows `virtual drive` or something similar.

The `duid` ❺ is the DUID for this disk. If you've ever managed a system with more than a couple of disks in it, you know how easy it is to confuse disks. The hardware BIOS identifies disks by the physical port they're attached to. If you need to replace a SATA or SCSI card, and you get the disks mixed up as you rerun cables, you will have a hard time finding your boot drive again. By using the DUID in your system configuration instead of the BIOS-assigned device name, you will always have the same disk used for the same purpose. As noted earlier, the DUID is the one editable field in the top of the disklabel information.

The bytes per sector, sectors per track, tracks per cylinder, and sectors per cylinder ❻ all describe the disk's geometry. These numbers are all lies, but the total number of sectors on the disk ❼ *is* accurate. You also see the first sector you may fill with disklabel partitions ❽, and the last sector you may use ❾. (You lose a few sectors due to the hard drive's geometry transformations. Don't try to hold the hardware accountable. You can't win that argument.)

The next section displays the disklabel partitions, and you can alter it as needed. Here's a disklabel from my desktop:

```
16 partitions:
#             ❶ size          ❷ offset ❸fstype ❹[fsize bsize  cpg]
❺  a:         2097121                64  4.2BSD      2048 16384    1 # /
❻  b:         4698424           2097185    swap
❼  c:       312581808                 0  unused
   d:         8388576           6795617  4.2BSD      2048 16384    1 # /tmp
   e:        16736864          15184193  4.2BSD      2048 16384    1 # /var
   f:         4194304          31921057  4.2BSD      2048 16384    1 # /usr
   g:         2097152          36115361  4.2BSD      2048 16384    1 # /usr/X11R6
   h:        20971520          38212513  4.2BSD      2048 16384    1 # /usr/local
   i:         4194304          59184033  4.2BSD      2048 16384    1 # /usr/src
   j:         4194304          63378337  4.2BSD      2048 16384    1 # /usr/obj
   k:       245003968          67572641  4.2BSD      2048 16384    1 # /home
```

This disklabel declares that it has 16 partitions, but lists only 11. The disklabel has space for 16 partitions, but like the MBR partition table, not all of them have space allocated to them. As with most configuration files in Unix-like operating systems, a hash mark (`#`) indicates the beginning of a comment. The comments here give the headers for the table above.

The first column is the partition letter. A unique letter identifies each disklabel partition. The first partition in our example is *a* ❺, the second is *b* ❻, the third is *c* ❼, and so on.

The `size` ❶ is the number of sectors the drive uses. In this example, partition *a* fills 2097121 sectors, partition *b* 4698424 sectors, and partition *c* 312581808 sectors.

The `offset` ❷ is the number of sectors from the beginning of the MBR partition where the disklabel partition begins. If a disk is bootable, it has a master boot record (MBR) flagging it as such. The MBR record takes the first 63 disk sectors, numbers 0 through 62. The first sector available for a disklabel partition is sector number 63. Partition *a* begins on sector 64 in order to correctly align with the memory cells in solid-state disks.

Take a look at partition *b*. It has an offset of 2097185, meaning it starts in sector 2097185. How do we get there? Well, partition *a* starts in sector 64 and has a size of 2097121. 2097121+64=2097185, or the first free sector after partition *a* ends. This seems perfectly sensible until you look at partition *c*. Disklabel partition *c* is magical. On every disklabel partition, *c* represents the entire disk. It has an offset of 0 and a size equal to the number of sectors on the disk. You cannot put a filesystem on partition *c*; it's there only for reference. Partition *d* picks up where partition *b* left off.

The `fstype` ❸ marks the type of filesystem on this partition. OpenBSD filesystems, such as partition *a*, are labeled as 4.2BSD. (The OpenBSD filesystem is no longer exactly the same as that from BSD 4.2, mind you.) Partition *b* is swap space.

The next two columns ❹ display the fragmentation behavior of the filesystem on this partition. These values are set by the filesystem creation tool when putting the filesystem on the partition, and should not be changed by hand. If you're curious, read `newfs(8)` and its related man pages. The `fsize` is the fragment size for any file fragments on the partition. The *b* is the size of a block on disk, in bytes. We talk about FFS fragmentation in Chapter 8. All you really need to know at this point is that FFS and FFS2 are both highly fragmentation-resistant, and neither requires any sort of defragmentation process.

The last column shows the number of cylinders per cylinder group. This is almost always 1 for modern disks.

One interesting thing is that the disklabel can be considered a configuration file for formatting a disk. You could save this disklabel to a file, get an identical hard drive, write this label to that new disk, and perfectly duplicate the partitioning of the old disk on the new.

If at any time you feel confused about your partitioning, print out your current disklabel and compare it to how you would like your system to look.

## Other Information

If this machine is going to be on the Internet, you must know its network configuration before starting. If your network has DHCP, you're all set. If not, you need a valid IP address, netmask, default gateway, and name server IP addresses.

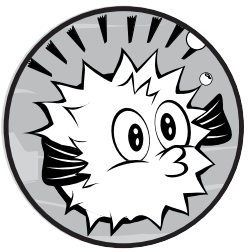
Decide in advance if this machine will run the X Window System. Generally, desktops run X and servers do not.

At this point, you have all the background you need to install OpenBSD on i386 or amd64 hardware. Break out your equipment, and let's get started.

# 3

# INSTALLATION WALK-THROUGH

*Straightforward questions.*
*Will you take the default prompts?*
*Think before you choose.*



Armed with your OpenBSD software and a computer with supported hardware, you are now ready to start an actual installation. This chapter takes you through a full installation on amd64 and i386 systems via CD and FTP, booting from a CD or floppy disk.

In this chapter, I assume that you're dedicating your computer to OpenBSD. You can install multiple operating systems on a single computer, of course, but that's a less common use case. If you want to install multiple operating systems on your computer, follow the instructions in the OpenBSD FAQ. (When installing multiple operating systems on a single computer, it's easy to accidentally damage one of those operating systems, so proceed with caution.)

Before you begin OpenBSD installation, make sure the data on your machine is backed up! When you dedicate your machine to OpenBSD, you'll overwrite the entire hard drive.

## Hardware Setup

Before you begin, verify that OpenBSD supports your hardware. You'll find the supported hardware list for the most recent version of OpenBSD on the platform-specific pages of the OpenBSD website (*http://www.OpenBSD.org/i386.html* for i386 and *http://www.OpenBSD.org/amd64.html* for amd64), listing hardware that has been verified to work by the OpenBSD team.

If you find that your hardware isn't listed, it might still run OpenBSD. In fact, a lot of unsupported hardware will run OpenBSD perfectly, but not all hardware has been tested, simply because the OpenBSD team doesn't have access to all hardware ever manufactured. If you're worried about a particular device, search the mailing list archives to see if it's supported.

The hardware compatibility lists frequently identify devices by chipset, not by vendor or model. The chipset is the actual hardware name, not the model name, which can cause a bit of confusion because, after all, when you buy a computer, the network card is frequently listed as a "gigabit Ethernet," not as an "Intel PRO/1000MT Dual Port Server Adapter model PWLA8492MT." To make matters worse, many vendors use identical hardware under a separate brand or model name or use different hardware under the same brand or model name. For example, Linksys sold many different network card models under the model name EtherLink. (Fortunately, this issue mostly applies to the lower end of the market, and OpenBSD almost always supports these older chipsets.)

Even if you're not sure that you hardware is supported, you can still try installing OpenBSD to see what happens. The boot messages will offer a lot of information about the hardware you have.

## BIOS Configuration

Be sure to evaluate your system's Basic Input/Output System (BIOS) before installing OpenBSD. Because every BIOS differs, I can't offer exact instructions on configuring yours. Your best bet is to consult your motherboard's manual or the Internet.

Also, if your BIOS needs updating, take care of that before installing OpenBSD. Finally, check the boot device order, and be sure that it makes sense for how you plan to install your system.

With your hardware set up, get the boot media.

## Making Boot Media

We'll cover booting the OpenBSD installer from a CD or floppy disk. Generally, booting via CD is preferable because all amd64 systems can boot from CD, as can most functioning i386 systems. We'll start by making floppies for installation on old i386 hardware and then move on to CDs. While installing from USB and into virtual systems is possible, neither is supported. We'll cover both of those installation types later in the book, in Chapter 23.

## Making Boot Floppies

You need to make boot floppies only if your hardware does not boot from CD, or if you have a floppy but not a CD drive. The OpenBSD boot floppies contain a very limited subset of OpenBSD—just enough to recognize your hardware, format your disk, and download and extract the file sets. In addition to the floppies themselves, you'll also need a working Internet connection via Ethernet.[1] Because the full kernel is larger than a single floppy can hold, OpenBSD provides three floppy images for i386 hardware, each targeting a specific type of hardware. Each image name includes the release number. For example, the floppy images for release 5.3 are named *floppy53.fs*, *floppyB53.fs*, and *floppyC53.fs*. Download the image that most closely describes your system, as follows:

***floppyXX.fs*** This is the image for the most common i386 hardware. It will boot the average workstation or low-end server.

***floppyBXX.fs*** This image includes drivers for gigabit Ethernet cards, SCSI, and RAID. It's meant for higher-end i386 servers.

***floppyCXX.fs*** This image supports PCMCIA and CardBus. It's meant for laptops.

OpenBSD provides only one floppy image for amd64 hardware: *floppyXX.fs*. (The amd64 platform doesn't carry around 20 years of legacy drivers as baggage, so everything fits on a single disk.) Be sure to use the floppy image found in the amd64 directory. The amd64 image uses the same name as the standard i386 floppy.

Once you have the appropriate image file, you must copy it onto a floppy disk. You cannot use basic filesystem-level copying, such as Windows drag-and-drop, because the image files include not only files but also a filesystem. You must use appropriate tools to copy the images to a floppy.

### Creating Floppies on Unix-like Systems

If you're already running a Unix-like system, create your floppy with `dd(1)`. You'll need to know your floppy drive's device name, which is probably */dev/fd0*, */dev/floppy*, */dev/rfd0*, or */dev/rsd0* (for USB floppy drives). Once you know the device name, tell `dd` to copy the image to that disk device with a command like this:

```
# dd if=filename of=full-path-to-floppy-device
```

For example, to create a disk from image *floppyB52.fs* with the floppy device name */dev/fd0c*, enter the following:

```
# dd if=floppyB52.fs of=/dev/fd0c
```

1. Yes, some of us have half-suppressed memories of i386 hardware that couldn't boot OpenBSD from a CD, but would let you fetch the install sets from one once you had it boot from a floppy. But seriously, if your hardware is that aged and picky, please save yourself some pain. Go back to the dumpster you found that computer in. Find something more recent.

If `dd` gives you an error immediately or exits silently without writing to the floppy disk, try specifying a different floppy disk device.

#### Creating Floppies on Microsoft Systems

If you need to create a floppy on a descendant of Windows NT (including all modern Windows desktop operating systems), you'll need an image-writing program. In the *tools* directory of your OpenBSD release, you'll find a program named *ntrw.exe*. This program copies disk images to a disk. Download the program, open a command prompt, navigate to the folder containing *ntrw.exe*, put your blank floppy in the drive, and run this command:

```
C:> ntrw floppyB53.fs a:
```

If you get a permissions error, you might need to run your command prompt as Administrator. If the command still fails, chances are good that you're using the bad floppy disk you tucked away in a drawer 15 years ago. Try another one.

### Making Boot CDs

OpenBSD provides three ISO images for i386 and two for amd64, as follows:

***cdXX.iso*** This image contains the kernel and installer, but no file sets. It's used to boot a system into the minimal state where the installer can run. Once the system has booted, it fetches the file sets over the network.

***installXX.iso*** This image contains everything in the *cdXX.iso* image, as well as the file sets. Use it to install this version of OpenBSD on multiple systems.

***cdemuXX.iso*** Some older i386 systems have a BIOS that makes CD drives emulate floppy drives. If you have a system like this, use *cdemuXX.iso*. If you're unsure whether you need this image, you don't. If you've ever owned one of these CD drives, you've probably replaced it by now. If you haven't, maybe you should.

**NOTE** *Remember that you can save yourself the trouble of selecting an ISO by buying an official CD set, which will Just Work and will also contain precompiled packages.*

The process of getting the ISO onto a physical disk varies widely from operating system to operating system. On a Microsoft Windows system, right-click the ISO and select **Burn to Disc**. Unix-like systems use several different programs, such as `burncd` and `cdrecord`. Different Linux versions have innumerable ISO-burning front ends integrated into their desktop environments. Check online for instructions on burning a CD on your particular operating system.

## Installing OpenBSD

Once you boot from your chosen media, you should see something like this:

```
> OpenBSD/amd64 BOOT 3.18
boot>
```

If you need to interrupt the boot process for any reason, you can do so at this point. We'll discuss how to interrupt the boot process in Chapter 5, and reasons for doing so throughout the book.

If you wait five seconds, OpenBSD should boot. The kernel will then introduce itself and begin identifying your hardware.

```
booting ❶cd0a:/5.3/amd64/bsd.rd: 2986868+913996+2861496+0+504624
[89+318288+205653]=0xb6f578
entry point at 0x1001e0 [7205c766, 34000004, 24448b12, 1608a304]
Copyright (c) 1982, 1986, 1989, 1991, 1993
      The Regents of the University of California.  All rights reserved.
Copyright (c) 1995-2012 OpenBSD. All rights reserved.  http://www.OpenBSD.org

❷ OpenBSD 5.3 (RAMDISK_CD) #23: Sun Feb 12 09:45:07 MST 2012
    deraadt@amd64.openbsd.org:/usr/src/sys/arch/amd64/compile/RAMDISK_CD
real mem = 1072627712 (1022MB)
avail mem = 1032290304 (984MB)
...
```

In this output, you can tell at ❶ from which device the system is booting—CD drive 0 in this case. Next, you see the copyright information, followed by the directory in which your kernel was compiled at ❷. You can see that this is an OpenBSD snapshot kernel, compiled by user `deraadt` on host *amd64.openbsd.org*.

At this point, OpenBSD should probe your hardware and display the results as it attaches device drivers.

### *Running the Installation Program*

Once the boot messages pass, you should see the following text:

```
Welcome to the OpenBSD/amd64 5.3 installation program.
(I)nstall, (U)pgrade or (S)hell? i
```

As you can see, there are three options: Install, Upgrade, and Shell. The OpenBSD installer is a shell script that calls programs to download files, format disks, and otherwise prepare your system. It might not be pretty, but it is extremely fast and, in educated hands, extremely powerful.

The Shell option will drop you into an OpenBSD command line, where you have access to the commands on the installation disk. These minimal commands might suffice to repair a damaged system. We'll examine the Upgrade option in Chapter 20.

Enter **i** to choose Install. You should see a welcome message and a few basic instructions:

```
At any prompt except password prompts you can escape to a shell by
typing '!'. Default answers are shown in []'s and are selected by
pressing RETURN.  You can exit this program at any time by pressing
Control-C, but this can leave your system in an inconsistent state.

❶ Terminal type? [vt220]
❷ System hostname? (short form, e.g. 'foo') caddis
```

The installer shows default answers in square brackets. To use the default, just press ENTER.

If your system has a standard keyboard and monitor, OpenBSD will use it as the standard VT220 terminal, as shown at ❶. If you have an unusual terminal connected to your system, you're probably an old geezer who knows exactly what terminal type it is. If you're a young kid using some ancient, unidentified, dust-covered terminal found in a disused laboratory at the back of an abandoned fireworks factory because you thought it would be nifty, stop now and get a standard monitor and keyboard. While OpenBSD probably supports that antediluvian console, this is not the time to try it.

Next, the installer should prompt you for the system's short hostname at ❷, which will be a single word to identify your system. This particular computer is named `caddis`; you can name yours whatever you like.

Now to configure the network:

```
❶ Available network interfaces are: em0 em1 vlan0.
❷ Which one do you wish to configure? (or 'done') [em0]
❸ IPv4 address for em0? (or 'dhcp' or 'none') [dhcp] 192.0.2.85
❹ Netmask? [255.255.255.0] 255.255.255.128
❺ IPv6 address for em0? (or 'rtsol' or 'none') [none]
  Available network interfaces are: em0 em1 vlan0.
❻ Which one do you wish to configure? (or 'done') [done]
❼ Default IPv4 route? (IPv4 address, 'dhcp' or 'none') 192.0.2.1
  add net default: gateway 192.0.2.1
❽ DNS domain name? (e.g. 'bar.com') [my.domain] blackhelicopters.org
❾ DNS nameservers? (IP address list or 'none') [none] 192.0.2.2 192.0.2.10
```

At ❶, the installer lists the network interfaces it recognizes on your machine. It has found three: `em0`, `em1`, and `vlan0`. The first two, `em0` and `em1`, are network cards. I chose `em0` at ❷, the installer's default, by pressing ENTER. Avoid configuring a virtual local area network (VLAN) during installation if possible, especially on your first installation. If you need a VLAN to connect to the Internet, see Chapter 12.

When asked at ❸ if you want to give a static IP address, you can choose to use DHCP by pressing ENTER. I chose to enter a static address because I'll be using this machine as a server. (If you don't need a static address, you can just let DHCP automatically assign you an IP address.)

When you use a static address, you must also enter a netmask at ❹ and (if desired) an IPv6 address at ❺. Now, having configured one network card, OpenBSD asks at ❻ if you've finished configuring the network. If you wanted the installer to walk you through configuring the second network card, you would enter `em1` instead of accepting the default of `done`.

If you assign a static IP address, you must also configure a static route if you want to access the Internet, as shown at ❼. Similarly, you need to tell your host its domain name at ❽ and the IP address of at least one name server at ❾.

At this point, you should be on your local network. If you can't access the network, you probably entered something incorrectly. If nothing else, you can use an exclamation point (`!`) to interrupt the installation and get a shell prompt. (Chapter 12 discusses OpenBSD's network configuration in greater depth.)

### *Multiple Network Cards*

Our example server has multiple network interfaces. I chose to configure interface `em0` because that machine was in front of me, and if I chose the wrong network card, I could move the cable. But what if you don't have physical access to your machine? If you had two different network cards (say, an Intel and a 3Com), you would have a better idea which card is which, but having two identical cards leaves you guessing which card has a cable plugged into which network.

Luckily, the OpenBSD installer lets you escape to a command prompt to do a little investigating. How is this useful here? Network interfaces that are plugged in will tell you what kind of connection they have, and disconnected or otherwise failed interfaces will report that they have no media. Here's how you can interrupt the installer to identify the live interface:

```
Available network interfaces are: em0 em1 vlan0.
❶ Which one do you wish to configure? (or 'done') [em0] !
Type 'exit' to return to install.
❷ # ifconfig
lo0: flags=8008<LOOPBACK,MULTICAST> mtu 33152
em0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
        lladdr 00:0c:29:aa:09:21
❸       media: Ethernet autoselect (1000baseT full-duplex,master)
        status: unknown
em1: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
        lladdr 00:0c:29:aa:09:2b
❹       media: Ethernet autoselect (none)
        status: unknown
vlan0: flags=0<> mtu 1500
        lladdr 00:00:00:00:00:00
```

Rather than choosing an interface, escape to a command prompt at ❶ by entering an exclamation point (`!`). Then ask OpenBSD at ❷ to tell you about its network interfaces by running `ifconfig`. You can see interfaces `em0` and `em1` in the output. While `em0` reports at ❸ that it's running 1000baseT

at full-duplex, at ❹ you can see that em1 has a media type of none. Interface em0 is plugged in, so that's the interface I want to configure. Enter **exit** to return to the installer, and proceed to configure card em0.

### *Setting Up Services and the First User*

The installer should now ask you to configure some basic system parameters:

```
❶ Password for root account? (will not echo)
  Password for root account? (again)
❷ Start sshd(8) by default? [yes]
❸ Start ntpd(8) by default? [no] yes
  NTP server? (hostname or 'default') [default]
❹ Do you expect to run the X Window System? [yes]
❺ Do you want the X Window System to be started by xdm(1)? [no]
❻ Change the default console to com0? [no]
```

At ❶, enter your root password twice. If the passwords don't match, the installer will make you do it over until they do.

You can enable the Secure Shell (SSH) daemon at ❷ so that you can remotely connect to this machine immediately after installation. If you enable SSH but do not create a user later in the installation, you can SSH to the machine as root. This is a Very Bad Idea when using password authentication and will let intruders more easily compromise your server. If you enable sshd here, be absolutely certain to create a user during the installation process! If you don't, at least disable SSH logins by the root account immediately after installing OpenBSD, as discussed in Chapter 4.

Correct time is important on a network. I usually enable the Network Time Protocol (NTP) daemon ntpd(8) during the installation process, as shown at ❸. OpenBSD chooses a set of publicly accessible time servers by default, but you can specify a local time server if you have one available.

Now tell the installer at ❹ if you intend to run X Windows. X requires that software be permitted fairly broad access into the kernel. If the installer detects a graphic console, it defaults to permitting X. If you don't need a graphic console, disable X access.

If you're running X, you might also want the X display manager xdm(1). At ❺, tell the installer if you want xdm. By default, OpenBSD doesn't start xdm when it boots; you're generally better off installing OpenBSD on your system than configuring X, so I've accepted the default of no here.

If you want this system to use a serial port as the console, you can set that during the installation at ❻. I discuss serial consoles in Chapter 5.

**NOTE** *For the basic system parameters, I've used the default for all but one. Enabling time service certainly isn't mandatory—I could easily enable ntpd after installation instead. I could have also told the installer to disable X, but I can change that after installation as well.*

Now to set up your first user.

```
Setup a user? (enter a lower-case loginname, or 'no') [no] mwlucas
Full user name for mwlucas? [mwlucas] Michael W Lucas
Password for mwlucas account? (will not echo)
Password for mwlucas account? (again)
Since you set up a user, disable sshd(8) logins to root? [yes]
```

My usual user account name is `mwlucas`. Here, I enter that username, along with a real name entry. The installer creates this account and gives it permission to use the root password (see Chapter 6). You should be prompted twice for the user's password.

**NOTE** *You're offered a chance to disable root logins over SSH. Use this default. The root account should never be permitted to log in via SSH, unless using public key authentication, and even then, those logins should be restricted. For the reasons to avoid root logins over SSH, do an Internet search for "Hail Mary Cloud."*

### Setting the Time Zone

Set your time zone during installation. If you have Internet access when you install OpenBSD, the installer should try to determine your time zone. OpenBSD assumes that the BIOS clock is set in Coordinated Universal Time (UTC). If the BIOS clock is set in some other time zone, you'll need to correct the system time after installation.

I'm in Detroit, Michigan. If you're familiar with US geography, you might think that I need US Eastern Time, but my state has its own time zone.

```
❶ What timezone are you in? ('?' for list) [US/Eastern] ?
  Africa/      Chile/       GB-Eire      Israel       NZ-CHAT      UCT
  America/     Cuba         GMT          Jamaica      Navajo       US/
  Antarctica/  EET          GMT+0        Japan        PRC          UTC
  Arctic/      EST          GMT-0        Kwajalein    PST8PDT      Universal
  Asia/        EST5EDT      GMT0         Libya        Pacific/     W-SU
  Atlantic/    Egypt        Greenwich    MET          Poland       WET
  Australia/   Eire         HST          MST          Portugal     Zulu
  Brazil/      Etc/         Hongkong     MST7MDT      ROC          posix/
  CET          Europe/      Iceland      Mexico/      ROK          posixrules
  CST6CDT      Factory      Indian/      Mideast/     Singapore    right/
  Canada/      GB           Iran         NZ           Turkey
❷ What timezone are you in? ('?' for list) [US/Eastern] US
❸ What sub-timezone of 'US' are you in? ('?' for list) ?
  Alaska          Central         Hawaii          Mountain        Samoa
  Aleutian        East-Indiana    Indiana-Starke  Pacific
  Arizona         Eastern         Michigan        Pacific-New
❹ What timezone are you in? ('?' for list) [US/Eastern] US/Michigan
```

I don't recall my exact time zone, but I know it isn't plain old US Eastern Time. I enter a question mark (**?**) at ❶ to see the available options. I don't recognize any of the time zones listed at ❷ as correct for my city, but I know I'm in a US time zone, so I enter **US**. I don't know what my choices of sub-time zones are, so I enter a question mark (**?**) at ❸ to see the US time zones. And there's Michigan! At ❹, I enter the full time zone name.[2]

### *Setting Up the Disk*

As noted earlier, in a dedicated installation, the installer erases all data on the drive. Unlike most other operating system installers, the OpenBSD installer doesn't warn you about this; it assumes that you understand the implications of repartitioning your hard drive.

For this first installation, we'll use OpenBSD's default partitioning scheme. (We'll discuss custom partitioning later in this chapter.) Our demo server has a single disk. We'll first create an MBR partition on this disk and then add OpenBSD partitions.

```
Available disks are: sd0.
Which one is the root disk? (or 'done') [sd0]
Use DUIDs rather than device names in fstab? [yes]
```

The installer tells us that it sees one disk, device `sd0`. The installer must know which disk will hold the root partition. (With only a single disk this seems superfluous, but it becomes important if you system has we'll see an example with multiple disks, as discussed in "Custom Disk Layout" on page 49.) When you have only one disk, OpenBSD assumes that you'll use it. It also asks if you want to use the disk's DUID in the filesystem table rather than the device name. For reasons we'll discuss in Chapter 8, always answer **yes** to this.

The installer will now show you the MBR partition table.

```
Disk: sd0       geometry: 6527/ 255/ 63 [ 104857600 Sectors]
Offset: 0       Signature: 0xAA55
            Starting         Ending         LBA Info:
 #: id      C   H   S -      C   H   S [       start:        size ]
-------------------------------------------------------------------------------
 0: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 1: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 2: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 3: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
Use (W)hole disk, use the (O)penBSD area, or (E)dit the MBR? [whole]
Setting OpenBSD MBR partition to whole sd0...done.
```

2. Of course, the US/Michigan time zone applies only to the four counties on the west end of the Upper Peninsula. But accepting the default wouldn't let me illustrate this, and if I have to make something up, it might as well be vaguely plausible.

The first line shows the detected hard drive geometry. This particular drive has 6527 cylinders, 255 heads, and 63 sectors per cylinder. If you compare this to the label on the physical drive, it almost certainly won't match (because hard drives lie). But note that this translated geometry has exactly the same number of sectors as shown in the hard drive documentation.

Beneath this line, you see the existing MBR partition table. The partitions are all zeroed out, which means that this drive has no partitions. We want only OpenBSD on this machine, so take the default and let OpenBSD swallow the whole drive.

Now it's time to consider your OpenBSD partitions.

```
The auto-allocated layout for sd0 is:
  #              size           offset  fstype [fsize bsize cpg]
❶ a:             1.0G               64  4.2BSD   2048 16384    1 # /
  b:             1.2G          2097216    swap
  c:            50.0G                0  unused
  d:             3.6G          4716480  4.2BSD   2048 16384    1 # /tmp
  e:             5.7G         12176320  4.2BSD   2048 16384    1 # /var
  f:             2.0G         24063040  4.2BSD   2048 16384    1 # /usr
  g:             1.0G         28257344  4.2BSD   2048 16384    1 # /usr/X11R6
  h:             6.3G         30354496  4.2BSD   2048 16384    1 # /usr/local
  i:             1.9G         43566400  4.2BSD   2048 16384    1 # /usr/src
  j:             2.0G         47467072  4.2BSD   2048 16384    1 # /usr/obj
  k:            25.4G         51661376  4.2BSD   2048 16384    1 # /home
❷ Use (A)uto layout, (E)dit auto layout, or create (C)ustom layout? [a]
❸ /dev/rsd0a: 1024.0MB in 2097152 sectors of 512 bytes
  6 cylinder groups of 202.47MB, 12958 blocks, 25984 inodes each
  ...
```

Our first partition at ❶ is a, which occupies 1GB and will be used as the root partition (/). On the installed system, this will be known as partition sd0a. Look down the list to see all of the standard partitions discussed in Chapter 2.

We could do custom disk partitioning at this point, but for our first installation, we'll use the defaults, as shown at ❷. The installer should then label the disk and ❸ create filesystems on all the partitions.

### Choosing File Sets

Now that you have allocated disk space, let's put the operating system onto the disk. The installer starts by asking some basic questions about how to get the sets.

```
Let's install the sets!
Location of sets? (cd disk ftp http or 'done') [cd] ❶ ftp
HTTP/FTP proxy URL? (e.g. 'http://proxy:8080', or 'none') [none]
Server? (hostname, list#, 'done' or '?') [ftp5.usa.openbsd.org] ❷ ftp.lambdaserver.com
Server directory? [pub/OpenBSD/5.3/amd64]
Login? [anonymous]
```

Although I booted this system off a CD, I'm going to install the file sets via ❶ FTP. If my network needed to use a proxy to access the Internet, I would tell the installer.

While the installer will choose an FTP server for you at ❷, you can specify an FTP server that you know is close or fast. If you're installing a snapshot, give the file path to the desired snapshot on the FTP server. Finally, if this FTP server requires a username and password, enter it here.

At this point, the installer should log in to the FTP server, find all available file sets, and display them for your approval.

```
Select sets by entering a set name, a file name pattern or 'all'. De-select
sets by prepending a '-' to the set name, name pattern or 'all'. Selected
sets are labelled '[X]'.
    [X] bsd           [X] etc53.tgz     [X] xbase53.tgz   [X] xserv53.tgz
    [X] bsd.rd        [X] comp53.tgz    [X] xetc53.tgz
    [X] bsd.mp        [X] man53.tgz     [X] xshare53.tgz
    [X] base53.tgz    [X] game53.tgz    [X] xfont53.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

I suggest you install everything, but you can choose to remove one or more sets.

For example, suppose you are building a firewall machine. Firewalls traditionally don't have compilers, documentation, or X. You can remove file sets by entering a minus sign (-) and the name of the file set.

```
Set name(s)? (or 'abort' or 'done') [done] ❶ -comp53.tgz -man53.tgz
    [X] bsd           [X] etc53.tgz     [X] xbase53.tgz   [X] xserv53.tgz
    [X] bsd.rd        [ ] comp53.tgz    [X] xetc53.tgz
    [X] bsd.mp        [ ] man53.tgz     [X] xshare53.tgz
    [X] base53.tgz    [X] game53.tgz    [X] xfont53.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

This example removes the compiler and manual file sets at ❶. You can see that they're no longer selected in the list of file sets.

You can also use wildcards when selecting file sets. For example, here's how to remove all file sets beginning with an x:

```
Set name(s)? (or 'abort' or 'done') [done] -x*
    [X] bsd           [X] etc53.tgz     [ ] xbase53.tgz   [ ] xserv53.tgz
    [X] bsd.rd        [ ] comp53.tgz    [ ] xetc53.tgz
    [X] bsd.mp        [ ] man53.tgz     [ ] xshare53.tgz
    [X] base53.tgz    [X] game53.tgz    [ ] xfont53.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

If you change your mind, you can add file sets back in by entering a plus (+) sign and the file set name. Here, I add back everything by using a wildcard (*):

```
Set name(s)? (or 'abort' or 'done') [done] *
    [X] bsd           [X] etc53.tgz     [X] xbase53.tgz   [X] xserv53.tgz
    [X] bsd.rd        [X] comp53.tgz    [X] xetc53.tgz
    [X] bsd.mp        [X] man53.tgz     [X] xshare53.tgz
    [X] base53.tgz    [X] game53.tgz    [X] xfont53.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

Once you're ready, press ENTER to install the default or selected file sets.

After the installer unpacks all of the file sets on the hard drive, it will ask if you have more file sets to install.

```
Location of sets? (cd disk ftp http or 'done') [done]
```

If you have any custom file sets, you could install them at this point.

### Finishing the Installation

After unpacking the file sets, the installer cleans up after itself and tells you it's finished with this message:

```
CONGRATULATIONS! Your OpenBSD install has been successfully completed!
To boot the new system, enter 'reboot' at the command prompt.
When you login to your new system the first time, please read your mail
using the 'mail' command.
```

Do as you're told and enter **`reboot`**, and then remove the CD if necessary. If you're content with a default installation, you can skip to Chapter 4 now.

## Custom Disk Layout

If you have multiple hard disks in a system, or if you want a different partition layout than the default, you must manually edit your disk layout.

The installer partitions one disk at a time, and you can't easily bounce between multiple disks. To successfully use multiple disks, decide on your partitioning scheme *before* you start the installation, and write down exactly which partitions you want on which disks as specifically as possible.

My system has two 50GB hard disks. I plan to divide the disks like this:

**Disk 1** 1GB */*, 1.2GB swap, 5GB */tmp*, 1GB */usr/X11R6*, 2GB */usr/src*, 2GB */usr/obj*, and everything else */home*

**Disk 2** 1GB */altroot*, 1.2GB swap, 6GB */var*, 10GB */usr/local*, and everything else */var/postgresql*

This layout includes all of the standard OpenBSD partitions, plus a few additions: I've increased some partition sizes above the installer-generated defaults, and I've added an extra swap partition on the second hard drive. OpenBSD doesn't include a separate */var/postgresql* partition, but I've added one because I want my database data on its own partition. (We'll discuss the */altroot* partition in Chapter 9.)

The installer runs as usual until you get to the disk portion.

```
Available disks are: sd0 sd1.
Which one is the root disk? (or 'done') [sd0]
```

By default, the installer puts the root partition on the first hard drive, `sd0`. I'll use this disk for the root partition and use the entire disk for OpenBSD.

The installer then presents a list of automatically generated disklabel partitions. We don't want to use these partitions; we want to create our own from scratch.

```
Use (A)uto layout, (E)dit auto layout, or create (C)ustom layout? [a] c
```

We want a custom layout, so enter **c**.

The installer should now drop us to the `disklabel(8)` command prompt, indicated here by the > symbol:

```
You will now create an OpenBSD disklabel inside the OpenBSD MBR
partition. The disklabel defines how OpenBSD splits up the MBR partition
into OpenBSD partitions in which filesystems and swap space are created.
You must provide each filesystem's mountpoint in this program.

The offsets used in the disklabel are ABSOLUTE, i.e. relative to the
start of the disk, NOT the start of the OpenBSD MBR partition.

Label editor (enter '?' for help at any prompt)
>
```

We can now use the interactive disklabel editor to create OpenBSD partitions within the MBR partition, as discussed in the following sections.

### Viewing Disklabels

The `p` command prints the partition's existing disklabel:

```
 > p
OpenBSD area: 64-104856255; size: 104856191; free: 32
#                size           offset  fstype [fsize bsize  cpg]
  a:          2104448               64  4.2BSD   2048 16384    1
  b:          2506143          2104512    swap
  c:        104857600                0  unused
  d:         10490432          4610656  4.2BSD   2048 16384    1
...
>
```

This is exactly the same information discussed in "Understanding Disklabels" on page 31. This hard drive previously had an OpenBSD installation, and the disklabel has those old partitions.

To display partition sizes in megabytes, enter **p m**:

```
> p m
OpenBSD area: 64-104856255; size: 51199.3M; free: 0.0M
#                size           offset  fstype [fsize bsize  cpg]
  a:          1027.6M               64  4.2BSD   2048 16384    1
  b:          1223.7M          2104512    swap
  c:         51200.0M                0  unused
  d:          5122.3M          4610656  4.2BSD   2048 16384    1
...
```

You can also display partition sizes in gigabytes by entering **p g**:

```
> p g
OpenBSD area: 64-104856255; size: 50.0G; free: 0.0G
#                size           offset  fstype [fsize bsize  cpg]
  a:             1.0G               64  4.2BSD   2048 16384    1
  b:             1.2G          2104512    swap
  c:            50.0G                0  unused
  d:             5.0G          4610656  4.2BSD   2048 16384    1
...
```

Choose the unit of measurement best suited to your disk.

### Deleting Partitions

Use the `d` command to delete partitions:

```
> d
partition to delete: [] a
>
```

That's it. Tell `disklabel` to delete a partition on this disk, give it the partition letter, and it's gone. But beware: `disklabel` won't ask you to verify your choice, so be sure to choose the correct partition.

### Erasing Existing Disklabels

You could manually delete all partitions, but it's much easier to zero out the existing disklabel with the `z` command:

```
> z
> p
OpenBSD area: 64-104856255; size: 104856191; free: 104856191
#                size           offset  fstype [fsize bsize  cpg]
  c:        104857600                0  unused
>
```

Here, we tell `disklabel` to erase the partition table with **z**, and then print the partition table with **p**. The output should be an empty disklabel, because the `c` disklabel partition represents the entire MBR partition. We can now create our desired partitions.

### Creating Disklabel Partitions

This first disk needs the following partitions:

- 1GB */* (root)
- 1.2GB swap
- 5GB */tmp*
- 1GB */usr/X11R6*
- 2GB */usr/src*

- 2GB */usr/obj*
- Everything else */home*

By default, `disklabel` creates partitions in order. You can manually create partitions in any order you want, but you'll need to track sectors and cylinders in order to figure out where each partition should begin and end. I *strongly* recommend creating partitions in order and letting `disklabel` do the math.

Use the `a` command to create a partition beginning with `/`:

```
> a
❶ partition: [a]
❷ offset: [64]
❸ size: [104856191] 1g
❹ Rounding size to cylinder (16065 sectors): 2104451
❺ FS type: [4.2BSD]
❻ mount point: [none] /
❼ Rounding size to bsize (32 sectors): 2104448
>
```

By default, at ❶, `disklabel` offers the next free letter for your new partition. The first partition on the disk is `a`. Press ENTER to accept it.

The offset for a disklabel partition is the number of sectors from the beginning of the disk where the partition starts, not from the beginning of the MBR partition, which is the actual beginning of the disk. The first 63 sectors of a disk, numbers 0 through 62, contain the MBR. We could use sector 63, but OpenBSD starts on sector 64 to better align with memory cells in solid-state disks. At ❷, you can see that `disklabel` offers 64 as the default offset.

The size at ❸ is the number of sectors the partition uses. By default, `disklabel` offers all the remaining space on the disk, but I want a 1GB root partition. I could do the math to figure out how many sectors are in a gigabyte, but I'm lazy, so I use an abbreviation instead. The `disklabel` command recognizes the following abbreviations for sizes:

- `b` for bytes
- `c` for cylinders
- `k` for kilobytes
- `m` for megabytes
- `g` for gigabytes

All partitions must end on a cylinder boundary, so `disklabel` figures out the closest boundary and, at ❹, sizes my root partition to match. My root partition will be pretty close to 1GB.

The `FS type` at ❺ shows the filesystem used on this partition. For an OpenBSD disk, every data partition needs type `4.2BSD`. Your swap partition will be of type `swap`.

The mount point at ❻ is where you want this partition mounted. By default, `disklabel` doesn't assign a mount point because it can't guess what you want. Enter the partition's mount point.

Partitions must end on a cylinder boundary, but should end with a whole block for the filesystem. The `disklabel` command ❼ adjusts the partition size again, based on the standard block size of the filesystem.

Our next partition is swap space.

```
> a
❶ partition: [b]
❷ offset: [2104512]
❸ size: [102751743] 1.2g
❹ Rounding size to cylinder (16065 sectors): 2506143
❺ FS type: [swap]
>
```

The `disklabel` command assumes at ❶ that you're using the next partition letter, `b`. It automatically calculates the offset at ❷, which is the next free sector after the previous partition. I use decimal fractions at ❸ to set the size (I could alternatively enter `1200m`). The size at ❹ is rounded to the nearest cylinder boundary. Finally, `disklabel` knows that partition `b` is traditionally swap space, so it offers ❺ that as the default. Swap space doesn't need a mount point, and it doesn't have a block size.

We can create the remaining partitions in the same way. Creating the last partition, */home*, is even easier:

```
> a
partition: [h]
offset: [25575456]
❶ size: [79280799]
FS type: [4.2BSD]
mount point: [none] /home
Rounding size to bsize (32 sectors): 79280768
>
```

As you can see at ❶, we don't need to track how much empty disk space remains, because `disklabel` does that for us. Press ENTER to swallow it all. Now is your chance to leave empty space on your disk.

Now that you've created all your partitions, print the disklabel (with the `p` command, as described earlier in the chapter) to double-check your work.

### Writing the New Disklabel

When you're satisfied with your partition scheme, enter `q` to write your disklabel to disk:

```
> q
Write new label?: [y] y
/dev/rsd0a: 1027.6MB in 2104448 sectors of 512 bytes
...
```

`disklabel` gives you one last chance to change your mind. Once you write a new disklabel, recovering any data on the disk becomes extremely

difficult, so be sure you backed up any vital data on this disk before starting the installation. (This is a good time to make sure that you didn't microwave your backup.)

### Adding More Disks

After you partition your first disk, the installer offers you a chance to partition any other hard drives:

```
Available disks are: sd1.
Which one do you wish to initialize? (or 'done') [done] sd1
```

The default is to not partition any other disks. If you choose another disk, you'll need to create MBR partitions and then disklabel partitions.

Once all of your hard drives have been formatted, you'll return to installing the file sets.

## Advanced Disklabel Commands

While the basic commands should suffice to partition your disk, `disklabel` supports a variety of advanced commands. We'll look at a few of them now.

### Changing Basic Drive Parameters

Remember all that stuff at the top of the disklabel that shows the drive's basic physical characteristics? You can change all that, but it's almost never necessary. In fact, if you think doing this is a good way to solve a problem, you're probably on the wrong track.

If you enter `e`, `disklabel` walks you through each entry on the upper part of the disklabel. The existing values are presented as defaults, allowing you to quickly walk through the variables until you reach the one you want to change:

```
> e
Changing device parameters for /dev/rsd2c:
disk type: [SCSI]
label name: [Samsung HVX8812]
sectors/track: [63]
...
```

Edit this information at your own risk because you can render your disk unbootable or your partitions unusable by changing it! Changing the drive's physical description means you're lying to your computer, and computers go ballistic when you lie to them about their hardware.

### Modifying Existing Partitions

The `m` command modifies existing partitions. The `disklabel` tool walks you through each of the values you entered when creating the disk, offering your original values as defaults and allowing you to change them. But most of the time, it's easier to just delete the partition and re-create it.

### Entering Expert Mode

Expert mode gives the advanced user access to some rarely used options in `disklabel`. Most people don't need these and find them simply clutter. (It's not as if `disklabel` isn't complicated enough already.)

To access expert mode, use the `X` command. You won't immediately see all of the options available, but entering other commands will produce more options and more output.

### Getting More Help

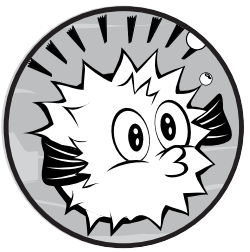
You can enter a single question mark (`?`) at the `disklabel` prompt for a brief list of all available commands. If you want more detailed help, the `M` command displays the `disklabel(8)` man page.

You've now installed OpenBSD. Let's see what to do next.

# 4

# POST-INSTALL SETUP

*Installation first,*
*now configure the software.*
*Server is ready.*



You've installed OpenBSD and rebooted into a bare-bones system. Of course, a minimal Unix-like system is actually pretty boring. While it makes for a powerful foundation, it doesn't actually *do* much of anything.

To get you started, this chapter covers some of the basic steps you should take after installing OpenBSD to establish a firm platform for later work. We'll jump right into basic tasks such as correcting the time zone, setting a default gateway, and setting an email alias for the root account.

But a bit of forewarning: You can change a surprising amount of OpenBSD's configuration when the system is up and running. You can reconfigure the hostname, network configuration, and time and date, as well as stop, start, or reset daemons as you see fit. But just because you can doesn't mean that you should.

While playing arbitrarily with a desktop or laptop machine might be fine, if you're running a server, you should test your configuration by rebooting. Make sure that the system boots exactly as desired before adding services.

If you find that OpenBSD boots fine but you must poke the network card before it works, fix that before proceeding.

**NOTE** *The `afterboot(8)` man page has up-to-date advice for systems administrators who have just installed their first OpenBSD system. Much of this advice overlaps material that we'll cover in this book (in a much more exciting fashion, I'm sure), while some of it applies only to specific use cases. Read the `afterboot` documentation on your system for the very latest information.*

All of the tasks in this chapter must be performed as root. We'll discuss creating additional users in Chapter 6 and ways to avoid using the root account in Chapter 7, but you don't need to do that on a newly installed system. Configure the system properly before you start letting people log on, or you'll wish you had.[1]

## First Steps

The first two things you should do after installing a new system are check for any operating system patches or errata and change the root administrative password. These steps are critical, so don't skip them.

### Checking the System Errata

Believe it or not, OpenBSD isn't perfect. Releases sometimes have bugs. Some of these are serious problems; others not so much.

When the OpenBSD team learns of a serious problem with a release, it issues an errata list, and whenever you build a new server, you should check the errata list at *http://www.OpenBSD.org/errata.html*. Critical errata are also announced on *security-announce@OpenBSD.org*, so if you're on that mailing list, you'll get notifications of new errata. You'll also see errata notices on *http://www.undeadly.org/*.

Errata won't always affect your use case. For example, as I write this, OpenBSD 5.0 has one errata notice: a problem in the BIND name server. If this server won't run BIND, don't worry about this errata. If you're building a name server, however, you need this information before going into production.

If you're in doubt, correct your system as recommended in the errata, which may require building one or more parts of OpenBSD from source. (I'll discuss errata and building OpenBSD at length in Chapter 20.)

### Setting the Root Password

You needed to choose a root password during installation. To change it, use the `passwd(1)` command. Of course, you must be root to change root's password.

1. Saying "Sorry about the timestamps errors in your vital data, but I hadn't set the system clock yet" is roughly equivalent to saying "I don't care about you or your data." If you feel that way, I'm not going to argue, but at least have the confidence to tell the user what you really think.

## Software Configuration

When the OpenBSD kernel finishes its initial system setup and hands control of the system over to userland, `init(8)` runs the shell script */etc/rc*. This script starts all of the programs integrated with the system and performs general system configuration, such as configuring network interfaces and starting server software. To enable, disable, or otherwise configure integrated software, modify the files */etc/rc.conf* and */etc/rc.conf.local*. (I'll cover the OpenBSD boot process in detail in Chapter 5, but for now, this section will get you started.)

The files *rc.conf* and *rc.conf.local* contain shell script variable assignments that control what */etc/rc* runs and the command-line options for the various programs. Keep in mind that any entries in *rc.conf.local* override *rc.conf* statements. Most variable assignments have three legitimate values: an uppercase `NO`, command-line flags in quotation marks (`"-D"`), or double quotes (`""`), which are equivalent to empty. Each variable looks something like this entry from *rc.conf*:

```
ntpd_flags=NO          # for normal use: ""
```

The variable `ntpd_flags` controls the command-line flags that */etc/rc* uses when starting `ntpd(8)`.

A `NO` disables this particular piece of functionality. In the preceding example, the NTP daemon `ntpd(8)` is disabled.

If the variable is empty, */etc/rc* starts the program without any command-line arguments. For example, this `ntpd_flags` entry means that `ntpd` is to be started without any arguments.

```
ntpd_flags=""
```

Anything within quotes is used as a command-line argument to the program. (If a program has typical default flags, they'll usually appear in *rc.conf*.) The following example assigns the variable `ntpd_flags` the value `-s`. When the system boots, rather than running `ntpd`, it will run `ntpd -s`:

```
ntpd_flags="-s"
```

Some variables have additional possible values. For example, the PF packet filter (see Chapter 21) is enabled with a `YES`. To enable the NFS automounter daemon, you'll need to use a path to the master map. (If you don't know what the automounter is, that's fine—not many do these days.) Just realize that weird values for *rc.conf* variables do exist. You'll see these values listed in *rc.conf*.

**NOTE** *OpenBSD defaults appear in* /etc/rc.conf*, but do not edit this file! This is a core system file, and will be replaced during an upgrade. Put your local changes in* /etc/rc.conf.local*. Entries in* rc.conf.local *will override the defaults in* rc.conf.

## Time and Date

Correct system time is not only a convenience, but also a security issue, because many attacks rely on changing the system clock. However, if your system clock is wrong to start with, you won't notice a change. Without coherent time across all your servers, you'll never be able to correlate your logs when troubleshooting. What's the solution? Fix your time settings before you do anything else. Correcting the time requires both setting a time zone and the clock.

### *Setting the Time Zone*

The installer tries really hard to guess your time zone, using geolocation tricks and a script at the OpenBSD website. If these didn't work for you, or if you weren't on the Internet when you installed OpenBSD, or if your company policy says that all servers will run in time zone *X*, fix your time zone before anyone notices.

The directory */usr/share/zoneinfo* contains all of the time zones, as well as several subdirectories for countries or continents with various time zones. For example, Western Siberia runs on Omsk time (found in the file */usr/share/zoneinfo/Asia/Omsk*). Presumably, you have some idea of your local time zone and where it might be filed.

To set the system time zone, create a symbolic link to it from */etc/localtime*. Use `date(1)` to make sure that the time zone has been set correctly:

```
# ln -fs /usr/share/zoneinfo/Asia/Omsk /etc/localtime
# date
Thu Mar 14 06:02:56 OMST 2013
```

OpenBSD also supports POSIX time zones found in */usr/share/zoneinfo/Etc*. POSIX time zones have their own rules. Do not use them unless you are absolutely sure you understand them. (Hint: You don't.)

### *Setting the Date and Time*

Now that you have set a time zone, set the correct time and date. OpenBSD includes OpenNTPD, a BSD-licensed simplified NTP daemon. If at all possible, use `ntpd(8)` to manage the time. If you can't access NTP servers (say, if you're on a private network without them), set up your own. And if you can't set up time servers, set the system time manually.

#### Setting the Time with ntpd(8)

Configure OpenNTPD in */etc/ntpd.conf*. The syntax should be familiar to you if you've managed any other NTP daemon.

For basic time, you need time servers, ideally three or more. If you don't have local time servers, use publicly accessible time servers, such as the hosts available at *http://pool.ntp.org/*.

List your servers in */etc/ntpd.conf*:

```
servers pool.ntp.org
```

Then enable `ntpd` in */etc/rc.conf.local*:

```
ntpd_flags=
```

By default, `ntpd` slowly adjusts system time by skewing the system clock. If the system time is a few seconds off, slow adjustment will usually suffice, but if it's off by minutes or more, have `ntpd` correct the system time on startup and then adjust the time as needed. To enable time correction at startup, use the `-s` flag:

```
ntpd_flags="-s"
```

Time skews most badly on heavily used hardware, lousy hardware, and virtual machines.

### Setting the Date Manually

To set the date and time manually, use `date(1)`. First, make sure that you know the current year, month, day of the month, and time (in 24-hour format). Then set the date and time using this format:

```
# date YYYYmmDDhhMM
```

For example, to set the date to February 3, 2013 and the time to 1:17 PM, run this:

```
# date 201302031317
Sun Feb  3 13:17:00 GMT 2013
```

That said, `date(1)` will not correct your clock on an ongoing basis, and on some hardware with poor clocks, the time will slowly skew. A virtual machine on heavily loaded hardware will almost certainly lose time. Use NTP to deal with that.

## Hostname

Set the system's hostname in */etc/myname*. My test system is called *caddis.blackhelicopters.org*.

```
$ cat /etc/myname
caddis.blackhelicopters.org
```

To change the hostname, edit */etc/myname*. The new hostname takes effect after the next reboot.

To change the hostname until the next boot, use `hostname -s` and the new hostname, like this:

```
# hostname -s treble.blackhelicopters.org
# hostname
treble.blackhelicopters.org
```

You can edit */etc/myname* and run `hostname -s` to make a change take effect immediately and persist after the next boot.

## Networking

If you installed OpenBSD over the Internet, at least one Ethernet card should be configured and working. But if you installed from CD, you didn't need to configure the network to install OpenBSD. If you installed OpenBSD on one network and want to move the machine to another network, you'll need to reconfigure the network on your system.

I cover network principles in Chapter 11 and configuration in Chapter 12, but this brief entry will attach valid network addresses to your system, install a default route, and get DNS resolution working. If you're not sure what to do here, don't do anything until you read the later chapters.

To make network changes take effect, you can either reboot or run the network startup script */etc/netstart*, like this:

```
# sh /etc/netstart
```

To configure only one interface, give the interface's name as an argument:

```
# sh /etc/netstart em0
```

Again, if your system is a server, reboot before you declare the server ready for production.

### *Configuring Ethernet Interfaces*

For a complete list of network interfaces recognized by your host, run `ifconfig(8)`. You should see a bunch of entries, like this:

```
❶ em0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        lladdr 00:0c:29:d2:37:be
        priority: 0
        groups: egress
        media: Ethernet autoselect (1000baseT full-duplex,master)
        status: active
❷       inet 192.0.2.36 netmask 0xfffffe0 broadcast 192.0.2.63
        inet6 fe80::20c:29ff:fed2:37be%em0 prefixlen 64 scopeid 0x1
```

Every OpenBSD system comes with the default interfaces `lo0` (loopback), `enc0` (encapsulating interface), and `pflog0` (PF logging, discussed in Chapter 21). These are virtual interfaces that don't actually attach your system to the local Ethernet. Other interfaces will be physical network ports, like the Ethernet interface `em0` at ❶.

Every Ethernet card has its own configuration file, */etc/hostname* .interfacename. The `em0` interface in the example is configured in the file */etc/hostname.em0*. If the file doesn't exist, create it.

At ❷, you see the IP address. The format of static IP addresses depends on the IP version in use.

### Static IP Addresses

For IP version 4 (IPv4) addresses, the common format is as follows:

```
inet ipaddress netmask broadcastaddress options
```

This format includes these elements:

- The `inet` keyword indicates this is an IPv4 address.
- The IP address (*`ipaddress`*) appears in standard dotted-quad notation.
- The *`netmask`* can appear in dotted-quad format (255.255.255.224) or in hexadecimal (0xffffffe0).
- The broadcast address (*`broadcastaddress`*) gives you the option to hardcode the broadcast address on this network. If you leave this blank or use the word `NONE`, OpenBSD computes the correct broadcast address from the IP address and netmask given earlier. If you use `ifconfig(8)` options, you must use the word `NONE` to provide spacing. (You can also provide the netmask in "slash" notation directly after the IP address, as in `192.0.2.2/24`.)
- The *`options`* space is where you should put any specific `ifconfig(8)` commands needed for this interface, like hardcoded speed or duplex. (See Chapters 11 and 12 for examples, and the `hostname.if(5)` man page for the full details.)

When working with IP version 6 (IPv6) addresses, the format is as follows:

```
inet6 address prefixlength options
```

This format includes these elements:

- The `inet6` keyword tells the system that this is an IPv6 address.
- The *`address`* space is for the IPv6 address, without a prefix length.
- The prefix length (*`prefixlength`*) appears separately, without a slash.
- As with IPv4, you can use `ifconfig(8)` *`options`* as needed.

Even a very simple configuration will get a machine on the network. The following configures `em0` with the IPv4 address 192.0.2.2 and netmask 255.255.255.224. It also has the IPv6 address of 2001:DB8:7700::2/64.

```
$ cat /etc/hostname.em0
inet 192.0.2.2 255.255.255.224
inet6 2001:DB8::2 64
```

Anything that doesn't follow these IPv4 and IPv6 formats is passed directly to `ifconfig`. However, if you don't know if a particular configuration will work, try it at the command line first.

#### Dynamic Configuration

When performing dynamic configuration, if the machine is an IPv4 DHCP client, use the string `dhcp` in *hostname.if*. For IPv6 autoconfiguration, use the string `rtsol`, by itself on a single line, to tell OpenBSD to use the `rtsol(8)` IPv6 autoconfiguration program.

```
$ cat /etc/hostname.em0
dhcp
rtsol
```

In order for IPv6 autoconfiguration to work, you must disable IPv6 routing with these two entries in */etc/sysctl.conf*:

```
net.inet6.ip6.forwarding=0
net.inet6.ip6.accept_rtadv=1
```

These values already exist in */etc/sysctl.conf*, but they're commented out.

### Setting a Default Gateway

To set either the IPv4 or IPv6 default gateway, place the gateway IP address on a single line in */etc/mygate*, with no other entries in the file. You can configure default gateways for both protocols, each on its own line. The change should take place on your next reboot, or use `route(8)` to manually change the default gateway. The following sets both an IPv4 and an IPv6 default gateway.

```
192.0.2.1
2001:DB8::1
```

Dynamic configuration requires setting a default route. If your */etc/hostname.if* file contains a dynamic configuration statement, */etc/mygate* will not be used for that IP protocol.

### Setting Name Service Servers

If you want to contact other machines by hostname, you need to set Domain Name Service (DNS) servers.

Chapter 12 covers DNS resolution in detail, but */etc/resolv.conf* contains the basic client settings. Its first line defines the local domain with the `domain` keyword and a domain name. Name servers appear on subsequent lines, defined with the keyword `nameserver` and an IP address, as shown here:

```
domain blackhelicopters.org
nameserver 192.0.2.1
nameserver 192.0.2.3
```

## Mail Aliases and Status Mail

Every OpenBSD system runs maintenance tasks daily, weekly, and monthly, and sends email messages with the results to the local root account. I discuss these maintenance jobs in Chapter 15. If you have more than a couple of servers, you should probably forward these email messages to a single central account.

The OpenBSD system redirects email messages addressed to local users to other users or remote email addresses, as configured in */etc/mail/aliases*. Here are a few entries:

```
...
# Basic system aliases -- these MUST be present
MAILER-DAEMON: postmaster
postmaster: root
...
```

The original recipient appears on the left, followed by a colon, and a list of people to forward the messages to. If you have multiple recipients separate them with commas. Mail addressed to MAILER-DAEMON on the local system is forwarded to the postmaster account, which, in turn, is forwarded to the root account.

You should create an alias for root, directing mail sent to root to your systems administration team:

```
root: mwlucas@bigcompany.com, sysadminstaff@bigcompany.com
```

After changing */etc/mail/aliases*, run `newaliases(8)` to update email forwarding.

## Keyboard Mapping

OpenBSD tries to guess your correct keyboard mapping. USB keyboards have mechanisms to declare their country code. If autodetection doesn't work, you can change the keyboard layout with `kbd(8)`, and set it at boot with */etc/kbdtype*.

Before touching the keyboard layout, use `kbd` to find your current keyboard map. `kbd -l` lists the more than 100 keyboard encodings OpenBSD supports. Browse the list for your supported keyboard layout, or use `grep` to reduce the list. I'm a Dvorak user, so I search for it like this:

```
# kbd -l | grep dvorak
fr.dvorak
us.dvorak
...
```

My preferred layout is `us.dvorak`. I enter **`us.dvorak`** in */etc/kbdtype*, and after my next reboot, the console should use the Dvorak layout.

To set the keymap immediately to Dvorak, I could use `kbd`:

```
# kbd us.dvorak
kbd: keyboard mapping set to us.dvorak
```

Read more about changing the console in Chapter 17.

## Installing Ports and Source Code

If you intend to build your own OpenBSD releases or heavily customize OpenBSD, you'll need the operating system source code (see Chapters 18, 19, and 20). If you intend to build your own packages (covered in Chapter 13), you'll need the ports tree. Both the ports tree and the system source code are specific to an OpenBSD release, and if you need them, install them when you install the system.

The ports tree is the compressed file *ports.tar.gz* in the release directory where you stored OpenBSD—either on the mirror site or the CD. All architectures share one ports tree. Download this file to your home directory and extract it in */usr*.

```
# cd /usr/
# tar -xzvf $HOME/ports.tar.gz
```

This extracts the ports tree to */usr/ports*.

The system source code is found in three files in the release directory: the kernel source code *sys.tar.gz* (see Chapter 19), userland source code *src.tar.gz* (see Chapter 20), and the Xenocara *xenocara.tar.gz* (see Chapter 20). Extract Xenocara to */usr*, and the others to */usr/src*.

## Booting to a Graphic Console

OpenBSD boots into a text console by default. To boot into an X-based graphic console, use the `xdm(1)` command in */etc/rc.conf.local*. The default `xdm` setting is `NO`, so by changing it to empty quotes you enable it.

```
xdm_flags=""
```

If you need a more complicated `xdm` setup, put any command-line arguments inside the quotes.

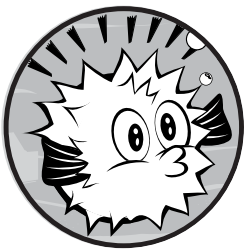
## Onward!

Armed with the information in this chapter, you should be able to get your system on your local network and make it at least minimally comfortable to work with. Next, let's take a look at the OpenBSD boot process.

# 5

# THE BOOT PROCESS

*Single-user mode*
*unscheduled in the nighttime?*
*Something just went "boom"!*



In order to properly manage any computing platform, you must understand the boot process. Many systems administration tasks cannot be done while the system is running. OpenBSD specifically requires that certain tasks be done before the boot process has completed. And, of course, on any operating system, sometimes a process starting up prevents the system from completing its boot. The only way to fix these problems is to interrupt the boot partway through.

First, we'll look at the key to OpenBSD's booting process: the boot loader. Then we'll move on to single-user mode, and finally multiuser startup. You can perform useful work at any of these stages.

I recommend playing with the OpenBSD boot process on a test machine *before* one of your machines won't boot. That way, when something breaks in the wee hours of the morning, you can spend your time fixing the problem instead of fumbling around with unfamiliar commands.

## Power-On and the Boot Loader

In general, when a PC-style computer first boots, it starts the BIOS. The BIOS is a small piece of software that figures out things like which drives are attached and what they're attached to, what sort of CPU is installed, and how much memory is available. After getting that information, the BIOS loads a minimal boot loader from some kind of storage device.[1]

The *boot loader* is a small program that handles initial system configuration and boots the kernel. It finds and starts the kernel, which in turn detects hardware, attaches device drivers, and performs other core setup. Finally, the kernel calls `init(8)`, which starts processes and enables user programs, network interfaces, server software, and so on.

While most of this process cannot be managed—no one actually configures `init`!—there's plenty you can do before the system finishes booting and dumps you at the login screen.

The OpenBSD boot loader lets you interrupt the boot process, configure the system before it boots, adjust kernel settings, and even boot an alternate kernel.

When the hardware hands control of the boot process over to the OpenBSD partition, you'll see the boot loader prompt, which looks something like this:

```
>> OpenBSD/amd64 BOOT 3.18
boot>
```

The boot loader's main purpose is to find the kernel, load it into memory, and start it. Because it runs before the kernel starts, the boot loader can pass instructions to the kernel itself.

Here are some of the things you can do before booting is complete:

**Use built-in help**

Use the `help` function to print a brief list of commands that the boot loader supports.

```
boot> help
commands: # boot echo env help ls machine reboot set stty time
machine: boot diskinfo memory
```

**Delay the boot process**

By default, the loader waits five seconds for instructions, and then boots the kernel. To pause the boot at the prompt, press the spacebar.

**Set the boot timeout**

To set a new boot idle timeout, specify a number of seconds with the `set timeout` command.

1. On i386 and amd64 systems, this is where the MBR comes in.

```
boot> set timeout 10
```

After the boot prompt is idle for 10 seconds, the system should boot.

**Boot the system**
If you've paused the boot process, the system won't boot until you tell it to. When you're ready to boot, use the `boot` command:

```
> boot
```

We'll use various permutations of `boot` to configure the kernel, boot single-user mode, and so on. I'll cover other boot commands in the appropriate sections. For full details on what you can do at the boot loader prompt, read the `boot(8)` man page.

## Booting in Single-User Mode

Single-user mode is the earliest point when OpenBSD can give you a Unix-style shell prompt. At this point, the kernel has probed all the hardware, attached drivers to all the hardware that it's going to acknowledge, and started `init`. The system hasn't mounted any filesystems except for the root partition, which is mounted in read-only mode. The network isn't started, no services are running, security is not implemented, and filesystem permissions are ignored.

To boot OpenBSD in single-user mode, enter **`boot -s`** at the loader prompt.

```
boot> boot -s
```

Why would you want to boot into single-user mode? If your computer has a problem that is preventing it from booting, you should be able to access single-user mode and fix the problem. Suppose a failed disk is preventing the system from booting during a multiuser boot, or you changed your terminal settings in */etc/ttys* and now you can't log on to the system. Or maybe you put a daft setting in *rc.conf.local*, and the boot process hangs because it's trying to do something impossible. At times like these, single-user mode is your best friend.

Also, some system administration tasks, such as clearing filesystem flags (see Chapter 8), can be done only in single-user mode.

### *Mounting Disks in Single-User Mode*

Usually, you should have a fully functional filesystem before doing anything in single-user mode. If your system crashed, be sure to check the integrity of your filesystems before mounting them:

```
# fsck -p
/dev/sd0a (e4bf0318329fe596.a): file system is clean; not checking
```

```
/dev/sd0h (e4bf0318329fe596.h): file system is clean; not checking
...
# mount -a
```

`fsck` and `mount` have many more options. We'll cover them in more detail in Chapter 8.

Once you've mounted all of your filesystems, all usual command-line software should be available. You should be able to edit configuration files, start and stop programs, and generally do whatever you like to the system (including destroy it).

### Starting the Network in Single-User Mode

Use the shell script */etc/netstart* to configure the network while in single-user mode. (You could run all the appropriate commands by hand, but */etc/netstart* will read your system's configuration files and do the grunt work for you.) You must explicitly run this script through `sh`:

```
# sh /etc/netstart
```

If you're booting into single-user mode because of network problems, this script will conveniently reproduce the issue for you.

## Booting an Alternate Kernel

As we'll cover in tedious detail in Chapter 18, you *can* configure the OpenBSD kernel, but before you do so, be sure that you can boot alternate kernels. You'll need to be able to boot a different kernel if, say, you hose your filesystem so badly that it won't even boot to single-user mode, and you need to recover using the installation kernel.

### Booting a Different Kernel File

An OpenBSD installation includes three kernels out of the box: the single-processor kernel */bsd*, the multiprocessor kernel */bsd.mp*, and the upgrade and install kernel */bsd.rd*. (If your machine has multiple processors, the installer renames */bsd* to */bsd.sp* and */bsd.mp* to */bsd*.)

To boot a nonstandard kernel, first reboot and interrupt the boot process at the boot loader prompt. Run `boot`, and give the full path to the kernel you want to boot:

```
boot> boot /bsd.rd
```

This will start the system using your chosen kernel. You can use other boot options as well, such as booting the alternate kernel in single-user mode:

```
boot> boot -s /bsd.sp
```

This will let you recover from a bad kernel, try a new kernel, or anything in between.

### Booting from an Alternate Hard Disk

Suppose you've really fouled everything up beyond all recognition, and you don't have a usable kernel on your root partition. Fortunately, if you have a usable kernel on a different hard drive, you can boot from that. (Usually, this kernel lives on an alternate root partition, */altroot*, as discussed in Chapter 8.) In this section, I'll break the task of booting from that alternate kernel into a few steps: finding the hard disk with the partition, finding the partition with the file, and booting the right file on that partition.

#### Finding the Disk

Once you're familiar with OpenBSD, you may begin to think of the hard drives in your system by their device names, such as */dev/sd0*, */dev/wd1*, and so on. Unfortunately, those are the kernel's names for the disks; the boot loader recognizes only the BIOS's disk names.

To ask the boot loader about disks, use the `machine diskinfo` command:

```
boot> machine diskinfo
Disk    BIOS#   Type    Cyls    Heads   Secs    Flags   Checksum
fd0     0x0     *none*  80      2       18      0x4     0x0
hd0     0x80    label   1024    255     63      0x2     0x51db843d
hd1     0x81    label   1024    255     63      0x2     0x9329b723
hd2     0x82    label   1024    255     63      0x2     0xcfadb343
boot>
```

Here, the boot loader has found four disk devices. The first, `fd0`, is a floppy disk drive. This drive might or might not have a disk in it, but whatever it has, it's almost certainly not your alternate kernel. (It might be an installation disk, though, so don't automatically rule out using it for disaster recovery.)

The other three devices—`hd0`, `hd1`, and `hd2`—are hard disks. The first, `hd0`, is the default system boot disk. If you can't boot from that disk, you need to find the hard disk that contains your kernel.

#### Finding the Partition

Vague stirrings of memory in this output lead me to think that `hd2` might be the disk that holds my backup root partition. To try it, tell the loader that disk partition `hd2a` is the new root partition:

```
boot> set device hd2a
```

Before trying to boot from this partition, look at its contents:

```
boot> ls
stat(hd2a:/.): Invalid argument
boot>
```

Apparently, disk `hd2` has no partition `a`. After service is restored, I'll take this disk out behind my garage and beat its weakness out of it. For now, let's try the only remaining disk, `hd1`.

```
boot> set device hd1a
boot> ls
drwxr-xr-x 0,0  512     .
drwxr-xr-x 0,0  512     ..
drwxr-xr-x 0,0  512     altroot
drwxr-xr-x 0,0  512     home
drwxr-xr-x 0,0  512     tmp
...
```

This looks like an actual root partition (`altroot` offers a hint).

### Booting the Kernel

At this point, we could boot a different kernel, but we'll just boot the */bsd* kernel on this partition in single-user mode, because the filesystem table would have the incorrect entry for the root filesystem, which would mess up all sorts of stuff.

```
boot> boot -s
booting hd1a:/bsd: 5669864+1601484+935608+0+617568 [89+499848+323884]=0xd351b8
...
```

Alternatively, you could give the device name at the boot prompt:

```
boot> boot -s hd1a:/bsd
```

As a general rule, you should mount the actual root partition on */mnt*, make the necessary changes for normal operation, and reboot into the proper root partition. You could also boot the */bsd.rd* kernel, giving you a cleaner boot at the cost of having fewer tools available.

## Making Boot Loader Settings Permanent

To make boot loader options permanent, edit */etc/boot.conf*. The boot loader reads and runs entries from this file before giving you the `boot>` prompt, which means you can use it to automatically run boot loader commands every time your computer boots. (Although if you would rather sit at your computer and enter your settings every time you reboot, don't let me stop you.)

Any command you might give at the loader prompt is a valid *boot.conf* entry. For example, if the default boot speed is too slow for your liking, you can set your boot timeout to two seconds by adding this line to *boot.conf*:

```
set timeout 2
```

You can also tell the system to boot a different kernel with the correct *boot.conf* command.

```
set image /bsd.mp
```

By far, *boot.conf* is most often used to configure a serial console.

## Serial Consoles

All of these nifty boot functions let you do useful stuff when your system is in trouble, but how can you use them when your computer isn't right in front of you? If your computer is in a data center on the other side of the country, or sitting in the basement behind the last decade of payroll records, a serial console will make your life far more pleasant.

A hardware serial console allows you to run a serial cable between a computer and a terminal server (on another computer) to access BIOS messages and operating system boot and startup messages which simplifies managing remote systems. Serial consoles are invaluable when debugging system crashes, too; error messages come over the serial port, where you can easily capture them.[2]

True UNIX hardware has serial console capabilities, as does most server-grade i386 and amd64 hardware. Most desktop-grade hardware, however, does not. But fortunately, even if you don't have a hardware serial console, you can access all of OpenBSD's startup messages with a serial port and a software serial console. While OpenBSD's software serial console won't give you access to the hardware BIOS, it will let you interface with the boot loader and remotely access the system console, even when the network is down.

### Other Platform Serial Consoles

Every hardware platform has its own standards for serial consoles. If you're running a less common platform, check your hardware's documentation.

If your hardware supports a real serial console, you should usually configure it in the BIOS. OpenBSD supports whatever the hardware supports, so your Sparc64 hardware will support OpenBSD's serial console just as well as it supports any other operating system's serial console.

### Serial Console Physical Setup

A serial console requires a null modem cable, which you should be able to get from any computer store or an online vendor. While gold-plated cables aren't worth the money, don't buy the cheapest cable you can find either. If you have an emergency and need the serial console right *now*, you won't be in the mood to deal with a defective cable.

2. Granted, a remote keyboard-video-mouse (KVM) system can give you all of this, but very few KVM applications let you copy and paste text from the remote console. That means you'll need to copy error messages by hand.

Plug one end of the null modem cable into your OpenBSD machine's first serial port. (The serial console is supported on only the first serial port, or `com0` on i386 and amd64 hardware.) Plug the null modem cable's other end into an open serial port on another system. (For simplicity's sake, use either another OpenBSD or Unix-like system.)

If you have two OpenBSD machines at a remote location and you want to use serial consoles on both, you can have each machine act as the console client for the other. Attach the first serial port on each server to the second serial port on the other. If you have three machines, you can daisy-chain them in a loop. If you have four or more machines, pick up a used terminal server from your favorite auction site.

You can also use two DB9-to-RJ45 converters, one standard and one crossover, which will allow you to run your console connections over a standard CAT5 cable. If you have a lights-out data center where human beings are forbidden unless they are installing or removing equipment, you can stretch your serial console cables about 12 meters, which should reach into your warm room. (Most modern data facilities are better equipped to handle CAT5 cables than serial cables.)

## Serial Console Configuration

Now that you have the console physically ready, the next step is to configure your client to access the serial console. Then you can set up the serial console.

### Configuring the Serial Console Client

The following are the default settings for an OpenBSD i386 or amd64 system:

- 9600 baud
- 8 bits
- No parity
- 1 stop bit

Enter these values into any terminal emulator on the client computer, and the serial console should Just Work. You can find terminal emulators for Microsoft platforms (I recommend PuTTY), OS X, and just about any other operating system.

OpenBSD includes the terminal emulator `tip(1)`, which reads its configuration from */etc/remote*. The configuration `ttyOO` in */etc/remote* matches the default OpenBSD serial console configuration for i386 and amd64 systems (as well as several other platforms). If you've attached your null modem cable to the first serial port on the client, connect with this command:

```
# tip ttyOO
connected
```

If it doesn't say `connected`, your serial client is misconfigured. Fix your client before enabling your serial console on the server. You want your serial client ready before configuring the console.

#### Setting Up the Serial Console

OpenBSD normally uses the local physical keyboard, video, and mouse as the console, but it can also use the first serial port as a serial console.

To set the console, use the boot loader. You must know the loader's device name for your preferred console: `com0` for the first serial port or `pc0` for the physically attached video and keyboard.

The first time you try to use a serial console, use a local test machine. Set up your client beforehand and start your terminal emulator, and then boot your test machine. At the boot loader prompt, enter this command:

```
boot> set tty com0
```

Your server's monitor and keyboard should stop responding, and if you've set up everything correctly, you should see the boot loader prompt in your terminal emulator.

To switch back to the physical console, tell the boot loader to use the `pc0` device:

```
boot> set tty pc0
```

Poof! The server's keyboard and monitor should work again.

To have your machine use the serial console at every boot, add this statement in */etc/boot.conf*:

```
set tty com0
```

Be sure to test your serial console after the machine is installed in its permanent location, and always screw the serial cables to the server. A loose serial cable provides only a comforting illusion that betrays you when it will hurt the most.

#### Testing the Serial Configuration

After configuring your serial console, return to your serial client and press ENTER. You should see something like this:

```
OpenBSD/amd64 (caddis.blackhelicopters.org) (tty00)

login:
```

### Changing the Serial Console Speed

Newer serial ports (meaning anything made within the past 10 years) can run at speeds far above 9600 baud. I have servers with serial consoles that

run only at 115,200 baud. The BIOS messages display at 115,200 baud, but then the OpenBSD console runs at 9600 baud. My client displays one or the other as gibberish. (A lot of OpenBSD folks think that anything that won't do serial at 9600 baud is broken, but you won't always have control over the hardware you work with.)

To use these ports, I can either change my connection speed in my serial console client when switching between the BIOS messages and the OpenBSD messages, or change the speed of my OpenBSD console to match the hardware.

At the boot loader, tell the serial console to run at 115,200 baud:

```
boot> stty com0 115200
boot> set tty com0
```

If these settings work, copy them to */etc/boot.conf*.

Now configure your serial client. Modify `tip` to use the higher speed. First, find the entry for `tty00` in */etc/remote*:

```
tty00|For hp300,i386,mac68k,macppc,vax:\
        :dv=/dev/tty00:tc=direct:tc=unixhost:
```

But don't modify this entry! We'll use it to illustrate the style of */etc/remote* entries.

**NOTE** /etc/remote *is designed much like a* `termcap(5)` *database. If you ever need to write your own* `termcap` *entries from scratch, you're living your life wrong. But you can recognize the contents and modify existing entries without much pain. If you really want to learn everything about these entries, read the* `remote(5)` *man page.*

Backslashes (`\`) in this entry mean "continued on the next line." Colons separate fields. Each line after the first must start with a colon, and each field is a key/value pair.

Now, to create a console entry that runs at 115,200 baud, use the following:

```
console:br#115200:tc=tty00:
```

The first field in an */etc/remote* entry is the name, and every entry must have a unique name. I named this entry `console`. The second field is the `br` value. According to `remote(5)`, `br` stands for bit rate. I've set the bit rate to 115,200 baud. The third field is `tc`, for "table continues," which is equal to `tty00`. This means that the description of this entry continues in entry `tty00`.

Taken as a whole, this entry means "copy the `tty00` entry, and add a bit rate of 115,200."

### Changing the Client Serial Port

If you have two OpenBSD machines, each sending its serial console out its first serial port to the other machine's second serial port, you must tell `tip`

to connect to the second serial port. The command `tip tty00` doesn't actually connect to the serial port named `tty00`—it connects to a port defined by the */etc/remote* entry named `tty00`. That means that you can't run, say, `tip tty03` and connect to serial port tty03 unless you have an */etc/remote* entry named `tty03`. By default, there isn't one, but you can define one easily, as follows:

```
tty03:dv=/dev/tty03:tc=tty00:
```

This entry is named `tty01`. The `dv` setting tells */etc/remote* the physical device to use. Other than this, all settings are copied from the entry called `tty00`.

With these examples, you should be able to use OpenBSD's `tip` to connect to almost any serial console.

### Serial Logins

The serial console lets you interact with the boot process. Once your machine is fully multiuser, however, a default serial console will not let you actually log in to OpenBSD. In multiuser mode, OpenBSD uses `getty(8)` to initialize terminals and handle logins, and in order to log in to your machine over a serial port, you will need to tell `getty` to take charge of the serial line by configuring */etc/ttys*.

We'll discuss */etc/ttys* further in Chapter 14, but for now, here's how to allow logins over the first serial port. Find the entry for `tty00`, which should look like this:

```
tty00   "/usr/libexec/getty std.9600"   unknown off
```

Remove the last two words, and replace them to match the following:

```
tty00   "/usr/libexec/getty std.9600"   vt220    on secure
```

Now run `kill -1 1`, and you should get a login prompt over your serial line.

## Multiuser Startup

When the kernel finishes its core setup and hands control over to userland, `init(8)` runs the shell script */etc/rc*. This script handles all system setup, including mounting filesystems, configuring device nodes, identifying shared libraries, and any other task required to make the system usable. Some tasks are delegated to separate scripts; for example, */etc/netstart* is used to configure the network.

In this section, we'll cover how */etc/rc* and other startup scripts function, and the flow of the startup process. Armed with this understanding, you should be able to easily configure your OpenBSD machine to start exactly what you need—no more, no less.

## Startup System Scripts

The startup system includes the scripts */etc/rc*, */etc/rc.conf*, */etc/rc.conf.local*, */etc/netstart*, */etc/rc.securelevel*, */etc/rc.local*, */etc/rc.shutdown*, */etc/rc.firsttime*, */etc/fastboot*, and the contents of the */etc/rc.d* directory.

### The /etc/rc Script

On OpenBSD, everything outside the kernel is configured with a shell command, from setting the hostname to starting server daemons. The master script is */etc/rc*, and it runs all of these commands in the correct order, ensuring that the system is configured exactly the same way at every boot. As a final step, */etc/rc* runs `getty(8)` to present login prompts on all the appropriate terminals.

Never edit */etc/rc* unless you're a very experienced systems administrator with truly unique needs. This is one of the several files in */etc* that is technically editable, but mere mortals are well advised to *treat as binary*. Instead, whenever you need to disable functions, deactivate them in */etc/rc.conf.local*. To add new functionality to the startup process, use the shell scripts */etc/rc.securelevel* and */etc/rc.local,* or write a shell script for */etc/rc.d*.

### The /etc/rc.conf Script

The */etc/rc.conf* file contains nothing but the default values for all other startup scripts. Read this file to see the configuration options for different system services. Here's a small snippet of what you'll find in *rc.conf*:

```
...
bgpd_flags=NO           # for normal use: ""
rarpd_flags=NO          # for normal use: "-a"
bootparamd_flags=NO     # for normal use: ""
rbootd_flags=NO         # for normal use: ""
sshd_flags=""           # for normal use: ""
named_flags=NO          # for normal use: ""
...
```

If a variable is set to `NO`, the associated service is disabled by default.

As you can see, OpenBSD turns off almost everything by default, with one exception: the SSH daemon. Setting the variable to a pair of quotes, as shown after each entry in the preceding snippet, is enough to enable most daemons, and most daemons will run just fine without any command-line flags. However, if a daemon requires a command-line argument in order to run, that argument will be shown as it is in the `-a` attached to `rarpd_flags`.

**NOTE** *At the risk of beating my dead server senseless, never edit* /etc/rc.conf *(treat as binary—remember?). It will be replaced wholesale during a system upgrade. Instead, place your local values in* /etc/rc.conf.local.

### The /etc/rc.conf.local Script

I've mentioned this before, but I'm going to beat you over the head with it: Place your changes to *rc.conf* in *rc.conf.local*. Entries in *rc.conf.local* override the defaults in *rc.conf*.

For example, say that on a particular machine, you want to run `sshd(8)` with extra debugging, and you also want to run `named(8)`. Additionally, you want to run the time server `ntpd(8)`, and have it correct the time at boot by using the `-s` flag. After consulting the documentation for those programs, you add the following lines to *rc.conf.local*:

```
sshd_flags="-D"
ntpd_flags="-s"
named_flags=""
```

OpenBSD will start the programs with the flags specified here. If you specify invalid, incorrect, or incompatible flags, the daemon will print error messages to the console.

### The /etc/netstart Script

While its name differs from the other scripts, */etc/netstart* is definitely a system startup script. It reads */etc/mygate*, */etc/myname*, and all the */etc/hostname.if* files, and uses the information in them to configure all network interfaces, bridges, routing, and so forth. The file */etc/rc* runs this script before starting any server daemons, network filesystems, and so on. In single-user mode, you'll run this script by hand to bring up the network.

### The /etc/rc.securelevel Script

The */etc/rc.securelevel* shell script runs early in the boot process, before */etc/rc* raises the system securelevel, but after starting the network. Many programs, particularly those that touch the kernel or intimately affect the filesystem, will not run once the securelevel is raised. If you run such a program, you can add the command to start it to this script. If your local program doesn't need to run before the system securelevel is raised, you're better off starting it from *rc.local* or writing a proper *rc.d* script for it.

One important entry in *rc.securelevel* is the definition of the system securelevel. We'll discuss securelevels in Chapter 10. For now, don't touch the line that sets the securelevel unless you're already familiar with BSD-based systems and know exactly which toe you're shooting off.

### The /etc/rc.local Script

After */etc/rc* does just about everything else, it runs */etc/rc.local*. You can put commands to start local daemons in *rc.local*, but you're better off writing an *rc.d* script to start local daemons so you can easily and consistently restart them later. Of course, if you're lazy, you can get by with *rc.local*.

### The /etc/rc.shutdown Script

Whenever you use `reboot(8)` or `halt(8)`, OpenBSD runs the */etc/rc.shutdown* script, which you can count on to run extra commands needed to safely shut down your server. Most server software shuts down cleanly without any special intervention, but software that requires data integrity (like databases) may need help shutting down without losing data. Again, if at all possible, write an *rc.d* script to manage your software.

### The /etc/rc.firsttime Script

*/etc/rc* runs the script */etc/rc.firsttime* once, mails the output to root, and deletes *rc.firsttime*. The installer uses *rc.firsttime* for tasks such as fetching firmware that can't be legally redistributed. While you won't normally use *rc.firsttime*, you should know that it exists and that you can use it to perform one-time tasks when a machine boots.

### The /etc/fastboot Script

If the */etc/fastboot* file exists, OpenBSD assumes that all filesystems are clean (see Chapter 8), and the boot process skips checking filesystem integrity.

### The /etc/rc.d Directory

The */etc/rc.d* directory contains shell scripts for managing software, as discussed in the next section. While the system comes with scripts for software included in OpenBSD, add-on packages can provide their own scripts (see Chapter 13).

## *Software Startup Scripts*

OpenBSD uses shell scripts to start, stop, restart, check, and reconfigure server software. These scripts are found in the directory */etc/rc.d*. Every piece of server software that comes with OpenBSD has a script in this directory, as do most ports and packages that need scripts for proper startup and shutdown. Use these scripts to manage integrated software without rebooting the server.

The *rc.d* scripts read their configuration from *rc.conf* and *rc.conf.local*. Most servers run the SSH daemon `sshd`, which can be enabled by adding the line `sshd_enable=""` to *rc.conf.local*. Look in */etc/rc.d*, and you'll find the shell script *sshd*.

If you change your `sshd` configuration, you must restart the daemon. Use the shell script to do this consistently.

```
# cd /etc/rc.d/
# ./sshd restart
sshd(ok)
sshd(ok)
```

Of course, you could do the same thing without the shell script simply by identifying the currently running `sshd(8)` process, reading the man page

to see how to shut it down properly, and then restarting it with the same command-line flags. In the case of `sshd`, that's easy: Running `pkill -1 sshd` would tell the daemon to reread its configuration file. But restarting a daemon that requires all sorts of flags *is* a big deal. Automating these system administration tasks ensures that your daemons run consistently.

To see if a daemon is running, use the `check` command to check your shell for the return value. The script will return a `0` if the daemon is running and a `1` if it isn't, as shown here:

```
# ./nfsd check
# echo $?
1
```

As you can see by the `1`, `nfsd` is not running.

The most common use for `check` is in shell scripts. You can start the daemon with the argument `start` and terminate it with `stop`. Use the `restart` argument to tell the daemon to reload its configuration.

In OpenBSD, *rc.d* scripts run when the system boots and again when it shuts down. (Something needs to unmount all those hard drives, shut down daemons, and clean up.) At shutdown, every script in the */etc/rc.d* folder is called with the `stop` argument.

### Third-Party rc.d Scripts

OpenBSD packages for third-party software include *rc.d* scripts as necessary. For example, the popular database server MySQL `mysql-server` package installs the script */etc/rc.d/mysqld*. To use the package, you must enable it in *rc.conf.local*:

```
mysqld_flags=""
```

Once the package is enabled, you can manage your MySQL server just like any other OpenBSD daemon. However, packaged software will still not start automatically at boot, so you must tell OpenBSD to run this particular *rc.d* script at boot and shut down with the `pkg_scripts` variable in *rc.conf.local*:

```
pkg_scripts="mysqld"
```

The startup process runs the scripts in this variable, in the order given, at boot. The order is important for certain daemons. For example, if you have a database-driven website, you should start the database before the web server. At shutdown, it runs these scripts in reverse order.

### Force-Starting Software

Sometimes you don't want to enable software globally; you just want to run a certain daemon for a short time or to address a specific situation. You can use *rc.d* scripts to manage this software using the `-f` flag to force the software to run.

Now for a real-life example. I previously ran PostgreSQL on my server, but someone kidnapped my pet rats and blackmailed me into using MySQL in exchange for their safe return. I needed to check some data in the old database, however, so I force-started the disabled PostgreSQL server:

```
# ./postgresql -f start
postgresql(ok)
```

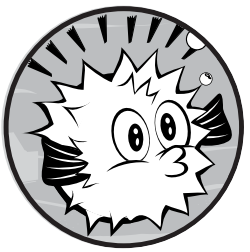
If you package or install your own software, I strongly recommend writing your own *rc.d* script. A few minutes spent reading the existing scripts will tell you most of what you need to know. For the rest, read the `rc.d(8)` and `rc.subr(8)` man pages.

Now that you can start OpenBSD, let's set up some user accounts.

# 6

# USER MANAGEMENT

*This one can log in,*
*this other can get email;*
*never give out root.*



While computer intrusions over the Internet make headlines, a system administrator's greatest security threats often come from a system's own users. Maybe they won't ship your data to a crime syndicate, but disgruntled and incompetent users will crash your servers given the chance—sometimes out of malice, but more often out of ignorance. Think about security as the combination of confidentiality, integrity, and availability, and it will immediately become clear how users with unrestricted system access can damage security.

Despite what you might have learned from the Bastard Operator from Hell, the system exists for the users, and proper management of those users' accounts is absolutely necessary. In this chapter, we'll cover one of the systems administrator's most common tasks: managing users by adding, removing, configuring, and modifying user accounts.

## The Root Account

In recent years, there has been a trend toward using the privileged root account for everyday tasks on systems that have only a single user.[1] Using a privileged account to read your email and browse the Web increases your risks from both user errors and malicious attacks. While a careless keystroke by a regular user will generate only a `permission denied` error, that same keystroke by root might render your system unusable and destroy all your data. Even if you're the only person using your OpenBSD system, you must use an unprivileged user account for day-to-day tasks.

If an intruder compromises an unprivileged account, the potential damage is limited only by that user's permissions. If the compromised account handles your email and web bookmarks, you might suffer only personal embarrassment. But if that account handles system administration tasks, your intruder can inflict unlimited system damage and send you scurrying for your backup. Using a regular account for day-to-day tasks means that you can take extra steps to restrict the root account.

Perform all tasks with the minimum level of privilege necessary. If you don't need root access to perform a task, don't use it! For example, OpenBSD's web server runs as the specific user `www`, rather than as root. If an intruder breaks into your web server and gains access your system as the `www` user, he can damage only the files the `www` user has permission to write to. Likewise, if the web server software goes into an error state and starts deleting files at random, this same principle limits the files it can delete. The least privilege approach protects the system from both intruders and its own software.

Operating systems that give every user privileged access have more problems as a result. Virus effectiveness, unexpected misconfiguration, and even crashes can be traced back to unnecessary privileged access. OpenBSD might be the most secure operating system in the world, but all those fancy security features can't protect you from poor system administration practices.

Using the root account for routine tasks also creates bad habits. People under pressure perform what they practice. If you use root on your desktop for routine work, you'll need to fight your habits to perform routine tasks when you work on a production server. This sort of sloppiness inevitably breeds security problems. Even on my OpenBSD desktop, where I'm the only user, I do everything as a regular user specifically to develop and maintain good sysadmin habits.

## Adding Users

OpenBSD uses many of the standard UNIX user- and password-management programs, such as `passwd(1)` and `vipw(8)`. It also includes

1. This probably leaked through from the Microsoft culture, where for many years, every user had administrative access.

a friendly interactive user-creation program, adduser(8). We'll cover adduser first, and then look at some of the more advanced tools.

## Adding Users Interactively

Only the root user can run adduser. If you start adduser at the command line without specifying any options, it drops you into a friendly interactive dialog where you can create new users.

### Configuring adduser

The first time adduser runs, it asks a series of questions to determine its default settings. It saves these default settings, but you can change the defaults later.

```
# adduser
Couldn't find /etc/adduser.conf: creating a new adduser configuration file
Reading /etc/shells
Enter your default shell: csh ksh nologin sh tcsh [ksh]: ❶
Your default shell is: ksh -> /bin/ksh
Default login class: authpf bgpd daemon default staff
[default]: ❷
Enter your default HOME partition: [/home]: ❸
Copy dotfiles from: /etc/skel no [/etc/skel]: ❹
Send welcome message?: /path/file default no [no]: ❺
Do not send message(s)
Prompt for passwords by default (y/n) [y]: ❻
Default encryption method for passwords: auto blowfish des md5 old
[auto]: ❼
```

adduser first asks for your preferred default shell. It reads */etc/shells* to see all the shells installed on your system. Though I've long used tcsh, I usually start new users with the OpenBSD standard of ksh ❶. That way, they have a shell that more closely resembles what is used by the rest of the world, and they quickly learn that I cannot answer questions about their shell.

Next, adduser asks for your default login class. I'll cover login classes later in this chapter. For now, assign new users to the default login class at ❷.

If you have a default OpenBSD installation, your user home directories are on the */home* partition. If not, specify the default home directory at ❸.

User accounts need configuration dotfiles (*.shrc*, *.login*, *.profile*, and so on). If you have a directory containing customized dotfiles, tell adduser about it at ❹. Otherwise, just accept the default.

Though OpenBSD doesn't include a welcome message by default, you can put one on the system so new users will have an email waiting for them on their first login. Give adduser the full path to the file containing your welcome message at ❺.

Depending on how you create user accounts, you might want to provide a password when you create the user account. Accounts created without passwords are disabled until a password is assigned. If you won't be assigning passwords when creating accounts, you can tell adduser not to prompt you for them at ❻.

Finally, you can choose the encryption algorithm used to hash user passwords, which are stored in */etc/master.passwd*. Unless you have specific interoperability needs or otherwise know what you're doing, accept the default at ❼.

From now on, `adduser` will use these chosen defaults. If you want to modify the defaults later on, change them in */etc/adduser.conf*. Read the `adduser(8)` man page for a complete list of configuration file options.

### Creating User Accounts

Now that you've set your default options, run `adduser` again to create user accounts.

Start by assigning a username. Many people are irrationally attached to particular usernames, and it's polite to ask them if they have a preference.

```
Ok, let's go.
Don't worry about mistakes. There will be a chance later to correct any input.
Enter username []: pkdick
```

Once you have a username, you'll get a chance to enter the user's real name or the account's intended purpose.

```
Enter full name []: Phil Dick
```

The shell you specify is a matter of user preference. The list of shells is taken from */etc/shells*, with the addition of the `nologin` option. Users can change their shell unless you specifically prevent that, so don't worry too much about which shell you assign.

```
Enter shell csh ksh nologin sh tcsh [ksh]:
```

Next, choose a user ID (UID) number. By default, UID numbering starts at 1000, and `adduser` uses the lowest available number. You can change this if needed to match some local standard.

```
Uid [1001]:
```

By default, new users are assigned to a group with the same name as their username. Each user can be assigned to only a single login group (or primary group), but you can assign user accounts to multiple secondary groups if needed. If you want this user to be able to use the root account, invite the user to the `wheel` group. Other common groups include `staff`, `users`, and `operator`.

```
Login group pkdick [pkdick]:
Login group is ``pkdick''. Invite pkdick into other groups: guest no
[no]: wheel
```

Choose a login class for the user. If you don't understand login classes yet, accept the default. I recommend assigning administrative users—for example, those in the `wheel` group—to the `staff` class. If you're a desktop user, you want to be in the `staff` login class.

```
Login class authpf bgpd daemon default staff [default]: staff
```

If you set `adduser` to ask for passwords, it will ask you for a password, and then ask again to confirm.

```
Enter password []:
Enter password again []:
```

Now `adduser` displays everything you selected.

```
Name:        pkdick
Password:    ****
Fullname:    Phil Dick
Uid:         1001
Gid:         1001 (pkdick)
Groups:      pkdick wheel
Login Class: staff
HOME:        /home/pkdick
Shell:       /bin/ksh
OK? (y/n) [y]: y
```

Either accept or reject the user at this point. If you accept, `adduser` will create the new user and ask if you want to create another user.

### Adding Users Noninteractively

If you need to create many users, you probably don't want to spend your day looping through `adduser` dialogs. If you have scripts, cron jobs, or web interfaces that add user accounts, you'll want to create users noninteractively. `adduser`'s `-batch` flag enables this. When you use batch mode, `adduser` takes four additional arguments: the username, the groups the username belongs to, the full name, and the password in encrypted format.

```
# adduser -batch username group 'Real Name' encryptedpassword
```

To create our user `pkdick` in batch mode, we would run this:

```
# adduser -batch pkdick wheel 'Phil Dick' NotThePassword
```

One thing to note here is that `pkdick`'s password is *not* `NotThePassword`. `adduser` expects us to provide a random salt that hashes to the string `NotThePassword`, not the password itself. For instructions on how to generate encrypted passwords, see "Passwords and Batch Mode" on page 90.

### Groups in Batch Mode

By default, new users are assigned a primary group with the same name as their login name. In batch mode, you must specify additional groups desired on the command line. Our example user `pkdick` is created with the login group of `pkdick`. If you want to set a different login group for a particular user, use the `-group` flag.

```
# adduser -group guest -batch jgballard customers 'Jim Ballard' NotThePassword
```

You'll need to add the user to another group. Here, I gave `jgballard` the login group of `guest` and added him to the group `customers`.

To assign a user to multiple groups, separate the groups using commas.

```
# adduser -batch jgballard customers,sftp-only 'Jim Ballard' NotThePassword
```

The end result here is that `jgballard` is assigned to the `jgballard` primary group and added to the `customers` and `sftp-only` secondary groups.

### Passwords and Batch Mode

If you actually follow any of the previous examples, you'll create an account with no known password. Modern Unix-like operating systems don't store passwords in readable format; instead, passwords are stored as a hash of the password and a random salt. When you assign a password to a user, the system takes the password, adds the salt, and performs some horrible computations to generate a hash of the password. The system then stores that hash and salt in the */etc/master.passwd* file. When you attempt to log in, the login process takes your password, adds the salt, and computes the hash of that combination. If the computed hash matches what's stored in */etc/master.passwd*, the login is permitted.

The examples create an account with a password hash of `NotThePassword`. Because this isn't a legitimate hash, no entered password will match it. We need to provide a pregenerated encrypted password, enter an unencrypted password, and let `adduser` calculate the hash for us, or create an account without a password.

Creating a new account without a password is the simplest option. OpenBSD will disable the account until you assign a password to it, but this is acceptable for accounts used to run daemons, or if you have a help desk staff to assist new users in setting passwords. To create an account without a password, simply omit the password from the account-creation process.

```
# adduser -batch pkdick wheel 'Phil Dick'
```

If you want to enter an unencrypted password on the command line, use the `-unencrypted` option. Put this option before the `-batch` option. For example, to give Phil's account the password `IsThePassword`, enter the following:

```
# adduser -unencrypted -batch pkdick wheel 'Phil Dick' IsThePassword
```

This account now has a password of `IsThePassword`. You might use this inside a script or when no one is around to look over your shoulder. The password will appear in the system's process list, however, so any users on the system can see the password if they're quick enough to notice.

Another option is to generate a prehashed password using `encrypt(1)`. By default, `encrypt` gives you a blank line. When you enter a word, it returns the hash of that word. It defaults to using the encryption algorithm defined in the `default` login class. (For the past several years, this has been Blowfish.) You can enter any number of words, and each will be hashed separately. Press CTRL-C to exit `encrypt`.

```
# encrypt
gerbil
$2a$06$V/VO91VVAKSNslesQNH6pezXsGhoKUMcnvWxyDOJUmWRk3fflX5cy
weasel
$2a$06$652ngShUnOBuFEL7X2yrf.EOU2GUw/FseVq/BkVgaiyqvp4wt.Nsy
^C
#
```

If you're encrypting only one password or creating passwords interactively, give the `-p` option to `encrypt`. This gives you a non-echoing password prompt.

```
# encrypt -p
Enter string:
$2a$06$nyA.mygoei/6VGS2tq4wA.VOzB6inwlK9pWOIAsiUWBkWfOCqOJ7.
#
```

### Other Batch Mode Options

I frequently create administrator accounts with one set of standards and unprivileged accounts with another. I create sysadmin accounts by hand using `adduser` in interactive mode (I don't create sysadmin accounts very often). Someone else creates unprivileged user accounts using an `adduser` batch mode script I wrote. *adduser.conf* contains the default settings for sysadmins, which I then override in the script. This approach requires less of my organic memory and ensures that unprivileged accounts are consistent.

All of these options must appear on the command line before the `-batch` argument. `adduser` treats everything after `-batch` as account information.

The `-noconfig` option tells `adduser` to not read defaults from *adduser.conf*. Using this option in a script guarantees that sysadmin-friendly defaults in *adduser.conf* don't leak into unprivileged accounts.

The `-dotdir` option specifies a directory for user dotfiles. All files in this directory are copied to the new user's home directory. I often have special dotfiles for unprivileged users.

The `-home` option tells `adduser` where to create the new user's home directory. This is not the actual home directory, but the base directory where the home directory will be created. For example, if all of your web server customers have home directories on the */www* partition, you might use `-home /www`.

To assign a nondefault login class, use the `-class` option.

The `-message` option gives a path to the new user message. To turn off a default of sending a message, use `-message no`.

To assign a shell, use `-shell` and the shell name as it appears in */etc/shells*, or `nologin` to disable logins.

Perhaps you want to assign your batch-created users UIDs in a specific range. Maybe all of your customers have a UID above 10000, while sysadmins have a UID in the thousands. Specify a minimum UID with `-uid_start` and a maximum with `-uid_end`. If available, the login group created will be given a GID equal to the UID.

### *User Account Restrictions*

User accounts are subject to the following restrictions, fully documented in `adduser(8)`.

- Usernames can contain characters (preferably lowercase) and digits, as well as nonleading hyphens, periods, underscores, and a trailing `$`. Usernames can be no longer than 31 characters.
- Full names cannot contain a colon (`:`).
- Other values must exist in the relevant files: shells must appear in */etc/shells*, login classes in */etc/login.conf*, and so on.

## Removing User Accounts

Removing unneeded user accounts is just as important as adding new ones. Use `rmuser(8)` to delete accounts.

```
# rmuser pkdick
Matching password entry:

pkdick:*:1001:1001::0:0:phil dick:/home/pkdick:/bin/ksh

Is this the entry you wish to remove? y
Remove user's home directory (/home/pkdick)? y
Updating password file, updating databases, done.
Updating group file: Removing group pkdick -- personal group is empty
 done.
Removing user's home directory (/home/pkdick): done.
```

The `rmuser` command displays the account entry from */etc/passwd*, giving you a chance to verify that you really want to delete this particular user. Read the account's real name, and verify that you're deleting the correct account. Next, `rmuser` asks if you want to delete the user's home directory. If you suspect that you might need some files from that user account, you could choose to keep the directory around for a while. It automatically deletes the user's cron jobs and incoming mail file.

## Editing User Accounts

You create users with privileges based on the knowledge you have at the time. The information you have is probably wrong, so get comfortable with editing users. In most cases, `chpass(1)` does everything you need in a user-friendly way.

Users can edit their own accounts by running `chpass` without any arguments.

```
$ chpass
$ Changing user database information for mwlucas.
Shell: /usr/local/bin/tcsh
Full Name: mwlucas
Office Location:
Office Phone:
Home Phone:
```

Here, users can update their shell or change their directory information. Many applications ignore the directory information (phone numbers and office location) stored in */etc/passwd*, but in some places, it's important. Make changes, save, and exit.

If you run `chpass` as root, giving a username as an argument, you get a very different picture.

```
# chpass mwlucas
# Changing user database information for mwlucas.
Login: mwlucas
Encrypted password: $2a$08$s2EVX.cAhYHskOaHk/4C5eLn76atAmGPU7z5DqRKAYe/V.OGgWXVi
Uid [#]: 1000
Gid [# or name]: 1000
Change [month day year]:
Expire [month day year]:
Class: staff
Home directory: /home/mwlucas
Shell: /usr/local/bin/tcsh
Full Name: mwlucas
Office Location:
Office Phone:
Home Phone:
```

Here, you can forcibly change the user's password (although there are better ways to do this), shell, UID, password expiration, and so on, in addition to all of the user's directory information.

Changes made through `chpass` affect only */etc/passwd*, */etc/master.passwd*, and */etc/group*. If you change a user's UID, GID, or home directory, you must also make the corresponding changes to the files the user owns and his home directory; otherwise, the user's account won't work correctly. If */etc/passwd* lists your home directory as */newhome/mwlucas* in */etc/passwd*, but your files are in */home/mwlucas*, you'll have trouble on your hands.

Note that you can't edit */etc/master.passwd* or */etc/passwd* with just any text editor; you need to use tools that manage the corresponding password

databases. If you insist on editing the password file by hand, you can use `vipw(8)` to directly edit */etc/passwd*. If you're not familiar with `vipw`, stick with `chpass`. The most common use for `vipw` is when the password file is damaged, and the most common way someone damages the password file is by using `vipw`.

## Login Classes

A user's shell can be used to limit what a user can do, but OpenBSD provides very specific access controls with login classes. Login classes, set in */etc/login.conf*, define the resources and information accessible to users. Login classes also let you control password length and expiration times, as well as external authentication mechanisms.

Each user is assigned to a class, and each class places limits on available resources. When you change the limits on a class, the new limits are applied to each user the next time the user logs in. Define a user's class when creating the account, or change it with `chpass`.

By default, *login.conf* offers two classes for users, one class for daemons, and a few special-case classes. The `default` user class gives the user wide-ranging access to system resources and is suitable for machines with a limited number of shell users. The `staff` user class gives the user no restrictions on memory use, sets very high limits on the number of processes a user can run concurrently, and allows the user to log in even when logins are forbidden.

If these two classes meet your needs, and if you won't be using an alternative authentication protocol like Remote Authentication Dial In User Service (RADIUS) or Kerberos, you can skip this section. If not, read on.

### Login Class Definitions

Each class definition consists of a series of variable assignments describing the class's resource limits, authentication, and environment. Each variable assignment in the class definition begins and ends with a colon. The backslash character indicates that the class continues on the next line, which makes the file more readable.

Here's the definition of the `default` class:

```
default:\
❶      :path=/usr/bin /bin /usr/sbin /sbin /usr/X11R6/bin /usr/local/bin /usr/
local/sbin:\
❷      :umask=022:\
❸      :datasize-max=512M:\
       :datasize-cur=512M:\
       :maxproc-max=256:\
       :maxproc-cur=128:\
       :openfiles-cur=512:\
       :stacksize-cur=4M:\
       :localcipher=blowfish,6:\
       :ypcipher=old:\
❹      :tc=auth-defaults:\
       :tc=auth-ftp-defaults:
```

The `default` class has several variables. Some of these have fairly obvious interpretations. For example, the `path` variable at ❶ assigns a default command search path to the user's shell, usually visible to the user as `$PATH`. The `umask` setting at ❷ assigns a default umask to the user's shell. The user can override both of these.

Other settings, such as `datasize-max` and `maxproc-max` at ❸, are harder to define by guesswork. We'll go through some of the more commonly used values in the next section.

Similar in behavior to the `termcap` `tc` variables at ❹ used to configure serial console clients in Chapter 5, the `default` class copies settings from the entries `auth-defaults` and `auth-ftp-defaults` elsewhere in *login.conf*.

Some variables don't require a value to trigger behavior; these values trigger a specified behavior simply by adding them to *login.conf*. For example, the presence of `requirehome` means that the user must have a valid home directory to log in.

### Changing login.conf

On many BSD systems, you must transform the *login.conf* file to a program-friendly database file, *login.conf.db*, with `cap_mkdb(8)`. OpenBSD doesn't require this. Programs that check login classes first look for the login class database, and if they don't find it, they directly parse *login.conf*. You can use `cap_mkdb` to create such a database, which will very slightly improve the performance of software that checks *login.conf*.

```
# cap_mkdb /etc/login.conf
```

Note that once you create this database, you must rebuild it every time you edit *login.conf*. Database values in *login.conf.db* will always override your *login.conf* settings. Alternatively, you can remove *login.conf.db* and force programs to always parse *login.conf*.

I recommend skipping `cap_mkdb` on modern hardware.

### Legal Values for login.conf Variables

The *login.conf* variables accept only very specific values, including the following:

- A full path to a text file or a program
- A comma-separated list of environment variables
- A comma-separated list of values
- A number (put a 0x in front of the number for hexadecimal, or a 0 in front for octal)
- A space-separated list of pathnames
- A size, in bytes (default), kilobytes (K), megabytes (M), gigabytes (G), or 512-byte blocks (T)
- A time in some combination of seconds (assumed if no unit is given), minutes (m), hours (h), days (d), weeks (w), or years (y)

Variables that use pathnames accept the special symbols tilde (~) and dollar sign ($). A tilde followed by a slash or the user's login name, or at the end of a pathname represents the user's home directory. You can use `~/bin` to represent a `bin` directory in the user's home directory. The dollar sign represents the username. For example, you might use `/var/mail/$` to represent the user's incoming mail file.

Some variables require particular types of values. A path to the user's home directory must be a full path, while the amount of memory a user can allocate must be a size. In most cases, legitimate answers are fairly obvious, but check `login.conf(5)` for a full listing of acceptable values.

### Setting Resource Limits

Resource limits allow you to control the amount of system resources any one user can monopolize at any one time. If several hundred users are logged in to one machine, and one user decides to compile LibreOffice, that person will consume far more than his fair share of processor time, memory, and I/O. By limiting the resources any one user can use, you can make the system more responsive for all users.

Resource limits were more commonly used back when computing facilities were very expensive and departments received bills for the amount of computing time they used. These days, utilization accounting isn't so important. It's generally cheaper to buy more computing power than it is to configure accounting or resource limits. That said, if you have a buggy daemon that sometimes leaks and starts to soak up CPU time or memory, giving it a login class can prevent it from devouring the system.

Table 6-1 lists some resource-limiting *login.conf* variables.

**Table 6-1:** Some login.conf Resource Limits

| Variable | Description |
|---|---|
| `coredumpsize` | Maximum size of a core dump file |
| `cputime` | Maximum CPU time any one process can use |
| `datasize` | Maximum data size per process |
| `filesize` | Maximum size of any one file |
| `maxproc` | Maximum number of processes |
| `memorylocked` | Maximum locked-in core memory use per process |
| `memoryuse` | Maximum core memory use per process |
| `openfiles` | Maximum open file descriptors per process |
| `stacksize` | Maximum stack size per process |
| `vmemoryuse` | Maximum virtual memory use per process |

Resource limits are generally set per process. If you permit each process 200MB of RAM and allow 40 processes per user, you've just allocated each user 8GB of memory. Perhaps your system has a lot of memory, but does it really have that much?

All resource-limiting variables except `vmemoryuse` support maximum and current (advisory) limits. Users are warned by the system when they exceed current limits and cannot exceed the maximum limits. This works well on a cooperative system, where multiple users share resources but need to be notified when they are approaching their limit.

To specify a current limit, add `-cur` to the variable name. To make a maximum limit, add `-max`. For example, to set a current and maximum limit on the number of processes a user can have, use this definition in the class:

```
...
:maxproc-cur: 50:\
:maxproc-max: 60:\
...
```

A user in this class will receive a warning when he uses more than 50 processes and will not be able to use more than 60 processes. If you do not specify a limit as current or maximum, it acts as both.

### Modifying the Shell Environment

You can define environment settings in a user class. This can work better than setting them in the default shell profile, because changes affect all users immediately upon their next login. This setting will impact all user shells, even those that don't read *.profile* or *.cshrc*.

Table 6-2 lists popular user class variables that affect the user environment.

**Table 6-2:** Some login.conf Environment Variables

| Variable | Description |
|---|---|
| `hushlogin` | If present, no system information is given out during login. |
| `ignorenologin` | User can log in even when */etc/nologin* file is present. |
| `nologin` | Path to a file. If the file exists, when a user tries to log in, the file contents are displayed and login is denied. |
| `path` | Default command search path. |
| `priority` | User's priority (nice) level. See `renice(1)`. |
| `requirehome` | If present, user must have valid home directory to log in. |
| `setenv` | A comma-separated list of environment variables and values. |
| `shell` | User shell. Overrides user shell selection in */etc/passwd*. The user's `$SHELL` environment variable reflects */etc/passwd*, resulting in an inconsistent environment. Playing games with this is an excellent way to annoy your users. |
| `term` | Default terminal type, if environment can't figure out terminal type. |
| `umask` | Initial umask. Should always start with a 0. |
| `welcome` | Path to a file containing the login message. |

### Password and Login Options

Unlike the user environment, which can be configured in several different places, many password controls can be configured only via the user class. The password controls affect only the local password database, not Lightweight Directory Access Protocol (LDAP), Kerberos, RADIUS, or other remote password databases.

Let's have a look at some commonly used password controls.

**`localcipher`**
: This controls the password hashing method used in */etc/master.passwd*. The default is Blowfish. Don't change the password hashing method unless you're trying to be compatible with a specific foreign Unix-like operating system. See `login.conf(5)` for the list of supported hashing algorithms.

**`login-backoff`**
: This controls how quickly a user can struggle to remember his password. After this many unsuccessful login attempts, `login(1)` slows down how quickly it offers a new username and password prompt.

**`passwordcheck`**
: This gives the full path to an external program that checks new passwords for quality. OpenBSD passes the password to the program on standard input. The program is expected to return a 0 if the password is adequate and a 1 if the password is inadequate. OpenBSD includes a very simple and limited password-quality checker; if you need a password-quality checker, check out `passwdqc` (*/usr/ports/security/passwdqc*).

**`passwordtries`**
: This is the number of times `passwd(1)` uses the password-quality checker. If the user cannot come up with a sufficiently complicated password in this many tries, the new password is accepted anyway. If this is set to 0, a new password is accepted only when it passes the quality check.

**`minpasswordlen`**
: This is the minimum length of a new password. Password length is not a measure of quality—a stream of 128 `A` characters is still a lousy password, but it might help you meet site requirements.

**`passwordtime`**
: This is the maximum age of a password, in seconds. Use this to require regular password changes.

**`password-warn`**
: This is the length of time, in seconds, before `login(1)` begins warning the user of an expiring password.

`password-dead`
: This is the length of time, in seconds, after password expiration when the user may log in one last time, just to reset his own password. If the user does not reset his password, he cannot log in. This is a last-chance grace period; if the user blows this chance, sysadmin intervention is required to reset the password.

## Changing Authentication Methods

OpenBSD supports many different authentication mechanisms, such as the local password file, Kerberos, S/Key, RADIUS, and so on. Specify the authentication method desired in the user class definition, and OpenBSD will use it. This system behind this is called *BSD Authentication*.

Setting an authentication mechanism does not configure the authentication mechanism. For example, configuring a login class to authenticate via Kerberos doesn't magically establish a Kerberos domain. If the specified authentication method is unavailable, classes configured to use that method will be unable to log in.

Not all authentication methods interoperate with all protocols. For example, while SSH works with physical tokens, it doesn't work with the `lchpass` authentication protocol, which allows users to change their password but disallows logins. Review the man page for each authentication method for details.

Some authentication methods require additional configuration. For example, if you want to use RADIUS authentication, you must tell your system where to find your RADIUS server. The special *login.conf* variables and their use are documented in the authentication method's man page.

Table 6-3 lists the authentication methods supported by OpenBSD's built-in BSD Authentication.

**Table 6-3:** BSD Authentication Methods

| Method | Man Page | Description |
|---|---|---|
| `activ` | `login_activ(8)` | Authenticate via ActivCard token |
| `chpass` | `login_chpass(8)` | Change password, no shell |
| `crypto` | `login_crypto(8)` | Authenticate via CRYPTOCard token |
| `krb5` | `login_krb5(8)` | Authenticate via Kerberos |
| `krb5-or-pwd` | `login_krb5-or-pwd(8)` | Try Kerberos, then local password database |
| `lchpass` | `login_lchpass(8)` | Change local password |
| `passwd` | `login_passwd(8)` | Authenticate against local password file |
| `radius` | `login_radius(8)` | Authenticate against RADIUS server |
| `reject` | `login_reject(8)` | Request a password, then deny the login |
| `skey` | `login_skey(8)` | Authenticate via S/Key |
| `snk` | `login_snk(8)` | Authenticate via SecureNet token |
| `token` | `login_token(8)` | Authenticate via X9.9 token |
| `yubikey` | `login_yubikey(8)` | Authenticate via Yubico YubiKey token |

The ports collection (discussed in Chapter 13) contains a few additional login methods, such as fingerprint scanners (*sysutils/login_fingerprint*), OATH one-time passwords (*sysutils/login_oath*), and LDAP integration (*sysutils/login_ldap*). You can also create your own custom authentication methods; see `login.conf(5)` for details.

Set the authentication method using the `auth` variable in *login.conf*:

```
:auth=token,passwd:\
```

Users in a class with this set try to authenticate via an X9.9 token. If that's not possible, the system falls back on the local password database.

BSD Authentication supports different authentication methods for different daemons. You can specify a service name after the `auth` keyword, indicating that this set of authentication methods applies to only that particular service. You'll frequently see login classes like `auth-ssh` and `auth-su`.

Here are a couple of sample entries from the default *login.conf* file:

```
# Default allowed authentication styles
auth-defaults:auth=passwd,skey:

# Default allowed authentication styles for authentication type ftp
auth-ftp-defaults:auth-ftp=passwd:
```

This defines the class `auth-defaults`, with only one entry. By default, users in this class first use password authentication, and then S/Key authentication. The `auth-ftp-defaults` class defines `auth-ftp` as using the password database, and only the password database.

Earlier in this chapter, I mentioned that the default class included two other classes. These are the `auth-defaults` and `auth-ftp-defaults` classes. Every other login class in the default *login.conf* file includes them by reference. If you change the authentication methods used by the `auth-defaults` class, that change will apply to every other login class.

### Using Login Classes for RADIUS Authentication

I have a long-running love/hate relationship with RADIUS. It's the lowest common denominator of authentication protocols. Just about every operating system and hardware device supports it, but it's a finicky protocol with innumerable edge cases. Luckily, configuring OpenBSD as a RADIUS client is simple. Any RADIUS server can provide authentication services for OpenBSD.

I encourage you to use another login service, such as LDAP or Kerberos, rather than RADIUS. But in certain cases, for certain users, RADIUS is adequate. RADIUS combined with Microsoft's Internet Authentication Service gives you easy password synchronization with the local Windows domain and reduces your support load.

First, read `login_radius(8)`, and then configure your RADIUS server to permit access from your OpenBSD host. To configure RADIUS authentication, you need the RADIUS server's IP address, the port RADIUS runs on, and a shared secret. (For historical reasons, it's best to specify the RADIUS port explicitly rather than relying on */etc/services*.) In our example, the RADIUS server is 192.0.2.2, the port is 1812, and the secret is the string `Insubordination88`.

First, create a directory to hold the server configuration file and set its permissions appropriately, as per `login_radius(8)`.

```
# mkdir /etc/raddb
# chgrp _radius /etc/raddb/
# chmod 755 /etc/raddb/
```

Now create the file */etc/raddb/servers*. This file should contain a server and its secret, each on one line. Our *servers* file has only one line:

```
192.0.2.2        Insubordination88
```

Now change *login.conf* to use RADIUS by default.

```
auth-defaults:\
        :auth=radius:\
        :radius-port=1812:\
        :radius-server=192.0.2.2:
```

The `auth-defaults` class is OpenBSD's default authentication class. If we change it, we change how every other class authenticates. We set the `auth` type to `radius`, and set the port and the server.

Immediately upon saving the file, OpenBSD will try to authenticate all user accounts against the RADIUS server. You might want to change the `auth-ftp` class to match.[2]

Until you confirm everything is working, keep an SSH session logged in as root so you can change *login.conf*. Otherwise, you might lock yourself out of the system, or at least out of the root account. If you can't get into the system, you'll need to reboot into single-user mode and edit *login.conf*.

Changing the authentication scheme for all users might not be desirable, either. You might want `authpf(8)` users to authenticate against RADIUS, but have users in the `staff` class authenticate against the local password database. Perhaps you don't want your root account to authenticate via RADIUS, so you need an `auth-su` login class that points at the local password database. Using login classes, you can configure user authentication to fit your specific needs.

2. Or you might not want to make this change. FTP transmits passwords in clear text, so you might want to use a separate password source for FTP connections. Why transmit passwords securely over one protocol, while transmitting them insecurely on a neighboring port?

## Unprivileged User Accounts

An unprivileged user account is a user account with no privileges to any programs or files. Many programs run as unprivileged users or use unprivileged users to perform specific duties. These unprivileged users get only the rights needed to perform a limited task.

"Only the rights needed to perform a limited task" sounds like every user account, doesn't it? That's true, but the account used by the least privileged human being still has more rights than many programs need. Any user with shell access usually has a home directory. Users can create files in their home directory, run text editors, process email, run scripts, and compile (if not install) software. An average shell user needs these minimal privileges, but programs do not. By having a program run as a very restricted user, you control the amount of damage the software or intruders can do to the system.

OpenBSD includes several unprivileged users out of the box. Take a look at */etc/passwd*, and you'll see accounts like `sshd`, `named`, `_ntp`, and so on. These are all unprivileged accounts used by specific server daemons. Examine them, and you'll find several common characteristics.

Unprivileged users do not have normal home directories. Most share the home directory of */var/empty*, which is owned by root and contains nothing except a logging socket. Having a home directory the user cannot write to makes the account less flexible, but is good enough for most server daemons. If these users do own files on the system, file permissions are usually set so that the user cannot write to them.

Similarly, no one should ever log in to the system with these accounts. If the `named` user account is reserved for the DNS subsystem, why would anyone actually need to log in as that account? Unprivileged users are assigned a shell that specifically forbids logging in: */sbin/nologin*.

How does all this enhance system security? Let's pick on the web server, a common intrusion vector, as an example. OpenBSD runs its web server as the user `www`. Suppose an intruder discovers a security flaw in your website and can use this to make the web server execute arbitrary code. This is a security nightmare; our intruder can now make the server program do absolutely anything within its power. But what, exactly, is within the web server's power?

A command prompt permits much more mischief and mayhem than a website, so the intruder will probably try to access a command prompt on the system. The `www` user has a shell that specifically disallows a command prompt. While this doesn't categorically prevent the intruder from getting a command prompt, it does make it much more difficult.

But our intruder is clever. Through really excellent intrusion skills, he makes the web server open a high-numbered port that dumps clients into a root shell. He now has access to a command prompt and can wreak untold damage . . . or can he?

He has no home directory, and no permissions to create one. Any files he wants to store must go into a globally accessible directory such as */tmp* or */var/tmp*, increasing his visibility. The web server configuration file is not

owned by the www user. Even if the intruder has a path into the web server, he cannot reconfigure it. He can't change the website files, as the www user doesn't own them. The www user doesn't have access to anything on the system, actually. Additionally, OpenBSD's built-in web server chroots itself. Having broken into the web server program, the intruder now must escape the chroot and penetrate a privileged program.

Can he penetrate your system? Possibly, but it will be much more difficult. If he is specifically targeting you or your company, he might go to the trouble. If he is just looking for easy meat, however, he will probably give up and go bother someone running a Linux or Windows system.

Using unprivileged users doesn't solve all security problems, mind you. The compromised www user can view web application source files. If your application is badly written or has database passwords hardcoded into hidden files, you're still in trouble. But if you don't use poorly written applications and you've kept your system updated and patched, the intruder will have a very hard time penetrating the rest of your server.

### The nobody Account

The first unprivileged account was nobody. It was created for use by the Network File System (NFS, discussed in Chapter 9) to map files owned by root on foreign systems. Decades ago, people started using nobody as a generic unprivileged user, running web servers, proxy servers, and other daemons as nobody. While this was better than running those programs as root, it's still poor practice. If an intruder penetrated one of those programs, he would gain access to all processes owned by nobody. Our hypothetical web server intruder would suddenly have access not only to the web server, but also to the database, NFS, or anything else running as nobody!

Every daemon that needs to run as a user needs its own unprivileged accounts—the whole point of using unprivileged users is to minimize the damage one piece of software can inflict. Use them liberally. OpenBSD provides discrete unprivileged users for services as small as finger(1) and the audio system. Follow this example.

#### _username

If you take a look at */etc/passwd*, you'll see that many unprivileged users have an underscore before their name, such as _syslogd, _ldapd, and _dhcp. This is an OpenBSD convention for identifying unprivileged users. Most add-on software also uses unprivileged usernames beginning with an underscore, such as _mysql and _postgresql.

Not all unprivileged usernames start with an underscore, however. Some of these are legacy users that OpenBSD retains for compatibility reasons, such as nobody. Others have a long history or support inflexible software, and changing them would be more annoyance than it's worth.

The presence of an underscore means that a user is unprivileged. The absence of an underscore means nothing; the user might be a normal

account or it might be unprivileged. If you create your own unprivileged users, you don't need to include a leading underscore, but doing so will help other system administrators understand what the user does.

### Creating Unprivileged Users

Here are common settings used for unprivileged users. You can change any of these as needed for your application.

**username** Assign a username related to the user's functions, so that you'll easily recognize it. Giving an unprivileged user a username like `_fgcrl` might seem like a good way to conceal its purpose, but it will confuse your sysadmins and an intruder will quickly figure it out.

**home directory** */var/empty* is a common setting for unprivileged users.

**shell** */sbin/nologin* is a common setting for unprivileged users.

**UID/GID** Choose a specific range of UIDs and GIDs for your custom unprivileged users. OpenBSD reserves all UIDs below 1000 for system-assigned unprivileged users.

**full name** Assign a name describing the user's role.

**password** Use `chpass(1)` to assign the user a single asterisk as their encrypted password. This disables the account password.

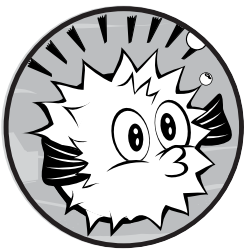
These settings make your unprivileged user very unprivileged indeed. You can set all of these options except the password using `adduser(8)`.

Now that you understand how to create, manage, and use user accounts, let's discuss how to manage privileged users.

# 7

# ROOT, AND HOW TO AVOID IT

*The root of all evil*
*is never far from your touch.*
*sudo saves your life.*



The security of most Unix-like operating systems has long been considered coarsely grained. One superuser, root, can do anything. Other users are lowly sharecroppers who endure the shackles root places upon them. The problem is that root doesn't have many shackles and it can't individualize the ones that it has very well. Some operating systems use POSIX access control lists (ACLs) to provide more fine-grained access controls, but these are difficult to configure correctly.[1]

While it's true that Unix-like operating systems don't have detailed access controls, the fact is that most people don't bother using the controls that *do* exist. Fortunately, you can combine groups and permissions to handle almost any problem securely.

---

1. I could just say that "I have never seen POSIX ACLs configured correctly," but personal anecdotal evidence is not proof. Even the dozens of horrifying personal anecdotes I've gathered over decades in this business are not proof. Feel free to prove me wrong, but please, do it on *your* server.

## The Root Password

The root user owns the system and has absolute power over every piece of hardware as well as certain actions that require absolute control, such as manipulating the kernel and changing authentication sources. You need root permissions to perform these tasks. You can log in as root, use `su(1)` to become root, or use `sudo(8)` (discussed later this chapter) to get certain root-level privileges without actually using the root account.

To use the root password, you can either log in as root at a console login prompt or, if you belong to the group `wheel`, log in as yourself and use the switch user command `su(1)`. Of the two, I recommend using `su`; it logs who uses it and can be used when you are logged in from a remote system. To use `su`, run the following:

```
$ su
Password:
#
```

When prompted, enter the root password. Now check your current user ID with `id(1)`.

```
# id
uid=0(root) gid=0(wheel) groups=0(wheel), 2(kmem), 3(sys), 4(tty),
5(operator), 20(staff), 31(guest)
```

As you can see, the UID is 0, which means that you now own the system, and I do mean *own* it. Consider every keystroke carefully. Carelessness could return your hard drive to its primordial, unformatted state.

Only users in the group `wheel` can use the root password to become root via `su`. If you give the root password to users without physical console access and who are in the `wheel` group, they can enter `su` and the root password as many times as they want, and it won't work. (But anyone can use the root account and password at the system console, so don't make a habit of blabbing the root password all around the office.)

Requiring group membership to use the root password leads to the question, "Who needs root access?" Root is required to configure many parts of OpenBSD, but once the system is running properly, you can greatly decrease or discontinue your use of root. For any remaining tasks that absolutely require root, use `sudo`.

## Using Groups

One of the simplest ways to reduce the need for root is with groups. Unix-like operating systems classify users into groups, which consist of accounts of users who perform similar administrative functions. You can, for example, define a group named `dnsadmins` and add the accounts of every user who edits DNS zone files to that group. Then, by setting the permissions of the zone files and their directory appropriately, members of that group can

edit zone files and reload the name server without the root password. The good news is that you could create such a group for almost any system function, and thereby avoid giving those users root access. Using groups in this manner is a powerful and often neglected system administration tool. I use groups for administering my own servers—just because I *can* use root doesn't mean that I *want* to use root. Users can identify the groups they belong to by using `id(1)`.

```
# id
uid=1000(mwlucas) gid=1000(mwlucas) groups=1000(mwlucas), 0(wheel),
2005(dnsadmin)
```

My UID is 1000, and my username is `mwlucas`. My GID, the primary group ID, is also 1000 and is also named `mwlucas`. I'm also in the `wheel` and `dnsadmin` groups.

### The /etc/group File

The file */etc/group* contains all group information. Each line contains four colon-delimited fields: the group name, password, ID number, and list of members.

```
wheel:*:0:root,mwlucas,pkdick
```

The *group name* is a human-friendly name for the group. This group is named `wheel`. Group names are completely arbitrary and you could call a group `lickspittles` if you want, but you should choose a name that gives an idea of the group's purpose. While you might remember that `lickspittles` can edit the company web page, will that group name make any sense to your coworkers? If it does, you probably need better coworkers.

The second field, the group password, was a great theory that became an appalling practice once exposed to the real world. Modern Unix-like systems don't do anything with the group password, but the field remains because old programs expect to find something here. The asterisk is just a placeholder to placate such software. (While OpenBSD could eliminate this field, some enterprises share */etc/group* across operating systems.)

The third field gives the group's unique numeric GID. Many programs use the GID rather than the name to identify a group. The `wheel` group has a GID of 0. The maximum GID is 232, or 4,294,967,296.

Last is a comma-separated list of all users in the group. As you can see, the users `root`, `mwlucas`, and `pkdick` are all members of the `wheel` group. To add users to a group, add their username to this list, but remember that no */etc/group* entry can contain more than 200 users or be longer than 1024 characters.

### Creating Groups

In order to create a new group, you need a name and GID number. OpenBSD usually assigns the next free GID to a newly created group with GIDs below 1000 reserved for OpenBSD. Programs included in OpenBSD that

need a dedicated group ID use one below 1000. Software installed via the OpenBSD package system or ports (discussed in Chapter 13) assigns dedicated GIDs in the 500 to 1000 range. GIDs for user accounts start at 1000 and go up. If you create groups for special roles, start at a high GID so that these administrative groups will be obviously different from user accounts.

### Groups, Unprivileged Users, and Group Permissions

The simplest way to create a new group is to use `adduser` to create an unprivileged user for the role, and use that user's group to assign file permissions. As with any other unprivileged user, give this account the home directory */var/empty* and a shell of `nologin`. Do not add this user to any other groups (especially not `wheel`). Lastly, let `adduser` disable the account. Sure, the shell will prevent logins, but an extra layer of defense won't hurt.

Now that you have an administrative user and a group, you can assign file ownership. A user and a group own every file. To view the permissions on existing files, including hidden ones, use `ls -la`. (If you've forgotten how file ownership and permissions work, read `ls(1)` and `chmod(1)`.) Many system administrators focus on file ownership and owner permissions, invest somewhat less time on worldwide permissions, and gloss over group permissions as if they don't exist. Look closely at the sample DNS files that follow.

```
# ls -la
total 22
drwxr-xr-x  2 mwlucas  wheel     512 Apr 16 22:02 .
drwxrwxrwt  8 root     wheel     512 Apr 16 22:00 ..
-rw-rw-r--  1 mwlucas  mwlucas 14595 Apr 16 22:02 michaelwlucas.com.db
-rw-r-----  1 mwlucas  wheel     198 Apr 16 22:02 rndc.key
```

This directory contains two files. The file *rndc.key* can be read and written by the user `mwlucas`; anyone in the `wheel` group can read *rndc.key*; and no one else can even read it. The file *michaelwlucas.com.db* can be read or written by the user `mwlucas` or anyone in the group `wheel`, but others can only read it. If you're in the group `mwlucas`, you can edit this file.

Say I want my junior DNS administrators to be able to edit zone files but not be able to edit the `rndc(8)` configuration. The file permissions are correct, but I need the files to be owned by my DNS administrative user, `dnsadmin`. I also want my DNS admins to be able to create new zone files, so they need write permissions on the directory. Here's how I would do that:

```
# chown dnsadmin:dnsadmin michaelwlucas.com.db
# chgrp dnsadmin rndc.key
# chown dnsadmin:dnsadmin .
# chmod 775 .
# ls -la
total 22
drwxrwxr-x  2 dnsadmin  dnsadmin    512 Apr 16 22:02 .
drwxrwxrwt  8 root      wheel      512 Apr 16 22:08 ..
-rw-rw-r--  1 dnsadmin  dnsadmin  14595 Apr 16 22:02 michaelwlucas.com
-rw-r--r--  1 root      dnsadmin    198 Apr 16 22:02 rndc.key
```

As you can see, these files are now owned by the user dnsadmin and the group dnsadmin. Anyone in the group dnsadmin should be able to edit *michaelwlucas.com.db* without using the root password. The user named—the unprivileged user for the DNS server—should be able to read both files. Add your DNS administrators to the dnsadmin group in */etc/group*, and they should no longer need the root password to do their jobs.

This model has limitations, however. While your junior admins can't accidentally edit *rndc.conf*, they can delete and replace it. It would be better to put that file in a directory they can read but not edit. And while our DNS administrators might think that they need the root password to restart the name server, they're wrong. Use rndc(8) to manage the DNS server; other tasks can be managed via cron(8) or through sudo.

## Hiding Root with sudo

While the proper use of groups can almost eliminate the need for root access to edit files, that won't help with commands that can be run only by root. You could set up a cron job to reload the name server each day at midnight, but every piece of software occasionally needs a manual restart. Because root is an all-or-nothing affair, people who have one minor task to perform have traditionally needed the root password.

OpenBSD includes sudo(8) and its associated tools, which implement fine-grained access control for commands that can be run only by particular users. When configured properly, sudo lets normal users run specific programs as other users, including root. Configured improperly, sudo permits full root access. I'll explain a basic sudo setup that covers almost all uses, but remember that many more combinations are possible. And don't be afraid to read sudo(8), sudoers(5), and the documentation at the sudo home page (*http://www.gratisoft.us/sudo/*).

### Why Use sudo?

The sudo tool provides benefits beyond fine-grained privilege control. Every command run via sudo is logged, making it very easy to track who did what. The senior sysadmin can change the root password and not give it out, even to people who have root-level access.

The sudo configuration file is designed to be shared across multiple systems, so one sudo policy can cover your entire network and every operating system. Admittedly, you'll have trouble using a single sudo configuration on operating systems with wildly unique directory layouts, such as Mac OS X, but you can easily share one configuration among OpenBSD, other BSDs, Linux, and even OpenSolaris or AIX.

### sudo Disadvantages

The most common problem with sudo is getting your users to accept it. People who have historically had access to the root account think they "lose something" by working through sudo.

The key to overcoming this is to give users access only to what's required to perform the tasks for which they're responsible. A junior administrator who complains about insufficient privileges has either overreached his responsibilities or needs more privileges. One sure way to discover what people actually do is to implement a minimal `sudo` permissions scheme and wait for complaints. If no one complains, they're not working very hard.

The configuration syntax for `sudo` can be confusing because its configuration doesn't closely resemble any other configuration file, and getting everything right can be difficult at first. The configuration file is actually well suited to its purpose, however. Once you understand it, adjusting privileges is quick and easy.

**NOTE** *More seriously, a faulty* `sudo` *setup can create the appearance of security while leaving gaps for a user to become root. Be sure to test* `sudo` *every time you make a change, and avoid the common configuration mistakes I document here.*

Some users will do their best to push the limits of their access, for no other reason than to see if they can outsmart you. These users are best managed with a combination of careful configuration, administrative policy, and a cricket bat.

### An Overview of the sudo Software

The `sudo` program is a `setuid` root wrapper that can run commands as any other user. Use `sudo` by giving it the command you want to run.

```
$ sudo /etc/rc.d/named restart
```

The `sudo` software compares the desired command (in this case, `/etc/rc.d/named restart`) to its internal list of permissions and privileges. If the configuration file allows that particular user to run that command as root, `sudo` runs it as root. And, because root can run any command as any user, `sudo` can also run commands as any arbitrary system user. You can use this fact to grant any user the ability to run specific commands as chosen users; for example, administrators of certain database servers must frequently run commands as the database user.

The `sudo` software is a suite with four pieces. The first piece is the actual `sudo(8)` command, the `setuid` root wrapper. The second is the configuration file */etc/sudoers*, which describes who may run which commands as what user. (*/etc/sudoers* is fully documented in `sudoers(5)`.) Third is the `visudo(8)` command that opens */etc/sudoers* in an editor and checks the configuration file syntax before exiting. Finally, the `sudoedit(8)` program is specifically for editing files as another user.

### The visudo(8) Command

If */etc/sudoers* contains incorrect syntax, `sudo` will not run. If you rely on `sudo` to provide root-level access to the system and you break your *sudoers* file,

you'll lock yourself out of the root account and lose the ability to correct your error. That is bad.

Fortunately, the `visudo(8)` program provides some protection against this sort of error by locking */etc/sudoers* so that only one person can edit the configuration at a time. It then opens */etc/sudoers* in a text editor (vi by default, but it respects the `$EDITOR` environment variable). Make your changes and save your work. When you exit the editor, `visudo` should parse the file for syntactic correctness.

If `visudo` detects an error, it prints out the offending line number and asks what you want to do.

```
>>> /etc/sudoers: syntax error near line 34 <<<
What now?
```

Here, I've made an error near line 34. I can reedit the file to fix the error, quit without saving any changes, or force `visudo` to accept this file.

Press the E key, and `visudo` should return you to the editor. Go to the offending line, fix your error, save the file, and exit the editor again.

Enter the X key, and `visudo` should quit and revert the configuration file to its original state. Your changes will be lost, but that might be acceptable. It's better to have an old, working configuration than a new, broken one.

Pressing Q forces `visudo` to accept the file, busted syntax and all. If `sudo` can't parse */etc/sudoers*, it will immediately exit. Essentially, you're telling `visudo` to break `sudo` until you log in as root to fix the problem. If you think you understand */etc/sudoers* better than `visudo` does, you're probably wrong. Even if you're right, you're wrong.

The `visudo` program doesn't guarantee that the configuration will do what you desire, only that the configuration parses and is valid. A properly formatted configuration that declares "No one may do anything via `sudo`" is perfectly acceptable to `visudo`.

### The /etc/sudoers File

The */etc/sudoers* file determines who may run which commands as which users. Never edit */etc/sudoers* directly, even if you think you know exactly what change you want to make. Always use `visudo` to change */etc/sudoers*.

The various *sudoers* sample configurations you'll find are usually very complicated, as they demonstrate all the nifty things `sudo` can do. At this point, however, you want to do only simple, boring things, like giving particular users access to run specific commands. And the bare syntax is very simple. Every *sudoers* rule follows this format:

```
Username    host=command
```

- The *username* is the username of the user who may execute the command, an alias for usernames, or a system group.
- The *host* is the hostname of the system this rule applies to. You can share */etc/sudoers* across multiple systems. This entry permits per-host rules.

- The *command* space lists the commands this rule applies to. You must list the full path to each command, or `sudo` will not recognize it. If this weren't a requirement, some untrustworthy soul could just adjust his `$PATH` to access renamed versions of commands.

For example, suppose I trust user `sbaxter` to run any command, on any system, as root. I use the keyword `ALL` to match all possible options for host and command:

```
sbaxter    ALL=ALL
```

As the lead sysadmin, I should know which duties I have assigned `sbaxter`, and exactly which commands he needs. Suppose `sbaxter` is my DNS minion. I control the actual editing of zone files with group permissions, but there are many legitimate occasions for him to stop, restart, or otherwise slap around the name server program. I want him to use the system script */etc/rc.d/named* for this task, and this *sudoers* entry gives him permission to use the script on all machines.

```
sbaxter    ALL=/etc/rc.d/named
```

If I share this file across several machines, it's likely that many of those machines don't even run a name server. To restrict my minion's access to only the DNS server, I'll change the host field.

```
sbaxter    dns1=/etc/rc.d/named
```

Then again, `sbaxter` is the administrator of the email server `mail1`. This server is his responsibility, so he needs to run any command. I can set entirely different privileges for him on the mail server and still use the same *sudoers* file on all the systems.

```
sbaxter    dns1=/etc/rc.d/named
sbaxter    mail1=ALL
```

Yes, `sbaxter` can use `visudo` on `mail1`, but he already has full privileges on that machine. I'm comfortable with this, as he knows I'll hold him responsible for any downtime.

### Multiple Entries in a sudoers Field

Separate multiple entries in a single field with commas. For example, after a while, I get tired of `sbaxter` asking me to mount NFS shares on the DNS server, so I add `mount_nfs` to his privileges.

```
sbaxter    dns1=/etc/rc.d/named,/sbin/mount_nfs
```

He can now mount his own blasted NFS shares and leave me alone.

### Running Commands As Non-root Users

Specify a username in parentheses before a command to say that the user can use `sudo` to run commands as a particular user. For example, my user `dwsmith` is a database administrator and needs to run any command as the user `_postgresql` on the database server `db1`.

```
dwsmith    db1 = (_postgresql) ALL
```

The `_postgresql` user can't successfully run critical system programs like `fdisk` and `newfs`, but it can restart the database, back it up, and perform other database-administration tasks. By choosing a specific user, a specific machine, and a specific command, you can define arbitrarily complex *sudoers* policies.

### Long Lines

If you have several commands, usernames, or hosts on a line, that line might become uncomfortably long. Use a backslash (`\`) to indicate that a rule continues on the next line.

```
sbaxter    dns1=/etc/rc.d/named,/sbin/mount_nfs, \
       /sbin/reboot, /sbin/dump
```

Use as many lines as you like to make your *sudoers* file easier to manage.

## /etc/sudoers Aliases

Take several machines with different roles, add multiple sysadmins with differing privilege levels, and your */etc/sudoers* file will quickly become complicated. When you have a few users with identical privileges and long lists of commands that you would like them to access, maintaining consistency in each user's privilege list becomes tedious. *Aliases* simplify these tasks and make */etc/sudoers* much more comprehensible, which makes your life easier.

An alias is a group of users, hosts, or commands. You can use aliases anywhere you would normally use users, hosts, or commands. You might, for example, create an alias called `DATABASE_COMMANDS` that contains all of the commands your database administrators need to run using `sudo`.

Let's take database administrator `dwsmith` and use an alias to specify his commands.

```
dwsmith    db1 = (_postgresql) DATABASE_COMMANDS
```

This alias might not seem to save us much, but suppose we have several database administrators. We could create an alias called `DBAs` that includes all of them.

```
DBAs    db1 = (_postgresql) DATABASE_COMMANDS
```

Suddenly, this one line represents multiple rules. All of the database admins have identical `sudo` privileges, and when you discover that you need

to give them access to an additional command, add the command to the alias, and it immediately becomes available to every database admin. There's no tedious and error-prone copying of entries between users.

You must define an alias before you can use it, so aliases normally appear at the top of the file. Each alias is made up of a label identifying its type, a name, and a list of its items. Alias types include user aliases, run as aliases, host aliases, and command aliases.

### User Aliases

A *user alias* is a group of users, and it is labeled with the string `User_Alias`. Put only usernames in this alias.

```
User_Alias    DBAs = dwsmith, kkrusch
```

Here, the user alias `DBAs` contains the users `dwsmith` and `kkrusch`. By using the alias in my *sudoers* rules instead of the usernames, I ensure that these users receive exactly the same `sudo` privileges.

You can use system groups in user aliases by prefacing them with a percent sign (`%`). I might create a group in */etc/groups* called `databaseteam`, and make `dwsmith` and `kkrusch` part of that team.

```
%databaseteam db1 = (_postgresql) DATABASE_COMMANDS
```

Perhaps the most common usage of this is giving the `wheel` group unlimited `sudo` access.

```
%wheel ALL = ALL
```

This rule permits the `wheel` group to run any command as root through `sudo`. It doesn't change the group members' privileges, but gives them access via `sudo`. This is convenient for running single commands.

### Run as Aliases

A *run as* alias is a list of users that other users can run commands as. For example, on certain application servers, the database admins need to run commands both as the database owner `_postgresql` and as the web server owner `www`. If the user must run commands as multiple users, however, you would need a separate *sudoers* entry for each target user.

A run as alias lets you group these accounts:

```
Runas_Alias    APPOWNER = _postgresql, www
```

You can now write a single rule allowing users to run commands as either `_postgresql` or `www`.

### Host Aliases

A *host alias* is a list of hosts, defined as hostnames, IP addresses, or network blocks. Label host aliases with the string `Host_Alias`. Here are examples of all host alias types:

```
Host_Alias    DB = db1, db2, db3
Host_Alias    DMZ = 192.0.2.0/24
Host_Alias    FIREWALL = 192.0.2.1, 192.0.2.2, 192.0.2.3
```

**NOTE** *I warn elsewhere in this book about how security rules based on a hostname are vulnerable to DNS spoofing attacks. An intruder can't spoof the machine's local hostname, however, so you can safely use the hostname from* /etc/myname *in* sudoers.

### Command Aliases

A *command alias* is a list of commands. For example, you might have a command alias that includes all of the commands needed to back up the system or restore from a backup. They're labeled with the string `Cmnd_Alias`.

```
Cmnd_Alias    BACKUPS = /bin/mt, /sbin/restore, /sbin/dump
```

You can tell a command alias to include everything in a particular directory by using a wildcard.

```
Cmnd_Alias       APPCOMMANDS = /home/appuser/bin/*
```

You can also list partial command names. For example, most of PostgreSQL's commands begin with the `pg_` prefix. To give a user access to these commands, use a wildcard like so:

```
Cmnd_Alias    APPCOMMANDS = /home/appuser/bin/*,/usr/local/bin/pg_*
```

If you find yourself writing command aliases that include paths like */sbin/**, stop and reconsider, because you're essentially giving the user unlimited root access.

### Using Aliases in /etc/sudoers

Use an alias exactly as you would normally list the user, command, or hostname. In the previous examples, I defined the user alias `DBAs`, the run as alias `APPOWNER`, the host alias `DB`, and the command alias `APPCOMMANDS`. Here's how they might be used:

```
DBAs    DB = ALL
```

Here, the user group DBAs can run any command on any server in the DB group, as any user. The members of the group own the servers, and if they screw them up, it's not my problem.

Well, this attitude sounds good, but the truth is that when they destroy the server, I must get involved. Even if it's not my fault that they drove the database server into the ditch, it *is* my problem. I must lock down the commands that they can run, restricting them to only the commands in the APPCOMMANDS alias. So, the DBAs group can now run any command in APPCOMMANDS on the DB servers.

```
DBAs    DB = APPCOMMANDS
```

Then I discover that my database admins are either cleverer or dafter than I thought. They run certain database commands as root, creating log files owned by root. The unprivileged database user _postgresql cannot write to these log files, and so the application server crashes. Fixing this requires changing the permissions on those log files, but the database admins do not have permission to run chown. If I give them the ability to change the permissions on arbitrary files, I might as well just give them root access.

To keep this from happening again, I restrict their privileges so they can run their commands only as the application unprivileged users.

```
DBAs    DB = (APPOWNER) APPCOMMANDS
```

Everyone in the DBAs group can run any command in APPCOMMANDS, as any user in APPOWNER, on any server in DB. I can change their access by adding entries to the various aliases.

Without aliases, what would this rule look like?

```
dwsmith,kkrusch    db1,db2,db3 = (_postgresql,www) \
     /home/appowner/bin/*,/usr/local/bin/pg_*
```

That's ugly, and it does exactly the same thing.

If you name your aliases well, you'll find rules easier to understand. While these example aliases are fairly short, I've used aliases with up to 20 members. The resulting rules are appalling without aliases.

**NOTE** *Some of the permissions granted by sudo in this case are unnecessary. For example, the unprivileged web server user doesn't need to run the various PostgreSQL utilities, and if www did try to run the database, nothing much would happen. If you don't like this, make two separate rules. Either way, it's tighter security than giving database administrators the root password.*

### Nesting Aliases

You can include aliases in aliases. Here, I combine two user aliases into a single alias for my application administrators:

```
User_Alias    APPADMINS = DBAs, WEBMASTERS
```

### Alias Naming Conventions

It's traditional, but not mandatory, to give aliases names in all capital letters to help differentiate them from users, hosts, and so on. And though it's valid syntax, it's best to avoid naming aliases after users or hosts. Here's an example:

```
User_Alias    MWLUCAS    = mwlucas,pkdick,sbaxter,dwsmith
```

This would quickly drive me batty.[2]

You can also reuse alias names if they are for different types of aliases. For example, the following is perfectly legal, but perfectly offensive.

```
User_Alias    DB = dwsmith,kkrusch
Runas_Alias    DB = _postgresql,www
Host_Alias    DB = db1, db2, db3
Cmnd_Alias    DB = /usr/local/bin/pg_*, /home/appowner/bin/*
DB    DB = (DB) DB
```

If you do this, anyone who must debug your `sudo` configuration will curse your name. Even if you consider being cursed a job perk, this naming scheme makes your phone ring at inconvenient times.

## *Changing sudo's Default Behavior*

You can customize `sudo`'s behavior, or its behavior for certain users, hosts, or aliases, with the `Defaults` field. For example, one feature of `sudo` is that if you enter the wrong password, it insults you.

```
$ sudo -l
Password:
My pet rat can type better than you!
Password:
```

I typed my password incorrectly. `sudo` insulted me and offered me a chance to enter my password again. If I enter the wrong password three times, `sudo` exits.

Insulting the user is just fine in an open source environment, but if you're in a company, someone will complain to management. You can either go to sensitivity training or proactively disable insults by adding the following line to *sudoers*:

```
Defaults !insults
```

The `Defaults` statement indicates that the following item affects one or more `sudo` defaults. The `insults` option controls insulting the user. The exclamation point (`!`) is a negation symbol. By putting an exclamation

2. Oh, all right—battier. Happy?

point in front of the option, you turn off the feature. The system will no longer insult users when they demonstrate that they cannot type as well as my pet rat.

```
$ sudo -l
Password:
Sorry, try again.
Password:
```

You can override defaults globally or on a per-alias basis.

### Overriding Defaults per Host

To override the defaults on a per-host basis, use an `@` symbol after `Defaults` and give either a host or a host alias. Here, I want to insult users who can't type their password on `caddis` or on a machine in the alias `APPSERVERS`, while leaving insults disabled for all other servers:

```
Defaults !insults
Defaults@caddis insults
Defaults@APPSERVERS insults
```

This lets me enable or disable functions for any combination of servers.

### Overriding Defaults per User

To change `sudo` defaults on a per-user basis, use a `%` and the user or user alias.

```
Defaults !insults
Defaults%lasnyder insults
Defaults%DBAs insults
```

It doesn't matter where `lasnyder` logs in—I'm going to insult him, as well as the users in the `DBAs` alias. But database administrators are used to poor treatment by their software, and to not insult them would confuse and disappoint them.

### Overriding Defaults per Command

You can also change how `sudo` behaves on a command-by-command basis by putting an exclamation point between `Defaults` and the command list.

```
Defaults !insults
Defaults!/sbin/newfs,/sbin/fsck insults
Defaults%APPCOMMANDS insults
```

Anyone who tries to use `newfs(8)` or `fsck(8)` (discussed in Chapter 8) and cannot type their password needs insulting. The application administration commands might not merit insults, but I can always claim it was an oversight.

### Overriding Defaults per Run As

Lastly, you can change the defaults based on who the command is being run as. Use a right angle bracket (<) to indicate changing behavior for a run as alias.

```
Defaults !insults
Defaults<_postgresql insults
Defaults<APPOWNER insults
```

If a user runs a command as `_postgresql`, or as any user in the `APPOWNER` run as alias, and types his password incorrectly, he gets insulted.

**NOTE** *In the rest of this chapter, we'll use `Default` widely. Please assume that each section includes the text "Restrict this as necessary by user, host, command, or run as."*

## sudo and the Environment

Certain environment variables can cause problems. For example, `$HOME` is an obvious one—a user cannot create files in another user's home directory. Others, such as `LD_LIBRARY_PATH`, can cause endless annoyance as well as security issues, as applications try to link against the wrong libraries. The `sudo` program can remove suspicious environment variables, completely reset the user's environment, or be configured to preserve the original user's environment.

The `env_reset` *sudoers* option is set by default. It purges all environment variables except `LOGNAME`, `SHELL`, `USER`, `USERNAME`, and anything beginning with `SUDO_`. You can change this behavior by disabling `env_reset`, but I strongly recommend against disabling environment purging.

Instead of letting users blindly carry all the random garbage in their environment along with them, create a list of necessary and safe environment variables that they can retain. You'll see examples in OpenBSD's default *sudoers* file using the `env_keep` option.

```
Defaults env_keep +="DESTDIR DISTDIR EDITOR FETCH_CMD FLAVOR FTPMODE GROUP MAKE"
Defaults env_keep +="MAKECONF MULTI_PACKAGES NOMAN OKAY_FILES OWNER PKG_CACHE"
Defaults env_keep +="PKG_DBDIR PKG_DESTDIR PKG_PATH PKG_TMPDIR PORTSDIR"
Defaults env_keep +="RELEASEDIR SHARED_ONLY SSH_AUTH_SOCK SUBPACKAGE VISUAL"
Defaults env_keep +="WRKOBJDIR"
```

The OpenBSD team deems these environment variables safe to pass into a new user account. The `+=` means "add these to the existing list of items to keep." The environment variables themselves are in quotation marks.

If you need to pass your SSH environment around your servers, you can use `scp(1)` and `sftp(1)` to move files to other servers. Read the documentation, create a list of approved environment variables, and add an entry.

```
Defaults env_keep += "SSH_CLIENT SSH_CONNECTION SSH_TTY SSH_AUTH_SOCK"
```

**NOTE** *The ability to copy files to other servers probably should be restricted to people in a certain group. Sysadmins might need to copy files to other servers, but many other users don't need this access.*

## Using sudo

Now that you know how to set `sudo` permissions, let's see how to actually use it. First, let's tell `sudo` that your account has permission to run any command. (You should have root access on your test machine, at least, so this won't be a security issue.)

The easy way to accomplish this is to uncomment the *sudoers* entry allowing `wheel` members access to all commands.

```
%wheel ALL=(ALL) SETENV: ALL
```

As a user in `wheel`, check your `sudo` permissions.

```
$ sudo -l
Password:
Matching Defaults entries for mwlucas on this host:
    env_keep+="DESTDIR DISTDIR EDITOR FETCH_CMD FLAVOR FTPMODE GROUP MAKE",
    env_keep+="MAKECONF MULTI_PACKAGES NOMAN OKAY_FILES OWNER PKG_CACHE",
    env_keep+="PKG_DBDIR PKG_DESTDIR PKG_PATH PKG_TMPDIR PORTSDIR",
    env_keep+="RELEASEDIR SHARED_ONLY SSH_AUTH_SOCK SUBPACKAGE VISUAL",
    env_keep+=WRKOBJDIR

User mwlucas may run the following commands on this host:
    (ALL) SETENV: ALL
```

When `sudo` asks for a password, enter your own password, not the root password.

The `-l` flag tells `sudo` to show you which privileges and settings you have. In response, `sudo` parses */etc/sudoers* and spits out all of the settings that apply to your account on this system. Any host-specific limitations are already evaluated and do not appear.

### *sudo Password Caching*

When you enter your password correctly, `sudo` records the time, and for the next five minutes, it remembers that you've recently entered your password and will work without requiring you to enter it again. After five minutes, you must reauthenticate. This simplifies work when entering a series of `sudo` commands, but it times out reasonably quickly.

You can tell `sudo` to forget your cached password by running `sudo -k`. You can control the number of minutes before `sudo` asks for the password again with the `timestamp_timeout` option in *sudoers*. Here, we tell `sudo` to not time out the password for 10 minutes:

```
Defaults timestamp_timeout 10
```

If you set the timeout to 0, `sudo` always asks for a password. If you set it to a negative value, `sudo` caches the password throughout this login session. You must run `sudo -k` to make `sudo` forget that you entered your password.

### Running Commands Under sudo

To run commands via `sudo`, just put the command name after the `sudo` command. For example, here's how you would run `tcpdump` via `sudo`:

```
$ sudo tcpdump
```

The `sudo` command should prompt for your password. Enter it correctly, and `tcpdump` should run as root.

You can also run commands that include arguments under `sudo`. For example, I use `tail -f` to view the end of a log file and show new entries as they appear. But some log files are accessible only to root, such as the authentication log and the log that contains detailed `sudo` logs. You can view these logs without becoming root by using `sudo`.

```
$ sudo tail -f /var/log/authlog
```

You can configure *sudoers* to permit any combination of commands and arguments.

### Running Commands as Other Users

Earlier, you saw how to give some users permission to run commands as users other than root. Specify the user with the `-u` flag.

```
$ sudo -u _postgresql pg_dump
```

If you don't have permission to run that command as that user, you'll get an error.

## sudoedit

My flunky `sbaxter` needs to edit the *named* configuration file, */etc/named.conf*. Consider this `sudo` configuration:

```
sbaxter    dns1=/etc/rc.d/named,/sbin/mount_nfs,/usr/bin/vi /etc/named.conf
```

Looks good, right?

Uh, no.

The first problem is that I'm requiring `sbaxter` to use a specific editor. Minimal competence in vi is required for system administrators, but I don't want to force him to use a specific editor to do his day-to-day job. Also, many editors offer shell escapes. While most people are aware of escaping

to a shell in vi, emacs has a shell escape as well. If my flunky can escape to a shell while running an editor as root, he gains root access. This is exactly what I want to avoid.

The sudoedit feature lets users edit specific files with their preferred editor, or a default chosen by the sysadmin, without working as root.

```
sbaxter    dns1=/etc/rc.d/named,/sbin/mount_nfs, \
         sudoedit /etc/named.conf, /etc/rndc.key
```

The keyword sudoedit is followed by a list of the files that the user can edit, thereby permitting the user to change those files without root privileges.

The user edits the file by passing a filename to sudoedit.

```
$ sudoedit /etc/named.conf
```

Technically, the user doesn't edit the actual file; instead, sudoedit copies the file to a temporary file owned by the user, and when the user closes the editor, it copies the temporary file to the original location. The user never runs the editor as root.

The sudoedit keyword uses the editor given by the environment variable $SUDO_EDITOR, $VISUAL, or $EDITOR. Users can set that variable in their shell if they don't like what the system offers them.

## The Biggest sudo Mistake: Exclusions

Now that you know the basics of sudo, let's consider a configuration that trips up even experienced system administrators. Sometimes you want to prevent users from executing specific commands but give them access to every other command. The *sudoers* documentation says that you can do this using the exclamation point (!) as a negation character, but that's not entirely effective. Because this is a popular method, however, I'll discuss how it works, and then demonstrate how your users automatically get root if you use it.

Start by defining command aliases that contain the forbidden commands. One popular exclusion is su. Another common exclusion is user shells, because if you execute a shell as a user, you become that user.

```
Cmnd_Alias    SHELLS = /bin/sh,/bin/csh,/usr/local/bin/tcsh
Cmnd_Alias    SU = /usr/bin/su
```

Now configure a command alias that excludes those commands.

```
pkdick   ALL = ALL, !SHELLS,!SU
```

Looks sensible, doesn't it? And it seems to work.

```
$ sudo sh
Password:
Sorry, user pkdick is not allowed to execute '/usr/bin/su' as root.
```

Here's the catch: Commands are defined by full paths. You're allowing the user to run any command except for a few specified by full path. All this user needs to do is copy the command to another location and run it.

```
$ cp /bin/sh /tmp/sh
$ sudo /tmp/sh
#
```

Welcome to root!

Negating commands can be bypassed by anyone who understands even the basics of `sudo`, as you'll find well documented in the `sudo` manual and other literature. People *still* insist on using it to protect production systems. Don't be one of those people.

## sudo Logs

Every `sudo` command is logged to */var/log/secure* by `syslogd`. Each log message contains a timestamp, a username, a terminal, the directory where the command was run, the user the command was run as, and the command used.

```
Apr 30 14:16:50 treble sudo:  mwlucas : TTY=ttyp8 ; PWD=/home/mwlucas ;
USER=root ; COMMAND=/usr/bin/su -m
```

By checking the file *secure*, you can track exactly who did what and when. (Send your *syslog* messages to a logging server that your users cannot access to prevent those who screw up from deleting the logs of their screwup.)

```
May 15 09:14:55 treble sudo:  lasnyder : TTY=ttyp4 ; PWD=/etc ; USER=root ;
COMMAND=/bin/rm pf.conf
```

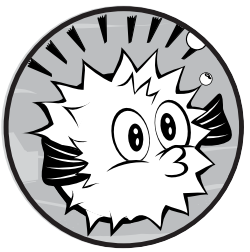
I know exactly who broke this system and when. The log entry transforms what's about to happen from "homicide" to "justifiable manslaughter." That alone makes `sudo` worth using properly.

This chapter has given you some tips on how to avoid screwing up your system accidentally. Now let's look at ways to really mess up your system, by mucking with disks and filesystems.

# 8

# DISKS AND FILESYSTEMS

*Oh, my head hurts bad.*
*Rings of ones and zeros, ouch!*
*Filesystems hide them.*



Proper data management is perhaps a systems administrator's most vital duty. You can replace almost every computer component, but the data on your disk is irreplaceable. Perhaps that data isn't important or it's backed up, but losing files will ruin your day. As a sysadmin, you must protect important data by carefully managing your disks and filesystems.

We covered the basics of disklabels and MBR partitions in Chapter 2, but OpenBSD lets you use and abuse disks and filesystems in any number of ways. You'll learn how in this chapter.

## Device Nodes

A *device node* is a file that provides a logical interface to a piece of hardware. By reading from a device node, sending data to it, or using a command on it, you're telling the operating system to perform an action on a piece of hardware or, in some cases, a logical device.

Different devices behave differently when data is sent to them. For example, writing to the console makes text appear on the screen or terminal, while writing to a disk device puts data on that disk. (OpenBSD puts device nodes in */dev* and disallows device nodes on other filesystems.)

Many disk management programs expect to be given a device name as an argument. Unfortunately, device node names are frequently cryptic and vary widely among operating systems—even on closely related operating systems that run on the same hardware. To simplify your life just a bit, Table 8-1 lists the device node names for common OpenBSD disk devices.

**Table 8-1:** Common Disk Device Node Names

| Device Node | Description |
|---|---|
| */dev/fd** | Floppy disk (block) |
| */dev/rfd** | Floppy disk (raw) |
| */dev/wd** | IDE and some SATA disks (block) |
| */dev/rwd** | IDE and some SATA disks (raw) |
| */dev/sd** | SCSI/SAS/SATA/USB/RAID/non-IDE disk (block) |
| */dev/rsd** | SCSI/SAS/SATA/USB/RAID/non-IDE disk (raw) |
| */dev/cd** | CD/DVD drive (block) |

Device names also have a number that tells you which instance of that device it refers to. The numbering starts at 0. The first IDE hard drive is */dev/wd0*, */dev/wd1* is the second, and */dev/cd1* is the second CD drive.

Every partition is assigned a letter. For example, the root partition is *a*, the swap area is *b*, the whole disk is *c*, and so on. Each partition also has a separate device node, the result of appending the partition letter to your disk device name. For example, if you install to a single IDE drive, your root partition is */dev/wd0a*.

### *Raw and Block Devices*

Notice in Table 8-1 that devices are listed in either block or raw (character) mode. This refers to how the devices are accessed.

#### Block Devices

Hard disks are usually accessed using a block device node (sometimes called a *cooked* device node). When accessing a device as a block, data transmitted to or from the device is *buffered*, or collected until there is sufficient data to

make accessing the device worth the trouble. Block devices are generally considered more efficient than raw devices.

The device nodes for block devices are named after the device driver; for example, */dev/wd3*.

#### Raw Devices

Raw devices are sometimes called *character* devices, because they access a device one character at a time. If you need to control exactly how data appears on a disk (for example, when creating a filesystem) use a raw device. Raw device nodes have an *r* in front of their name, as in */dev/rwd3*.

Raw devices do no buffering. When you tell your system to write to a raw device, the data is transmitted immediately. Raw mode works best with software that provides its own buffering or that wants to arrange data in a specific way.

Here's an easy way to remember the difference between block and raw throughput: Say you spill a bottle of aspirin. If you pick up each aspirin individually and deposit it directly in the bottle, you're doing an unbuffered, or raw, transfer. If you pick up the aspirin with your right hand and collect them in your left, then dump a bunch into the bottle at once (along with all of the dirt from your floor), you're doing a buffered transfer.[1]

#### Choosing Your Mode

Address disks (and many other devices) as raw or block by choosing the corresponding device node. Some programs expect to access raw devices, while others expect block devices. If a program opens */dev/sd1a*, it's accessing partition *a* on disk *sd1* as a block device. If it opens */dev/rsd1a*, it's accessing the exact same partition as a character device.

Regardless of the mode, the underlying hardware remains the same; the only thing that changes is how you exchange information with the device.

### Device Attachment vs. Device Name

Not long ago, most disks were permanently affixed to a single physical location on the system. If your computer had two IDE buses, each with two hard drives, the operating system knew exactly where to find them, usually at */wd1* and */wd2*. A SCSI disk had a SCSI ID and a logical unit number (LUN), and changing them required rebooting the computer. Traditionally, you could use the disk's location in the system to identify the disk. For example, a booting i386 computer would find the root partition by looking for the hard drive attached to the first port on the first IDE controller, finding the *a* partition on that disk, and reading the filesystem table from that disk. You could go into the BIOS to tell the computer to look for the root partition on a different disk, but the computer still identified the disk by where it was physically attached to the computer.

---

1. If it's buffered aspirin, then you're doing buffered buffered aspirin transfers. But let's not go there.

Today, disks can appear and disappear from multiple locations on the system. For example, you might attach and remove several flash drives as needed, or hot swap Serial Attached SCSI (SAS) or Serial ATA (SATA) drives from bus to bus. Physical location is no longer a safe way to identify a disk. While */dev/sd0* is the device node for the first SCSI disk, you cannot assume that the disk currently attached to the first SCSI port is the same disk that was plugged in there the last time the system booted. OpenBSD labels actual disks with unique IDs, as discussed in the next section.

## DUIDs and /etc/fstab

All OpenBSD platforms use the disklabel to identify partitions and other information about a disk. When you label a disk (as we did in Chapter 3 and will do by hand later this chapter), `disklabel` adds a *disklabel unique identifier*, or DUID, to the disk label. The DUID is a unique hexadecimal number that lets OpenBSD identify a specific disk.

To find a disk's DUID, pass the device name to `disklabel` and look for the `duid` entry:

```
# disklabel sd0
...
duid: 55128c3700af5491
...
```

The disk currently attached as `sd0` has a DUID of `55128c3700af5491`. Even if you physically move the disk so that it becomes `sd9` or `sd18`, OpenBSD can use the DUID to uniquely identify this disk.

OpenBSD uses the filesystem table */etc/fstab* to map filesystems on a disk to mount points using either the disk location or the DUID. Each filesystem appears on its own line in */etc/fstab*, as shown here:

```
❶ 55128c3700af5491.b ❷none ❸swap ❹sw
55128c3700af5491.a / ffs rw 1 1
55128c3700af5491.k /home ffs rw,nodev,nosuid 1 2
55128c3700af5491.d /tmp ffs rw,nodev,nosuid 1 2
...
```

We'll focus on the first entry to explore what's going on here. The first field, `55128c3700af5491.b` ❶, is the location of the partition. Whereas older systems used the disk device name and the partition letter (such as */dev/sd0a*), newer systems can use the DUID, a period, and the partition letter (as in `55128c3700af5491.a`). By using DUIDs in the filesystem table, OpenBSD can always mount the same disk at the same location, no matter how it's attached.

The second field, `none` ❷, lists the *mount point*, which is the directory where the filesystem is attached to the directory tree. Every partition you can write files to is attached to a mount point (such as */usr*, */var*, and so on), with one partition being the root partition (/). Swap space uses a mount point of `none`.

Next, `swap` ❸, is the filesystem type. The standard OpenBSD partition uses type `ffs`, the UNIX Fast File System. Other options include, but are not limited to, `msdos` (Microsoft-style FAT partitions), `mfs` (Memory File System), and `cd9660` (CD).

The fourth field, `sw` ❹, shows the mount options used for this filesystem. I'll cover mount options in more detail in "FFS Mount Options" on page 135, but here are a few that frequently appear in */etc/fstab*:

**`ro`** The filesystem is mounted read-only. Not even root can write to it.

**`rw`** The filesystem is mounted read-write.

**`nodev`** Device nodes are not interpreted.

**`nosuid`** `setuid` files are forbidden.

**`noauto`** OpenBSD won't automatically mount the filesystem at boot or when running `mount -a`. This option is useful for removable media drives that might not have media in them, such as CD and USB flash drives.

The fifth field indicates whether `dump(8)` should back up this filesystem. If this field is 0 (or absent), `dump` doesn't routinely back up the filesystem. Otherwise, the number given is the minimum dump level needed to back up the filesystem.

The last field is the *pass number*. It tells `fsck` when to check the filesystem during boot. Filesystems with a pass number of 1 are checked first, filesystems with a pass number of 2 are checked second, and so on. A pass number of 0 tells `fsck` to not check the filesystem during boot. If a filesystem doesn't have a pass number, it's equivalent to 0.

I strongly recommend using DUIDs in */etc/fstab* and anywhere else, rather than using device node names. While a device node name might change, a DUID will not.

## MBR Partitions and fdisk(8)

Some hardware platforms have specific ideas about disk partitioning that differ from what OpenBSD expects. For example, the i386 and amd64 platforms expect to find MBR partitions on hard drives, and OpenBSD accommodates this quirk by putting its own disklabel partitions inside MBR partitions. We briefly touched on creating partitions during the installation process, but if you add hard drives to an existing system, you'll need to edit the MBR partition table by hand using `fdisk(8)`.

My particular test system has two hard drives: *wd0* and *wd1*. I think that *wd1* is completely blank but before I can use this drive, I need to verify that it is empty, and then create MBR partitions. While `fdisk` has all sorts of commands to edit disks, I find the simplest way is to use the interactive disk editor. Run `fdisk -e` and give it the device node for the new disk.

```
# fdisk -e wd1
Enter 'help' for information
fdisk: 1>
```

The editor is minimal, but lets you view, add, remove, and edit MBR partitions. If you forget the commands at any time, entering `help` will print out all the commands `fdisk` supports.

### Viewing MBR Partitions

To see the MBR partitions on the current disk, enter **`print`** or **`p`**. Here's an example:

```
fdisk: 1> print
Disk: wd1       geometry: 2088/255/63 [33554304 Sectors]
Offset: 0       Signature: 0x0
            Starting         Ending         LBA Info:
 #: id      C   H   S -      C   H   S [       start:        size ]
--------------------------------------------------------------------------------
 0: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 1: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 2: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 3: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
```

The first line shows the disk geometry (as discussed in Chapter 2). Every value in this disk's MBR table is set to 0, meaning that it has no configured partitions.

### Adding and Removing Partitions

Say we want to create an MBR partition on this disk. I habitually use partition 0, but the OpenBSD installer usually uses partition 3. The specific number you pick doesn't matter unless you want multiple MBR partitions on the disk.

To edit a partition, enter **`edit`** or **`e`** followed by the partition number. For example, to edit partition 0, enter the following:

```
fdisk: 1> e 0
            Starting         Ending         LBA Info:
 #: id      C   H   S -      C   H   S [       start:        size ]
--------------------------------------------------------------------------------
 0: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
❶ Partition id ('0' to disable)  [0 - FF]: [0] (? for help) a6
  Do you wish to edit in CHS mode? [n]
❷ offset: [0]
❸ size: [0] *
```

**WARNING** *Conveniently, `fdisk` prints the current information on this MBR partition. Make sure it's the partition you think it is before you muck it up.*

First, at ❶, set a partition ID. This is a label indicating what kind of filesystem will be on the disk. OpenBSD uses partition ID `a6`, so enter that.

The offset at ❷ is the number of sectors from the beginning of the disk to the start of the partition. We want to use this entire disk for OpenBSD, so set it to `0`.

Finally, the size at ❸ is the number of sectors the MBR partition fills. There is no need to copy the number of sectors in the disk here; OpenBSD `fdisk` uses * to mean "all free space."

Now print the MBR table again to check your work.

```
fdisk:*1> p
Disk: wd1       geometry: 2088/255/63 [33554304 Sectors]
Offset: 0       Signature: 0x0
            Starting         Ending         LBA Info:
 #: id      C   H   S -      C   H   S [       start:        size ]
------------------------------------------------------------------------------
 0: A6      0   0   1 -   2088 167  63 [           0:    33554304 ] OpenBSD
 1: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 2: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
 3: 00      0   0   0 -      0   0   0 [           0:           0 ] unused
```

Notice that the entry for partition 0 is type A6 and extends from cylinder 0, head 0, sector 1, to cylinder 2088, head 167, sector 63. It fills 33,554,304 sectors—the same as the number of sectors in the disk. This MBR partition fills the entire disk.

If you had recycled this disk from another operating system, it would probably have a partition already on it. To remove a partition, edit the partition and set its partition ID to 0.

### Making a Partition Bootable

In order to boot from a hard drive, you'll need to mark a partition as active. Use the `flag` command and a partition number to do this.

```
fdisk: 1> flag 0
Partition 0 marked active.
```

Include this hard drive in your BIOS boot order, and the computer should try to boot from it. Simply marking a partition as active doesn't mean that the computer *can* boot from it; however, you will still need a kernel, boot loader, and all the other things that go into bootstrapping a computer.

To mark a partition as no longer active, delete and re-create it. (There is no `unflag` command.)

### Exiting fdisk

Once you're satisfied with your work, enter **`quit`** or **`q`**, and `fdisk` should write the new MBR table to disk and exit. If you changed your mind, and don't want to make any changes, enter **`abort`** or **`exit`**, and `fdisk` should exit without saving changes to the MBR partition table.

## Labeling Disks

OpenBSD uses `disklabel` to set up partitions on all hardware platforms. We used `disklabel(8)` as part of the installation process, but you need to partition new disks before you can use them. (You can also use `disklabel` to back up, restore, and duplicate partition tables.)

### *Viewing Labels*

To view the current disklabel, just give the disk name as an argument. Here's how to see the disklabel of the empty disk from the previous section:

```
# disklabel wd1
❶ # /dev/rwd1c:
...
❷ duid: 0000000000000000
...
16 partitions:
#                size           offset  fstype [fsize bsize  cpg]
❸  c:         33554304                0  unused
```

This looks much like the disklabel we saw in Chapter 2, with a few critical differences.

First, note the device at ❶. The `disklabel` command accesses the raw device, but you should use the block device at the command line.

This label at ❷ has no DUID. This is the default empty disklabel. We will generate a DUID later.

At ❸, we see that this disk has only one partition, *c*, which represents the entire disk. You could create and use a filesystem on partition *c*, but it's not standard practice to do so.

### *Creating Disklabel Partitions*

The simplest way to create partitions is to use the same interactive disklabel editor that we used to install OpenBSD. Give the disklabel editor the `-E` flag and the disk name:

```
# disklabel -E wd1
Label editor (enter '?' for help at any prompt)
>
```

Now you can add, remove, and edit partitions, just as in Chapter 3.

Throughout the rest of the book, we'll edit disklabels as needed to change partition and filesystem characteristics.

### Backing Up and Restoring Disklabels

Before messing with a disk, back up its disklabel so that you can fall back to the old label if you screw up. You can back up the disklabel with this command:

```
# disklabel wd1 > wd1.disklabel.saved
```

To apply a saved disklabel to a disk, give `disklabel` the `-R` flag, the disk device, and the label file:

```
# disklabel -R wd1 wd1.disklabel.saved
```

This writes the saved label to the disk. You can use saved disklabels to duplicate partitioning across identical disks.

Now that you have partitions, let's put a filesystem on them.

## The Fast File System

OpenBSD's filesystem, FFS, is an improved version of the filesystem shipped with BSD 4.4. FFS is sometimes called UFS (for Unix File System), and many system utilities still use UFS.[2]

FFS is designed to be fast, reliable, and able to handle the most common situations effectively while still supporting weird configurations. By default, OpenBSD tunes FFS for general use, but you can optimize it to fit your needs—whether you need to hold trillions of tiny files or a half dozen 30GB files. You don't need to know much about FFS internals, but you should at least understand blocks, fragments, and inodes.

### FFS Versions

The original FFS was written in the 1980s and included hard-coded limits that were ample for the day. Filesystems could have up to $2^{31-1}$ blocks, or just under a terabyte (TB). In 1983, a 1TB filesystem was unthinkable. In 2013, 1TB drives are cheap.

For larger file systems, we have FFS version 2. FFS2 can support filesystems up to 8 zettabytes—unthinkable by 2013 standards. (FFS2 is likely to reach other limits before hitting the filesystem size limit, mind you.) OpenBSD supports both FFS and FFS2.

The i386 and amd64 boot floppies support only FFS, not FFS2. The installation CD, however, supports both. Most machines that need to boot from floppy don't need FFS2, and probably don't have a BIOS that can support 2TB drives anyway. The filesystem creation program `newfs(1)` is smart

2. OpenBSD is not the only operating system that still uses the BSD 4.4 filesystem or a descendant thereof. If a Unix vendor doesn't specifically tout its "improved and advanced" filesystem, it's almost certainly running a derivative of FFS.

enough to use FFS2 on filesystems large enough to need it, so for most installations, you don't need to worry about the difference between FFS and FFS2.

**NOTE** *In the exceedingly unlikely event that you actually require FFS2 on a machine that must be installed via floppy, be sure to format the critical system partitions of root (/), /var, and /usr as FFS, not FFS2. Use FFS2 only for partitions that are not critical to the system. Otherwise, you won't be able to use the installation disk for upgrades or emergency repairs.*

## Blocks, Fragments, and Inodes

Both FFS and FFS2 are managed through blocks, fragments, and inodes. This arrangement isn't unique to FFS and FFS2; filesystems such as NTFS use data blocks and index nodes, too. The indexing system used by each filesystem is largely unique, however.

### Blocks

*Blocks* are sections of disk that contain data. Files are placed in one or more blocks. OpenBSD's FFS uses a default block size of 16KB, or eight times the fragment size, whichever is smaller. Not all files are even multiples of 16KB, so leftover bits go in *fragments*. A fragment is one-eighth of the block size, or 2KB by default. A 20KB file fills one block and two fragments.

### Inodes

*Inodes*, or index nodes, contain basic data about files, such as the file's size, permissions, and the list of blocks that contain the file. Collectively, the data in an inode is known as *metadata*, or data about data.

### Superblocks

You'll also see references to *superblocks*, which are blocks that contain vital information about the filesystem's size and specifications. Superblocks are so important that FFS makes many backup copies of them. If you need to meddle with superblocks, you've probably done something wrong or your filesystem is FUBAR.

## Creating FFS Filesystems

Use `newfs(8)` to create FFS and FFS2 filesystems and make sure that the disk has a disklabel. The `newfs` command takes one argument: the partition device node.

```
# newfs wd1a
/dev/rwd1a: 16383.9MB in 33554304 sectors of 512 bytes
81 cylinder groups of 202.47MB, 12958 blocks, 25984 inodes each
super-block backups (for fsck -b #) at:
```

```
 32, 414688, 829344, 1244000, 1658656, 2073312, 2487968, 2902624, 3317280,
3731936,
 ...
```

You'll see details about the filesystem size, how many blocks it includes, and so on. The location of each superblock backup is printed as `newfs` proceeds. (When computers and disks were much slower, this told the operator that the computer was actually doing something and hadn't seized up.)

The partition size determines which filesystem `newfs` uses. Partitions smaller than 1TB are formatted with FFS; larger partitions with FFS2. If you want to specify a particular filesystem format (yes, you can even specify the old-fashioned 4.3BSD format if you like), use the `-O` flag. It makes no sense to demand an FFS filesystem on a large partition, but you might have a reason to use FFS2 on a small partition.

```
# newfs -O 2 wd1a
```

If you think you need to specify which filesystem format to use on a new filesystem, you're probably wrong.

## FFS Mount Options

OpenBSD can handle FFS partitions in several special ways, controlling what sorts of changes the filesystem supports and what sorts of files may exist. These are called *mount options*. You can specify mount options either when you mount partitions on the command line, as we'll discuss in "Mounting and Unmounting Partitions" on page 140, or in */etc/fstab*.

### Mount Options and /etc/fstab

Specify a filesystem's mount options in a comma-separated list in the fourth field of the filesystem's */etc/fstab* entry. For example, here's an */etc/fstab* entry for the partition that contains my */home* directory:

```
244f6d3acd6374ad.k /home ffs rw,nodev,nosuid,softdep 1 2
```

I've specified the options `rw` (read-write), `nodev` (device nodes forbidden), `nosuid` (`setuid` programs forbidden), and `softdep` (soft updates). I'll cover these and other common mount options, and explain why you might want to use them.

### Read-Only Mounts

If you only want to read the contents of a partition, and never write to it, you can mount the partition as *read-only*. In most cases, this is the safest way to mount a disk because you cannot alter the data on the disk or write any new data. If a filesystem should never change, mounting it read-only might make sense.

Read-only mounts are especially valuable when a particular filesystem is damaged. While OpenBSD won't let you perform a standard read-write

mount on a damaged or dirty filesystem, it can often mount those filesystems read-only. This gives you a chance to recover some data from the partition. (Not a large chance, but a chance.)

To mount a filesystem read-only, use the option `rdonly` or `ro`.

### Read-Write Mounts

If you want to both read from and write to the disk, you'll want to mount the partition as *read-write*. By default, OpenBSD mounts all partitions as read-write.

Use the option `rw` to explicitly configure read-write mounts.

On modern hardware, I recommend using soft updates in conjunction with read-write mounts.

### Synchronous Mounts

Using a synchronous mount is the safest way to mount a filesystem. OpenBSD can read data from a synchronous-mounted partition as fast as the hardware permits. Whenever you write to the disk, however, the kernel feeds a chunk of data to the disk, waits to receive confirmation that the disk has accepted the data and written it to disk, and then tells the program that requested the write that the data is now on disk.

You should know that even if you're using a synchronous mount, most hard drives lie about whether they have actually written the data to disk. These drives perform *write caching*, where writes are cached in a small flash or RAM buffer on the disk itself before the drive actually writes the data. This raises the question: Is a synchronous mount really synchronous? Hard drive vendors usually claim that in the event of a power failure, these disks retain just enough power to write the cache to disk.

Although they provide the greatest data integrity in the case of a crash, synchronous mounts are slow. You might use synchronous mounts when data integrity is crucial, but in most cases, it's overkill and you have little ability to verify that the mount is truly synchronous.

Activate synchronous mounts with the `sync` keyword.

### Asynchronous Mounts

To write data quickly, but with a higher risk of data loss, mount partitions asynchronously. When using asynchronous mounts, the kernel informs software that all disk writes are successful before the disk confirms that the data was written. This is fast, but a system failure can leave inconsistent data on your disk.

Asynchronous mounts are useful when restoring a filesystem from backup, because if you get a power failure halfway through the restore procedure, you'll need to start over anyway. Don't use asynchronous mounts in production if you care about your data or would object to re-creating the filesystem.

Activate asynchronous mounts with the `async` keyword.

### Soft Update Mounts

Soft update mounts organize and arrange disk writes so that filesystem metadata remains consistent at all times. This gives performance similar to that of an asynchronous mount with the reliability of a synchronous mount. While that doesn't mean that all data will be written to disk—a power failure at the wrong moment will result in lost data—using soft updates prevents a lot of filesystem integrity problems caused by that lost data. It's not the default because some older, smaller hardware doesn't have enough memory to support it, but if you're using modern i386 and amd64 hardware, I recommend enabling soft updates for all FFS partitions.

To mount a filesystem with soft updates, use the `softdep` option.

### "Don't Track Access Time" Mounts

FFS records the last time a file was read, executed, or otherwise viewed. Updating these access times consumes a small but measurable amount of disk I/O and performance. You can use the `noatime` mount option to tell OpenBSD to not update the access time on any file.

Using `noatime` makes sense on laptops, where minimizing power usage is critical. If you're tempted to use this option on your server to squeeze out a little extra performance, you should buy a faster disk instead. Some software, such as the Mutt mail client, will break if run on filesystems mounted `noatime`.

### No Device Nodes Permitted Mount

By using the `nodev` mount option, you can tell OpenBSD to not interpret any device nodes on any given filesystem. Intruders can try to create "rogue" device nodes and use them to write files or attack the network, but if the kernel won't recognize those device nodes, it cuts off this whole category of attacks.

This type of mount is also useful if you have hard drives from multiple operating systems on your computer. For example, if you dual-boot OpenBSD and Linux on your computer, but you don't want to accidentally access a Linux device node when using OpenBSD, the `nodev` option will prevent you from doing so. (You might think you would notice that you had typed */linux/dev/hda* rather than */dev/wd1*, but never underestimate your ability to screw up.) In most cases, the partition containing */dev* is the only one that should contain device nodes.

### Execution Forbidden Mounts

The `noexec` mount option prevents any binaries on the partition from being executed. Mounting */home* with the `noexec` option helps prevent users from installing and running their own programs, but for it to be effective, you'll need to make sure users can't install binaries in any shared areas, such as */tmp* and */var/tmp*.

Note that forbidding execution of binaries doesn't prevent users from running interpreted scripts from that partition. Maybe the users can't run a compiled C program, but if they can run `perl $HOME/rootkit.pl`, then `noexec` won't slow them down very much.

#### setuid Forbidden

The `nosuid` option disallows `setuid` behavior from programs on this filesystem. Many partitions should not have `setuid` files, and setting this is an easy way to disrupt them. OpenBSD sets this on partitions such as */home* and */tmp* by default. You must carefully place this option on all user-writable filesystems for it to prevent undesired behavior.

#### Do Not Automatically Mount This Filesystem

`noauto` isn't actually a mount option, but rather a way of telling OpenBSD to not mount a given partition listed in */etc/fstab* at boot. I frequently make */etc/fstab* entries for removable media drives, but the system should not try to mount these at boot. The boot will hang if a partition required by */etc/fstab* is not available, and I don't want my computer to refuse to boot just because I unplugged a flash drive.

### Filesystem Integrity

Both versions of FFS go to a great deal of trouble to ensure that the data on disk is correct and intact. The blocks that contain a file should be recorded in an inode, the inodes should all be referenced by directory entries, and so on. When you remove a file, all references to that file should be removed.

After a system failure, however, data might not be consistent. Metadata might reference blocks that were previously erased; a file might be in a different location than the inode record specifies; and the filesystem might have all kinds of references pointing to things that have moved, changed, or disappeared. These inconsistent, or *dirty*, filesystems cannot be trusted and must be rationalized, or *cleaned*, before you can mount them read-write. If you mount a dirty filesystem read-only, it might only panic your system, but if you force OpenBSD to mount a dirty filesystem read-write, you will damage the dirty filesystem even more.

At boot, OpenBSD performs a minimal inspection and cleaning, or *preening*, of the filesystems and will automatically correct any minor problems found. If preening cannot fully clean the filesystem, the boot will hang until you intervene.

When confronted with a dirty filesystem, you have a few options: use the filesystem checking tool `fsck(8)`, debug the filesystem with `fsdb(8)` and `clri(8)`, or throw the filesystem away and run `newfs(8)`. Most of the time, you'll attempt to repair the filesystem with `fsck`. Using `fsdb` successfully requires more knowledge about FFS innards than I possess, so I recommend it to only those who really want to develop an in-depth knowledge of FFS and have

a whole bunch of time to devote to it. Rebuilding the filesystem with `newfs` destroys everything on the filesystem, but it's a decent choice for partitions that contain only ephemeral data, such as */usr/obj*.

You can use `dump(8)` to copy the damaged filesystem before trying any of the repairs. This gives you the option to fall back to the current state if attempts at repairing the disk fail. (If you have to do this, though, you should probably reevaluate your backup strategy.)

### Running fsck

If you try to mount a dirty filesystem either at boot time or during routine operation, you'll see a message that looks like this:

```
/dev/rwd1a: UNEXPECTED INCONSISTENCY; RUN fsck_ffs MANUALLY
```

The `fsck(8)` program is a frontend for several filesystem-specific integrity-checking programs. When you run it, `fsck` identifies the type of filesystem and calls the correct integrity checker for you. Run `fsck` by giving it the device name of the filesystem you want to check:

```
# fsck /dev/wd1a
```

You can use either the raw or cooked device name; `fsck` is smart enough to use the raw node even if you give the cooked device name.

Examining the filesystem can take quite a while, so be patient.

When run on a dirty filesystem, `fsck` will probably find a number of problems: blocks that have become disassociated from their inodes, inodes that reference empty blocks, and so on. It can often make a good guess as to how everything fits together.

When `fsck` finds a problem that it isn't absolutely sure about, it will suggest a fix and ask if you want to make the change. If you answer `y`, `fsck` makes the change. If you answer `n`, `fsck` leaves the filesystem unchanged. If you tell `fsck` not to make the change it suggests, the filesystem will still be dirty, and you'll need to fire up `fsdb` or `clri` and make the change you think more appropriate.

Sometimes, `fsck` can't identify the name or directory of a file recovered from a damaged filesystem. These files go into the partition's *lost+found* directory (for example, */usr/lost+found*). You'll need to use programs such as `grep` and `strings` to try to identify these files by their contents.

### Blindly Trusting fsck

Those of us who lack the skills to debug a filesystem find ourselves in a difficult situation, where we can either accept that `fsck(8)` knows what's best or just restore from backup. If your filesystem was performing a lot of disk I/O just before system failure, `fsck` might need to make dozens or hundreds of changes. You could spend an hour sitting at the console pressing `y` repeatedly.

If you decide to trust `fsck` and hope it's right, run `fsck -y`. This means "answer `y` to every question." You might wind up with the entire contents of the filesystem in the *lost+found* directory, or you might lose every file on the filesystem. But unless you're intimately familiar with the innards of FFS, you would need to restore from backup anyway.

If you run `fsck` and realize partway through that you would like to answer `y` to all the questions that follow, enter `F`. That tells `fsck` to answer `y` to all remaining questions.

At the end of the procedure, you've either recovered your system or need to restore from backup.

## What's Currently Mounted?

While performing routine work, inevitably you'll need to check which disks are currently mounted and which are not. To see a list of all mounted filesystems and their mount options, run `mount(8)` without any options:

```
$ mount
/dev/wd0a on / type ffs (local)
/dev/wd0k on /home type ffs (local, nodev, nosuid)
/dev/wd0d on /tmp type ffs (local, nodev, nosuid)
/dev/wd0f on /usr type ffs (local, nodev)
/dev/wd0g on /usr/X11R6 type ffs (local, nodev)
/dev/wd0h on /usr/local type ffs (local, nodev)
/dev/wd0j on /usr/obj type ffs (local, nodev, nosuid)
/dev/wd0i on /usr/src type ffs (local, nodev, nosuid)
/dev/wd0e on /var type ffs (local, nodev, nosuid)
```

Both FFS and FFS2 partitions show up as `type ffs`. The word `local` means that the partition is on a physical drive attached to this machine. We covered the various mount options (`nodev`, `nosuid`, and so on) earlier in this chapter.

Note that `mount` displays the device node mounted at each partition, not the DUID. If you want to see the DUID of a disk, check the disklabel.

## Mounting and Unmounting Partitions

To attach filesystems to your directory tree, or *mount* them, use `mount(8)`. If you've never manually mounted filesystems before, boot your OpenBSD machine into single-user mode (see Chapter 5) and follow along.

In single-user mode, OpenBSD mounts only one partition: the root partition, which it mounts read-only. The root partition contains just enough of the system to perform basic setup, establish core services, and find the other filesystems.

Because filesystems other than the root are not mounted, their content is not accessible. Look in, say, */usr* on a system in single-user mode, and you'll find that it's empty. OpenBSD hasn't lost the files; it just hasn't mounted the partition containing those files.

To get any real work done in single-user mode, you probably need to mount other filesystems.

### Mounting Standard Filesystems

To manually mount a single filesystem listed in */etc/fstab*, give `mount(8)` the name of the filesystem you want to mount. Here, we'll mount our */usr* partition:

```
# mount /usr
```

This mounts the partition exactly as described in */etc/fstab*, with all the options specified therein.

To mount all of the partitions listed in */etc/fstab*, give `mount` the `-a` flag:

```
# mount -a
```

All of your filesystems (except those not listed in */etc/fstab* and those with the `noauto` option) should now be mounted.

### Mounting at Nonstandard Locations

Perhaps you must mount a filesystem at a location not specified in */etc/fstab*. I do this most commonly when adding a disk to a machine. To mount a partition at a location other than that specified in */etc/fstab*, or to mount a partition without an */etc/fstab* entry, give the partition device name and the mount point.

```
# mount /dev/sd0d /mnt
```

You must use the full path for the device node, not just the brief device node name.

Instead of the path to the device node, you could use the DUID, a period, and the partition letter, but on the command line, that's more painful than using the path to the device node.

### Unmounting Partitions

To disconnect a filesystem from the directory tree, use `umount(8)` on a mount point. (Note that there is only one `n` in this command.) Here, we'll use `umount` to unmount our */usr* partition:

```
# umount /usr
```

You cannot unmount filesystems that are in use by any program. Even a command prompt in the mounted directory will prevent you from unmounting the partition.

To unmount all partitions except the root partition, pass `umount` the `-a` flag:

```
# umount -a
```

As programs almost certainly have files open on every partition, this probably works only in single-user mode. Note that you don't need to unmount all partitions to leave single-user mode.

### Mounting with Options

Suppose you pull a disk from a decommissioned OpenBSD machine and you need to retrieve some files from it. You want to mount the disk read-only so that you don't change any of the files on the disk. To manually mount a partition with options not specified in */etc/fstab*, use the `-o` flag.

For example, if the disk shows up as */dev/sd0* and you want to mount partition *a*, run this command:

```
# mount -o ro /dev/sd0a /mnt
```

To prevent old software from running on your newer system, it might be a good idea to use some of the options we covered earlier, such as `noexec`, `nodev`, and `nosuid`.

## How Full Is That Partition?

To get an idea how much free space remains on your partitions, use `df(1)`. This program displays the total number of filesystem blocks on each partition, how many blocks are in use, and how many blocks are free. It also gives you the percent in use.

One annoying thing about `df` is that it offers this information in 512-byte blocks by default. This was fine when disks were much smaller, but today, it's like measuring the distance of an airplane flight in yards. Some people have done this for so long that they automatically perform block transformations in the back of their mind.[3] For the rest of us, the `-h` flag tells `df` to provide human-readable output, such as megabytes or gigabytes, giving us something like this:

```
# df -h
Filesystem     Size    Used   Avail Capacity  Mounted on
/dev/sd0a     1005M   39.1M    916M     4%    /
/dev/sd0k     26.9G   27.0G   -104M    -1%    /home
/dev/sd0d      3.5G   12.0K    3.3G     0%    /tmp
...
```

You might wonder why the */home* partition in this example has negative free space. How is that possible? By default, FFS reserves 5 percent of each partition for moving files and reducing fragmentation. When you exceed 100 percent disk utilization, you begin tapping into this reserved space.

FFS performance degrades quickly when the partition is overfull. It's best to keep some free space on your disk so that FFS can defragment itself.

3. Hi, Henning!

You can reduce the amount of space FFS reserves, but doing so will impact performance. See `tunefs(8)` for instructions on how to shoot yourself in the foot.

### What's All That Stuff?

When you see a partition is full, the obvious question is "What's filling up my disk?" Every hard drive I've ever owned has gradually filled up for no apparent reason. You can identify individual large files with `ls -l`, but recursively examining every directory in the filesystem is impractical and tedious (not to mention annoying).

To check the number of filesystem blocks used within each directory below the current directory, use `du(1)`.

```
$ du
164     ./.ssh
2       ./old
6       ./.mozilla/firefox/bcpuv16e.default/chrome
80      ./.mozilla/firefox/bcpuv16e.default/Cache/0/B0
354     ./.mozilla/firefox/bcpuv16e.default/Cache/0/31
28      ./.mozilla/firefox/bcpuv16e.default/Cache/0/7A
...
```

When I run `du` in my home directory, I get 700 entries; of those, 563 are related to some Mozilla tool. This kind of list intimidates the new sysadmin and makes the experienced sysadmin work too hard. Rather than cull through this list manually, tell `du` to show only the total for directories in the current directory, and then sort the output so that the largest directories appear first.

```
$ du -s * | sort -rnk 1
25224805  Dark_Shadows_Complete_Series
141104    mibs
14948     tarballs
4668      work
1864      pix
...
```

I now know why my */home* partition is full.

You can tell `du` to display human-readable values with the `-h` flag, but doing so will show values in a mix of gigabytes, megabytes, and kilobytes, making `sort` far less useful.

### Setting $BLOCKSIZE

Many disk tools—including, but not limited to, `du(1)` and `df(1)`—display information in 512-byte blocks. If you're accustomed to working in blocks, you probably won't mind seeing them. If you're not used to working in blocks, however, they'll probably make you want to tear out your hair.

The environment variable BLOCKSIZE tells these programs to display information using blocks of a different size. If you set BLOCKSIZE to K, df and du will display totals in kilobytes. If you set it to M, these tools will show megabytes instead. Check your shell manual page or the dotfiles in your home directory for examples of setting environment variables.

## Adding New Hard Disks

The OpenBSD installer walks you through formatting and partitioning your initial hard disks. If you need to add a disk to an existing system, however, you must run these commands yourself. The good news is that if you can install OpenBSD, you already know how to use the commands, and the only hard part is learning which commands to run.

I'll show you how to move */home* to a new disk as an example. You could create a new partition on your existing disk if you have some empty space, but that would eliminate the need for this example, so I'm going to pretend I never gave you that advice. (Also, moving partitions to a separate disk controller channel will improve performance.)

**WARNING** *Before touching anything involving disk partitioning or filesystems, back up your system. Verify that backup before starting. You have been warned.*

### Creating an MBR Partition

The i386 and amd64 platforms require disks to have MBR partitions as well as OpenBSD partitions. A standard new disk needs a single OpenBSD MBR partition covering the entire disk. Passing the -i argument to fdisk does exactly this. Let's create a new MBR partition on wd1, our new disk:

```
# fdisk -i wd1
Do you wish to write new MBR and partition table? [n] y
Writing MBR at offset 0.
```

Once you have an MBR partition on your disk, you can create disklabel partitions.

### Creating a Disklabel

All OpenBSD platforms use disklabel partitions. To activate the same disklabel editor we used during the install process, give disklabel the -E flag and the disk name:

```
# disklabel -E wd1
```

This should look familiar from earlier in this chapter. Use the interactive disklabel editor to create your new partitions. For a single */home* directory, we'll use one large partition, *wd1a*. The new label should look like this:

```
#               size           offset  fstype [fsize bsize  cpg]
  a:        33543648               64  4.2BSD   2048 16384    1
  c:        33554304                0  unused
```

When you've finished editing partitions, check your work by printing the disklabel. This should also give you the DUID of the new disk.

When you're satisfied with the partitioning, use `newfs` to create a filesystem on the new partition:

```
# newfs wd1a
```

You're now ready to add the filesystem to your computer.

### Moving Partitions

Moving data from one disk to another is slightly more complex than adding new partitions. You must first mount the new drive in a temporary location, copy files to that location, remove them from the old location, and mount the new drive in its previous home.

Our new */home* filesystem is on disk partition *wd1a*. The default "temporary mount" location is */mnt*, so mount it there. This is strictly temporary, so there's no need to mount it via the DUID or make an */etc/fstab* entry for this.

```
# mount wd1a /mnt
```

You can then use `tar(1)`, `cpio(1)`, or `dump(8)` and `restore(8)` to copy the files to the temporary location. Here, we copy everything in */home* to */mnt*.

```
# (cd /home && tar cf - . ) | (cd /mnt && tar xpf - )
```

You could also use `cp(1)` or `mv(1)` for this, but these commands don't guarantee that file permissions and ownership will copy intact. OpenBSD's versions of these programs have never given me errors when I copy or move files, but I've learned from other Unix-like operating systems that `tar` and `cpio` are both more reliable when moving entire file hierarchies. If you're using file flags for security (see Chapter 10), you must use `dump(8)` and `restore(8)` to retain those flags.

Using `tar` or `cpio` does not delete files from their original location. This means that if a user changes files in his home directory after you copy them but before you change the mount point, he will lose his changes as you shuffle disks around. [4]

Now update */etc/fstab* to reflect your new disk.

4. Presumably you warn your users before doing maintenance. Or at least *during* maintenance. Or . . . maybe afterward.

### Adding New Filesystems

Look at the disklabel for the new disk and get the disk's DUID. This new disk has a DUID of `fea9194ee78362d8`. Use the DUID and the partition letter to make an */etc/fstab* entry for your new partitions.

```
fea9194ee78362d8.a /home ffs rw,nodev,nosuid,softdep 1 2
```

You might want to keep the old partition available at a new location, such as */oldhome*.

If you're not sure about the mount options to use for your new partitions, the options `nodev`, `nosuid`, and `softdep` are generally safe. You probably want the partition mounted read-write (`rw`) as well.

Now unmount the old and mount the new.

```
# umount /home
# mount /oldhome
# mount /home
```

When you unmount a partition, `umount` doesn't check */etc/fstab*. You tell it to unmount a partition, and it unmounts that partition.

### Stackable Mounts

OpenBSD filesystems are *stackable*, which means that you can mount one partition over another. The partition on top hides any files in the filesystem below.

Look at your system in single-user mode. By default, only the root partition is mounted. You can go look in the */home* directory, and it will be empty. There's no reason you can't put files in the */home* directory, even when */home* isn't mounted. Suppose you copy a couple of core files into */home* while in single-user mode, and then go into multiuser mode. All the usual partitions are mounted. If you then look in */home*, you won't find your core files.

What happened? Where did those files go?

The files are in the directory */home*, but on the root partition. The */home* partition is mounted above that directory, so the */home* partition obscures the files in the */home* directory on the root partition. To access those hidden files, you must unmount the */home* partition. Those hidden files continue to take up space on the root partition, however.

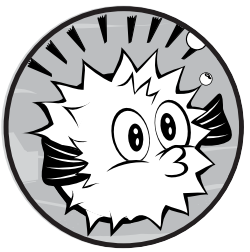
This happens more commonly when splitting a partition. For example, if you find that your */var* partition is too small, you might move */var/www* into its own partition on a separate disk. To free up space on the original */var*, delete the files you copied to */var/www*.

With the basics of filesystem management under your belt, you're now ready to look at some of OpenBSD's more interesting filesystem tricks.

# 9

# MORE FILESYSTEMS

*Encrypt your hard drive?*
*Software RAID can save your day,*
*or ruin your life.*



Disk management isn't complicated, but there's enough material that it gets two chapters. Lucky you! In this chapter, we'll start with how to automatically back up your vital root partition to a second disk. Then we'll explore how OpenBSD can use additional memory as disk space via a memory filesystem and how to set that up. Next, we'll access disks formatted for other operating systems, such as NTFS, ext2, and FAT. Removable media isn't difficult to work with, but has its own concerns. If you don't need the actual media, but can work with disk images, you can access those. Both topics are covered in this chapter. We'll also discuss using NFS, as both a server and a client. Our final topic is OpenBSD's disk redundancy and disk encryption features.

## Backing Up to the /altroot Partition

You can lose most of your partitions and still hope to recover the rest of the system. If you lose your root filesystem, however, recovery becomes a much more difficult task. While you could back up critical files from */etc* and use them to restore your system, OpenBSD provides the */altroot* partition as an easy way to automatically duplicate the root partition on a second disk.

An emergency root partition on a second disk gives you an easier path to recovery in the event of a disk failure. Booting to the second disk lets you pull any data off that disk, and possibly even from undamaged partitions on the first disk, before replacing the failed disk. There's no reason to back up your root partition to the same disk, however, as the whole disk will probably be unusable.

This backup requires a free disk partition the same size as your root partition, located on a different disk. The OpenBSD installer defaults assume that you have only one disk. If you have a second disk during installation, you need to use a custom install process to create the */altroot* partition, as we did in the multiple disk installation in Chapter 3. While configuring partitions is easiest during the installation, you can add more disks later if needed, as discussed in Chapter 8.

Your */altroot* partition needs an */etc/fstab* entry. If you created the partition during the install process, that */etc/fstab* entry already exists but has the wrong mount type. If you created this partition after installation, you'll need to create an */etc/fstab* entry yourself. The */altroot* partition needs a mount type of `xx`, as shown here:

```
a914f9a264fa64e6.a /altroot ffs xx 0 0
```

You cannot mount this partition from its */etc/fstab* entry, as `xx` is not a valid mount type. (You could run, say, `mount /dev/sd1a /altroot` if you want to manually mount this partition.) The daily system maintenance job */etc/daily* uses this mount option to identify the root backup partition.

To enable the */altroot* backup, add `ROOTBACKUP=1` to your */etc/daily.local* file.

## Memory Filesystems

In addition to creating partitions on raw disk, OpenBSD lets you create partitions in system memory. A *memory filesystem* (*MFS*), or *memory disk*, lives in your machine's RAM, rather than on a physical disk. Reading and writing files to and from such a filesystem is much faster than accessing those same files on a spinning disk, which makes a memory-backed filesystem a huge optimization for certain applications.

If MFSs sound too good to be true for high-performance environments, that's because they are. Understand their limits before you implement them everywhere. First, RAM does not persist across reboots or shutdowns, so either will erase the contents of an MFS. While this might seem obvious,

I've surprised myself more than once by losing a file stored on a filesystem I had forgotten was an MFS. Furthermore, if your system crashes, you'll lose any data stored on an MFS.

You can use an MFS partition as scratch space to rapidly compile, compress, decompress, or otherwise manipulate temporary files. I've seen news server histories, database locks, and other application-specific files stored on MFSs.

An MFS works even in situations where the system regularly swaps. The kernel retains any information being actively used in memory, while transferring unused information to swap space. This is excellent for small partitions like */tmp*, in which small, frequently used files can be quickly accessed. Files that are less frequently accessed end up in swap space, which gives performance similar to accessing a physical disk.

One last word of caution: Don't make heavy use of MFSs if you don't have RAM to spare. If you run short on combined memory and swap space, your system will perform very poorly.

### Creating MFS Partitions

Create temporary MFS partitions with `mount_mfs(8)`. Like other `mount_` commands, `mount_mfs` takes two arguments: the physical device and a mount point. Unlike physical disks, memory doesn't have a device node, so use the device node of the system swap space. If you have multiple swap partitions, pick whichever you like.

Here is how you can create a memory-backed filesystem by passing a swap partition, */dev/sd0b*, and a desired mount point, */mnt*, as arguments to `mount_mfs`:

```
# mount_mfs /dev/sd0b /mnt
```

The size of this partition will be limited only by the size of your swap partition.

You can create smaller memory-backed filesystems, so that you will have memory and/or swap space available if you fill the memory disk. Specify the size with the `-s` flag and a number of sectors, or with a trailing `b` (bytes), `m` (megabytes), or `g` (gigabytes). Here's how to create a 128MB MFS on */mnt*:

```
# mount_mfs -s 128m /dev/sd0b /mnt
```

If you request an MFS larger than your system can support, you'll get a warning like `mmap: Cannot allocate memory`. Try again, this time with a more reasonable size.

### Mounting an MFS at Boot

You can mount an MFS at boot by adding an */etc/fstab* entry. You only need a mount point and the partition size.

```
❶swap    ❷/mnt    ❸mfs    ❹rw,async,-s=128m    ❺0    ❻0
```

You don't need to specify a specific swap device; OpenBSD is smart enough to let you say the memory disk is generically swap-backed ❶. Just as with any other partition, you also need to specify the mount point ❷ and the filesystem type ❸.

When dealing with a memory disk, you can use different options than you would for a traditional disk ❹. Since a system crash would destroy all files on the MFS anyway, you can safely mount an MFS partition as asynchronous using the `async` option. You might also want to use `nodev` and `nosuid` mount options on this partition. You can specify the size with the `-s` option, but make sure that you put an equal sign (`=`) between the `-s` and the size. Because */etc/fstab* uses whitespace to separate fields, OpenBSD will think the dump level is 128m if you don't use an equal sign.[1]

Data on a memory disk is by definition disposable, so don't back it up ❺. Similarly, never use `fsck(8)` with a memory disk at boot ❻. The memory disk is created anew at each boot, so it is automatically internally consistent.

## Foreign Filesystems

Any partition that uses a non-FFS filesystem is foreign to OpenBSD. Although OpenBSD can access many foreign filesystems, don't expect it to be seamless.

Support for some filesystems is incomplete. For example, you can mount Microsoft NTFS partitions only as read-only. Other filesystems don't support the full range of OpenBSD commands. Because FAT filesystems don't have any concept of file ownership or permissions, commands like `chmod` and `chown` won't change anything on the disk.

Each supported filesystem has its own mount program to handle the vagaries of that filesystem. To simplify your life, `mount` can usually recognize supported filesystems from the on-disk format and call the correct mount program as needed. To mount a foreign filesystem, you need the device node and a mount point. Depending on the filesystem, you may also need to know the type of filesystem you'll be mounting.

### *Inodes vs. Vnodes*

Before we talk about foreign filesystems, let's touch on something that confused me for a long time: the difference between inodes and vnodes.

The FFS uses index nodes, or *inodes*, to map blocks of disk that contain data. This worked just dandy when hard drives were big, expensive things that no one moved between computers. Over the years, however, swapping disks between machines has become more popular.

Although Unix-like systems think in terms of accessing files via inodes, the FAT32 filesystem doesn't use inodes, ext2fs's inodes don't map directly onto FFS inodes, and CDs use a completely different layout. To access all of these filesystems in a consistent way, BSD needed another layer of abstraction.

1. I don't know what a dump level of 128m means, other than "not what I want."

The virtual node, or *vnode*, is an abstraction layer the kernel uses to access all filesystems. Users never manipulate vnodes directly, but you'll see references to them throughout OpenBSD's documentation. Every tool that reads or writes to disks does so through vnodes, which map the requests to the filesystem. When you write to an FFS block or inode, the kernel addresses data to a vnode, which in turn maps to an inode. When you write to a FAT32 filesystem, the kernel addresses data to a vnode mapped to a point in the FAT32 filesystem. You use inodes only when dealing with FFS systems, but your data will pass through a vnode when accessing any filesystem.

Don't let references to vnodes on non-FFS systems confuse you. They're part of OpenBSD, not the filesystem.

### Common Foreign Filesystems

Common foreign filesystems include MS-DOS, NTFS, ext2fs, and CD. We'll look at how to access disks formatted for those operating systems with OpenBSD.

#### MS-DOS

OpenBSD supports the FAT, FAT16, and FAT32 filesystems. These formats are commonly found on flash media, old Microsoft operating systems, and floppy disks.

To mount a filesystem with a FAT filesystem partition, use `mount_msdos(8)`.

```
# mount_msdos /dev/sd3i /mnt
```

Not sure which partition on the disk is the FAT filesystem? Run `disklabel(8)` on the drive and see. FAT filesystems are often located on the *i* partition. And even if you try inserting your USB drive and mounting its *i* partition, OpenBSD will probably figure out that it's a FAT system.

If you work with FAT disks often, you might investigate */usr/ports/sysutils/mtools*, a collection of software for working with FAT filesystems without mounting them. While `mount_msdos` is quite reliable, mtools offers a more elegant interface.

#### NTFS

To mount disks formatted for modern Microsoft operating systems, use `mount_ntfs(8)`.

```
# mount_ntfs /dev/sd3k /mnt
```

As I write this, OpenBSD supports NTFS4 (from Windows NT) and NTFS5 (in Windows 2000 and XP). Windows Vista and newer systems are not yet supported, but they might be by the time you read this.

If you need to view file attributes specific to the NTFS filesystem, check the `mount_ntfs` man page for details.

#### ext2fs

To mount ext2fs and ext3fs filesystems, use `mount_ext2fs(8)`. (The one program mounts both types of filesystem.)

```
# mount_ext2fs /dev/sd3l /mnt
```

Owing to their shared Unix heritage, the Linux ext2fs and ext3fs filesystems support many FFS-like features. Unlike with NTFS, you can safely read and write ext2fs and ext3fs disks in OpenBSD. You cannot, however, read ext4fs partitions using OpenBSD.

#### CD

Compact discs formatted for data use the ISO-9660 filesystem. To mount a CD, use `mount_cd9660(8)`.

```
# mount_cd9660 /dev/cd0a /mnt
```

Mount CDs using either the *a* or *c* partition on the device. If you would like to save yourself a few keystrokes, `mount(8)` is very good at automatically detecting ISO-9660 filesystems. The device node for a CD is tied to the CD drive, not the disk itself, so the node shouldn't change unless you add another drive.

If you're interested in burning a CD, look at `mkhybrid(8)` and `cdio(1)`.

### *Foreign Filesystem Ownership*

Most foreign filesystems either have no concept of file ownership or have an ownership scheme incompatible with that of Unix-like operating systems. (Notable among these filesystems are FAT and NTFS.) The programs that mount these kinds of filesystems thoughtfully allow you to specify the ownership of files on the filesystem. The `-u` flag lets you specify a file owner, and the `-g` flag lets you specify the group.

For example, here's how I would mount a FAT filesystem as owned by my account:

```
# mount_msdos -u mwlucas -g mwlucas /dev/sd3c /mnt
```

Some other filesystems use permissions schemes compatible with OpenBSD's permissions. For example, all of the information OpenBSD needs to assign permissions to files and directories is contained within an ext2fs filesystem. That doesn't mean that an ext2fs filesystem will perform seamlessly on OpenBSD, however. Though OpenBSD will respect the ext2fs disk's permissions, the user ID numbers probably won't match up between the operating systems.

## Removable Media

These days, the removable media you'll most likely deal with are external hard drives, flash drives, and CDs. The CD is the simplest, because you know how to use `mount(8)` and `umount(8)`, and you know its device node and filesystem type will always be the same. But how do you identify the device name of a removable hard drive?

When you attach a drive to your machine, OpenBSD automatically assigns your drive a device node to your console and prints a message to the console. You can check the console as you attach the drive, or you can watch your messages log by running `tail -f /var/log/messages` before attaching the drive.

If you frequently use a particular removable disk, you can simplify your routine by making an */etc/fstab* entry for it. Here are some sample */etc/fstab* entries for a CD and a FAT flash drive.

```
/dev/cd0c /cdrom cd9660 ro,noauto
/dev/sd3i /mnt msdos rw,noauto
```

You can't use DUIDs for removable media, because the actual media might change.

Now you can mount your CD on */cdrom* by entering `mount /cdrom`, and your FAT flash drive on */mnt* by entering `mount /mnt`.

Note that OpenBSD does not create a */cdrom* directory by default; you'll need to create it yourself. You could point both of these at */mnt*, but I like having a dedicated CD mount point on my systems, and having two devices share a mount point risks concealing one of the filesystems. (Remember that OpenBSD has stackable mounts, as discussed in Chapter 8.)

## Mounting Filesystem Images

You can mount a disk image and access the image just as you would a disk partition. This is very useful for those times you want to extract a few files from an ISO but don't want to bother burning the image to physical media. The trick to mounting a disk image is attaching the image to a device node so that you can use the proper `mount` command.

OpenBSD uses the `vnconfig(8)` program to attach disk images to device nodes. (Remember that a vnode is an abstraction layer between the kernel and a filesystem.) Use `vnconfig` to "wire" vnodes between a file and a device node, and then access them through OpenBSD's */dev/svnd* devices. Depending on the disk image type, the image might have MBR partitions, disklabel partitions, or just a filesystem.

The default kernel has four vnode devices. If you need to mount more than four disk images simultaneously, edit your kernel binary using `config(8)`'s `-e` option, as discussed in Chapter 18.

### Attaching Vnode Devices to Disk Images

The `vnconfig(8)` command takes two arguments: the device node you want to use and the disk image you want to mount.

```
# vnconfig /dev/svndXc /path/to/file
```

Note that this example uses the *c* partition of the device. This allows you to treat the disk image as a whole disk.

Suppose you have an ISO image named *install52.iso* that you would like to mount. First, use `vnconfig` to attach this image to vnode device 0.

```
# vnconfig /dev/vnd0c install52.iso
```

You can then use `mount` to attach the vnode to an */mnt* directory.

```
# mount /dev/vnd0c /mnt/
```

OpenBSD's `mount(8)` is smart enough to recognize this as a CD filesystem and mount it as such. If you're mounting a disk image that uses a less detectable filesystem, you need to use the specific `mount` command for that filesystem.

### Detaching Vnode Devices from Images

Vnode devices attached to a file remain attached until specifically disconnected, and you can attach a vnode device to only one file at a time. To disconnect the vnode device from the file, use the `-u` flag with `vnconfig`. For example, to disconnect the vnode device located at *vnd0c*, run this command:

```
# vnconfig -u vnd0c
```

You can now attach this vnode device to another file.

Using the full path to the device is optional in `vnconfig`. If you know the device name, you can use it without the leading */dev*, as in the preceding example.

## Basic NFS Setup

NFS allows one machine to access files on another machine. NFS has its origins in UNIX, but today appears in most operating systems, including those from Microsoft and Apple. OpenBSD supports NFS versions 1 through 3 as both a client and a server.

Entire books can be—and have been—written about NFS. We won't go into the intimate details of NFS, but rather focus on getting a basic NFS share working on OpenBSD. Configuring NFS the first time can be intimidating, but after setting up a file share or two, you'll find it straightforward.

If you have a complicated NFS environment—involving multiple versions of multiple operating systems—or if you want to share a directory among hundreds of active clients, you should do further research, but even a basic setup will help to simplify parts of your job.

NFS works on the client/server model. One computer, the server, offers filesystems to other computers. The server is *exporting* a filesystem, and the filesystems on offer are called *exports*. NFS clients can mount exports in a manner almost identical to that used to mount local filesystems.

One important thing to remember about NFS is that it is *stateless*, which means that NFS does not track the condition of a connection. You can reboot an NFS server, and the client won't throw a fit. The client cannot access files on the server while the server is down, but once the server returns, the client will pick up right where things left off. Other network filesystems are not always so resilient. Statelessness causes its own problems as well. For example, clients cannot know when a file they are currently reading has been modified by another client.

If you're just learning NFS (or OpenBSD's implementation of NFS), check */var/log/messages* for NFS-related error messages. If you've repeatedly reconfigured your NFS server as part of learning, and things just don't work correctly, reboot your NFS server and/or client. NFS is complicated, and sometimes starting with a clean stack clears up a lot of problems. Once you understand how all the pieces fit together, a reboot to resolve problems should never be necessary.

**NOTE** *The NFS protocol has evolved over the years, and every operating system has implemented a slightly different version of NFS. Other BSDs, Illumos, Linux, Apple, Microsoft, and most other operating systems can work with OpenBSD's NFS support, but each may require an occasional tweak for specific environments. If you're having trouble getting NFS to work with OpenBSD and another operating system, read* `mount_nfs(8)` *and feed the details to your favorite search engine. The odds that someone else has experienced this problem before are good.*

## The OpenBSD NFS Server

By default, OpenBSD includes all the programs necessary to act as an NFS server, but you must turn it on. The NFS server requires three daemons:

**`portmap(8)`** Maps requests for remote procedure call (RPC) services to TCP/IP port numbers.

**`mountd(8)`** Listens for incoming NFS mount requests.

**`nfsd(8)`** Processes requests for filesystem actions.

The `portmap(8)` daemon has its own *rc.conf* flag, as it can be used by many other RPC services. The `mountd(8)` and `nfsd(8)` daemons are controlled by a single *rc.conf* flag.

Add the following entries to *rc.conf.local* to start all three processes at boot time:

```
portmap=YES
nfs_server=YES
```

You can start these three daemons from scripts in */etc/rc.d*. If you try to start these daemons now, however, they won't run. You must configure at least one export before the NFS server daemons will start.

### Exporting Filesystems

To export filesystems, define which clients may mount which filesystems and/or directories in */etc/exports*. This file takes a separate line for each disk device on the server and each client or group of clients that can access that disk device. Each line has up to three parts:

- Directories or partitions to be exported
- Options on that export
- Clients permitted to connect

Of the three components of an */etc/exports* entry, only the directory is mandatory. The directory path cannot contain symlinks, double dots, or single dots.

If I wanted to export my home directory as read-write to every host on the Internet, I could use an *exports* line containing only the path to my */home* folder:

```
/home/mwlucas
```

This perfectly valid (but perfectly foolish) entry contains no options and no host restrictions.

To export multiple directories that reside on the same partition, separate them with a single space.

```
/home/mwlucas /home/lasnyder
```

You can list any number of directories on one line, as long as they exist on the same partition.

NFS clients can mount only exactly the directory specified in */etc/exports*. If you export */home/mwlucas*, clients can attach only */home/mwlucas* to a mount point. They cannot mount, say, */home/mwlucas/bin* instead. If you would like to export an entire partition, you can do that, too. If you want to let clients mount any directories beneath that mount point, specify the mount point and the `-alldirs` option. You cannot use `-alldirs` with a subdirectory; it must be the actual mount point. This next entry lets anyone mount any directory in */home*:

```
/home -alldirs
```

To export multiple partitions, or directories from multiple partitions, specify them on separate lines.

```
/home -alldirs
/var/log
```

Any time you change */etc/exports*, you must signal `mountd` to reread its configuration. You can do this by passing the `reload` argument to the `mountd` startup script:

```
# /etc/rc.d/mountd reload
```

While these simple mounts give you an idea of how NFS works, they're very insecure. To make an intelligent export, you need a few options and an access list. Let's take a look at some of NFS's more commonly used options.

### Read-Only Mounts

You might want to share files without worrying about whether your underlings will delete, modify, or otherwise undo your hard work. You can share files as read-only by using the `-ro` option. Here, I offer my home directory to all the computers in the world, but as a read-only share:

```
/home/mwlucas -ro
```

This is slightly more intelligent than offering my NFS exports to the entire world read-write, but only slightly.

### NFS and Users

You already know that file ownership and permissions are tied to UID numbers. Unlike many other file-sharing protocols, NFS also uses UIDs to identify file ownership. For example, on my test server, my account `mwlucas` uses the UID 1000; on my client, my `mwlucas` account also uses the UID 1000. This simplifies my life, as I don't need to worry too much about file ownership; files owned by `mwlucas` on the server are owned by `mwlucas` on the client.

On a small network with only a few users and machines,[2] you can probably keep UID numbers synchronized without a problem by assigning the same UID to the same user on all of your systems. But on a large network, with more than one user and where users have root on their own machines, file ownership can quickly become a serious problem. The best way around this is to maintain a central repository of authorized users via LDAP or Kerberos.

Regardless of how you manage your users, NFS handles the root account differently. An NFS server cannot trust root on client machines to execute commands or write files as root on the server; if that were the case, a breach

2. How many users do I mean by "a few?" When synchronizing UIDs across all of your systems begins to really, *really* annoy you, you no longer have a few users.

on one NFS client would mean a breach on the NFS server. By default, requests from root on the client are mapped to UID and GID 32767 (also known as `nobody`).

If you want to map root to a specific user rather than the generic UID `nobody`, use the `-maproot` option and specify either a username or UID. Here, we map incoming requests from root on the client to the user `nfsroot` on the server:

```
/home/mwlucas -maproot=nfsroot
```

You can give the mapped root user a list of groups that the remote root account can access by specifying them after the username, separated by colons. Here, we give the client's root user access to the server as the user `nfsroot` and the groups `customers` and `webmasters`:

```
/home/mwlucas -maproot=nfsroot:customers:webmasters
```

If you want to explicitly remove the mapped root user from all groups, put a colon after the username or UID, as in this example:

```
/home/mwlucas -maproot=nfsroot:
```

Suppose you want all the NFS clients, regardless of username on the client system, to use a single user ID on the NFS server. The `-mapall` option allows you to do this. This option uses the same format as the `-maproot` option. Here, we map all NFS users to the username `nfsuser` on the server:

```
/home/mwlucas -mapall=nfsuser
```

Correct control of user access will help protect your NFS server.

### Permitted Clients

By default, every host can access your NFS server. For many reasons, that's not a great idea. You can restrict the clients permitted to access your NFS server by listing their IP addresses at the end of the export entry.

```
/home/mwlucas 192.0.2.1
```

You can also specify clients by their hostname, but if the server has a DNS failure, it won't allow any clients access.

```
/home/mwlucas treble.blackhelicopters.org
```

To permit access to an entire network, use the `-network` and `-mask` options. The next example permits access to the addresses 192.0.2.0 through 192.0.2.15, using a subnet mask. (If you're not familiar with subnet masks, read Chapter 11.)

```
/home/mwlucas -network=192.0.2.0 -mask=255.255.255.240
```

When setting up your NFS server, I recommend you grant access to only the hosts who need it.

### *Multiple Exports for One Partition*

You can have only one line for each combination of partition and permitted clients. If */home* is a single partition, you can't have an exports file that looks like this:

```
/home/mwlucas -maproot=nfsroot: 192.0.2.1
/home/pkdick 192.0.2.1
```

If two directories are located on the same partition, NFS will not allow you to export them to the same host using different permissions. You can, however, export directories on one partition to different hosts with different permissions, as shown here:

```
/home/mwlucas -maproot=nfsroot: 192.0.2.1
/home/pkdick 192.0.2.2
```

You can export directories on a partition to different hosts with different permissions.

```
/home/mwlucas -maproot=nfsroot: 192.0.2.1
/home/mwlucas -maproot=root 192.0.2.2
```

Only by combining IP restrictions and controlling user permissions can you can effectively control NFS server access.

## NFS Clients

OpenBSD's NFS client doesn't need any daemons or configuration. Just `mount` the remote filesystem. Here, I mount my home directory from my server `treble` on */mnt*:

```
# mount treble:/home/mwlucas /mnt
```

When mounting remote filesystems over NFS, enter the hostname or IP address, a colon, and the directory. Because I have the same UID on both the client and server, I can access, alter, remove, and add files in */mnt* exactly as if I were dealing with files on a local filesystem.

Verify your mount with `df(1)` or `mount(8)`.

```
$ df -h
Filesystem             Size    Used   Avail Capacity  Mounted on
/dev/sd0a             1005M    266M    689M    28%    /
...
treble:/home/mwlucas  26.9G   21.5M   25.5G     0%    /mnt
```

The NFS-mounted directory shows up like any other mount point.

To mount an NFS share automatically at boot, or just record it for future convenience, you may use an */etc/fstab* entry. If your system might not have DNS available to it at boot time, use an IP address for the NFS server. The following example specifies two *fstab* entries: one using a hostname and one using an IP address:

```
treble:/home/mwlucas /mnt nfs,noauto rw 0 0
192.0.2.88:/usr/ports /usr/ports nfs,noauto ro 0 0
```

Give all NFS partitions dump and `fsck` numbers of `0`. Do not run `fsck` or `dump` on an NFS mount, as those programs require raw disk access that NFS doesn't provide.

Use any other mount options you like. The OpenBSD folks recommend using `noexec`, `nodev`, and `nosuid` "when applicable." I recommend `noauto` on NFS partitions that aren't required for normal server operation, so that an unavailable NFS server does not hang your machine's boot process.

NFS performance depends a great deal on your hardware, your local network, the clients and servers involved, the phase of the moon, and any number of other factors. If you're not happy with your NFS performance, read `mount_nfs(8)` and experiment with using TCP or UDP, the read and write sizes, and perhaps the timeout. If you need a complicated NFS environment, you should definitely invest some time in learning more about NFS.

## Software RAID

The Redundant Array of Independent Disks (RAID) technology has become the standard way of mirroring hard drives within a machine or combining multiple hard drives to form one giant partition. In many types of RAID arrays, if one disk fails, the system can continue to run without data loss until you replace the failed disk or a second disk fails.

You can get RAID from the hardware or have the operating system perform the RAID operations. Hardware RAID controllers seem nice, but are in reality just decent disk controllers that run special software. Using the `softraid(4)` driver, OpenBSD can do the same thing, letting you build RAID arrays out of plain disks. You can do just about everything you can with a hardware RAID controller with a bunch of disks and OpenBSD's RAID management program `bioctl(8)` and the `softraid(4)` software RAID driver.

**NOTE** *In addition to managing software RAID, OpenBSD's `bioctl(8)` can manage most sorts of hardware RAID controllers. If you're planning to use hardware RAID, reading the `bioctl` manual is definitely worth your time.*

### RAID Types

OpenBSD supports the following RAID configurations:

**RAID-0, or *striping***
: This type is not redundant. It requires at least two disks of the same size, and data is shared between the disks to increase partition size and throughput. You can use RAID-0 to combine five 4TB disks into a 20TB virtual disk, but be warned: If one hard drive in the array fails, you'll lose all your data. RAID-0 is useful when you need a really big filesystem, but it's more vulnerable than a single disk because it provides multiple points of failure (or as one of my quasi-literary, quasi-humorous friends once said, "RAID-0 gives a whole new meaning to the phrase one disk to rule them all"). The size of a RAID-0 array is the size of all the hard drives combined.

**RAID-1, or *mirroring***
: With this type, the contents of one disk are duplicated on another. Mirroring requires at least two disks of the same size, and the size of a RAID-1 array is equal to the size of the smallest drive in the array. I use mirroring to protect all vital data, as it gives even a cheap desktop-chassis server some measure of data protection. OpenBSD's software RAID fully supports this level.

**RAID-4, or *striping data across disks, with a dedicated parity disk***
: This type requires at least three disks of the same size. Parity data lets a RAID array recover data on missing disks, and RAID-4 stores that parity data on a specific disk. This means that you can lose any one of the disks without losing data. As I write this, `bioctl`'s RAID-4 support is experimental. Hopefully this support will be complete before the book reaches you, but if not, you'll need to use a hardware RAID card to get RAID-4.

**RAID-5, or *striping with parity shared across all drives***
: This is the current industry standard for redundancy. Parity data provides data redundancy—the loss of a single drive doesn't destroy any data. It requires at least three disks of the same size. Unlike RAID-4, RAID-5 shares the parity data across all the drives simultaneously. While throughput isn't as good as that of RAID-0, a RAID-5 array can simultaneously serve multiple I/O requests. The size of your RAID-5 array is the combined size of all but one of your hard drives. If you have five 4TB drives, the array will be 16TB ((5 – 1) × 4TB). Like RAID-4, RAID-5 support in `bioctl` is incomplete and experimental. I hope it will be complete before you read this, but if not, you'll need to use a hardware RAID card for RAID-5.

According to the RAID standards, each of these levels requires disks of the same size. That said, OpenBSD's `softraid` uses partitions rather than disks. You can use disks of different sizes, but your RAID array will use only

an amount of space on each disk equal to the smallest drive. If you want to mirror a 1TB drive and a 2TB drive, your mirror will offer only 1TB of space. The excess space on the larger drive is wasted.[3]

In addition to the standard RAID methods, `softraid` also allows you to encrypt your data across all disks in a RAID array (as described in "Encrypted Disk Partitions" on page 166). It also lets you *concatenate* disks. Concatenated disks are just run together to create one large virtual disk. You could concatenate two 500GB disks and a 1TB disk to create a single 2TB partition. These disks don't need to be the same size, but as with RAID-0, they are vulnerable. Damage to any one disk will completely wreck the virtual disk and lose all data. As the process for creating a concatenated disk closely resembles that of creating a RAID-0 disk, we'll cover it in "Creating softraid Devices" on page 163.

### Preparing Disks for softraid

The `softraid` software RAID device builds its virtual disks out of disklabel partitions. To use a disk in a `softraid` array, prepare it just as you would a disk for a regular filesystem.

On i386 and amd64, disks underlying a `softraid` device need an MBR partition. To mark a whole disk with a single MBR partition, run `fdisk -i` on the disk.

Suppose you have five disks to use in a RAID array: `sd2`, `sd3`, `sd4`, `sd5`, and `sd6`. You'll need to prepare each of them as follows:

```
# fdisk -i sd2
Do you wish to write new MBR and partition table? [n] y
Writing MBR at offset 0.
```

Repeat this for every disk in your array.

Once you've added an MBR to all your disks, you'll need to put a disklabel partition on each disk. I tend to use partition letter *p* (the last available partition letter) for `softraid` devices. Here's how to set up a disk for `softraid`:

```
# disklabel -E sd2
Label editor (enter '?' for help at any prompt)
❶ > a
❷ partition: [a] p
offset: [64]
size: [104856191]
❸ FS type: [4.2BSD] RAID
❹ > q
❺ Write new label?: [y] y
```

3. You could add a non-RAID partition in the unused space on the larger drive, but that would do terrible things to your system's performance. Just buy more hard drives, you cheapskate.

First, we add a partition with `a` ❶ and assign it partition letter `p` ❷. Instead of our usual filesystem type of 4.2BSD, we assign a filesystem type of `RAID` ❸. Then we quit ❹ and let `disklabel` write the changes to the disklabel partition ❺.

If you have multiple identical disks, you can use `disklabel` to save this disk's configuration, as follows:

```
# disklabel sd2 > disklabel.sd2.raid
```

This saves the label on disk `sd2` to the file *disklabel.sd2.raid*. You can make `disklabel(8)` copy this partitioning to other disks, and `disklabel` will assign each disk a unique DUID as it copies. This saves you from needing to walk through the interactive editor for each disk. Let's apply this disklabel to each partition:

```
# disklabel -R sd3 disklabel.sd2.raid
# disklabel -R sd4 disklabel.sd2.raid
# disklabel -R sd5 disklabel.sd2.raid
# disklabel -R sd6 disklabel.sd2.raid
```

Disks `sd2` through `sd6` are now ready for assimilation into `softraid`.

### Creating softraid Devices

Use `bioctl(8)` to drag disks into a software RAID. You'll need the disk partitions you want to include in the RAID. OpenBSD software RAID arrays are named `softraid`, followed by a number. Use the `-c` argument to give a RAID type, and `-l` to give the partitions, and end with the name of the `softraid` you're creating.

```
# bioctl -c raidlevel -l partition1,partition2... softraidX
```

We have five disk partitions—`sd2p`, `sd3p`, `sd4p`, `sd5p`, and `sd6p`—to add to a `softraid` device. To build a RAID-5 device out of these partitions, run this command:

```
# bioctl -c 5 -l sd2p,sd3p,sd4p,sd5p,sd6p softraid0
softraid0: SR ❶ RAID 5 volume attached as ❷ sd7
```

The response indicates that we've successfully created a RAID-5 device ❶, and it's available as device `/dev/sd7` ❷. On a blank RAID disk, which you need to prepare just as you would any other new disk, run `fdisk -i sd7` and `disklabel` to create MBR and OpenBSD partitions, use `newfs` to create a filesystem on the new partitions, and you're ready to go. (See the instructions for adding a new disk in Chapter 8 for details.)

You could have made this a RAID-0, RAID-1, or RAID-4 device by choosing a different `-c` option. The tricky one is a concatenated `softraid`. To dump all the disks together into a single concatenated virtual partition, use `-c c`.

```
# bioctl -c c -l sd2p,sd3p,sd4p,sd5p,sd6p softraid0
softraid0: SR CONCAT volume attached as sd7
```

### softraid Status

To check the health of each device in a RAID array, give `bioctl` the device name of the `softraid` device.

```
# bioctl softraid0
Volume      Status               Size Device
softraid0 0 Online       214744170496 sd7     RAID5
          0 Online        53686099456 0:0.0   noencl <sd2p>
          1 Online        53686099456 0:1.0   noencl <sd3p>
          2 Online        53686099456 0:2.0   noencl <sd4p>
          3 Online        53686099456 0:3.0   noencl <sd5p>
          4 Online        53686099456 0:4.0   noencl <sd6p>
```

We see that the five drives are in use, all assembled into a RAID-5 virtual drive. Everything here is healthy. Anything that doesn't look roughly like this indicates a problem.

### Identifying Failed softraid Volumes

If you have a RAID-1, RAID-4, or RAID-5 `softraid` volume, you can lose a drive and not lose your data. `bioctl` tells you if a drive fails. Here, one of the drives in my `softraid` volume has failed:

```
# bioctl softraid0
Volume      Status               Size Device
softraid0 0 Degraded     214744170496 sd7     RAID5
          0 Online        53686099456 0:0.0   noencl <sd2p>
          1 Offline                  0 0:1.0   noencl <>
          2 Online        53686099456 0:2.0   noencl <sd3p>
          3 Online        53686099456 0:3.0   noencl <sd4p>
          4 Online        53686099456 0:4.0   noencl <sd6p>
```

Looking closely at this, I can see that drives `sd2`, `sd3`, `sd4`, and `sd6` are still available and in use. All my data should still be intact, but I need to replace `sd5` before another disk fails.

### Rebuilding Failed softraid Volumes

As of this writing, you cannot rebuild a failed `softraid` RAID-4 or RAID-5 device. You must back up your data, replace the failed drive, delete the `softraid` device, re-create the filesystem, and restore from backup. You can, however, rebuild a RAID-1 device.

Let's look at replacing a disk in a RAID-1 device. Here's what a healthy, three-disk `softraid` mirror might look like:

```
# bioctl softraid0
Volume      Status               Size Device
softraid0 0 Online        53686099456 sd5❶  RAID1
          0 Online        53686099456 0:0.0   noencl <sd2p>❷
          1 Online        53686099456 0:1.0   noencl <sd3p>
          2 Online        53686099456 0:2.0   noencl <sd4p>
```

Note that this RAID device has device node `sd5` ❶ and includes the partitions *sd2p*, *sd3p*, and *sd4p* ❷.

We replace two disks and reboot this machine. Suddenly, the *softraid* device looks very different.

```
# bioctl softraid0
Volume      Status               Size Device
softraid0 0 Degraded      53686099456 sd5     RAID1
          0 Offline               0 0:0.0   noencl <>
          1 Offline               0 0:1.0   noencl <>
          2 Online        53686099456 0:2.0   noencl <sd2p>
```

Partitions *sd3p* and *sd4p* are missing. That's because the underlying disks have been replaced.[4] Prepare the replacement disks for software RAID, as discussed in "Preparing Disks for softraid" on page 162. Then run `bioctl`, using the `-R` flag to specify the disk to replace in the `softraid` device.

```
# bioctl -R /dev/sd3p sd5
softraid0: rebuild of sd5 started on sd3p
```

If you check the status of the device using `bioctl`, you'll see the disk status now says "Rebuilding."

If you have a mirror with more than two disks, you must rebuild each disk separately. Rebuild the first disk, and then rebuild the second disk.

### Deleting softraid Devices

To remove a `softraid` device from your system, pass `bioctl` the `-d` flag and the device name for the `softraid` device. Here's how to remove the RAID-5 device we just created:

```
# bioctl -d sd7
```

**WARNING** *Once you delete the RAID device, you can't get it back unless you re-create it and restore your data from backup.*

4. If you need to force an error on a hard disk, removing the disk from the machine will certainly do it.

### Reusing softraid Disks

softraid writes metadata at the beginning of the disks it uses. You need to overwrite this metadata before you can use the disks in another softraid device. Overwrite the first megabyte or so of the disk with dd(1).

```
# dd if=/dev/zero of=/dev/sd2c bs=1k count=1024
1024+0 records in
1024+0 records out
1048576 bytes transferred in 0.594 secs (1765074 bytes/sec)
```

This erases the MBR partitions, any initial disklabels, and any filesystem information on the disk. You can now reuse these disks in softraid devices as normal disks.

### Booting from a softraid Device

The softraid feature is still in development. Eventually, you'll be able to use the installer to build a software RAID device, install OpenBSD on that device, and run a full RAID configuration out of the box. But as I write this, you'll need to jump through some hoops to make that happen. Rather than document a specific procedure that will change as OpenBSD completes softraid development, I'm going to tell you to search the Internet and the *misc@OpenBSD.org* archives for the most recent instructions.

## Encrypted Disk Partitions

Sometimes I can see the future. When someone says, "I've encrypted my hard drive!" I have a psychic vision of them saying "I've lost all my data!" While encrypting a hard drive partition is warranted in some cases, most of the time, it's just pretentious. In this section, I will do you the courtesy of assuming that you understand when you truly need disk encryption if you will do me the courtesy of not complaining to me when you lose your data.[5]

### Creating Encrypted Partitions

OpenBSD includes disk encryption as a bioctl(8) option—specifically, like a RAID discipline. Where disk activity would normally be passed through a RAID discipline, here they pass through an encryption discipline. The encrypted disk even shows up as a softraid device. Much like the support for RAID-5, support for encrypted filesystems is experimental. Although it *should* work, don't be shocked if some features are not yet included or if it eats your entire disk. Keep good backups. Reread the previous paragraph. And again—*please* don't complain to me when it doesn't work.

5. Not that I can help you—all I can do is say "I told you so." On a related note: You can get tired of anything, no matter how pleasant, if you have to do it often enough.

Under OpenBSD, an encrypted volume can include only a single partition. Use the RAID type `C` to specify an encrypted volume. Here's, how to create an encrypted volume on the *sd4p* partition:

```
# bioctl -c C -l sd4p softraid0
❶ New passphrase:
Re-type passphrase:
softraid0: SR CRYPTO volume attached as sd5
```

When prompted ❶, enter a passphrase twice. A good passphrase is several words long, and includes a mix of characters, symbols, numbers, punctuation, and whitespace. The passphrase is the secret code used to encrypt and decrypt data, so the longer and more varied it is, the better. Remember this passphrase; you must enter it again to recover your data. Once you've entered your passphrase twice, `bioctl` creates the encrypted disk device. In this case, it has created encrypted disk `softraid0` as `disk sd5`.

### Using Encrypted Partitions

Do not mount this new disk yet! Instead, use `fdisk` to check our new, encrypted partition.

```
# fdisk sd5
Disk: sd5       geometry: 6526/255/63 [104855663 Sectors]
Offset: 0       Signature: 0x8BF9
            Starting         Ending         LBA Info:
 #: id      C   H   S -      C   H   S [       start:        size ]
-------------------------------------------------------------------------------
 0: D9 230285  63  36 - 134263  55  58 [  3699532529:  2752373385 ] <Unknown ID>
 1: 8C  73068 221  44 - 176434  56  49 [  1173851386:  1660564401 ] <Unknown ID>
 2: C9 218148  78  47 - 141866 243  13 [  3504552580:  3069507328 ] <Unknown ID>
 3: AC 125252   6   1 - 245307  77  22 [  2012173758:  1928688070 ] <Unknown ID>
```

The underlying disk is blank, and our `fdisk` output looks like garbage, but this disk is now an encrypted volume.

Now that the encrypted disk exists, create an MBR partition and add disklabel partitions, just as when you add any other disk. Then you can mount your encrypted device partition using the device node—again, just as with any other disk.

To unmount the decrypted partition, destroy the `softraid` device by passing `bioctl` the `-d` argument.

```
# bioctl -d sd5
```

To anyone who doesn't have the passphrase, this partition now looks like random garbage.

### Automatic Decryption

If you have an encrypted partition, presumably you don't want OpenBSD to automatically decrypt and mount it when the system boots. (The whole point of an encrypted partition is that only a person who has the passphrase can access the encrypted data.) Still, I'm not one to tell you not to shoot yourself in the foot, so if you must automatically decrypt the partition, you can do so.

First, create a file containing your passphrase. Give ownership of this file to root and set the permissions to `600` (read-write by owner; no access by other users), and then give this file to `bioctl(8)` with the `-p` flag. In this example, the encrypted disk is created as */dev/sd5* and there is a partition on */dev/sd5a*. I've stored my passphrase in the file */etc/passphrase*, so I could run something like this:

```
# bioctl -c C -l sd4p -p /etc/passphrase softraid0
# mount /dev/sd5a /home/mwlucas
```

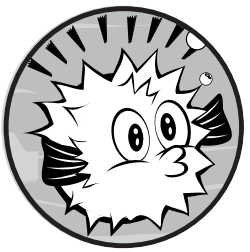
Adding this to */etc/rc.securelevel* will mount this encrypted partition at boot.

You should now have a good idea of how to manage OpenBSD disks and filesystems. Next, we'll look at some of OpenBSD's special security features.

# 10

# SECURING YOUR SYSTEM

*Hackers at the gates?*
*Puffy the Barbarian*
*defends against fiends.*



Securing your system means ensuring that your computer's resources are used only by authorized people and for authorized purposes. Even if a system has no important data, it still has valuable CPU time, memory, storage, and bandwidth. People who think that their systems are too unimportant for anyone to bother breaking into risk finding their equipment hosting pornography or relaying attacks against industrial or military sites. If you're like me, you would rather not discover that your computers took down a government agency by having law enforcement agents kick in your door.

Taking over large numbers of remote computers gets easier all the time. Every year, more and more point-and-click toolkits for penetrating servers crop up. When one bright attacker posts an exploit, anyone can use it. Breaking into computers is big business, and if your computer is left unprotected, it *will* be penetrated. The only question is how.

Generally speaking, intruders don't break into operating systems; they break into server programs running on the operating system. Even the most paranoiac, secure-by-default operating system cannot protect poorly written programs from themselves. OpenBSD features like W^X and address space layout randomization do a lot to protect the operating system from the side effects of buggy programs, but programs themselves still crash and burn. OpenBSD has undergone extensive auditing and testing to eliminate the most common security flaws, but there's no guarantee that every security flaw has been eradicated. New features appear constantly, and can interact with older functions (and each other) in unexpected ways. For more details on the OpenBSD-specific features, check the papers and presentations collection at *http://www.OpenBSD.org/papers/*.

No single tool can protect your server against all threats, and no single tool is applicable to all environments. Learning about OpenBSD's security features helps you to understand not only what the tools do, but when they should be used and when they won't help your particular situation. The best place to start is by understanding the threat.

## Who Is the Enemy?

Books dedicated to security break attackers down into smaller, more specific groups and include various edge cases, but that's not what you're here for. I lump potential attackers into four groups: script kiddies, botnets, disaffected users, and skilled attackers. These categories are easily understood and include 99 percent of all the attackers you're likely to encounter.

### *Script Kiddies*

The most common type of attackers, script kiddies, are not sysadmins. They are amateurs who download attack scripts and go looking for poorly defended, vulnerable systems.

Script kiddies are easy to defend against: Keep your software up-to-date and follow good computing practices. Like locusts, script kiddies are easy to squash, but there are just so darned *many* of the little buggers!

### *Botnets*

Botnets are composed of machines compromised by worms or viruses and are controlled from a central point. The botnet's controllers might use the victim machines to search for more vulnerable hosts, to send spam, or to break into secure sites. Most botnets are composed of Windows or Linux machines, but there's no reason why such a worm couldn't target OpenBSD. The virus author would need to work hard, but it's conceivable—if he finds a suitable security flaw.

Fortunately, botnet defense is much like script kiddie defense. You shouldn't have much to worry about if you keep your software patched, configure your server software securely, and follow good computing practices.

### Disaffected Users

Security pundits commonly claim that a system's legitimate users cause the majority of security problems.[1] Legitimate users are most likely to know where your security gaps are, to feel that the system rules don't apply to them, and to have the necessary access and time to experiment with breaking your security. If you tell an employee that company policy forbids him access to a computer resource, and the employee feels that he *should* have access to it, he is likely to search for a way around the restriction. You can patch all of your servers and protect them with an outright hostile firewall, but if someone has physical access and knows the root password, your protections are useless.

Deal with this problem on two levels. The first is technical: Keep your servers patched and up-to-date. The second is human: Don't leave projects half finished or half documented. That unsecured modem you installed for emergency incoming access until the VPN is solid? Get rid of it, or put a password on it. Ditto for that telnet server running on a nonstandard port.

Security by obscurity is feeble at best. When a privileged user leaves the company, immediately disable his account, change all administrative passwords, inform employees of the person's departure, and remind them not to share confidential information with that person. Implement a computer security policy with real penalties for violations. If you have a Human Resources department, get the staff members to agree to the policy and insist they enforce it.

What's the best way to protect yourself against the disaffected user? Don't be lazy.

### Skilled Attackers

As the most dangerous group, skilled attackers are competent system administrators, security researchers, penetration specialists, and criminals who want access to specific resources. Taking over computers is a lucrative business these days. Sending junk email or launching distributed denial-of-service attacks can bring in large sums of money. These intruders don't care who they attack, as long as they secure the computing resources they need.

If your company has valuable secrets, however, you might attract an entirely different type of intruder: someone who wants access to your network in particular. If your employer creates anything—from software to cast-iron tulips for front-wheel-drive vehicles—there's likely a market for illicit copies of your product. Someone will find it worthwhile to probe every port on every IP address you expose to the Internet. It might take a long time, but that's okay. Your data has a price tag, and the scan is cheap. This is often called the advanced persistent threat, or APT.

---

1. I've seen too many botnet or script kiddie intrusions go undetected for months to be comfortable blaming legitimate users for the majority of security problems. I would agree that "insider intrusions" are the most commonly identified intrusions, but frequently, that's because the guilty user can't keep his mouth shut.

Security measures that stop the other types of intruders affect the techniques used by skilled attackers. If you've ditched that unsecured inbound access method, the intruder can't find it. If your servers and programs are up to date and correctly configured, the intruder will need to find a previously unknown exploit to break into your network. If a skilled intruder really wants *your* company's data, he will need to change tactics. Maybe he will try dumpster diving for old sticky notes, or even show up dressed as a telco repairman and try to install a packet sniffer. If an intruder knows everything about your network and his easiest way to break in is *still* something out of a caper film, your security is pretty good.

**NOTE** *The word hacker has different meanings depending on who is talking. In the technical world, a hacker is someone not only interested in the inner workings of technology but also capable of creating new technology. The media has transformed the word to mean "someone who breaks into computers." I recommend completely avoiding the word "hacker," and using terms like "intruder" or "gravy sucking pig-dog" instead. When to use each is up to you, of course.*

## OpenBSD Security Announcements

Your best line of defense against all types of intruders is keeping your computer software up to date. This means you need to know when to update your system and what to update. The OpenBSD Project maintains a low-traffic mailing list, *security-announce@OpenBSD.org*, specifically to broadcast new security alerts to users. Subscribe to this list.

If you don't feel like subscribing to yet another mailing list, these security alerts are also posted on OpenBSD-specific sites such as *http://www.undeadly.org*.

Note that this won't get you security alerts for third-party software running on OpenBSD. You must get updates for those programs separately. Check the software's website for details on how to get their security announcements. All the time you've spent securing your operating system will be wasted if someone hijacks the insecure web application you neglected to update.

## OpenBSD Memory Protection

One of the most common intrusion paths is to attack what's in the computer's memory. If intruders can access memory that they shouldn't be able to access, or if they can make a program access memory it shouldn't, they have any number of ways to get into the system.

OpenBSD includes a whole bunch of security features for system memory that the sysadmin never actually sees. You don't need to turn on the nonexecutable stack; it's just there.

Some of these features appear only in OpenBSD. Some appeared first in OpenBSD, and then spread elsewhere. Some came from research papers. Others build on hardware features.

The OpenBSD team takes a more proactive attitude about security features than many other projects. As an example, consider the ProPolice deployment several years ago. ProPolice is a compiler feature that prevents certain classes of buffer overflows. When you enabled ProPolice in the early days, a lot of software could not be built. Even more software could be built, but it crashed when used. These failures were not ProPolice problems. ProPolice simply exposed programming errors in the software. But many users and developers said that "enabling ProPolice breaks all kinds of stuff, so don't turn it on."

The OpenBSD team enabled ProPolice by default in a development snapshot. What happened? Stuff—a lot of stuff—broke. Many third-party applications needed by OpenBSD users either could not build or would not run. Third-party application vendors started receiving bug reports from OpenBSD users who were able to say exactly how the software was broken. Software vendors started fixing bugs.

ProPolice didn't cause these crashes; it merely exposed bugs. By enabling ProPolice by default, OpenBSD gave the free software world incentive to fix those bugs. Eventually, as the type of bugs revealed by ProPolice became less common, other operating systems also enabled ProPolice. OpenBSD's willingness to take this step improved computer security as a whole.

If you closely follow OpenBSD development, expect to see more of this behavior. The OpenBSD team does what it considers most correct, not what is most convenient or easiest.

The common memory security features you should know about include W^X, .rodata segments, guard pages, randomized memory allocations, ProPolice, and protecting `atexit` and `stdio`. We'll cover each in turn.

### W^X

W^X stands for Write Xor Execute. Once a program is loaded, that program's pages in memory are either writable or executable, but not both.

A common exploit technique is to trick a program into writing information to memory, and then executing that piece of memory. An attacker might convince a program to write to a chunk of memory, but the kernel will not allow that memory to be executed.

Some hardware platforms (such as amd64) have hardware support for W^X. If that support exists, OpenBSD uses it.

### .rodata Segments

A segment of memory containing program code traditionally had two parts: actual code and read-only data, or *.rodata segments*. In the past, some operating systems allowed programs to modify read-only memory. OpenBSD prevents this by leveraging hardware features when available.

### Guard Pages

Many pieces of software used to access memory beyond what they allocated. If a program writes to memory that doesn't belong to it, it's writing to memory that belongs to a different program. Intruders use this to exploit programs. A *guard page* is a single page of memory next to the memory allocated by a program. The program cannot write to this memory. If the program tries to write to the guard page, it probably will crash. By enforcing this limit, OpenBSD protects other programs.

Using guard pages everywhere would use a lot of memory, so OpenBSD enables guard pages only in carefully selected places.

### Address Space Layout Randomization

Traditionally, computers allocate memory consecutively. This can give intruders certain advantages. If they know that program A usually loads after program B, and they know they can make program B write to memory space outside its allocation, they can guess that they can write to program A's memory space and make program A fail in a predictable manner. Doing so requires a certain degree of skill, but once one person figures out this exploit, innumerable people can use it.

OpenBSD randomizes where it allocates memory. Two programs started one after the other don't get consecutive memory blocks. The randomization is done intelligently, to avoid wasting memory. Intruders cannot use one program against another in this manner.

### ProPolice

ProPolice protects code against attacks that manipulate the memory stack. When code is compiled, ProPolice adds additional code to keep a program within its own area of memory. If ProPolice determines that specific areas of memory (called *canaries*) have been changed, it immediately aborts the program. Where other memory protection techniques prevent writing to executable memory, ProPolice terminates a process when writable memory that *can* be written to, but specifically *should not*, is changed.

### And More!

OpenBSD includes a whole bunch of small memory guards scattered throughout. Here's a small sampling:

- The `malloc()` and `atexit()` system calls mark memory nonwritable after updating it.
- File descriptor handling has been carefully audited throughout.
- `snprintf` is async-signal-safe when no floats are involved.

And the list continues.

Could any of these be exploited in the real world? Some of them have, and some are just theoretical. But I would rather be protected against theoretical threats than assume no one can break something that has never been broken before.

## File Flags

All Unix-like operating systems share a common permissions scheme, but OpenBSD (and most BSD-based operating systems) extends the permissions scheme with *file flags*. File flags work with permissions to change file security. Flags can make a file unchangeable, make it so that existing data cannot be removed and users can only add to the file, and produce several other effects. Some flags have functions unrelated to security, but we'll pay special attention to the security flags. File flags are listed and documented in `chflags(1)`.

### File Flag Types

Many file flags have different effects depending on the system securelevel, which we'll cover in the next section. Understanding how securelevels work requires an understanding of file flags, while file flags rely on securelevels. For the moment, just nod and smile when I mention securelevels while discussing file flags. All will become clear, trust me.

OpenBSD's UFS and UFS2 filesystems support the following file flags:

**sappnd**
: Files with the system-level append-only flag can be added to but cannot be removed or otherwise edited. The `sappnd` flag is particularly useful for log files. For example, a common intruder tactic is to remove *.history* or symlink it to */dev/null* so that the administrator cannot see what happened. Setting `sappnd` on a user's *.history* file can be interesting if the account is compromised. Using the `sappnd` flag ensures that intruders cannot cover their tracks in this manner. Only root can set or remove the `sappnd` flag, and it cannot be removed when the system is running at securelevel 1 or higher.

**uappnd**
: The user-level append-only flag can be set only by the file owner or root. As with `sappnd`, a file with the `uappnd` flag can be added to but not otherwise edited or removed. This is most useful for personal logs and files; it primarily adds an extra layer of protection against users accidentally deleting their own files. The owner or root can set or remove this flag.

**schg**
: Files with the system-level immutable flag cannot be changed in any way. They cannot be edited, moved, replaced, or overwritten. Basically,

the filesystem itself prevents all attempts to alter this file. Only root can set or remove this flag, and it cannot be removed when the system is running at securelevel 1 or higher.

**uchg**
: The user-level immutable flag prevents anyone from changing the file. It's a user-level flag, so root can override it. This flag helps to prevent a file from being edited or removed by accident, but it's not a way to secure the system. The owner or root can set or remove this flag at any securelevel.

**nodump**
: The no dump flag tells `dump(8)` to not back up a file. Set this on files that don't need to be backed up to tape. Check your backup program's documentation to see if it honors this flag.

### Setting, Viewing, and Removing File Flags

Set file flags with `chflags(1)`. For example, if you are really worried about someone changing your kernel file, you could mark */bsd* with the system-level immutable flag.

```
# chflags schg /bsd
```

This would prevent anyone—including you—from changing the kernel, reconfiguring the kernel, or upgrading the system.

You can also recursively change the file flags on an entire directory tree with the `-R` flag. If you wanted to make the entirety of */bin* immutable, you would run this command:

```
# chflags -R schg /bin
```

And poof, you can no longer upgrade your system.

To view the flags on a file, use `ls -lo`.

```
$ ls -lo vitallog
-rw-r--r-- 1 root wheel - 20915343 Jul 17 16:56 vitallog
```

This file has no flags set on it. Let's set the system-level append-only flag.

```
$ chflags sappnd vitallog
chflags: vitallog: Operation not permitted
```

Oh, right—only root can set system-level flags. Let's try again:

```
$ sudo chflags sappnd vitallog
Password:
$ ls -lo vitallog
-rw-r--r-- 1 mwlucas mwlucas sappnd 20915343 Jul 17 16:56 vitallog
```

This file now has the sappnd flag. The system can add to it, but cannot otherwise edit or remove it.

OpenBSD doesn't flag any files out of the box, so you'll need to add flags yourself if you want them. Before you go nuts, however, note that adding file flags increases the overhead for system maintenance. If upgrading a system is hard, the sysadmin won't want to do it. Is it more secure to have all your programs in */bin* immutable, or is it more secure to simplify upgrades, updates, and application of security patches?

To remove a flag from a file, use chflags with a no before the flag name. For example, to unset the sappnd flag on the *vitallog* file, try this:

```
$ sudo chflags noschg vitallog
Password:
chflags: vitallog: Operation not permitted
```

Wait a minute! I'm running under sudo(8), and I have root-level privileges. What's going on?

By default, OpenBSD runs at securelevel 1. When running at securelevel 1 or higher, you cannot unset system-level file flags, so an attempt to do so failed. You can remove these flags only at securelevel -1 or in single-user mode. Read on to learn about securelevels.

## Securelevels

securelevel(7) is a kernel setting to restrict actions the system can perform. The kernel behaves slightly differently as you raise the securelevel. For example, at low securelevels, the file flags discussed in the previous section can be removed; a file might be marked immutable, but you can remove the marker, delete or edit the file, and restore the flag. When you increase the securelevel, however, you can no longer remove the flag. Similar changes take place in other parts of the system. Taken as a whole, these changes might frustrate or stop an intruder.

Securelevel settings range from -1 to 2. Though OpenBSD runs at securelevel 1 by default, you can change this setting to fit your environment.

Higher securelevels make system maintenance difficult. Many actions taken during normal upgrades and administration are also things that intruders might do to cover their tracks. It might make sense for you to run a highly secure, stable server at securelevel 2, and run your experimental machine at -1. On the other hand, the OpenBSD folks don't encourage changing from the default securelevel. Running your system at -1 may leave you open to attacks, while running at 2 complicates management and maintenance. Which securelevel you choose depends on your environment.

Despite the name, a securelevel is not an all-purpose general security dial. Arbitrarily increasing the securelevel will do nothing but annoy you and your users. While you can increase the securelevel at any time, you cannot reduce the securelevel without rebooting the system, so don't experiment blindly.

### Setting the System Securelevel

Set the boot-time securelevel in */etc/rc.securelevel*. In that file, you'll find a line like this:

```
securelevel=1
```

Change the `1` to your preferred securelevel. On your next reboot, the system will go to this securelevel when it enters multiuser mode. If you need to run a process before the boot process raises the securelevel, put the command to start the process in this file.

If you want to raise the securelevel without rebooting, adjust the `kern.securelevel sysctl(3)` to the desired value.

```
# sysctl kern.securelevel=2
kern.securelevel: 1 -> 2
```

Remember that you cannot lower the securelevel of a running system. If a sysadmin could lower the securelevel, so could an intruder.

### Securelevel Definitions

OpenBSD has four securelevels: -1, 0, 1 and 2. We'll cover each in turn.

#### Securelevel -1

Securelevel -1 is also called permanently insecure mode. The system isn't necessarily insecure—it's just that none of the securelevel protections are in place. I use securelevel -1 only to remove file flags that I never should have used in the first place.

#### Securelevel 0

Securelevel 0 is used only when the system is first booting. It offers no special features. When the system reaches multiuser mode, however, the securelevel is automatically raised to 1. Setting `securelevel=0` in */etc/rc.securelevel* is functionally equivalent to setting `securelevel=1`.

#### Securelevel 1

At securelevel 1, OpenBSD's default, things become interesting.

The securelevel affects certain kernel configuration settings, called sysctls (covered in Chapter 18). Early in the boot process, OpenBSD uses the settings in */etc/sysctl.conf* to set sysctls. When I say that a particular sysctl cannot be changed, read that as "without altering the configuration and rebooting."

Securelevel 1 implements the following limitations:

- No one can write to the */dev/mem* and */dev/kmem* devices. Many security exploits work by writing to these devices.

- The raw disk devices of all mounted file systems are read-only. (Writing to the raw devices of mounted filesystems would let you change files without regard to permissions.) Programs should access mounted filesystems only through the filesystem anyway, so this won't change day-to-day operations.
- The system-level file flags `schg` and `sappnd` cannot be removed.
- Kernel modules cannot be loaded or unloaded. OpenBSD supports kernel modules, but the default kernel is monolithic. There's no legitimate reason to load a kernel module on a running production system.
- The sysctl `fs.posix.setuid` cannot be changed. By default, `chown(1)` clears the `setuid` and `setgid` bits on files when changing file permissions, as per the POSIX standard. You can override this by setting `fs.posix.setuid` to 0.
- The sysctl `hw.allowpowerdown` cannot be changed. This controls the power button's interaction with the system. When it's set to 1, briefly pressing the power button shuts down the system cleanly. When it's set to 0, the power button does not shut down the system. (You can still shut down the system by holding down the power button for several seconds, but that's not a clean shutdown.) Not all platforms support this kind of shutdown or power management.
- The sysctl `net.inet.ip.sourceroute` cannot be changed. Source routing is a technique to permit the sender of a packet to control which route the packet takes across the network. It's caused many security problems, and its use is generally discouraged. OpenBSD ignores source routing by default. Setting `net.inet.ip.sourceroute` to 1 forces OpenBSD to pay attention to source routing.
- The sysctl `machdep.kbdreset` cannot be changed. When set to 1, `machdep.kbdreset` allows the system to be cleanly rebooted using CTRL-ALT-DELETE. When this sysctl is set to 0, the system ignores CTRL-ALT-DELETE.
- The `ddb.console` and `ddb.panic` sysctls may not be raised. Raising these sysctls enables certain kernel debugging options. Unauthorized users with physical access could gain unlimited system access through the debugger if they could raise these sysctls.
- The sysctl `machdep.allowaperture` cannot be raised. If you want to use the X Window System (discussed in Chapter 17), you must allow X access to specific parts of kernel memory by enabling this sysctl early during the boot process. If you're not running X, no one legitimately needs this access.
- General-purpose input/output (GPIO) controllers cannot be further configured. GPIO controllers support a wide variety of special-purpose hardware. See `gpio(4)` and `gpioctl(8)` for details on each.

These limitations have little effect on normal day-to-day operations, but they can interfere with debugging. If you're trying to discover why your GPIO device isn't working, you probably want to set your securelevel to -1.

#### Securelevel 2

Securelevel 2 is the highest securelevel in OpenBSD, and it disables a variety of features that you might need during normal maintenance. Use securelevel 2 only on a stable machine that you don't expect to change much. If you need to change anything restricted by securelevel 2, you must reboot the machine.

Securelevel 2 includes everything from securelevel 1, plus the following:

- Raw disk devices are always read-only. You cannot format, fdisk, or disklabel disks, even if they're not in use.
- The system clock cannot be moved backward, nor close to the overflow point. Make sure your system time is correct before entering multiuser mode!
- You cannot alter packet-filtering rules (covered in Chapters 21 and 22). Packet filters, network address translation (NAT), traffic queues, and so on are immutable.
- Kernel debugger sysctl values (those beginning with `ddb`) cannot be changed.

So, for example, you don't want your firewall at securelevel 2 unless you understand that packet filtering rules can change only with a reboot.

### What Securelevel Do You Need?

The securelevel appropriate for your environment depends entirely on your situation, but the overwhelming majority of the time, the default of securelevel 1 is most suitable.

If you are debugging and testing features and tools, you might find that you need to use securelevel -1 on a development machine. Once you've worked out how to configure your GPIO device or the correct debugger settings for your system, however, use securelevel 1 so that you mirror a production environment.

If you have a very stable system, you could try securelevel 2. In all my years of running OpenBSD, though, I've had only one system for which securelevel 2 was the right choice, and several cases where securelevel 2 created more trouble than it was worth.

### Securelevel Weaknesses

What can't securelevels do? Consider a case where someone compromises a web application on your server, uses that to bootstrap himself into a shell, and then uses the shell to bootstrap himself into root access. Securelevels don't do anything to prevent this.

Unless you've made copious use of the `schg` flag, the intruder can replace system binaries with ones that send your authentication credentials to a free email account registered in a bogus name. So you decide to run around applying the `schg` flag to the contents of critical directories like */bin* and */usr/lib*. That will stop the bugger! Well, that will work as long as you make

every file immutable, including the system configuration files in */etc*—you know, the ones that you need to change in order to do your job. If you leave one file unprotected, the intruder could add a command like `chflags -R noschg /` to an early part of the system startup, and poof—the next time you reboot your system, you unlock all your files. How often do you exhaustively audit your */etc* files? And you'll need to undo this tangled morass every time you patch or upgrade your system!

This is only one possible path. There are many ways for an intruder to lever himself into the system. Relying on securelevels to protect you is unwise. Use them and consider them a tool in your kit, but don't think they are a panacea for every problem.

## Keeping Secure

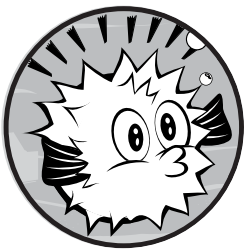
The tools discussed in this chapter are not OpenBSD's only security features. The OpenBSD team has put a lot of work into securing every part of the system. But this chapter covers some things that make OpenBSD special and gives you an idea of how those features work.

What's the best path to security? Keep your system updated and configure your server daemons securely. It's boring, but it works.

# 11

# OVERVIEW OF TCP/IP

*IP version 6:*
*All the pain of version 4,*
*plus brand-new problems!*



Securing a computer is easy: Disconnect it from all networks, remove all input and output, and lock it in a bunker. Oh, wait—did you want the system to *do* something? Then you'll probably want to connect your system to the Internet.

Many system administrators have a vague familiarity with the basics of networking, but to be a truly competent sysadmin, you need a real understanding of how everything fits together. You don't need to know when to use rapid spanning trees, how to choose between BGP and OSPF, or even what those acronyms represent. But you must know what an IP address is, how a netmask works, how port numbers differ from protocol numbers, and why you cannot use `telnet(1)` to test UDP connectivity. Without this basic knowledge, you'll fumble. Read this chapter and understand it, and you'll have an easier time convincing your network administrator to give you what you need.

While this chapter offers an overview of TCP/IP, it doesn't cover the innumerable details, caveats, annoyances, peccadilloes, and blatant outrages present in the protocol. If you find that you need to torture yourself with the finer points of TCP/IP, pick up one of the big, thick books on the subject. *The TCP/IP Guide* by Charles M. Kozierok (No Starch Press, 2005) is an excellent place to start.

This chapter covers both TCP/IP version 4 (the Internet protocol widely used for the last 30-odd years) and the new version of the protocol, TCP/IP version 6. Despite the different version numbers, the two protocols are more similar than not.

We'll start with the layers of the network and then delve into how the protocols work.

## Network Layers

The network protocol is divided into several layers. Each layer handles a specific task and interacts only with the layers immediately above and below it. At first, you might laugh at the idea that this layer model simplifies the network process, but it really does. The important thing to remember right now is that each layer communicates with only the layer directly above it and the layer directly beneath it (theoretically, anyway).

The classic Open Systems Interconnection (OSI) network protocol stack represents the network as seven layers. It's an exhaustively complete model and covers almost any situation using any network protocol and any application. Because the Internet is a very specific type of network, and because this isn't a book about networking or networked applications in general, I'll limit my discussion of TCP/IP to four specific layers of the network: physical, datalink, network, and transport. Don't worry—these four layers cover the Internet and (almost) all corporate networks.

### The Physical Layer

Whether it's copper or fiber-optic cable, or even radio waves, physical wire is a layer of the network. Without some physical media to run over, a network cannot function. Everything from the CAT5 cable plugged into your desktop to the fiber-optic cable connecting you to Asia is part of the physical layer. If it can be tripped over, backhoed, or interfered with, it's part of the physical layer. For simplicity's sake, I'll refer to the physical layer as the *wire*, although it can take innumerable forms.

This is the easiest layer to understand. If your wire meets the requirements of the physical protocol, you're in business. If not, your network won't work. One of the functions of Internet routers is to connect one sort of physical layer to another—for example, converting local Ethernet into an OC3 fiber connection.

The physical layer has no decision-making abilities of its own; everything that runs over it is dictated by the datalink layer.

### The Datalink Layer

The datalink layer is the protocol that runs over the physical wire. It transforms information into the actual signals that are sent over the physical layer, using the appropriate encoding for that physical media, as follows:

- Both Ethernet and Switched Multimegabit Data Service (SMDS) use Media Access Control (MAC) addresses and the Address Resolution Protocol (ARP).
- IPv6 over Ethernet uses Neighbor Discovery (ND).
- Dial-up and wide area networks (WANs) use either the Point-to-Point Protocol (PPP) or High-Level Data Link Control (HDLC).

OpenBSD supports other common datalink protocols, such as PPP over Ethernet (PPPoE). If you have unusual network requirements, check the OpenBSD website, mailing lists, or man pages to see if those requirements are supported.

Some datalink layers have been implemented over many different physical layers. Ethernet, for example, has been implemented over twinax, coax, CAT3, CAT5, CAT6, CAT7, optical fiber, and radio waves. And for true device independence, we have seen TCP/IP implemented with a biological transport layer: carrier pigeon.[1]

With minor changes to the device drivers, the datalink layer can address any sort of physical layer. This is one of the ways in which layers simplify the network.

Chapter 12 discusses Ethernet in detail, as it's the most common network type for OpenBSD systems. Once you understand how Ethernet works, you'll have no difficulty adding new datalink protocols as needed.

The datalink layer exchanges information with the physical layer and the network layer.

### The Network Layer

The network layer is the part that maps connectivity between network nodes, answering questions like "Where are other hosts?" and "Can I get there from here?" This logical protocol provides a consistent interface to programs that run over the network, no matter what the physical and datalink layers look like.

The network layer used on the Internet is the Internet Protocol, or IP. Both version 4 (IPv4) and version 6 (IPv6) provide each host with one or more unique *IP addresses*, so that any other host on the network can find it. Okay, IPv4 network address translation munges the whole "unique address" rule, but your network still has a unique IP address somewhere.

---

1. You laugh, but the technical reviewer for this book was part of the first IP-over-carrier-pigeon implementation team that tackled the practical tests as specified in RFC 1149. That's how I knew he had the time to review this book in excruciating detail. (If that's how he spends his time, he couldn't very well claim he was too busy, now could he?)

The network layer talks to the datalink layer below it and the transport layer above it.

### The Transport Layer

The transport layer is where actual data flows. The three most common transport layer protocols are the Internet Control Message Protocol (ICMP), Transmission Control Protocol (TCP), and User Datagram Protocol (UDP).

ICMP passes basic connectivity messages between hosts with IP addresses. If IP provides a road and addresses, ICMP provides traffic lights and highway exit signs. Most of the time, ICMP runs silently in the background.

UDP and TCP are the protocols that carry actual data between hosts, and they are so prevalent that the suite of Internet protocols is usually called TCP/IP. UDP is a bare-bones transport protocol, offering the minimum services needed to transfer data over the network. Its minimalism means that if you want to customize exactly how data flows in your application, you can build it out of valid UDP. TCP provides more sophisticated features, such as integrity checking and congestion control, but many of its settings are hard-coded.

In addition to these three, many other protocols run at the transport layer. The file */etc/protocols* contains a fairly comprehensive list of transport protocols built atop IP. While it lists many more protocols than you will ever actually deal with out in the wild, it doesn't include non-IP protocols like IPX/SPX or Digital Equipment Company's DECnet.

As an example, let's have a look at the first entry from */etc/protocols*:

```
ip      0       IP HOPOPT       # internet protocol, pseudo protocol number
```

Each */etc/protocols* entry has three key fields: an official name, a protocol number, and any aliases. The IP protocol, protocol 0, is known as IP and (*very* occasionally) as HOPOPT. Each protocol also has a comment giving it some context. Although some of the protocols in */etc/protocols* are long gone, some antediluvian devices out there might still speak them.

Note that ICMP, TCP, and UDP are slightly different when run over IPv4 versus IPv6. Each protocol has clearly defined fields in the IP packet header, leaving specific numbers of bits for things like checksums, destination addresses, and so on. You can't run a transport protocol over an incompatible network protocol—TCPv6 over IPv4 just doesn't work.

The transport layer speaks to the network layer below and to the applications layer above it.

### Applications

Applications are definitely part of the network. Applications request network connectivity, send data over the network, receive data from the network, and process that data. Web browsers, email clients, JavaServer Pages (JSP) servers, and so on are examples of network-aware applications. Applications need to communicate with only the transport protocol and the user. The upper three layers of the OSI network model are inside applications.

Problems with the user layer are beyond the scope of this book, but I find that many of these issues can be solved with proper application of a large chainsaw.

## The Life and Times of a Network Request

So how do all these layers fit together in the real world? Let's have a look at a hypothetical network request, and walk through how data traverses the layers and the network.

**NOTE** *Some of this discussion touches on topics covered later this chapter, so you might want to reread this section after finishing the chapter. Purists will notice that I skip a lot of parts of the process, but I'm trying to relay the basics of how TCP/IP works in practice, not model every painful detail of a real network transaction.*

Suppose a user connected to your network wants to look at a very important work-related website, such as Scott Meyer's Basic Instructions (*http://www.basicinstructions.net/*). The user opens his browser, enters the URL, and presses ENTER. The browser application transforms the user's request into the proper format and asks the transport layer for a TCP connection to a particular IP address on port 80.

The transport layer inside your computer examines the browser's request and allocates the appropriate resources for it. The request is broken up into digestible chunks, called *segments*, and handed down to the network layer.

The network layer doesn't care about the contents of the request; it's only concern is where that data is going. The network layer takes the TCP data and attaches the proper addressing information to it. The resulting chunk of data is called a *packet*. The network layer checks the packet's destination, chooses the interface closest to the gateway to that destination, and drops packets down into the datalink layer.

The datalink layer doesn't care about the contents of the packet, and it certainly doesn't care about IP addresses or routing. It has been given a lump of zeros and ones, and its job is to transmit those zeros and ones to another network node. The datalink layer adds the appropriate header and/or footer information to the packet, creating a *frame* appropriate for the physical layer. The frame's header and footer contain the addressing information for the physical layer. On most networks, the datalink layer prepares frames for the local Ethernet. Then the datalink layer hands off the frame to the physical layer for transmission.

The physical layer has no intelligence at all (think carrier pigeons). The datalink layer hands the physical layer a frame, and the physical layer transmits that frame to another physical device. For a web browsing client, this is usually the default router for the local Ethernet. The physical layer doesn't care about the upper-level protocols. Its only job is to make sure the frame gets to the destination without errors.

When the client computer's router receives the frame, it sends it up to the datalink layer. The datalink layer strips out the frame information and

hands the resulting packet up to the network layer. The router's network layer examines the packet, looks at its routing table, and decides which interface to send it out on. This might be another Ethernet interface, a T1, a DS3, an OC3, or whatever the router uses for upstream connectivity. Once the router chooses an interface, it hands the packet to the datalink layer for that interface.

The local router's upstream connection probably goes through a whole series of routers. Each router decides where to send the request based on its routing table. The request probably traverses a variety of datalink layers as it travels. Thanks to layering and abstraction, neither you nor your computer needs to know anything about any of them.

When the request reaches its destination, the computer at the other end of the transaction accepts the frame and sends it all the way back up the protocol stack. The frame is stripped down to packets, which are stripped down to segments, which are reassembled into a data stream. The data stream is then handed to the application (in this case, a web server). The application processes the request and returns an answer, which goes back down through the protocol stack and travels across the network, bouncing up and down through various datalink layers on the way as necessary.

This example shows why the layer model is important: Each layer knows only what it absolutely must about the layers above and below it, making it possible to swap out layers if necessary. When a new datalink protocol is created, the other layers don't need to change. The network layer just hands a packet to the datalink layer and lets the datalink do its thing. When you install a new network card, you need only a driver that interfaces with the datalink layer and the physical layer; you don't need to change anything higher in the network stack.

## Network Stacks

A network stack is the software that lets a host communicate with the network. A host can run with an IPv4-only network stack, an IPv6-only network stack, or a dual-stacked setup.

You're already familiar with an IPv4-only stack—it's what most hosts ran for much of the past 30 years. An IPv4-only stack can communicate only over IPv4. Today, an IPv4-only stack gets you access to the entire Internet, with a few deliberate exceptions. That will not be true in a few years.

Likewise, an IPv6-only stack can communicate with only IPv6 hosts. Because most Internet sites don't yet support IPv6, running an IPv6-only stack isn't practical at this point. It is, however, an excellent way to test your IPv6 infrastructure and connectivity.

The most common configuration these days is a dual-stack setup. Client hosts try to use both IPv4 and IPv6, preferring one over the other. I recommend configuring hosts with dual stacks, preferring the stack with better connectivity. (If you get IPv6 connectivity through a tunnel, it's not as fast

as your IPv4 connectivity.) If you have equal IPv4 and IPv6 connectivity, use whichever you prefer. IPv6 works well enough that I often don't realize that I'm using it until I analyze my traffic.

You don't need to do anything special to enable IPv6 on OpenBSD—an IPv6 address, a default router, and a DNS server, and away you go.

## IPv4 Addresses and Subnets

An *IP address* is a unique 32-bit number assigned to a specific network node. Some IP addresses are more or less permanent, such as those assigned to vital servers; others change as required, such as those used by desktop clients. Individual machines on a shared network use IP addresses from a range of addresses assigned to that network.

Rather than expressing that 32-bit address as a single number, an IP address is divided into four 8-bit numbers, usually expressed as decimals. While 192.0.2.1 and 11000000.00000000.00000010.00000001 represent the same address, the first option is easier for our feeble little brains to grasp.

Internet service providers (ISPs) issue IP addresses in blocks. These blocks are the smallest allocation that they can get away with giving you—say, 16 or 32 addresses. If your system is on a server farm, you might get only a few IP addresses out of a block of 256.

A *netmask* indicates the size of the block of IP addresses assigned to your local network. The size of your IP block determines your netmask—or, your netmask determines how many IP addresses the network has.

ISPs issue IP addresses by prefix length, commonly called a *slash*. You'll see IP address blocks described in forms like 192.0.2.128/26. Everyone who has worked with networking has seen the netmask 255.255.255.0, and most know that it's associated with a block of 256 IP addresses. That netmask is also called a /24. The number after the slash is the number of fixed bits in the netmask. Remember, an IPv4 address is a 32-bit number; on a /24 network, 24 of those bits will never change.

This isn't a textbook on binary math, so I won't quiz you on the conversions, but think of an IP address as a string of 32 binary digits. On your networks, you can change the bits on the far right, but not the bits on the far left. But where is the line that separates right from left?

Netmasks have traditionally been split on 8-bit boundaries, but there's no hard rule that says they must be. A /25 network has 25 fixed bits—one more fixed bit than what used to be called a class C network—leaving you with 7 bits to play with. The netmask's fixed bits are set to 1, and your network bits are set to 0, as in the following example of a /25 netmask:

```
11111111.11111111.11111111.10000000
```

The first three blocks are set to the binary 11111111, which is 255 in decimal. The last block is set to 1000000, which is 128. Mash these together, and your resulting netmask is 255.255.255.128.

If you reduce netmasks to binary, they're simple to figure out. While you won't need to work with this every day, if you don't understand the underlying concepts, the decimal conversion looks like total gibberish. With a little practice, you'll recognize certain decimal strings as legitimate netmasks.

So now that you know how netmasks work, what the heck does all this mean in the real world?

IP addresses are issued in multiples of 2. If you have 4 bits to play with, you have 16 addresses ($2^4$=16). If you have 8 bits to play with, you have 256 addresses ($2^8$=256). If someone says that you have exactly 17 IP addresses, you're either sharing a network with other people or they're wrong.

It's common to see a host's IP with the netmask attached, such as 192.0.2.130/26. This gives you everything you need to attach the host to the local network. (Finding the default gateway is a separate issue, but it's usually the top or bottom address in the block.)

### *Calculating a Decimal IPv4 Netmask*

Converting from binary to decimal to binary is error-prone and mildly annoying. Here's how to calculate your netmask while remaining in decimal land.

Find how many IP addresses you have on your network. This will be a multiple of 2, almost certainly smaller than 256. Subtract the number of IP addresses you have from 256. This is the last number of your netmask. You still need to recognize legitimate network sizes, however. If your IP address is 192.0.2.251/26, you'll need to know that a /26 is 26 fixed bits, or 64 IP addresses. Your netmask is 255.255.255.192 (256–64=192).

And I should also mention that netmasks occasionally appear in hexadecimal.

Before you travel to my house to bludgeon me repeatedly with this book, Table 11-1 shows netmasks, IP information, and related information for /24 and smaller networks.

**Table 11-1:** IPv4 Netmasks and IP Address Conversions

| Prefix | Binary Mask End | Decimal Mask | Hex Mask | Available IPs |
|---|---|---|---|---|
| /24 | 00000000 | 255.255.255.0 | 0xffffff00 | 256 |
| /25 | 10000000 | 255.255.255.128 | 0xffffff80 | 128 |
| /26 | 11000000 | 255.255.255.192 | 0xffffffc0 | 64 |
| /27 | 11100000 | 255.255.255.224 | 0xffffffe0 | 32 |
| /28 | 11110000 | 255.255.255.240 | 0xfffffff0 | 16 |
| /29 | 11111000 | 255.255.255.248 | 0xfffffff8 | 8 |
| /30 | 11111100 | 255.255.255.252 | 0xfffffffc | 4 |
| /31 | 11111110 | 255.255.255.254 | 0xfffffffe | 2 |

When you don't feel like doing the math, you can refer to Table 11-1 or install the `ipcalc` package for quick netmask calculations. Don't say I never take pity on my readers.[2]

### Viewing IPv4 Addresses

Display IP addresses with `ifconfig(8)`. If you run `ifconfig` without any arguments, it displays all interfaces on the machine.

```
$ ifconfig fxp0
...
        inet 192.0.2.226 netmask 0xfffffff0 broadcast 192.0.2.239
        inet 192.0.2.231 netmask 0xffffffff
...
```

The lines starting with `inet` are IPv6 addresses. This interface has the primary IPv4 address of 192.0.2.226 and a secondary, or *alias*, address of 192.0.2.231. You can also see the netmask of each of these addresses and the broadcast address for the subnet.

### Unusable IPv4 Addresses

Every block of IPv4 addresses reserves the first and last IP addresses for use by the network:

- The first IP address in a block is the *network address*, used for separating networks (and on primordial BSD systems, the broadcast address). On a /24 network, this would be an address ending in .0.
- The last IP address in the block is the *broadcast address*. On a /24 network, the broadcast address ends in .255.

**NOTE** *According to the IP specifications, every machine on a network is supposed to respond to a request to the broadcast address. Unfortunately, in the late 1990s, this feature was used as an attack technique: All you needed to do was ping the broadcast address on any given network, and you would have a list of all IP addresses currently in use. Consequently, this functionality is now disabled by default on most operating systems and network appliances.*

You cannot assign the first or the last IP address in a network to a device without risking network problems. Some systems fail gracefully, others fail painfully, and a rare few make it work. Although OpenBSD won't object if you use the top and bottom network addresses, prepare for mayhem the first time you plug in a commodity printer or other embedded device. It takes only one inflexible device to ruin your whole day.

2. I never do take pity on my readers; I just don't want you to actually *say* so.

### Special IPv4 Addresses

Quite a few blocks of IPv4 addresses are set aside for specific purposes. Although you don't need to know all of them, there are two groups you'll see pretty often. For a complete list of IPv4 subnets reserved for special purposes, read RFCs 5735 and 6598.

#### Localhost

The address range 127.0.0.1/8 is set aside for *localhost*, a machine's address for itself. Every Unix-like system—and most other operating systems—attaches 127.0.0.1/8 to a loopback interface. Everything knows that the localhost address is local to the specific machine. Packets to or from 127.0.0.0/8 should never cross the network; likewise, daemons bound only to 127.0.0.1 can be accessed on only the local machine.

#### Private Networks

Internet standard RFC 1918 sets aside three networks for use on private networks and behind network address translation (NAT) devices: 10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16. While public IP addresses must be issued by an ISP, anyone can use addresses within these three blocks as long as those hosts are not directly exposed to the public Internet. If you have a network where hosts do not have access to the Internet, or if you provide Internet access through a proxy server or NAT, you can use an RFC 1918 network.

### IPv4 Addressing Pitfalls

Common wisdom dictates that each computer on a network is assigned a single IP address for each of its network interfaces. One computer, one network card, one IP address—simple, right?

Not always. Some special-purpose interfaces (such as those dedicated to packet sniffing) function as intended without an IP address, and many operating systems will allow you to assign multiple IP addresses to a single network interface through a process called *aliasing*. You can also bond multiple physical cards into a single network interface, giving the computer one large virtual interface. While you might not deal with these configurations every day, keep them in mind when troubleshooting.

## IPv6 Addresses and Subnets

There's a basic problem with IPv4: It provides only 4.29 billion addresses, and that's just not enough. Without subnetting, that's fewer than one address for every human being. Eventually, every person will have at least one IP-capable device.

Although IPv4 addresses haven't run out yet, they're becoming an increasingly scarce resource. Overly generous allocations in the early days, along with large chunks of address space reservations for special purposes, have accelerated exhaustion. The world is slowly grinding toward IPv4's replacement: IPv6.

Some parts of the world already use IPv6 extensively. Even if your network doesn't use IPv6 today, one day you'll need it—probably without warning. Prepare yourself now, or one day you'll discover that you needed it the week before.

### IPv6 Basics

Like IPv4, IPv6 is a network layer protocol. IPv4 uses 32-bit addresses, usually expressed as four groups of decimal numbers from 0 to 255 (for example, 192.0.2.13). IPv6 uses 128-bit addresses, expressed as six groups of four hexadecimal characters separated by colons (for example, 2001:db8:0:bad:c0de:cafe). A 128-bit address space gives enough IPv6 addresses for every atom in the Earth to have more than 10 IP addresses. TCP, UDP, ICMP, and other protocols run atop it. IPv6 has its own layer 2 protocol, Neighbor Discovery, which replaces protocols such as Ethernet's ARP.

The good news is that you don't need to relearn the basics of networking. Hosts still need an IP address and a default gateway, routers still use a routing table, and you can almost—*almost*—substitute an IPv6 address for an IPv4 address and watch everything work. A web server doesn't care if it binds to port 80 on 192.0.2.13 or on 2001:db8:a12a:bad:c0de:café. The server just accepts requests sent to it and responds appropriately. That said, software does need to change slightly, because our web server must be able to log connections from both IPv4 and IPv6 addresses. These changes have wide-reaching repercussions, and we'll be sorting out edge cases for the next decade. But, in general, once you understand the new rules for IPv6, all of your networking knowledge is applicable.

### Understanding IPv6 Addresses

As noted, IPv6 addresses are 128 bits, expressed as six colon-delimited groups of four hexadecimal characters each. As with decimal IPv4 addresses, you don't need to display leading zeros in each group. The address 2001:db8:0:bad:c0de:cafe could also be written as 2001:db8:0000:0bad:c0de:cafe, but just as we wouldn't write 192.000.002.013, we strip out the leading zeros in an IPv6 address.[3]

IPv6 addresses often contain long strings of zeros. This had to do with subnetting, which I'll describe later in this section. As of this writing, the IPv6 address of Sprint's website is 2600:0:0:0:0:aaaa. When consecutive groups include only zeros, as in this address, they're replaced with two colons (`::`). This IP address is usually displayed as 2600::aaaa. You can do this only once per address, however. You can't, for example, have the address 2600::1::1, because it's ambiguous. Does 2600::1::1 represent 2600:0:0:1:0:1 or does it represent 2600:0:1:0:0:1? I don't know, and neither does your server.

You've probably seen a port number added to an IPv4 address, such as 192.0.2.13:80. Using a colon to glue a port number to an IPv6 address

3. Some operating systems treat addresses containing numbers that begin with 0 as octal. Don't actually use addresses like 192.000.002.013, or you might get a base-8 surprise.

would be confusing. The IPv6 address 2001:db8::bad:c0de:cafe:80 isn't ambiguous, but if you read it quickly, you might miss the double colon and think this is an IP address ending in 80. If you're adding a port number to an IPv6 address, enclose the address in square brackets, as in [2001:db8::bad:c0de:cafe]:80.

### Viewing IPv6 Addresses

Use `ifconfig(8)` to see all IPv6 addresses assigned on your machine. Here, I give `ifconfig` the name of my network card, `fxp0`.

```
$ ifconfig fxp0
...
        inet 192.0.2.13 netmask 0xffffff00 broadcast 198.0.2.255
        inet6 fe80::bad:c0de:cafe%fxp0 prefixlen 64 scopeid 0x2
        inet6 2001:db8::bad:c0de:cafe prefixlen 64 autoconf pltime 604399 vltime 2591599
...
```

The lines starting with `inet6` are my IPv6 addresses. This interface has been assigned two IPv6 addresses: `fe80::bad:c0de:cafe%fxp0` and `2001:db8::bad:c0de:cafe`. (Wait . . . where did that `%fxp0` come from? You'll find out in "Link Local Addresses" on page 195. For now, just nod and smile, and keep reading.)

### IPv6 Subnets

Unlike IPv4, where you can subnet at any bit, IPv6 is usually subnetted at colon boundaries. Colons appear every 16 bits, so the natural IPv6 subnets are /16, /32, /48, and /64. Though IPv6 standards recommend using /64 as the smallest possible network, many carriers use /80, /96, and /112 networks for special purposes. (I've also seen people use subnets not divided at 16-bit boundaries. I won't cover them, but don't let your brain explode when you encounter a /51.) IPv6 subnets are always expressed as a slash, also known as a *prefix length*, so you won't see a netmask of ffff:ffff:ffff:ffff::, as you might in IPv4.

ISPs are usually issued a /32 or a /48 subnet and are expected to issue end-user networks, such as the typical home network, a /64 network. If ISPs do issue /64 subnets to their users, an end-user network will provide $2^{64}$ IP addresses, or 18,446,744,073,709,551,616 IP addresses. (This will suffice for any number of televisions, phones, refrigerators, water faucets, vacuums, and network-enabled tacos.)

When you subnet at 16-bit boundaries, each network has 65,536 subnets of the next smaller size. A /32 contains 65,536 /48 networks, and a /48 contains 65,536 /64 networks.

### Special IPv6 Addresses

Like its predecessor, IPv6 reserves several blocks of addresses for special purposes. You don't need to memorize all of these reserved addresses, but some will appear in daily use.

### localhost

IPv6's localhost address, ::1/128, works much like 127.0.0.1 in IPv4: It always refers to the local machine. In OpenBSD, ::1/128 is always assigned to the `lo0` interface.

### Link Local Addresses

Addresses beginning with fe8*x*: (where *x* is variable) are local to their interface. Every link has such *link local* addresses that are valid only on a specific local network. Even if an IPv6 network has no router, the hosts on the local, directly attached network can find each other and communicate using these local addresses. These networks are always /64 subnets. You'll see identical IPv6 subnets on other interfaces and on networks completely disconnected from your network. That's okay. These addresses are local to the link. For example, here's a link local address on an OpenBSD machine:

```
inet6 fe80::bad:c0de:cafe%fxp0 prefixlen 64 scopeid 0x2
```

The link local address of this interface is `fe80::bad:code:cafe`. The trailing `%fxp0` indicates that this address is local to the interface `fxp0` and isn't usable on any other interface on the machine. If your machine has an interface `fxp1`, and a host on that network tries to reach the address fe80::bad:code:cafe, this machine will not respond. This particular address is valid only for the network attached to interface `fxp0`.

You might note that the link local address has a section in common with the public IPv6 address on this network. That's because an autoconfigured IPv6 address is usually calculated from the interface's physical address; it doesn't matter whether that autoconfigured address is on a public address or a link local address.

## Assigning IPv6 Addresses

IPv6 clients can usually use autoconfiguration through *router discovery*, anIPv6 protocol where routers announce their presence on the network and the legitimate addresses to clients. Unfortunately, IPv6 autoconfiguration does not support common Dynamic Host Configuration Protocol (DHCP) options, such as assigning a Domain Name Service (DNS) server, let alone the options used for diskless configuration. If you have configured a DNS server—even IPv4 servers accessible on a dual-stacked host—autoconfiguration works just fine. If you run an IPv6-only network, you must either set up an IPv6 DHCP server to provide DNS server information to clients or configure DNS servers manually.

Servers should not use IPv6 autoconfiguration. A server usually needs a static IP address, even in IPv6. Similarly, routers cannot use autoconfiguration. If a host can forward packets, it requires a static IPv6 address.

You can assign multiple IPv6 addresses to a single interface by using aliases, just as with IPv4.

In IPv6, a client on a /64 network can use autoconfiguration.

IPv6 autoconfiguration resembles a stripped-down DHCP service. The router broadcasts subnet and gateway information, and the hosts configure themselves to use it. Hosts on a network smaller than /64 must be manually configured.

## Remedial TCP/IP

Now that you have a simplified overview of how the IP system works, let's look at a real network protocol in some depth. The dominant transport protocol on the Internet is the Transmission Control Protocol over Internet Protocol, or TCP/IP. Although TCP is a transport protocol and IP is a network protocol, the two are so tightly intertwined that they're generally referred to as a single entity.

We'll start with ICMP, and proceed to UDP and TCP.

### *ICMP*

ICMP is used to transmit routing and availability messages across the network. Tools such as `ping(8)` and `traceroute(8)` use ICMP. ICMP includes all sorts of different protocols and tools.

While some people claim that you need to block ICMP for security purposes, those people don't understand that ICMP is just as diverse as the better-understood transport protocols TCP and UDP. Proper IPv4 network performance requires large chunks of ICMPv4. If you must block ICMPv4 for security reasons, do so selectively. For example, blocking source quench messages breaks path maximum transmission unit (MTU) discovery, which will steer you directly into a world of hurt. If you don't understand that last sentence, don't block ICMPv4.

IPv6 dies without ICMPv6, as IPv6 doesn't support packet fragmentation, so never block ICMPv6. If you don't know what packet fragmentation is, just trust me on this.[4]

### *UDP*

UDP is the most bare-bones data-transfer protocol that runs over IP. It offers no error handling, minimal integrity verification, and no defense whatsoever against data loss. The transport protocol considers each packet of UDP completely self-contained; there are no data-coherence checks at the protocol layer. Despite these drawbacks, UDP can be a good choice for particular sorts of data transfer, and many vital Internet services rely on it.

**NOTE** *This discussion covers both UDPv4 and UDPv6. While each runs over only the corresponding network protocol, they behave identically otherwise.*

UDP is also a datagram protocol, meaning that each network transmission is complete and self-contained, and received as a single integral

4. Or you can go look it up. Whatever—you not believing me won't hurt my feelings.

unit. While the application might not consider a single UDP packet a complete request, the network does.

When a host transmits data via UDP, it has no way of knowing if the data ever reaches its destination. Programs that receive UDP data just listen to the network and accept whatever happens to arrive. When a program receives data via UDP, it cannot verify the source of that data. Although each UDP packet does include a source address, this address is easily faked. Each UDP packet includes a checksum for the packet, but there's no integrity checking for the data stream as a whole. This is why UDP is called *connectionless*, or *stateless*.

No integrity checking, no guard against data loss, the potential for faked packets—all this sounds pretty unreliable. So why use UDP at all?

UDP-based applications often have their own error-correction methods or otherwise don't mesh well with more reliable protocols, such as TCP. For example, simple client DNS queries must time out within just a few seconds or users will whine uncontrollably. TCP connections time out only after two minutes. DNS requires quick failures and only a single packet per transaction, which makes UDP a better choice than TCP for simple DNS queries. Real-time streaming services, such as video conferencing applications, also use UDP. (After all, if a few pixels go missing during a video conference, you don't want those pixels a minute later.) Most other UDP-based applications use UDP for similar reasons.

Because the UDP protocol itself doesn't return anything when you connect to a port, there's no reliable way to remotely test if a UDP port is reachable (although tools such as `nmap` try to do so).

If you want a protocol that responds at the network layer, look at TCP.

### TCP

TCP includes nifty features, such as error correction and recovery. The receiver must acknowledge every packet it gets; otherwise, the sender retransmits any unacknowledged packets. Unlike UDP, applications that use TCP can expect reliable data transmission. This makes TCP a *connected*, or *stateful*, protocol.

**NOTE** *This discussion covers both TCPv6 and TCPv4. While they differ because of their underlying transport protocol, they behave in the same way.*

TCP is also a *streaming protocol*, which means that a single request can be split among several network packets. While the sender might transmit several chunks of data one after the other, that data might arrive out of order or fragmented. The recipient must track these chunks and assemble them properly to complete the network transaction.

For hosts to exchange TCP data, they must set up a channel for that data to flow across. One host requests a connection, the other host responds to the request, and then the first host starts transmitting. This setup process is known as the *three-way handshake*. Similarly, once transmission is complete, the systems must do a certain amount of work to tear down the connections.

To test if a TCP port is open, you can use `telnet(1)` or `nc(1)` to connect to the port. Here, I see if I can connect to port 22 on the host `caddis`.

```
$ telnet caddis 22
Trying 192.0.2.35...
Connected to caddis.
Escape character is '^]'.
SSH-2.0-OpenSSH_6.0
❶ ^]
❷ telnet> c
Connection closed.
```

I connect to the remote port and see information displayed by the port, use the telnet escape character **^]** (CTRL-]) to disconnect ❶, and enter **c** ❷ to close telnet.

TCP is commonly used by applications most suited to its fairly generic set of timeouts and transmission features, such as email programs, FTP clients, and web browsers.

### How Protocols Fit Together

You can compare the network stack to sitting with your family at a holiday dinner. The datalink layer (ARP, in the case of Ethernet) lets you see everyone else at the table. IP gives every person at the table their own unique chair (except for the twins using piano bench NAT). ICMP provides basic, lower-layer information such as "The quickest way to the baked sweet potatoes is to get Uncle Mike to pass them"[5] or "Aunt Liz can't lift the ham platter." TCP is where you hand someone the butter and the other person must say "thanks" before you let it go. UDP is like tossing a roll at Grandma Lucas; she might catch it or it might bounce off her forehead.

### Transport Protocol Ports

Transport protocol ports permit one server to serve many different services over a single transport protocol, multiplexing connections between machines. When a network server starts, it attaches, or *binds*, to one or more logical ports. A logical port is just an arbitrary number ranging from 0 to 65536, although nothing uses port 0. For example, Internet mail servers often bind to port 25.

Each TCP or UDP packet arriving at a system carries a field containing its desired destination port number. If an incoming packet asks for port 25, it is connected to the mail server running on that port. This means that other programs can run on other ports, clients can talk to those different ports, and no one gets confused except you.

Note that port assignments are not some sort of physical constant, but rather are mutually agreed upon. There's no reason that email services should run on port 25 other than the fact that everyone agrees that they

5. For the record, Uncle Mike's security policy prevents him from passing baked sweet potatoes. If you want them, you're going to have to take them by force.

should. If someone tries to send you email, their mail server will automatically connect to port 25 on your server. If you run email on port 80 and have a web server on port 25, you'll never get your email, and your web server won't get much traffic.

The file */etc/services* contains a list of port numbers and the associated services. The file has a very simple, five-column format, as shown in these two sample lines:

```
www             80/tcp          http    # WorldWideWeb
www             80/udp                  # HyperText Transfer Protocol
```

The first field is the name of the service assigned to this port. This entry is for the service `www`. Port 80 is assigned to `www`, both TCP and UDP. Then there's a list of any other names assigned to this port. Port 80 is also known as `http`. Finally, there's a comment that gives more detail about the service.

The HTTP protocol used on the Web runs over TCP, so why is UDP port 80 also reserved for HTTP? The answer is pretty simple: Computer people are easily confused. Having two services share the same port number but run on different protocols confuses people—for example, the `syslog` service runs on port 514 via UDP, and the `lpr` printer protocol runs on port 514 over TCP.[6]

Some server programs read */etc/services* to learn which port to bind to on startup, and many client programs read */etc/services* to learn which port they should try to connect to. If you run servers on unusual ports, you might need to edit this file to get these programs to attach where needed.

As with all standards, there are times you will want to break the rules. The SSH daemon `sshd` normally binds to port 22/TCP, but I've run it on ports 23 (`telnet`), 80 (`www`), 443 (`https`), and others to evade naïve packet-filtering firewalls. You will find your own reasons to break the standards. That's fine, as long as you understand what you're doing and how it affects others.

### Reserved Ports

Ports below 1024 in both TCP and UDP can be opened only by the root user. These ports are assigned (mostly) to core Internet infrastructure protocols, such as DNS, SSH, HTTP, LDAP, and so on—services that only a few select hosts on each network should offer. Only programs with root-level privileges can bind to reserved ports. For example, a user can run a game server on a high-numbered port if the system policy allows, but that's different from setting up a web page visible to the whole world that claims the machine's official purpose is a game server. The port assignment for these core protocols is generally permanent, and if you want to interoperate with other sites, you won't change them.

6. I used to count how many people confused 514/tcp and 514/udp, but the number got so high that I got depressed, so I stopped.

OpenBSD software usually binds to a reserved port as root and then drops privileges, performing the rest of its functions as an unprivileged user. These unprivileged users, discussed in Chapter 6, have even fewer privileges than a normal user account.

If you must run a service that binds to a reserved port, and it can run only as root, consider carefully whether you actually need it. Try to find an alternative server that does privilege separation. If you can't, at least install that service on a dedicated machine to reduce its threat to other services on your network.

## Which Ports Are Open?

So, network services are made available via TCP or UDP ports. Programs bind to ports to offer network services. This brings up two obvious questions:

- Which ports are open?
- What programs are listening to each port?

You can answer these questions with `netstat(1)` and `fstat(1)`.

### Using netstat

The `netstat(1)` program provides general visibility into the network stack. Use `netstat` to check your routing table, examine open sockets, see how many packets are traversing your interfaces, and so on. (I could write an entire book about `netstat`, but no one would buy it. Instead, I'll sprinkle bits of `netstat` magic throughout this book.)

When looking at network information, I recommend turning off DNS lookups by using the `-n` flag. You can always rerun a check with DNS turned on, but adding DNS queries to the network sockets can sometimes skew the information you're viewing, and almost always slows the command.

The `-f` argument lets you choose a protocol family to display. Use `-f inet` to see only IPv4 sockets, or `-f inet6` to see only IPv6. Read `netstat(1)` for the full protocol list.

Finally, `-a` tells `netstat` to show all sockets opened by any process, rather than just sockets owned by the user.

Let's put all those options together and have a look at the output. Here, I show the open IPv4 sockets on my system:

```
$ netstat -na -f inet
Active Internet connections (including servers)
Proto   Recv-Q Send-Q    Local Address         Foreign Address     (state)
❶tcp         ❷0      0  ❸192.0.2.135.22       ❹192.0.2.8.49997    ❺ESTABLISHED
tcp          0      0   127.0.0.1.587         ❻*.*                ❼LISTEN
tcp          0      0   127.0.0.1.25          *.*                  LISTEN
tcp          0      0  ❽*.22                  *.*                  LISTEN
Active Internet connections (including servers)
Proto   Recv-Q Send-Q    Local Address         Foreign Address     (state)
❾udp         0      0   127.0.0.1.512         *.*
udp          0      0   *.514                 *.*
```

The list starts with open TCP ports ❶. The `Recv-Q` and `Send-Q` columns ❷ show the number of bytes that the system is in the process of receiving or trying to send.

The `Local Address` column shows the IP address attached to the local machine where this socket is listening. It's possible—common, even—for a service to bind to a port on only a single address on a machine. If the port is part of an actual connection, as the first example ❸ shows, the IP address is followed by the port number. This particular TCP connection is attached to port 22 at the address 192.0.2.135. Port 22 is reserved for SSH, so this is probably an SSH connection.

If the local address is an asterisk followed by a port number ❽, this is a wildcard bind. A program has bound to this port, and has asked the kernel to figure out the IP address. It's probably (but not necessarily) a listening socket.

The `Foreign Address` column ❹ shows the IP address and port of the remote host involved in a connection. If there's a foreign address shown, it always includes the port. If this column shows two asterisks ❻, that means the service is waiting for a connection on the local port.

The (`state`) column applies only to TCP connections. A live and working TCP connection is in the `ESTABLISHED` state ❺. Other states (`SYN_RCVD`, `ACK`, and `SYN+ACK`) are all normal parts of connection creation, while `LAST_ACK`, `FIN_WAIT_1`, and `FIN_WAIT_2` mean that the connection is closing. A state of `LISTEN` ❼ means that this socket is waiting for an incoming connection.

UDP ports are given their own section ❾. You might see remote hosts in the UDP section, especially for long-running protocols such as NFS and NTP, but remember that UDP is stateless, so you'll never see state on a UDP connection.

If you're interested in only TCP or UDP sockets, you can use the `-p` flag to show only a particular protocol. Here, I look at TCP sockets:

```
$ netstat -na -p tcp
Active Internet connections (including servers)
Proto   Recv-Q Send-Q  Local Address          Foreign Address      (state)
tcp          0     52  192.0.2.135.22         192.0.2.8.49997      ESTABLISHED
tcp6         0      0  ::1.587                *.*                  LISTEN
tcp          0      0  127.0.0.1.587          *.*                  LISTEN
tcp6         0      0  ::1.25                 *.*                  LISTEN
tcp          0      0  127.0.0.1.25           *.*                  LISTEN
tcp          0      0  *.22                   *.*                  LISTEN
tcp6         0      0  *.22                   *.*                  LISTEN
```

While this looks similar to the first output example, note that we see both IPv4 and IPv6 TCP connections and services. TCP runs over both IPv4 and IPv6, so choosing it shows both address families. It's entirely possible to have a service running on one address family and not the other. Many of my systems listen for incoming SSH connections only on IPv6; doing so hides me from port scanners and worms (for now, anyway).

Rather than listing every service waiting for an incoming connection, you can show only live connections by dropping the -a flag:

```
$ netstat -np tcp
Active Internet connections
Proto   Recv-Q Send-Q  Local Address       Foreign Address    (state)
tcp          0     52  192.0.2.135.22      192.0.2.8.49997    ESTABLISHED
```

### Using fstat

Now that you know which TCP and UDP ports are open, how can you tell which programs are listening on them? OpenBSD includes `fstat(1)`, a program that displays all open files and sockets on the system. Network connections are open sockets. Running `fstat` on an idle system can generate hundreds of lines of output—one entry for each file opened by any process. While that's educational and useful, it's not what we're looking for. Specifically, we want to see which programs are holding network sockets open. The string `internet` indicates network sockets.

```
$ fstat | grep internet
mwlucas  sshd       21403    3* internet stream tcp 0xd5365994 192.0.2.235:22 <-- 192.0.2.8:49997
root     sendmail   19063    4* internet stream tcp 0xd537e330 127.0.0.1:25
root     sendmail   19063    5* internet6 stream tcp 0xd537e4c8 [::1]:25
root     sendmail   19063    6* internet stream tcp 0xd537e660 127.0.0.1:587
root     sendmail   19063    7* internet6 stream tcp 0xd537e7f8 [::1]:587
root     sshd       29561    3* internet6 stream tcp 0xd537e000 *:22
root     sshd       29561    4* internet stream tcp 0xd537e198 *:22
_syslogd syslogd    12885    4* internet dgram udp *:514
```

First, you see an `sshd` process owned by the user `mwlucas`. That's an unprivileged process, tied to a particular SSH session. Further down the list, you see an SSH daemon owned by root listening to the network. When a connection request arrives, the root-owned SSH daemon will hand it off to an unprivileged child process. You can also see that we have a variety of `sendmail` processes listening to the network.

This system runs the expected SSH and email servers, and no one has bound anything to odd ports. My nasty paranoid suspicions were unfounded (this time, anyway).

Between `netstat` and `fstat`, you should be able to get a good idea of what your system is doing on your network at any given time.

## IP Routing

Most sysadmins don't need to understand much about IP routing, because most servers have only one network interface and one default gateway. The network administrator gives you an IPv4 address and a default route, you put them in the appropriate configuration files, and you're routed.

You don't need even that for most IPv6 hosts, as autoconfiguration makes things magically work. Servers will need a static IPv6 address and a manual default route.

Some servers have multiple interfaces, such as one to their default gateway and another to a group of related application or backup servers. OpenBSD systems frequently wind up in the network infrastructure, however, or sit in demilitarized zones (DMZs) where the server must make routing decisions. If you want to use OpenBSD in such an environment, or as a firewall, you must understand the basics of routing.

*Routing* is simply deciding where to send packets. If your system is attached to a network, it doesn't need to make any decisions; it just sends the packet to that network. Your system on 192.0.2.0/24 already knows how to reach any IP address beginning with 192.0.2—it can just send everything out to the local Ethernet. Where does it send those packets?

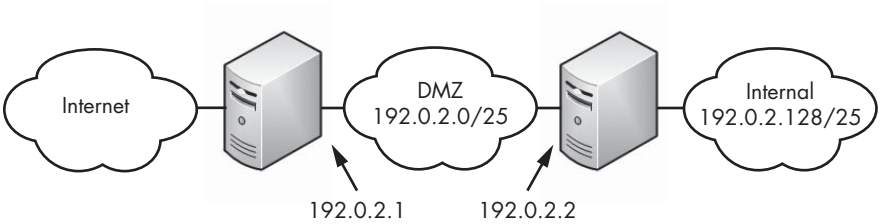
Most computers use a *default route*, which is an IP address on the local network where they send all packets bound for nonlocal IP addresses. This is very common where one router or firewall provides all network access. This device probably also has a default route that points to your ISP, which makes all the complicated routing decisions for you.

In other cases, you might have a dynamic routing protocol running on your network. If you're using Open Shortest Path First (OSPF), Border Gateway Protocol (BGP), or Routing Information Protocol (RIP), OpenBSD has daemons specifically for integrating these protocols. There's an introductory middle ground between full dynamic routing and simple default routes, however, and you should understand it before attempting full dynamic routing.

We'll cover a simple case here using an IPv4 example. (IPv6 routing is exactly like IPv4 routing, but with a lot more colons.)

### IPv4 Routed Network Example

If a network has multiple gateways leading to different networks, hosts on the network must make routing decisions. Suppose your network has multiple routers attached to it, each going to a different network. Machines on your network decide where to send packets. Here's an example of a common double-firewall situation:




In this network design, hosts must transit a DMZ before entering either the Internet or the internal network. (Other designs exist, such as the hub-and-spoke model, but I've specifically chosen a design where routing is needed.)

The external firewall provides one layer of protection. It permits only traffic specifically deemed necessary (we'll go into the default deny stance in Chapter 21). It does, however, permit incoming connections to hosts in your DMZ.

The hosts in the DMZ are to some extent vulnerable. They are not trusted enough to be on the internal network. Your intrusion-detection systems or your web servers might live here.

The internal firewall, like the external firewall, permits only traffic deemed necessary to organization purposes. It probably doesn't allow any connections from the outside world, however, and it doesn't trust the hosts on the DMZ.

Only highly trusted hosts are permitted on the internal network. This is where the organization keeps its most precious data, such as the financial records, customer databases, and movie collections.

Many of the hosts in this network need to make only very simple routing decisions. Anything on the internal network has just one way to reach anything, and any host on the Internet has only one way to reach the internal or DMZ networks.

The external firewall is directly attached to the DMZ network, so it can send packets to those hosts. It needs a default route pointing to the Internet so it can reach the rest of the world. To reach the hosts on the internal network, it must send packets to the internal firewall's external interface. If you don't configure this on the external firewall, data will never reach the internal firewall. Because the external firewall is responsible for the internal network's Internet access, losing this route would disconnect the internal network from the Internet; internal systems could send packets, but would never receive any. The external firewall needs routing.

Similarly, you could configure routing on each host inside the DMZ. In that case, ICMP redirects from the firewalls would provide routing for these hosts, but trusting ICMP redirects on a vulnerable network is unwise and messy because it assumes that every host on the DMZ and every firewall accepts and sends ICMP redirects. If you're using OpenBSD, you want your server to be secure, so configure routing on your DMZ systems.

In this example, I configure routing for the external firewall. Configuring routing for the DMZ hosts is nearly identical to this example.

## *Managing Routing with route(8)*

The `route(8)` command manages all system routing. Like `netstat`, `route` has several subfunctions that allow you to view, edit, and monitor the system routing table. While the `route(8)` man page has complete details, the ability to view, add, and delete routes should be enough to get you started.

### Viewing Routes

OpenBSD, like any other network device, keeps routes in a routing table. To view the IPv4 and IPv6 routes, enter **`route show`**. Add **`-n`** to remove IP-address-to-name translations.

Here's the IPv4 routing table:

```
$ route -n show
Routing tables

Internet:
Destination        Gateway            Flags   Refs      Use   Mtu  Prio Iface
❶ default            192.0.2.1          UGS        4     6414     -     8 vic0
❷ 127/8              127.0.0.1          UGRS       0        0 33196     8 lo0
❸ 127.0.0.1          127.0.0.1          UH         1      170 33196     4 lo0
❹ 192.0.2.32/24      link#1             UC         1        0     -     4 vic0
❺ 192.0.2.1          00:0c:42:20:7f:42  UHLc       1        0     -     4 vic0
❻ 224/4              127.0.0.1          URS        0        0 33196     8 lo0
```

The table shows the following information:

- The `Destination` field lists the range of IP addresses this route applies to—destination addresses. The `default` entry indicates the default gateway, which is where the system sends all packets that have no specific route.
- The `Gateway` field tells where packets for this route should be sent. A gateway could be a hostname, an IP address, or a network interface.
- The `Flags` field contains markers that indicate what sort of route this is and how it behaves. The next section covers the various route flags.
- The `Refs` field shows the number of references to the route in the kernel (also known as the *refcounter*). If the refcounter drops to zero, the route is removed. This has no practical use for system administration, because one reference is sufficient to keep the route in the routing table; additional references don't change anything.
- The `Use` counter increments each time a packet uses that route.
- The `Mtu` is the MTU—the largest frame size that can travel over this route. If the field contains a hyphen (`-`), OpenBSD uses the MTU of the underlying physical interface. The loopback interface, `lo0`, isn't a physical interface, so OpenBSD explicitly sets the MTU very high. You might see a route with a lower MTU if Path MTU Discovery has kicked in.
- The `Prio` field gives the route priority. OpenBSD supports multiple routes to a single destination. Some routes are more desirable than others, and OpenBSD will use the route with the lowest priority number. Routes provided by dynamic routing protocols, such as BGP or OSPF, get higher priority numbers than static routes.
- The `Iface` field shows which interface this route uses.

**NOTE** *OpenBSD also includes dynamic routing daemons such as `ospfd(8)` and `bgpd(8)`. I don't cover them here, because that topic would fill a book on its own.*

Let's see what's interesting in the routes in this sample. The first entry at ❶ is the system default route. If there is no more specific route, packets will be sent to the IP address 192.0.2.1.

To reach the network 127.0.0.0/8 at ❷, packets should go to the IP address 127.0.0.1. 127.0.0.0/8 is the address range reserved for loopback addresses, and 127.0.0.1 is always the local machine. Notice the high MTU; this is a software interface, so there's no physical limit on the size of frames sent through it.

To reach the IP address 127.0.0.1 at ❸, send the packets to the IP address 127.0.0.1. This might seem a bit pedantic, but it's a valid route and needs to be in the table. Remember that 127.0.0.1 is always the loopback address of the local machine.

To reach the IP address 192.0.2.0/24 at ❹, use a gateway of `link#1`. This is a local physical interface—in this case, our Ethernet interface. The interface named `link#1` is actually the interface with index `#1`, which isn't really exposed to the system administrator anywhere else. These addresses are local to the machine, and you must figure out which interface this is by the IP address attached to the machine. Addresses local to the machine don't actually need to be in the routing table, but no one has bothered to remove this historical nit.

To reach a specific IP address on the local network at ❺, you'll get a route of the IP address and the physical media address. Because this host is connected via Ethernet, the gateway is a MAC address. Every local address that the system needs to find gets a route entry, and you should almost always show a specific route for the default gateway.

The last route at ❻ is for the multicast address range 224/8. If you're not using multicast, it should go to the local host.

**NOTE** *Multicast is a complicated topic beyond the scope of this book (again). But if you're interested, OpenBSD supports multicast just fine.*

### Route Flags

The `Flags` column of the routing table indicates how routes are generated or used. `netstat(1)` contains a complete list of route flags. Table 11-2 lists the common ones.

**Table 11-2:** Common Route Flags

| Flag | Description |
|---|---|
| `C` | This route was cloned. |
| `c` | This is a protocol-specific route (such as to an Ethernet MAC address). |
| `D` | This route is dynamic. |
| `G` | This route goes via a gateway. |
| `H` | This route is for a specific host. |
| `L` | This route is for the local link layer. |
| `M` | This route was modified. |
| `R` | This is a reject route. Packets are dropped, and an error is sent. |
| `B` | This is a blackhole route. Packets are dropped silently. |

These flags tell you where a route came from and how it's used.

### Adding Routes

Add routes with the `route add` command. You must know the destination network, its netmask, and the gateway.

```
# route add address-block/netmask netmask gateway
```

In our example network, the outer firewall needs a route to reach the private network, 192.0.2.128/25. To route this network to the inner firewall at 192.0.2.2, run this command:

```
# route add -net 192.0.2.128/25 192.0.2.2
add net 192.0.2.128: gateway 192.0.2.2
```

Packets will use that route immediately. If you run `route show`, you'll see that new route.

To add a default route, run `route add default` with the IP address of the default gateway, like this:

```
# route add default 192.0.2.1
add net default: gateway 192.0.2.1
```

To add routes automatically at boot, put the `route` statement in the */etc/hostname.if* file that leads to the destination network. These routes appear when the interface is brought up, before */etc/rc.securelevel* runs or any local daemons start. You'll see examples of using *hostname.if* for routes in the next chapter.

To add a default route automatically at boot, put the default router IP address in */etc/mygate*.

### Deleting Routes

To delete a routing table entry, use `route delete` with the network address and netmask.

```
# route delete address-block -netmask netmask
```

To remove the route added in the previous example, run this command:

```
# route delete -net 192.0.2.128 -netmask 255.255.255.128
delete net 192.0.2.128
```

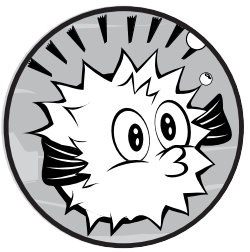
You should now have a decent idea of how routing works.

Now that you know how things are supposed to fit together, let's see how to configure Ethernet networks.

# 12

## CONNECTING TO THE NETWORK

*My tunnel is now up.*
*I can do IPv6.*
*Me and three others.*



All that theory of IPv4 and IPv6 is fine. Now let's do something with it, and actually connect to a network. While dial-up connections work with OpenBSD, they're not used much these days, so we'll focus on Ethernet connections. Ethernet is the most common network type today, and the most common network interface on OpenBSD systems.

Most people have IPv4 connectivity, but IPv6 is increasingly important. If you can't get native IPv6 to your network, you can use a tunnel to reach IPv6 address space and provide IPv6 to your clients. I'll cover acquiring and configuring such a tunnel in this chapter.

Finally, OpenBSD can combine network connections into trunks or split them into virtual local area networks (VLANs). This chapter covers both approaches.

## DNS Resolution

You'll probably want to use hostnames rather than IP addresses, so that you'll be able to browse to *http://www.cnn.com/* instead of *http://157.166.255.18*. Unix-like systems use the *resolver* to accomplish this feat.

Most hosts use two tools to map between IP addresses and hostnames: the *hosts* file and DNS. (Different operating systems support additional name services, such as YP, LDAP, NIS, and so on, but dang near every system supports these two.)

The *hosts* file is a text file on the local machine that contains static IP address and hostname lists. DNS is a more dynamic service that reaches across the network to find information. You can specify DNS servers by IP address, but we'll look at the *hosts* file in a little more detail.

What if you prefer IPv4 or IPv6 addresses? Or you want the *hosts* file to override DNS? Maybe you have a default domain that your queries should use. The resolver searches until it either finds the first answer or has exhausted its information sources, so these questions matter. Tell your resolver your needs in */etc/resolv.conf*.

### The /etc/resolv.conf File

You configure the resolver behavior in */etc/resolv.conf*. A system without */etc/resolv.conf* can find only hostnames listed in the *hosts* file. Because the *hosts* file starts off empty, that's probably not what you want. Start by specifying domain names.

#### Default Search Domains

If you wanted to ping a host on a remote network, you might expect to need to specify the whole domain. Entering **`ping www.openbsd.org`** should work. But if you wanted to ping your company's web server, it would make more sense to just type **`ping www`**. And you can, because OpenBSD allows you to specify default domains, so that when you type in a short hostname, it will try to find the proper host.

For example, if you have only one local domain, you would list the domain keyword in */etc/resolv.conf* like this:

```
domain michaelwlucas.com
```

Now, when I enter `ping ftp`, the resolver should get the IP address of the host *ftp.michaelwlucas.com*.

If you have more than one local domain, use the `search` keyword and a list of domains, like this:

```
search michaelwlucas.com openbsd.org
```

If I enter `ping ftp` now, the resolver should get the IP of the host *ftp.michaelwlucas.com*. Once the resolver learns that no such host exists,

it will check for *ftp.openbsd.org*. Because that host exists, `ping` will start to work. The `search` keyword can have up to six domains, and can be no longer than 1024 characters.

### Using Domain and Search

You can only use either `domain` or `search`. If you use both, the last entry in the file wins. If you list multiple search or domain lines, the last one in the file takes effect. Here's how not to do it:

```
search cnn.com openbsd.org
search sluggy.com michaelwlucas.com
domain blackhelicopters.org
```

You might as well get rid of the two `search` statements. The resolver will never go through those domain lists; it will use only the `domain` list because it's the last one.

### Name Servers

Now that the resolver knows which domains to check by default, tell it which name servers to use. List each name server on its own line, by IP address, in order of preference.

```
nameserver 192.0.2.5
nameserver 198.51.100.5
nameserver 2001:db8::5
```

You can list up to three name servers, by IP address. (Hostnames in a `nameserver` entry won't work, for fairly obvious reasons.)

If your *resolv.conf* doesn't list a name server, the resolver should check for a name server on the local machine.

### Lookup Order

You might get host information from DNS or from the *hosts* file. The resolver should stop once it finds an answer to a query. If you check the *hosts* file and then DNS, entries in the *hosts* file override the name server. If you check the name server before the *hosts* file, the *hosts* file is used only when no DNS record is available. Either approach has its uses, but by default, the resolver checks the *hosts* file, and then checks DNS. To reverse this, use the `lookup` keyword.

```
lookup bind file
```

The `file` option represents */etc/hosts*, while due to a historical accident, `bind` represents DNS. (The first DNS server software was the Berkeley Internet Name Domain server, or BIND.)The reverse (`file bind`) is the default, so there's no need to explicitly specify it.

#### Preferred IP Protocol

The resolver defaults to searching for IPv4 records first, and then looking for IPv6 records. To reverse this, use the `family` keyword.

```
family inet6 inet4
```

Again, the reverse is the default, so there's no need to use this keyword in that case.

### The /etc/hosts File

The */etc/hosts* file matches IP addresses to hostnames. While the *hosts* file is very simple, its contents are available only on the local machine. A *hosts* file is most useful on a small private network, such as in your home or test lab. You can also use a *hosts* file to override data from the DNS server, such as when you want to test a new system.

Each line in */etc/hosts* represents one host. The first entry on each line is an IP address. The second is the fully qualified domain name of the host. Following these two entries, you can have an arbitrary number of aliases for that host. I often add comments at the end of the line, prefixed with a hash mark (#).

There was a time when I had a small network at home with only four machines: the proxy/firewall, the wife's desktop, my laptop, and the crash machine where I did stupid things. The *hosts* file looked like this:

```
192.0.2.1 ❶nat.blackhelicopters.org     ❷nat firewall gateway
192.0.2.8   boss.blackhelicopters.org     boss wife  ❸#don't crash
192.0.2.20  crashbox.blackhelicopters.org crashbox test
192.0.10.21 laptop.blackhelicopters.org   laptop mwlucas
```

The machine `nat.blackhelicopters.org` at ❶ also had the names `firewall` and `gateway` at ❷. I added a note to remind myself at ❸ not to run security scanners against my wife's desktop. (The machine `crashbox` is also called `test`.)

Any machine with this *hosts* table could find any machine listed in the *hosts* table by name. For example, I could run `ping boss` or `ssh crashbox` and reach the desired machine.

The *hosts* file works just fine for finding networked hosts, but whenever you add, remove, or change a machine, you must edit */etc/hosts* on every computer. And every time you change an IP address, you must edit */etc/hosts* on every machine.

**NOTE** *Unfortunately,* /etc/hosts *does not scale. When I got a fifth machine, I added an internal-only DNS server and emptied the* hosts *file on all of my systems.*

### Resolver vs. Dynamic Configuration

If your OpenBSD system roams between networks, like a laptop, you probably use DHCP to configure your network connection.

DHCP overwrites */etc/resolv.conf* with the information for its network. This is appropriate for most users, but if you're carrying an OpenBSD laptop, you're not normal. You probably want some of your resolver configuration, such as your domain search list, to remain in effect no matter what network you're on.

OpenBSD supports permanent resolver configuration in the file */etc/resolv.conf.tail*. When OpenBSD's DHCP client gets */etc/resolv.conf* information from the server, it writes to */etc/resolv.conf* and adds `/etc/resolv.conf.tail` to the end.

Remember how only the last `search` or `domain` keyword works? *resolv.conf.tail* takes advantage of that, allowing you to override your network administrator's search order.

## Ethernet

Ethernet is a shared network, meaning that many different machines can connect to the same Ethernet and can communicate directly with each other. I'm going to assume that you're using Ethernet as found in an average office or datacenter. Also, although Ethernet has been implemented over many different physical media, I'll assume you're working with CAT5 or better cable—today's most popular choice. If you use some unusual media type, or your card supports multiple media, you might need to manually set your preferred media on your interface.

### Protocol and Hardware

Ethernet is a *broadcast protocol*, which means that every packet you transmit can be sent to every host on the network (although most Ethernet hardware limits recipients). Either your network card or your device driver separates the data intended for your computer from the data meant for other computers. A section of Ethernet where all hosts can communicate directly with all other hosts, without involving a router, is called a *collision domain* or *segment*.

You connect Ethernet segments with *hubs*, which are hardware items that can physically connect many Ethernet hosts. Network hubs forward all received frames to all other network devices, and each host is responsible for filtering traffic. This is old-school Ethernet, which can be useful for debugging network issues.

*Switches* have largely supplanted hubs. Every Ethernet connection needs a unique identifier, called a *MAC address* (or sometimes an *Ethernet address*), which is a 48-bit number. Switches control the traffic sent to each host by filtering on the MAC and IP address of attached devices and (mostly) forwarding frames only to the devices they are meant for. Switching reduces the amount of traffic and load on each individual system by decreasing the amount of traffic each host must sort through.

On i386 and amd64 hardware, the MAC address is a property of the card. On some other platforms, such as SPARC, the MAC address is a property of the server itself. Both IPv4 and IPv6 use the MAC address to find other hosts on the local network.

### IPv4 and ARP

When a system needs to transmit data to another IP-based host on the local Ethernet, it first broadcasts an Ethernet request asking, "Which MAC address is responsible for this IP address?" If a host responds, further data for that IP is transmitted to that MAC address. This process is handled by ARP.

Use `arp(8)` to view your system's ARP table, which is the list of hosts that your system knows. Enter `arp -a` to show all of the MAC addresses and IPv4 hostnames your computer knows.

```
$ arp -a
fly.blackhelicopters.org (192.0.2.225) at 00:a0:c8:10:eb:82 on fxp0
caddis.blackhelicopters.org (192.0.2.226) at 00:16:36:c0:58:a5 on fxp0 static
treble.blackhelicopters.org (192.0.2.227) at 00:0c:42:5a:58:ae on fxp0
salmon.blackhelicopters.org (192.0.2.232) at (incomplete) on fxp0
```

Here, you see the three hosts on my Ethernet network that this host has communicated with. I have more hosts, but because this machine hasn't spoken with them lately, they aren't in the local ARP table.

If a MAC address shows up as `incomplete`, your machine has attempted to communicate with this host but cannot get its MAC address. In this example, I've tried to send data to the host `salmon`, but my computer can't reach it. (Turning `salmon` back on would help.)

### IPv6 and Neighbor Discovery

IPv6 hosts also use MAC addresses to find each other through ND, an IPv6 protocol introduced in the previous chapter. Interrogate your ND cache with `ndp(8)`. The command-line flags used for `ndp` are intentionally similar to those for `arp`.

```
$ ndp -a
Neighbor                                Linklayer Address  Netif Expire    S Flags
2001:db8:0:12:20c:29ff:feb5:7565        0:c:29:b5:75:65    vic0  permanent R
2001:db8:0:12:5446:fbc:fca0:f2e9        0:c:29:b5:75:65    vic0  permanent R
...
fe80::20c:29ff:feb5:7565%vic0           0:c:29:b5:75:65    vic0  permanent R
fe80::20c:42ff:fe20:7f42%vic0           0:c:42:20:7f:42    vic0  11h20m47s S R
fe80::1%lo0                             (incomplete)       lo0   permanent R
```

Like the ARP cache, the ND cache shows an IPv6 address, a physical address, the interface, and other details for each host. You'll see more ND entries than ARP entries because all of the link local addresses show up in the ND cache.

If you try to reach a host that is directly attached to your local network and it doesn't respond, check the ND cache. If an ND cache entry shows up as `(incomplete)`, as with ARP, there's some sort of basic connectivity issue.

### Speed and Duplex

Ethernet supports a variety of speeds. The slowest speed you're likely to find today is 10 megabits per second (Mbps), but it's quickly disappearing. Most people use either 10/100Mbps or 1 gigabit per second (Gbps), although you'll see 10Gbps, 40Gbps, and 100Gbps Ethernet emerging.

The hosts and switch it's connected to on your network must agree on the speed of their connection. If the OpenBSD host thinks that it's connected at 100Mbps, but the switch thinks that the connection is 1Gbps, the connection will be flaky. While *autonegotiation* usually makes both sides agree on common settings (and is absolutely required for gigabit connections), you can manually set duplex and speed for 10/100Mbps connections. Although some switch vendors are notorious for poor autonegotiation, you should let your Ethernet configure itself whenever possible.

*Duplex* determines if a card can both transmit and receive data simultaneously. A *half-duplex* connection means that the Ethernet card is either transmitting or receiving at a given instant; it cannot do both. A *full-duplex* connection can both send and receive simultaneously. As with connection speed, if the switch and host disagree on the duplex setting, the connection will be flaky. Gigabit Ethernet connections involve much more than speed and duplex, and they *must* be autonegotiated.

Just because a device says that it can use the protocol defined as 10/100Mbps Ethernet doesn't mean that it can use that protocol with any speed. Also, a card labeled "1Gbps" might not actually pass a gigabit per second. Some network cards will pass their stated amount of traffic, while others will stagger and stumble at a few percent of that. Switch quality varies widely, too.

This may make more sense if you think of an Ethernet's stated speed as a language. For example, I could claim that I speak Russian and German, but I stopped studying foreign languages in 1985. When I went to Germany in 2007, I managed about three words a minute—with the aid of a translation card and phrase book. If I were an Ethernet card, the manufacturer would claim I spoke German and Russian, and ship me to Siberia.[1]

Get decent hardware. Don't ask on the OpenBSD mailing list, though. Someone has asked about hardware recommendations in the past few months. Check the archives. The advice hasn't changed.

## Configuring Ethernet

When configuring Ethernet for client computers, if your IPv4 network offers DHCP, you should be able to plug right in. If you're using IPv6, you should be able to attach the cable and let autoconfiguration take over.

1. Many people offer to ship me to Siberia. But they all forget to include a return ticket. Strange.

If a particular machine will be a server, a static IP address probably makes more sense. Before assigning a static address, you'll need the following:

- An IP address (IPv4, IPv6 or both)
- The netmask/prefix length(s)
- The IP address(es) of the default gateway

Armed with this information, attach your system to the network and keep reading. I'll first discuss using `ifconfig(8)` and `route(8)` to perform changes manually, and then review how to set these automatically at boot. In any case, you must configure the resolver as discussed at the beginning of this chapter.

### Using ifconfig(8)

If you installed OpenBSD over a network, your Ethernet connection should already be working, but it might not be set up exactly the way you like. To manage your network interfaces, use the `ifconfig(8)` tool.

Let's look at your Ethernet card and see what it has to say. Start by asking your system about all of the interfaces it has installed, by running `ifconfig`.

All OpenBSD systems have three logical interfaces out of the box: `lo0`, `enc0`, and `pflog0`. The `lo0` interface is the loopback interface, referring to the local machine. The `enc0` interface is an encapsulation interface, intended for IPsec traffic. Finally, `pflog0` is for logging PF traffic, as discussed in Chapter 22. The rest of the interfaces are physical ones.

Unlike some operating systems, OpenBSD network interfaces are named after the device driver of the underlying hardware. Here's a sample list:

```
$ ifconfig
fxp0: flags=8843<❶UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        lladdr 00:16:36:c0:58:a5
        priority: 0
        groups: egress
        media: Ethernet autoselect (100baseTX full-duplex)
     ❷ status: active
     ❸ inet 192.0.2.226 netmask 0xffffff00 broadcast 192.0.2.255
        inet6 2001:db8::216:36ff:fec0:58a5 prefixlen 64
        inet6 fe80::216:36ff:fec0:58a5%fxp0 prefixlen 64 scopeid 0x2
```

The interface `fxp0` uses the `fxp(4)` device driver, which the man page says is an Intel EtherExpress PRO 10/100 card. As you can see at ❶, the interface is up, meaning that it's active and ready to use. The `lladdr` is the link local address, or the MAC address of the card. This card is in the `egress` group. OpenBSD uses interface groups in several places, including the packet filter, as discussed in Chapter 22.

To see the type of physical media underlying the connection, check the `media` line. This particular connection runs at 100Mbps full-duplex. The connection is active, as shown at ❷; the physical layer has not only been

configured, but it also has a link light and is ready to go. The connection has been assigned an IPv4 address and netmask, as shown at ❸. You can see on the two lines that follow that both an IPv6 address and a link local IPv6 address have been assigned.

Use `ifconfig` to assign, change, or remove IP addresses from a network interface. The OpenBSD installer offers to configure your network cards at boot, but if you didn't configure all of your interfaces during installation, or if you add or remove network interfaces after installation, you will need to do so manually.

### Adding an IP Address

To add an IP address for IPv4, start with the interface's assigned IP address and netmask.

```
# ifconfig interface-name IP-address netmask
```

For example, if your network card is `fxp0`, your IP address is 192.0.2.55, and the netmask is 255.255.255.128, you would run this:

```
# ifconfig fxp0 192.0.2.55 255.255.255.128
```

Specify the netmask in dotted-quad notation, hexadecimal, or even slash notation, like this:

```
# ifconfig fxp0 192.0.2.55/25
```

You don't need to specify a netmask separately if you use a slash.

Adding an IP address with IPv6 is a little different. Specify the address, a slash, and the prefix length, but don't try to add a separate netmask; just use the slash that's part of the address. Here's an example:

```
# ifconfig fxp0 inet6 2001:db8:0:12::2/64
```

### Removing IP Addresses

If you need to remove an IP address from an interface, use the `delete` option of `ifconfig` for both IPv4 and IPv6 addresses.

```
# ifconfig fxp0 192.0.2.55 delete
```

The effect is immediate, so be sure you don't lock yourself out of the system by removing all of its reachable IP addresses, or by removing the only address your SSH daemon is attached to. (In certain rare cases, existing connections to deleted addresses might continue to work, but they probably won't, so don't count on it.)

### Multiple IP Addresses on One Ethernet Card

One network interface can respond to requests for multiple IP addresses, which is important because a server might support hundreds or thousands of domains and need an IP address for each. (This isn't so important for plain websites, but it can be important for SSL-based websites and protocols that rely on reverse DNS.)

To add extra IP addresses to an interface, use *IP aliases*. IP aliases tell a network card to "answer requests for this IP address as well as your own." To add aliased IP addresses, use `ifconfig` with the keyword `alias` after the interface name to tell `ifconfig` this is an alias. Be sure to always use a netmask of 255.255.255.255, or /32, for alias addresses.

```
# ifconfig fxp0 alias 192.0.2.230/32
# ifconfig fxp0
...
        inet 192.0.2.226 netmask 0xffffff0 broadcast 192.0.2.239
        inet 192.0.2.230 netmask 0xffffffff
```

The interface listed here has a main IP address of 192.0.2.226 and an alias IP address of 192.0.2.230.

When working with IPv6, add the `inet6` keyword, like this:

```
# ifconfig fxp0 inet6 alias 2001:db8:0:12::3/64
```

It's important to realize that all outgoing connections on a host with one network connection use the host's primary IP address. For example, you might have 2000 IP addresses bound to one interface, but when you `ssh` out, the connection comes from the primary address. Remember this when writing firewall rules and access control lists, because while some programs have an option to set a different source IP address, they're the exception.

The OpenBSD kernel doesn't really differentiate between the primary IP addresses and aliases—it just keeps a list of IP addresses—but it will use the first address on its list as the source address unless told otherwise. If a host has multiple network connections, the source address of outgoing connections is the main IP address of the network interface on which packets leave the system.

To remove an alias, use the `delete` option of `ifconfig` and give the IP address, without the netmask.

```
# ifconfig fxp0 delete 192.0.2.230
```

For IPv6, use `inet6 delete` instead.

```
# ifconfig fxp0 inet6 delete 2001:db8:0:12::3
```

**NOTE** *If you delete the main IP address on an interface, the first alias becomes the main IP address. If you have no IP address aliases remaining and you remove the interface's main IP address, that interface stops passing IP traffic.*

### Configuring Default Routes

Use `route(8)` to configure the default route for each protocol.

```
# route add default 192.0.2.1
add net default: gateway 192.0.2.1
```

An IPv6 default route is almost identical, but you must add the `-inet6` modifier.

```
# route add -inet6 default 2001:db8:0:12::1
add net default: gateway 2001:db8:0:12::1
```

Once you add IP addresses and default routes to your host, you should be able to reach the rest of your network and the Internet. Now let's see how to make those changes across reboots.

### Using Dynamic Configuration

To have OpenBSD get an IPv4 address from a DHCP server, run `dhclient(8)` and give it the name of the interface you want to configure.

```
# dhclient fxp0
```

`dhclient` gets an IP address, overwrites */etc/resolv.conf*, and configures the default route.

For IPv6, run `rtsol(8)` instead.

```
# rtsol fxp0
```

Remember that IPv6 autoconfiguration will not configure your resolver. You'll need to piggyback off your IPv4 DNS servers or manually configure */etc/resolv.conf*.

### Configuring the Network at Boot

While `ifconfig(8)` is fine for changes on the fly, your system should configure its interfaces correctly at boot, including any aliases on the interface, any routes added when the interface comes up, and so on.

Each interface has a configuration file, */etc/hostname.interfacename*, generically called *hostname.if*. The `fxp0` interface on my desktop uses a configuration file */etc/hostname.fxp0*, my wireless interface `wpi0` uses */etc/hostname.wpi0*, and so on. At boot, OpenBSD's */etc/netstart* script reads all of the *hostname.if* files and, if it finds a matching physical interface or can create a matching logical interface, it configures the interface accordingly.

To configure an interface's IPv4 address, enter a line in *hostname.if* in this format:

```
inet ipaddress netmask broadcastaddress ifconfig-options
```

The broadcast address and options are optional. To use options but not specify a broadcast address, use `NONE` for the broadcast address. You can also use a slash for the netmask instead of the decimal equivalent.

Similarly, add an IPv6 address with the following:

```
inet6 ipv6address/prefix ifconfig-options
```

To give `fxp0` the IPv4 address of 192.0.2.226 255.255.255.240 and the IPv6 address of 2001:db8:0:12::2/64 at boot, use the following in */etc/hostname.fxp0*:

```
inet 192.0.2.226 255.255.255.240 NONE description 'top card'
inet6 2001:db8:0:12::2/64
```

Here, I also define an interface description that will show up in `ifconfig` output.

To create an IP address alias at boot, use the `alias` keyword in *hostname.if*.

```
inet alias 192.0.2.230/32
inet6 alias 2001:db8:0:12::3/64
```

To run a command when the interface comes up, put an exclamation point in front of the command. Any commands run must be available on the root partition (for example, in */bin* or */sbin*). This feature is most commonly used for routing, but you could use other commands as well.

```
!route add 192.0.2.128/25 192.0.2.2
```

To configure an interface dynamically, via DHCP (IPv4) or `rtsol` (IPv6), put the string `dhcp` or `rtsol` on a line by itself.

```
dhcp
rtsol
```

Anything that's not formatted as shown here is passed unedited to `ifconfig(8)`. For example, to run a specific `ifconfig` command, put the arguments on their own line in *hostname.if*.

```
description 'lower card'
```

If you simply want to activate a card, but not configure it, use the word `up` on a line by itself to activate the interface.

```
up
```

And remember, you can test *hostname.if* changes with */etc/netstart*, specifying an interface name if appropriate, like so:

```
# /bin/sh /etc/netstart fxp0
```

Not including the interface name reconfigures all interfaces on the system.

## Trunking

Servers can have redundant hard drives, power supplies, and so on. OpenBSD supports redundant network connections by combining multiple Ethernet links into a single virtual link, or *trunk*. You might also know of this as *link aggregation*, *network adapter teaming*, or *bonding*.

**NOTE** *Cisco people know of* trunks *as Ethernet links that support multiple concurrent VLANs. Most vendors, including OpenBSD, don't use the word* trunk *in that way. OpenBSD supports sending multiple VLANs over a single link outside the* `trunk(4)` *functionality.*

### Link Aggregation Protocols

To use multiple physical links as a single large link, you need a way to distribute traffic between the links. OpenBSD supports five different ways to distribute frames between trunk members, though not all will work in all environments. For a complete list see `trunk(4)`, but the protocols I recommend for real-world use are Link Aggregation Control Protocol (LACP), roundrobin, and failover. LACP is the industry standard for link aggregation. The physical interfaces are bonded into a single virtual interface with roughly the same bandwidth as the sum of the individual interfaces. LACP is very fault-tolerant, and just about every high-end managed switch should support it. If your switch supports LACP, use it, but you must configure LACP on the switch ports before this kind of trunk will pass traffic.

In the roundrobin method, OpenBSD sends frames across the trunk's active connections using a roundrobin scheduler. The trunk accepts incoming packets on any port, and a roundrobin scheduler rotates between the trunk connections, with error and edge handling added on top. Roundrobin trunks don't need any special switch configuration; they just need two ports in the same VLAN.

In the case of failover, OpenBSD sends and receives all traffic over the first port in the trunk, and if that port fails, it switches to another active port. The failover method doesn't give you any additional bandwidth, but requires absolutely no support from the switch, and it even works on old-fashioned hubs.

### Trunk Configuration

As an example, let's configure ports `em0` and `em1` into failover trunk `trunk0`. The underlying ports have never been configured before, so begin by activating these interfaces without any configuration.

```
# ifconfig em0 up
# ifconfig em1 up
```

Now create the failover trunk with `ifconfig(8)` and add these ports to it to make the `trunk0` interface usable.

```
# ifconfig trunk0 trunkproto failover
# ifconfig trunk0 trunkport em0
# ifconfig trunk0 trunkport em1
```

You could do this all in one long `ifconfig` command, but I find simpler, shorter commands easier to understand when learning.

Assign the interface an IP address just as you would a physical interface, and add a default gateway to your system.

```
# ifconfig trunk0 192.0.2.8 netmask 255.255.255.0
# route add default 192.0.2.1
```

You should now have a failover trunk attached to your local network. To configure another trunk protocol, just specify the desired trunk protocol when you create the trunk. You'll find a complete list of trunk protocols in `trunk(4)`.

### Trunks at Boot

Configure your trunk in */etc/hostname.if*. For example, suppose you need to edit *hostname.em0*, *hostname.em1*, and *hostname.trunk0*. Both of the *em* files contain only a single word:

```
up
```

This activates the interfaces, but does no configuration.

*hostname.trunk0* is more complicated.

```
trunkproto failover
trunkport em0
trunkport em1
192.0.2.8 netmask 255.255.255.0
```

You can put all of these entries in a single line, just as you can configure the trunk with a single `ifconfig` command, but again, I find multiple lines easier to read and understand.

Your trunk should now start at boot.

Note that trunks do not necessarily need to consist of interfaces that use the same type of physical medium. If you're feeling adventurous, you could try to replicate what some OpenBSD developers and users have been known to do: Trunk together a wired and a wireless network interface, and have all your connections survive (graceful failover, remember?) when you yank the plug out of your Ethernet port, or if you plug yourself back in and take your access point down for maintenance.

## VLANs

VLANs are a way to get multiple Ethernet segments on a single piece of wire. You'll sometimes see this referred to as *802.1q*, *tagging*, or a combination of these terms.

In OpenBSD terms, one wire can carry multiple networks, and by configuring an additional interface, you can talk to those additional networks as if they had their own private wire. The wire can still carry only so much data, however, so all VLANs and the regular network (or *native VLAN*) that share the wire share the same pool of bandwidth.

VLAN frames that arrive at your network card are like regular Ethernet frames, with an additional header before the Ethernet frame that says "This is part of VLAN number such-and-such." Each VLAN is identified by a number. VLAN number 1 is usually the native VLAN—the VLAN that arrives without any tagging whatsoever. For convenience, I'll use the word "tagged" to describe how the VLAN is delivered to your host.

How would you use VLANs in OpenBSD? Perhaps you have a network divided into multiple Ethernet segments, such as outside the firewall, server area, and desktop clients. Or you might have one OpenBSD host that needs direct access to all of these segments. You could route all of these networks over a single physical wire. You might eventually hit bandwidth problems, but if you're pushing more than 1Gpbs through your server, you can afford a second network card.

### Configuring Switches

You must configure your switch to send the VLANs to your OpenBSD box as 802.1q or tagged, depending on the switch's syntax. Cisco uses *802.1q*, HP's Procurve switches use *tagged*, and other vendors use whatever their prejudices dictate. There are dozens of different syntaxes to do this, so I won't give a specific example. If the switch can't send tagged VLANs to your server, you cannot use VLANs.

### Configuring VLAN Devices

OpenBSD creates `vlan(4)` interfaces upon request. To create the device, you need to know which physical device you want to attach the VLAN to and the number of the VLAN you're expecting.

Create the `vlan` interface with `ifconfig`.

```
# ifconfig vlanX vlan vlan# vlandev interface
```

I number my `vlan` interfaces after the VLAN number they're used for. (You could create interface `vlan0` and attach it to VLAN 3, but that's too confusing for my feeble brain.) If you don't specify the VLAN number, OpenBSD assigns the VLAN number from the number on the interface.

For example, here I create interface `vlan3` and use it to access VLAN 3 over interface `fxp0`.

```
# ifconfig vlan3 vlandev fxp0
```

That's really all there is to it. Now you can use `ifconfig` to display your new interface:

```
$ ifconfig vlan3
vlan3: flags=48843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST,INET6_PRIVACY> mtu 1500
        lladdr 00:16:36:c0:58:a5
        priority: 0
        vlan: 3 parent interface: fxp0
        groups: vlan
        status: active
        inet6 fe80::216:36ff:fec0:58a5%vlan3 prefixlen 64 scopeid 0x7
```

This looks exactly like any physical interface, and from your point of view, it is. You can add IP addresses just as you would to any other interface, assign routes, and get on with your life.

### Configuring VLANs at Boot

To configure a VLAN interface at boot time, create a *hostname.if* file for it. For example, here's the contents of a */etc/hostname.vlan3* that creates the `vlan3` interface demonstrated in the previous section, assigns it to VLAN 3, and configures it automatically for both IPv4 and IPv6:

```
vlandev fxp0
dhcp
rtsol
```

OpenBSD should find this file at boot and create the interface according to your commands.

## IPv6 Over Tunnels

Let's say you've taken my badgering to heart and decided to experiment with IPv6, but your ISP doesn't offer IPv6. How can you play with IPv6 when all you get is an IPv4 feed?

Many companies offer a free IPv6 tunnel service, where they will route you through an IPv6 tunnel over IPv4. They will even give you an IPv6 /64 at no charge, so you can configure your home network for IPv6.

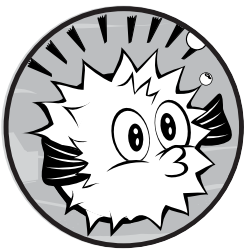
While I generally avoid recommending vendors in this book, I do recommend Hurricane Electric's IPv6 tunnel service at *http://www.tunnelbroker.net/*. Its web interface is intuitive, and it even provides configurations for OpenBSD clients.

You should now have some understanding of managing IPv4 and IPv6 on OpenBSD. While your brain is recovering from all this stuff, we'll turn to the topic of managing add-on software in OpenBSD.

# 13

# SOFTWARE MANAGEMENT

*Blowfish is solid,*
*but the third-party software?*
*Easy road to ruin.*



Most people don't use an operating system; they use software, which runs atop an underlying operating system. No matter how robust an operating system is, it's useless without applications.

Many commercial operating systems include hundreds or thousands of small programs: games, desktop toys, and everything from fancy-looking clocks to disk scrubbers and web browsers. Most users never touch most of these programs, but the programs take up disk space (and possibly other resources) just the same. Every program drags along some amount of infrastructure, and all of this software can cause any number of problems.

Unlike many other operating systems, OpenBSD deliberately includes relatively little software in the default installation. You get exactly what you need to provide the infrastructure for software, and nothing more. While a traditional UNIX or Unix-like system includes compilers, games, and man pages, you don't even need to install these when installing OpenBSD! Even

if you install everything included in OpenBSD, it will have far less software than any commercial operating system. That's because almost everything is considered an add-on package.

The advantage to this sparseness is that you know exactly what's on the system, which simplifies debugging. A random shared library from a program you've never used won't break your programs. The downside is that you need to think a bit to decide exactly what you do want to include, and you'll need to install those programs. OpenBSD makes installing software as easy as possible through the ports and packages system, which is introduced in this chapter. But first, let's take a look at building software.

## Making Software

Building software is complicated because source code must be very specifically processed to create a program that works—let alone a program that works well! The `make(1)` program makes building software easily reproducible, so that a program can be built exactly as the software author intends. `make` takes its instructions from a configuration file, or *makefile*, which tells `make` exactly how to build a program from source. You don't need to know the internals of a makefile, so we're not going to dissect one here.

A makefile includes one or more targets and a set of instructions to carry out. For example, typing `make install` tells `make` to check the makefile for a procedure called `install` and, if found, to execute it. A target's name usually relates to what `make` should be doing. The `make install` process, for example, usually installs the software built by previous steps. You'll find targets to install, configure, and uninstall most software, and `make` handles a huge variety of functions, some of which far outstrip the creators' original intentions.

## Source Code and Software

Source code is the human-readable instructions for building the actual machine code that makes up a program. You've probably already been exposed to some form of source code; if not, go look at a few files under */usr/src* (assuming, of course, that you installed the source code as I recommended back in Chapter 3). While you don't have to read source code, you should be able to recognize it.

Once you have a program's source code, you build (or compile) the program on the type of system on which you want to run it. (Building software for a foreign platform via cross-compiling demands that you know much more about building software, and is not always possible.) If the software was written for an operating system sufficiently similar to what you're building it on, you'll create a working program. If the operating system differs too much, either the build fails or the resulting software won't run. Once you've built the software successfully on your system, you can copy the

resulting program (or *binary*) to other systems on the same platform, with the same operating system version and supporting software, and expect it to run.

Some programs are sufficiently well written that you can compile them on many different platforms. A few programs specifically include support for widely divergent platforms. For example, you can compile the Apache web server on Windows, NetWare, and Unix-like platforms by typing `make install`. This is quite uncommon, however, and takes considerable effort on the part of the software authors. It also makes the code more complex, and supporting all these operating systems means that it cannot easily support all the features that make those operating systems special. (But note that the ability to *build* software on a variety of platforms doesn't necessarily mean that it *runs* well on all of those platforms.)

Generally speaking, if you can build a program from source, it usually runs. A sufficiently experienced sysadmin can use the source code and error messages to learn why a program won't build, or why it builds but doesn't run. In many cases, the problem is simple and can be fixed with minimal education.[1] This is one reason why access to source code is important.

Back when every sysadmin was a programmer, debugging software builds absorbed major portions of the sysadmin's time. Every Unix-like platform was slightly (or wildly) different. To build programs, sysadmins needed to understand their platform, the software's original platform, and the differences between the two. The duplication of effort to build common programs was truly horrendous. Tools such as `autoconf` and `configure` were intended to help simplify this problem, but these programs just paper over the underlying problems. Building many software packages requires much more time running `configure` scripts than they need to actually compile.

The OpenBSD ports and packages system removes all this pain.

## The Ports and Packages System

*Ports* are a mechanism for reproducibly and consistently building software on OpenBSD. *Packages* are precompiled ports for a specific OpenBSD version and platform. Packages install quickly and easily, and are recommended by the OpenBSD folks. Installing from a port takes more time and effort, but can be customized for your environment or server.

The basic idea behind the ports system is that if source code must be modified or tweaked to build or run on OpenBSD, the modification process should be automated. If you need other software to build this program from source code or run it, those dependencies should be automatically used. If you record exactly which files the software installs, you can easily uninstall it. And if you have all of these things, you can pick up the software and install it on any similar OpenBSD system.

1. In the IT industry, "minimal education" means a willingness to dig in and figure it out, plus a few years of college or professional experience; access to programming textbooks or other educational materials; or a whole lot of youth, stubbornness, and motivation.

Packages are the installable files produced by the ports system. You can install packages over the network, either from your own package repository or from an OpenBSD mirror site. But before you can use a package, you must find it.

## Using Packages

Packages are the preferred method to install OpenBSD software. Packages are built by the OpenBSD Project's ports team, and are expected to work without any special tweaks from the user. You must configure the software, of course, but the software itself should work as expected. Unless you are planning to make modifications to a specific piece of software, you'll be a lot happier simply installing the package fetched from a nearby mirror rather than building it from the port (or, worse, installing from the source code without the port).

### Package Files and $PKG_PATH

Every package is available as a single file named after the port it is found in, a version number, and a *.tgz* extension. For example, version 2.4.2 of the `adsuck` software is available in the file *adsuck-2.4.2.tgz*.

Before you can install packages, you need to find a source for them. Find package files on the official release CDs or on OpenBSD mirror sites.

The packages are on the FTP and HTTP mirrors in the directory */pub/OpenBSD/*release*/packages/*platform. For example, the packages for the amd64 platform for OpenBSD 5.3 are in the directory */pub/OpenBSD/5.3/packages/amd64*. Look at the OpenBSD mirror list. Choose a mirror server near you, and verify that it actually has the *packages* directory for the release and platform you run. My closest mirror is *http://ftp10.usa.openbsd.org*.[2] I find the 5.3 amd64 packages at *http://ftp10.usa.openbsd.org/pub/OpenBSD/5.3/packages/amd64*.

On the official CD, you'll find packages in /release/platform*/packages*. (Downloaded installation CDs do not include packages.) If you mounted the 5.3 CD at */mnt*, you would find the packages at */mnt/5.3/amd64/packages*.

Once you've chosen a package repository, set the `$PKG_PATH` variable in your shell to it. This tells OpenBSD's package management tools where to get the packages and gives you quick access to a single authoritative source of packages.

If you set `$PKG_PATH` to an invalid location, `pkg_add` (the command for installing a package) won't work. Using a location with packages for a different architecture makes `pkg_add` give an error that packages are "not for the right architecture." If you choose an incorrect release, you'll see "bad major" or other library version errors. Either of these types of errors mean that your `$PKG_PATH` is wrong.

2. No, it's not. There is no *ftp10.usa.openbsd.org*. Follow the instructions. Look at the mirror list and pick a mirror that actually exists and is close to you. Never blindly copy my examples!

You can also list multiple package repositories. If the package tools don't find a desired package in the first repository, they try the next one. This lets you use a local package repository for your custom packages, and then fall back to the official OpenBSD repository if you don't have a local package. I use this when I must build a custom package for my network and want to use it across multiple machines.

Installing packages via FTP or HTTP is not quite as secure as installing them from CD. While the OpenBSD release team has verified all the packages on the CD set, an intruder could have tampered with whatever mirror you choose. These intrusions would be caught comparatively quickly, but it's possible that you could install packages between the time of the intrusion and the time the damage is reversed. If you're deeply concerned about package integrity, get an official CD set.

## Finding Packages

As I write this, the latest OpenBSD/i386 snapshot has 7485 packages on the FTP site. This is a long list to browse through to find the specific package you want. If you have the ports tree installed, you can search it for packages, but if you wanted to use the ports tree, you wouldn't be using packages, now would you?

Say you need a piece of software that runs only on Apache 2.2. How can you find this? Find packages on the command line, or use a website.

**NOTE** *Most people don't need an external web server on OpenBSD; the web servers included with OpenBSD are perfectly fine for average users. I would install Apache 2.2 only if I had a specific application written for Apache 2.2. If you want to run, say, a PHP web application, just use OpenBSD's included* `nginx` *web server.*

### Finding Packages on the Command Line

`pkg_info(1)` displays information about packages. While you would normally use `pkg_info` to explore the packages you've already installed, you can use `-Q` to run a case-insensitive search on the packages in your package repository. If you know part of the package name, try the package search.

```
$ pkg_info -Q apache
apache-ant-1.8.2p3
apache-couchdb-1.0.1p2
apache-httpd-2.2.22
apachetop-0.12.6
modsecurity-apache-1.9.3p5
p5-Apache-ASP-2.61p0
...
```

From the names, you can guess that the package `apache-httpd-2.2.22` contains Apache 2.2.

### Finding Packages on the Web

The easiest way to search packages is to use the unofficial OpenBSD Ports website at *http://www.openports.se/*. While this isn't an official OpenBSD website, it has provided a good interface into the OpenBSD ports tree for several years. If I search for Apache on this site, the third hit is for "www/apache-httpd, apache HTTP server."

Once you know the name of the package containing the software you want, you can install it.

## *Installing Packages*

Use `pkg_add(1)` to install packages. You don't need the version number—just the package name. Here, I install the Apache package I found earlier:

```
# pkg_add apache-httpd
❶ apache-httpd-2.2.22:libiconv-1.14: ok
apache-httpd-2.2.22:pcre-8.30: ok
...
❷ apache-httpd-2.2.22: ok
❸ The following new rcscripts were installed: /etc/rc.d/httpd2
See rc.d(8) for details.
❹ --- +apache-httpd-2.2.22 -------------------
This is the official httpd distributed by the Apache Server Project,
provided as a port for those who, for various reasons, need to run
version 2.

OpenBSD provides a custom Apache server, httpd(8), in the base system
which has been audited for security and may run in a chroot(2)
environment. Users are STRONGLY encouraged to use the system httpd
rather than this port.
```

A great deal of software requires other software to run, and OpenBSD's package tools track these *dependencies*. `pkg_add` starts my Apache installation by installing the various dependencies of the chosen package, as shown at ❶. Apache 2.2.22 requires `libiconv` and `pcre`, among several other packages. As each package installs, you'll see a progress bar scroll across the screen. If a dependency cannot be installed, the package installation terminates.

After installing all the dependencies, `pkg_add` installs the actual Apache 2.2 package, as shown at ❷. At the end of package installation, you'll see notices for startup scripts added by the package, as shown at ❸, and then any notes from the OpenBSD team about the packages, like those at ❹.

### Which Files Are Installed?

Use the `-L` option to `pkg_info` to see which files a package installs.

```
$ pkg_info -L apache-httpd
Information for inst:apache-httpd-2.2.22
```

```
Files:
/usr/local/include/apache2/ap_compat.h
/usr/local/include/apache2/ap_config.h
/usr/local/include/apache2/ap_config_auto.h
/usr/local/include/apache2/ap_config_layout.h
/usr/local/include/apache2/ap_listen.h
...
```

As you can see, all of these files are installed under */usr/local*. OpenBSD installs all packages under */usr/local*.

### Verbose Installation

If you're interested in the details of how `pkg_add` works, use the `-v` flag to trigger verbose mode. You can specify multiple `-v` flags for added detail. I recommend trying verbose mode a few times, in varying levels of detail, to get a deeper understanding of what `pkg_add` actually does.

### Ambiguous Packages

Sometimes `pkg_add` needs an extra hint about what you want to install. For example, everything in my production network is tied together with LDAP, and I need to run an OpenLDAP mirror in each datacenter. (I could use OpenBSD's integrated LDAP daemon instead, but the master servers run OpenLDAP, and I don't want to mix LDAP servers.) The following is my attempt to install OpenLDAP.

```
# pkg_add openldap-server
❶ Ambiguous: choose package for openldap-server
 a       0: <None>
         1: openldap-server-2.3.43p10
         2: openldap-server-2.4.31p0
Your choice: 2
❷ Ambiguous: choose dependency for openldap-server-2.4.31p0:
 a       0: cyrus-sasl-2.1.25p3
         1: cyrus-sasl-2.1.25p3-db4
         2: cyrus-sasl-2.1.25p3-ldap
         3: cyrus-sasl-2.1.25p3-mysql
         4: cyrus-sasl-2.1.25p3-pgsql
         5: cyrus-sasl-2.1.25p3-sqlite3
Your choice: 2
❸ Detected loop, merging sets ok
| cyrus-sasl-2.1.25p3-ldap
| openldap-client-2.4.31
openldap-server-2.4.31p0:cyrus-sasl-2.1.25p3-ldap+openldap-client-2.4.31: ok
openldap-server-2.4.31p0:db-4.6.21v0: ok
openldap-server-2.4.31p0:icu4c-49.1.2p1: ok
openldap-server-2.4.31p0: ok
The following new rcscripts were installed: /etc/rc.d/saslauthd /etc/rc.d/
slapd
See rc.d(8) for details.
```

As you can see at ❶, OpenBSD has two OpenLDAP server packages: recent releases of version 2.3 and version 2.4. I want version 2.4. The OpenBSD OpenLDAP package is compiled with Cyrus SASL (Simple Authentication and Security Layer), which in turn comes in six different flavors, as you can see at ❷—one for each supported database. I choose the version that uses LDAP as its backend. (I don't need this particular SASL; any SASL will suffice.)

`pkg_add` realizes that this is something of a chicken-and-egg problem. LDAP is compiled using Cyrus, but Cyrus is compiled using LDAP. Fortunately, as you can see at ❸, it knows that this is a permissible configuration. The dependencies are installed, and then the OpenLDAP server that I want is added.

### Identifying Where Files Originate

As you've seen in earlier examples, many packages install other packages as dependencies. Once you've installed a few complicated software packages, */usr/local* starts to fill up with weird-looking files and programs. Eventually, you'll wonder which packages are needed or where a package was installed from.

OpenBSD maintains records for every installed package in */var/db/pkg*, including files installed and dependency information, but wading through these files resembles effort, and I won't do it. Also, many package names are obscure, opaque, obfuscated, or otherwise obtuse. (It's not that the OpenBSD packages team tries to make package names incomprehensible, but there's only so much it can do when the software has a name like `icu4c`.)

Thankfully, `pkg_info(1)` can easily answer most questions about your installed software. Start by getting a complete list of all software packages on the machine with the `-a` argument.

```
$ pkg_info -a
cyrus-sasl-2.1.25p3-ldap RFC 2222 SASL (Simple Authentication and Security Layer)
db-4.6.21v0          Berkeley DB package, revision 4
icu4c-49.1.2p1       International Components for Unicode
openldap-client-2.4.31 Open source LDAP software (client)
openldap-server-2.4.31p0 Open source LDAP software (server)
quirks-1.73          exceptions to pkg_add rules
tcsh-6.18.01         extended C-shell with many useful features
```

Hang on a minute! I've installed `tcsh`, of course, as my aged brain isn't up to learning a new shell. I installed OpenLDAP, and chose to add `cyrus-SASL` as a dependency. Did `pkg_add` really install all of these other packages as dependencies? Or has one of my junior admins installed extra cruft? Do I really *need* all of these packages, or do I just need to smack a minion?

OpenBSD records which software packages you've installed, versus those installed as dependencies. Use the `-m` flag to see only those packages you manually installed.

```
# pkg_info -m
openldap-server-2.4.31p0 Open source LDAP software (server)
quirks-1.73         exceptions to pkg_add rules
tcsh-6.18.01        extended C-shell with many useful features
```

This looks more familiar. Apparently everything else really is a dependency.

Now let's look at some options. For longer descriptions of each package, add the `-d` flag or use the `-a` flag to show information for all packages. If you want to run `pkg_info` for a single package, use the package name as an argument. For example, `-L` shows the list of files a package installs. With the `-a` flag, it will show all files included in all installed packages, but that's probably more than you want. To show all files installed by a package, use the `-L` flag and the package name.

```
$ pkg_info -L tcsh
Information for inst:tcsh-6.18.01

Files:
/usr/local/bin/tcsh
/usr/local/man/man1/tcsh.1
/usr/local/share/nls/C/tcsh.cat
/usr/local/share/nls/de_AT.ISO_8859-1/tcsh.cat
/usr/local/share/nls/de_CH.ISO_8859-1/tcsh.cat
/usr/local/share/nls/de_DE.ISO_8859-1/tcsh.cat
...
```

As you can see, the `tcsh(1)` package includes the actual `tcsh` binary, the man page, and a whole bunch of National Language Support (NLS) files. Given a package name, you can identify which files are part of the package.

Going the other way, sometimes you want to know where a particular file originated. For example, I occasionally browse my server filesystems looking for weird stuff. I define "weird stuff" as "things I don't recognize." If I see an unfamiliar program or file, I'll check to see which package installed it.

```
$ pkg_info -E /usr/local/sbin/pluginviewer
/usr/local/sbin/pluginviewer: cyrus-sasl-2.1.25p3-ldap
cyrus-sasl-2.1.25p3-ldap RFC 2222 SASL (Simple Authentication and Security
Layer)
```

The only `pluginviewer` I had previously encountered was one designed to help Unix web browsers run third-party software when a website demanded a plug-in. I don't know what this `pluginviewer` does, but apparently it's a legitimate part of `cyrus-SASL`. To find something to worry about, I need to keep looking.[3] If you do many file searches like this, you can get faster results by using `pkglocatedb` (*/usr/ports/databases/pkglocatedb*).

3. If you don't see anything to worry about on any given server, you aren't looking hard enough.

After installation, many packages show a message, which I frequently read and promptly forget. To display this information again, use `pkg_info` with the `-M` flag.

```
$ pkg_info -M apache-httpd
Information for inst:apache-httpd-2.2.22

Install notice:
This is the official httpd distributed by the Apache Server Project,
...
```

If you don't remember which package had the message you wanted, use the `-a` flag instead of a package name to display the messages for all packages that have one. To show all packages that are not required by other packages, use the `-t` flag, which you might think matches all packages you chose to install. If you didn't request a package, it could only be installed as a dependency to something you requested, right?

```
$ pkg_info -t
apache-httpd-2.2.22 apache HTTP server
icu4c-49.1.2p1      International Components for Unicode
quirks-1.73         exceptions to pkg_add rules
tcsh-6.18.01        extended C-shell with many useful features
```

I know that I did not choose to install `icu4c`. I have no moral objections to the software, mind you, but it's nothing I requested. How did a piece of software that I didn't choose to install, and isn't required by anything else, get on this system?

It's there because I uninstalled something that required it.

### *Uninstalling Packages*

To remove a previously installed package, use `pkg_delete(1)`.

```
# pkg_delete openldap-server
openldap-server-2.4.31p0: ok
Read shared items: ok
--- -openldap-server-2.4.31p0 -------------------
You should also run /usr/sbin/userdel _openldap
You should also run /usr/sbin/groupdel _openldap
```

`pkg_delete` does not request confirmation. It doesn't ask if you are sure. It just blasts the software off the disk and gets on with its day. It also doesn't remove the unprivileged users and groups created for the software, as you might still have files owned by them.

Remember that many packages require other packages. By default, `pkg_delete` doesn't remove dependencies of packages you remove. For example, earlier we saw that `icu4c` had been installed automatically as a leftover dependency from a removed OpenLDAP server package. To automatically

remove unneeded dependencies, use the `-a` flag. For example, to completely eradicate the `openldap-server` package and its infrastructure from the machine, run `pkg_delete` twice.

```
# pkg_delete openldap-server
# pkg_delete -a
```

This should clean your system of all packages installed as dependencies.

### Package Limitations

The package system is fast, efficient, reliable, and the OpenBSD Project's preferred way for users to install software. But the system does have a few limitations that you should be aware of, including lags in the software-porting process and the support for newer packages on older versions of OpenBSD.

Each OpenBSD release supports only packages built for that release, and new packages are not built for old releases. The packages issued with the release are all you'll get. (There are slight exceptions to this if you're running `-stable`; see Chapter 20.) If you're running OpenBSD 5.3 and try to install packages from OpenBSD 5.4, they won't work.

Most packages include software produced by third parties. OpenBSD provides the packaging, but the software itself is released on a schedule completely independent of OpenBSD's. After the software developers release their newest software, the OpenBSD package is updated, but there's a gap between the software's release date and the release of the OpenBSD package. A popular package might be updated in hours, while larger, less frequently used, or unpopular packages can languish at an older version for days or weeks. These packages are not officially available until the next OpenBSD release, so you might run software that's a point or two behind the latest for a few months. Usually, this is not a problem (if it is, investigate OpenBSD's `-stable` branch, discussed in Chapter 20.)

**NOTE** *If packages won't work for you, investigate building third-party software through ports. You won't get newer versions of the software, but you can get slightly different versions.*

## Using Ports

The ports collection is the toolkit to build OpenBSD packages. Installing software from ports takes longer than installing via packages, is more error-prone, and requires a deeper understanding of the system and the add-on software than packages demand. You can't get packages for every possible situation, however (one particularly annoying example is when the license for a particular piece of software makes it illegal for the OpenBSD project to create and distribute packages), and sometimes ports are the only way to get third-party software on your OpenBSD system short of compiling it yourself.

What makes ports interesting is their level of automation. With one command, a port can find the source code for a program, download it, verify its integrity, apply any patches needed to make it run on OpenBSD, toggle any flags needed for any custom features of your system, build the code into actual binaries, produce a package, and install it. If you have compiled software on other platforms, you'll quickly realize how ports simplify building software.

Like packages, ports work only on the version of OpenBSD for which they are released. That means that you must use the OpenBSD 5.4 ports collection on OpenBSD 5.4; the 5.5 ports collection won't work. Oh, it might look like it works sometimes, but the software will fail unpredictably, and no one will have sympathy for you (sympathy for your coworkers, perhaps, but not for you).

When you upgrade OpenBSD, the expectation is that you will upgrade your ports collection and all installed packages to the precise matching version. You might be able to use older packages on a newer OpenBSD, as long as you don't delete the older shared libraries required by the software.

### The Ports Tree

The ports tree is usually installed in */usr/ports*. If you want the ports tree, you must manually fetch the *ports.tar.gz* file from your OpenBSD release and extract it under */usr*.

**NOTE** *I suggested this way back in Chapter 4, but you can also get the ports tree and keep the files up to date using* `cvs(1)`*, as covered in Chapter 20. Look in this directory, and you'll find a whole bunch of directories and files.*

The *INDEX* file contains a list of every port in the system, in alphabetical order but machine-readable format. You can search this file for ports, but I recommend using one of the tools discussed later to do so.

The *Makefile* contains the basic machine instructions for making the ports system work. While it's intended for use by `make(1)`, you can learn a lot by reading the makefile for any port. Most of the really complicated ports code is in the *ports/infrastructure* directory, and all of the makefiles in the ports system build on that infrastructure.

The remaining directories are software categories. Each category contains a further layer of directories, and each directory under a category is a port of a specific piece of software. OpenBSD has more than 7600 ports as of this writing, so this hierarchical organization is vital to keeping them in some sort of manageable order.

For example, the following is a listing of the contents of the *news* directory, which contains programs for using and managing Usenet news. This is one of the smaller categories. Some categories have hundreds of entries, but they're arranged in much the same way.

```
CVS             leafnode        p5-News-Article  py-yenc         tin
Makefile        newsfetch       p5-News-Newsrc   sabnzbd         trn
aub             nn              pan              sickbeard       ubh
hellanzb        p5-Gateway      plor             slrn
yencode
```

Like the *CVS* directory in the main ports tree, the category's *CVS* directory contains CVS version control information that doesn't matter for day-to-day operation. The *Makefile* contains a list of valid ports within the category. You can build all of the ports in this category using this makefile, although that's mostly useful only when building packages en masse. (When the OpenBSD Project team builds everything in the ports tree, it uses */usr/ports/infrastructure/bin/dpb*.)

Let's go down another level. Here's the port for `tcsh`, one of my non-negotiable requirements as a sysadmin:

```
$ ls /usr/ports/shells/tcsh
CVS      Makefile distinfo patches  pkg
```

The *CVS* directory contains version control information, as in every *CVS* directory.

The *Makefile* gives specific instructions for building `tcsh` on OpenBSD, including where to get the software and any patches, how to extract it, where the package can be distributed from, and any supported customizations.

The *distinfo* file contains several different cryptographic hashes for the source code to be downloaded, to avoid building software from compromised source code, and the size of the source file. Newer ports contain only SHA-256 hashes.

**NOTE** *While it's possible (difficult, but possible) to have a compromised file match a specific hash, it's extremely unlikely that an altered source code file could match hashes computed with several different algorithms and have the same size as the uncompromised code. Even if people figure out how to break a particular hash, use of multiple hashes and the file size make compromising a source file nearly impossible.*

The *patches* directory contains code alterations needed to make this software run on OpenBSD. Some ports have no patches; others have dozens.

Finally, the *pkg* directory describes the package and lists the files that the complete package must include.

### Secondary Ports

Some ports include other ports. Here are the contents of the *emulators/fedora* port.

```
CVS    Makefile   Makefile.inc  base       cups       motif      sdl
```

The file *Makefile.inc* is new, as are the subdirectories *base*, *cups*, *motif*, and *sdl*. The subdirectories are independent ports. These four ports are often installed together, and as a whole, support OpenBSD's Linux emulation (documented in `compat_linux(8)`). All four ports call in the common instructions in *Makefile.inc*. (The ports tree doesn't include many of these, but don't be shocked when you find one.)

### Read-Only Ports Tree

The process of building a port creates an installable package and uses a whole bunch of temporary files, source files, and status files. By default, all of these files are placed inside the ports tree itself. While this works, I encourage you to treat */usr/ports* as a read-only OpenBSD directory tree, just like */usr/bin*, */usr/lib*, and so on. Doing so simplifies upgrading and identifying local changes, helps identify what you've built from ports, and saves space on the */usr* partition.

**NOTE** *Build files for ports can range from a few kilobytes to several gigabytes, so it's best to build ports on a large scratch partition. If you have unpartitioned disk space, create a partition just for building ports. Or use any partition with space, or even an NFS partition.*

Configure the ports collection by setting variables in */etc/mk.conf*. To use a read-only ports tree, set the variables in these directories:

**`WRKOBJDIR`** Directory where the software is extracted from source and compiled. These can be deleted and re-created as needed.

**`PACKAGE_REPOSITORY`** Directory where completed packages are stored. The ports collection builds packages, which you can then install.

**`PLIST_DB`** Directory where package packing lists are stored.

**`BULK_COOKIES_DIR`** Directory for storing status cookies during mass builds of packages.

**`UPDATE_COOKIES_DIR`** Directory for storing status cookies during mass updates of packages.

**`DISTDIR`** Directory where vendor source code is kept. Source code is usually retained for reuse.

If these directories are owned by your regular user account, you can do a large part of package building without being root.

On one particular test system, I have hundreds of gigabytes free in */home*, so I chose to put my package directories there. Here's my */etc/mk.conf*:

```
WRKOBJDIR=/home/ports/wrkobjdir
DISTDIR=/home/ports/distdir
PLIST_DB=/home/ports/plist
BULK_COOKIES_DIR=/home/ports/bulk_cookies
UPDATE_COOKIES_DIR=/home/ports/update_cookies
PACKAGE_REPOSITORY=/home/ports/pkgrepo
```

The ports system will build everything in */home/ports/wrkobjdir*. Original source code files go in */home/ports/distdir*. The ports system maintains various records in */home/ports/update_cookies* and */home/ports/bulk_cookies*. Completed packages go into */home/ports/pkgrepo*.

**NOTE** *If you have a dedicated port-building machine, consider per-release package repositories. For example, I might have three versions of OpenBSD running at any given time. The package-building machine always runs the latest release, but I don't want to throw away my old packages, so I use a package repository directory like* /home/ports/pkgrepo/5.4 *for packages built on a 5.4 system.*

## Finding Software

As with packages, the first problem with ports is finding software you want. (To randomly poke around the ports tree in a pretty interface, see the *http://www.openports.se* website.) OpenBSD has several ways to search the ports collection, including the ports index, keywords, and via SQL.

### The Ports Index

The file */usr/ports/INDEX* lists all software in the ports tree, sorted by category and then alphabetically. If you have a good idea what your port is called, you can search the file for your preferred software. The index describes each port in a single pipe-delimited line, much like this:

```
gcpio-2.11|archivers/gcpio||GNU copy-in/out (cpio)|archivers/gcpio/pkg/
DESCR|The OpenBSD ports mailing-list <ports@openbsd.org>|archivers|
STEM->=0.10.38:devel/gettext converters/libiconv|STEM->=0.10.38:devel/
gettext|STEM->=0.10.38:devel/gettext|any|y|y|y
```

While the ports tree itself finds this a convenient format, it's not particularly human-readable. To translate this to a human-friendly format, go into */usr/ports* and run **`make print-index`**. (This process goes on for tens of thousands of lines, so feed it to a pager.) Here's the same port in the human-readable format:

```
$ cd /usr/ports
$ make print-index | less
...
Port:   gcpio-2.11
Path:   archivers/gcpio
Info:   GNU copy-in/out (cpio)
Maint:  The OpenBSD ports mailing-list <ports@openbsd.org>
Index:  archivers
L-deps: STEM->=0.10.38:devel/gettext converters/libiconv
B-deps: STEM->=0.10.38:devel/gettext
R-deps: STEM->=0.10.38:devel/gettext
...
```

The `Port` statement gives the official name of the port and the version of the ported software. This software is called `gcpio`, and it's at version 2.11. The `Path` gives the ports tree category and directory where the port can be found—in this case, *archivers/gcpio*. The `Info` line gives a very brief description of the software. This is the GNU version of `cpio(1)`. The `Maint`, or maintainer, is the person or group responsible for maintaining this software in the ports tree. The OpenBSD ports team supports the `gcpio` port. The best-maintained ports usually have an individual as a maintainer, rather than the mailing list.

The final three entries describe other software required by this software. The `L-deps` line lists shared libraries, `B-deps` lists software needed to build this port, and `R-deps` lists the port's runtime dependencies.

What good does this do? Suppose you're still hung up on an Apache 2 web server. You can search *INDEX* for ports beginning with "apache."

```
$ grep -i ^apache INDEX
...
apache-httpd-2.2.20p1|www/apache-httpd||apache HTTP server|www/apache-httpd/
pkg/DESCR|The OpenBSD ports mailing-list <ports@openbsd.org>|www net|
apr-util-*-!ldap:devel/apr-util converters/libiconv devel/pcre|STEM->=1.21:
textproc/groff|converters/libiconv|any|y|y|y|y
```

The first three (omitted) entries are ports related to Apache, but they are not the web server software. The fourth line is our port.

Gathering this information from the index is rather limited, however. If you don't know the name of the software, or how OpenBSD packages the software, you can't easily find the port. In that case, try one of the other methods discussed next.

### Finding by Keyword

If you don't know a package's exact name, try the ports collection's search feature: `make search` and a key scans the index for a specific word. To search for Apache-related software, try this:

```
$ make search key=apache
```

On my system, this returns 62 results. You'll need to scroll through several pages of possibilities, but you'll find what you want.

You might need to try several possible keywords for a particular package, as some keywords have no hits and others generate too many.

### Finding via SQL

The `sqlports` package lets you build a database of the *INDEX* file, permitting you to search for ports based on highly arbitrary criteria via SQL. For example, say you want to know all ports that depend on `libiconv` and `expat`. In this case, `sqlports` is your friend. Install it from ports or packages, and it will automatically build a database in */usr/local/share/sqlports* from *INDEX*, and then use OpenBSD's `sqlite3` to query the database.

I won't teach SQL[4] here, but just as an example, here's how to search for ports whose name includes the string "apache" using `sqlports` (which can build much more complex queries than this one):

```
$ sqlite3 /usr/local/share/sqlports
sqlite> select fullpkgname from ports where fullpkgname like '%apache%';
apache-couchdb-1.0.1p2
apache-ant-1.8.2p3
apachetop-0.12.6
apache-httpd-2.2.22
modsecurity-apache-1.9.3p5
p5-Apache-ASP-2.61p0
p5-Apache-DB-0.14p3
...
```

The Apache `httpd` server is the fourth hit, but there are another dozen or so ports. Every name that begins with `p5-` is a Perl module.

## Building Ports

You've decided to ignore the OpenBSD team's recommendations to use packages, downloaded and extracted the ports tree, found software you need to install from ports, and designated an area for building ports. Now what?

The port directories don't contain actual source code. When you build a package from a port, the system does the following:

- Automatically downloads the appropriate source code from an approved Internet site
- Checks the downloaded code for integrity errors
- Extracts the code to the build area
- Patches the code
- Compiles the code
- Creates the package
- Installs the package (optional)

Additionally, if the port you're adding has unmet dependencies, the system also handles installing those dependencies.

To make all this happen, just go to the *port* directory and enter this command:

```
# make install
```

You should see the port build the software, create the package, and install the package on your system.

4. This example exhausts my understanding of SQL. As long as I maintain my database ignorance, people won't expect my help fixing their databases.

### What a Port Installation Does

It's time to dissect a port build and installation. Here's how to install `tcsh` from a port:

```
# cd /usr/ports/shells/tcsh
# make install
===>  Verifying specs: c termlib c termlib
===>  found c.65.0 termlib.12.1
===>  Checking files for tcsh-6.18.01
>> Fetch ftp://ftp.astron.com/pub/tcsh/tcsh-6.18.01.tar.gz
tcsh-6.18.01.tar.gz 100% |**************************************************
|   905 KB    00:00
>> (SHA256) tcsh-6.18.01.tar.gz: OK
```

The port first checks to see if the software's required libraries are in place. Building `tcsh` requires the `termlib` and `c` libraries. The port finds `termlib` but not a file containing the `tcsh` source code on the local system, so the port fetches the code. (When building a port, you should see the system downloading the appropriate source code.) The port then verifies the checksum of the downloaded code. If the port can't get all of the code, or the checksums don't match, the build process stops.

Once all necessary source code is downloaded and verified, the build continues with something like this:

```
...
===>  Extracting for tcsh-6.18.01
===>  Patching for tcsh-6.18.01
===>  Configuring for tcsh-6.18.01
Using /usr/ports/pobj/tcsh-6.18.01/config.site (generated)
configure: WARNING: unrecognized options: --disable-silent-rules
configure: loading site script /usr/ports/pobj/tcsh-6.18.01/config.site
checking for a BSD-compatible install... /usr/bin/install -c -o root -g bin
checking build system type... i386-unknown-openbsd5.2
checking host system type... i386-unknown-openbsd5.2
...
```

The port extracts the source code from the compressed file(s), applies any OpenBSD-specific patches, and starts the build process. (Many of you know that `configure` is not the same as building software, but not all software requires a `configure` step. The port knows what to do.)

The build process will go on for many lines. Building something like OpenOffice can take days and generate hundreds of thousands of lines of output.

**NOTE** *If you need to debug a port build failure, those messages that scroll off the top of your screen or terminal window contain all the clues you get. For that reason, I often build ports in a `script(1)` session. If you like the idea of keeping build messages around, see the `script` man page for details.*

Eventually, you should see a message that the build has finished and the port is installing the software.

```
...
===>  Faking installation for tcsh-6.18.01
install -c -s -o root -g bin -m 555 /home/ports/wrkobjdir/tcsh-6.18.01/tcsh-
6.18.01/tcsh /home/ports/wrkobjdir/tcsh-6.18.01/fake-i386/usr/local/bin/tcsh
install -c -o root -g bin -m 444 /home/ports/wrkobjdir/tcsh-6.18.01/tcsh-
6.18.01/tcsh.man /home/ports/wrkobjdir/tcsh-6.18.01/fake-i386/usr/local/man/
man1/tcsh.1
install -c -o root -g bin -m 444 /home/ports/wrkobjdir/tcsh-6.18.01/tcsh-
6.18.01/nls/C.cat /home/ports/wrkobjdir/tcsh-6.18.01/fake-i386/usr/local/
share/nls/C/tcsh.cat
...
```

The port installs the software in a temporary location in the port building directory, but that's not where we want the software installed! Remember that the ports system builds packages, and then installs from the package. This "fake" installation is for building the package.

```
...
===>  Building package for tcsh-6.18.01
Create /home/ports/pkgrepo/i386/all/tcsh-6.18.01.tgz
...
```

There's the package, retained in the package repository specified earlier. You might want to grab this file to install on your other machines, or perhaps even share the package repository via NFS.

Now, because we specified `make install` on the command line, the port installs the created package.

```
...
===>  Verifying specs: c termlib
===>  found c.65.0 termlib.12.1
===>  Installing tcsh-6.18.01 from /home/ports/pkgrepo/i386/all/
...
tcsh-6.18.01: ok
#
```

Installing the package requires making some of the same checks as building the package. Yes, the port could not have built the package without those libraries, but the ports system doesn't assume that the package was built on the local system.

### *Port Build Stages*

The package build process actually includes several stages, or smaller chunks of build procedure. Each stage performs all the stages before it. The final stage, `make install`, calls all of them, which provides several points where you can intervene in the port build process. If you want to make custom changes to a package, you can do it here.

Let's look at each of the stages called for every port build.

### The make fetch Stage

The `make fetch` stage gets the source code, or *distfiles*, for the port. First, it looks in any directories specified by the *mk.conf* variable `$DISTDIR`. If this variable isn't set, it looks in the directory specified by the shell environment variable `$DISTDIR`. If neither variable is set, it looks in */usr/ports/distfiles*. If `make fetch` finds the distribution files and thinks that they're the correct version, it hands control to the next requested stage, and the build continues.

If the source code is not on the local machine, `make fetch` tries to download it from an Internet site specified in the port's makefile as `MASTER_SITES`. (You can customize download locations, as discussed in "Customizing Ports" on page 246.)

You'll find the `make fetch` command very useful when there are certain times in your day when you can download more easily than other times. For example, I have a T1 to my house,[5] but my employer's office has roughly 66 times as much bandwidth as I have at home. I can run `make fetch` on my laptop while visiting my employer, go home, and build the port in peace. (And the boss thinks I come in because he buys lunch.)

### The make checksum Stage

The `make checksum` stage verifies that distfiles have not been corrupted, either by the download process or maliciously. OpenBSD includes several different checksums for each distfile, but only checks that the SHA-256 checksum matches the distfile. If the checksum matches, the build proceeds to the next stage. If the checksums do not match, the build immediately aborts. The build will not continue until you find a distfile that matches the checksum.

Not all software developers are conscientious about updating the names of their distfiles when they update their software. For these software packages, the *foo-1.0.tgz* file the port developer downloaded in the morning might differ from the *foo-1.0.tgz* file you download later that same day. Perhaps the original software author thought that no one would notice, but the OpenBSD folks would, if only via the logic built into the ports tools. After all, the ports system can't tell the difference between a source file quietly modified by the software author and a source file quietly modified by an intruder. If you get a distfile that doesn't match the recorded checksum, try to fetch a matching file by setting the `REFETCH` variable to `true`.

```
# make checksum REFETCH=true
```

Now `make` will walk through all the distfile sources listed in the port, downloading them successively in an effort to find a distfile that matches that used by the port developer.

If you are absolutely certain that the file you downloaded is the correct, untampered-with one, but it still doesn't pass `make checksum`, you're wrong. If you know that you're wrong, but you really do want to install compromised

5. Don't laugh. It's paid for.

or damaged software, set the environment variable `NO_CHECKSUM=yes` to skip the `make checksum` stage.

**WARNING** *Skipping the `make checksum` stage might be valid for debugging, but it certainly isn't the way to create a stable, useful, or secure package. You also might invalidate the rest of the port. Perhaps the OpenBSD patches will no longer apply cleanly, the software just won't run, or you could even be installing a backdoor, inviting scumbags to stash problematic content on your machine. You are utterly on your own if you insist on ignoring a checksum mismatch.*

### The make prepare Stage

At this point, the ports system gets into recursion. At `make prepare`, the port checks for any software needed to build or run the software you're trying to build. If the port lists any of these dependencies, it checks to see if they are installed. If the dependencies are not installed, this stage kicks off `make install` for those required ports. Once all of the required dependencies are installed, this stage ends.

### The make extract Stage

The ports system must extract the source code from the distfile before building the software. Source code is extracted into the directory defined by `$WRKOBJDIR`, or in a directory under */usr/ports/pobj/* named after the port. By default, my `tcsh` port would extract under */usr/ports/pobj/tcsh*, but because I defined a separate location for building software, it's built under */home/ports/wrkobjdir/tcsh*.

### The make patch Stage

Any patches included in the port's patches directory are applied in the `make patch` stage. If the patches all apply correctly, this stage ends. If the patches do not apply correctly, the port fails.

To apply your own patches to the port, or to review the code before compiling it, run `make patch` first. Your patches might conflict with the port patches if you apply them first, cause compilation failures, or bring up any number of other problems. By running `make patch` first, you get to see the code as OpenBSD can compile it. Anything you break after that is definitely your fault.

### The make configure Stage

Many software packages use a `configure` script to prepare themselves for compilation on a specific platform. The `make configure` command runs that script. If you want to edit the `configure` script, do so before running this stage! If there is no `configure` script, the port silently skips this stage.

#### The make build Stage

The `make build` stage compiles the fetched, extracted, patched, and configured software. If you type `make` in a port directory, the port calls `make build`. This stage doesn't assemble a package; it just performs the compilation and creates the actual program binaries in the port's work directory.

#### The make fake Stage

The `make fake` stage installs the software in a subdirectory, laid out exactly as it would be under the *root* directory. This fake root directory is in the work directory, named *fake-* with the architecture appended, such as *fake-amd64*. Everything that will be in the package is installed under this directory, with the same ownership and permissions that it will include in the package.

#### The make package Stage

The `make package` stage bundles up the port's fake installation directory, adds in packaging and installation instructions, and ties it all up in a package exactly like those available on the FTP site. The package will be stored under the *PKGREPO* directory you defined earlier (or in */usr/ports/packages* if you didn't define one), in a subdirectory organized by architecture, and in further subdirectories organized by available distribution locations.

`make package` means that you can build this port on one machine without installing it. You must install the build dependencies to build the port, however.

#### The make install Stage

The `make install` stage runs `pkg_add(1)` to install the package you compiled.

#### The make clean Stage

Some packages require a lot of disk space. The `make clean` stage removes all of the build files except the distfile and the completed package.

## Customizing Ports

OpenBSD includes a variety of hooks to let you easily customize how you get and build ports. If possible, you should use the OpenBSD-provided infrastructure, but there may be cases where that's not possible. Here, we'll look at some of the more commonly used customization settings.

### *Local Distfile Mirrors*

While ports provide several places to get source code, you might want to override those sites. Perhaps you share a network with a major mirror site, or you don't have unfettered Internet access. OpenBSD lets you set your own preferred mirror sites.

### Preferred Collection Mirrors

Many software sources can be grouped into *collections*, which tend to be mirrored together. An example is the official GNU software collection. A GNU mirror site probably has everything in the official GNU collection. The Gnu C Compiler Project has its own set of software and mirrors. There are older software collections, such as SunSITE, and newer ones, such as SourceForge.

Each collection is available from a list of mirror sites. OpenBSD maintains lists of these mirror sites in */usr/ports/infrastructure/templates/network.conf.template*. Never edit this file; it's a core ports file, and upgrading changes it.

For example, here's a list of mirrors for a smaller project, BerliOS:

```
...
MASTER_SITE_BERLIOS+=   \
        http://download.berlios.de/ \
        http://download2.berlios.de/ \
        http://spacehopper.org/mirrors/berlios/
...
```

Several ports want to fetch BerliOS-related software from the main BerliOS download site. The OpenBSD port developers have identified three desirable mirrors, as listed in the variable `MASTER_SITE_BERLIOS`.

But suppose you have a BerliOS mirror much closer to you. Perhaps it's not an official mirror, or you've managed to finagle access to a nonpublic mirror. It's closer, it's faster, and you would prefer to use it. OpenBSD looks at */usr/ports/infrastructure/db/network.conf* before the default mirror list. You could copy the default mirror list to this file and edit it, but then you would need to manually synchronize changes during upgrades. That's work, and therefore morally questionable. Instead, add entries only in *network.conf*, and include the default *network.conf.template*.

Suppose you have a private BerliOS mirror at *http://www.blackhelicopters.org/berlios/*. You would create a *network.conf* file like this:

```
MASTER_SITE_BERLIOS+=   \
        http://www.blackhelicopters.org/berlios/

.include "../templates/network.conf.template"
```

The `+=` used in both *network.conf* and *network.conf.template* means "Add this value to variable such-and-such." More desirable mirrors appear first in the list. This *network.conf* entry adds the private mirror to the variable `MASTER_SITE_BERLIOS`, and then calls in *network.conf.default*, which appends all of the other mirrors. The end result is that the BerliOS mirror list will contain four mirrors: your preferred mirror first and the default OpenBSD-approved mirrors later. If a file does not exist on a mirror, the port will try the other mirrors in order.

I used BerliOS as an example because it has a small mirror list, but the same applies to any other software collection that OpenBSD recognizes. Other collections available at this time are shown in Table 13-1.

**Table 13-1:** Some Software Collections

| Collection | Description |
|---|---|
| MASTER_SITE_GNU | Software from the GNU project |
| MASTER_SITE_GCC | Software from the GCC project |
| MASTER_SITE_XCONTRIB | Contributions to the X Window System |
| MASTER_SITE_R5CONTRIB | Older X Window System contributions |
| MASTER_SITE_SUNSITE | A collection of Sun software |
| MASTER_SITE_SOURCEFORGE | Software hosted by SourceForge |
| MASTER_SITE_SOURCEFORGE_JP | Japanese SourceForge mirrors |
| MASTER_SITE_GNOME | Software from the Gnome project |
| MASTER_SITE_PERL_CPAN | The biggest Perl module collection |
| MASTER_SITE_TEX_CTAN | Software for TeX typesetting |
| MASTER_SITE_KDE | Software related to KDE |
| MASTER_SITE_SAVANNAH | Software development hosted by the FSF |
| MASTER_SITE_AFTERSTEP | Software related to the AfterStep window manager |
| MASTER_SITE_WINDOWMAKER | Software related to the Window Maker window manager |
| MASTER_SITE_FREEBSD_LOCAL | Software distributed by the FreeBSD Project, but not included in FreeBSD |
| MASTER_SITE_PACKETSTORM | Security software part of the Packet Storm collection |
| MASTER_SITE_APACHE | Apache Foundation software |
| MASTER_SITE_BERLIOS | Parts of the BerliOS Linux project |
| MASTER_SITE_MYSQL | Software from the MySQL project (Oracle) |
| MASTER_SITE_PYPI | Python software |
| MASTER_SITE_RUBYGEMS | Modules for Ruby |
| MASTER_SITE_NPM | JavaScript packages |
| MASTER_SITE_ISC | Software from the Internet Software Consortium |

If you have a Debian mirror in your university datacenter, list it in *network.conf*. If it appears a second time, later in the list, because it's listed in *network.conf.template*, so what? Either the distfile is there, in which case you save time and bandwidth, or the *distfile* isn't there, in which case you waste 50 milliseconds checking the local mirror a second time.

### Fallback Mirrors

OpenBSD supports two fallback mirrors. If all other distfile sources fail, you can check either the OpenBSD or FreeBSD mirrors for the file. Both OpenBSD and FreeBSD tend to mirror distfiles for active ports. This isn't

preferred, because if everyone did this, it would use bandwidth that the projects need for distributing their own software. But if you're desperate, set MASTER_SITE_OPENBSD and/or MASTER_SITE_FREEBSD to YES in *network.conf*.

#### Primary Mirror

You can have the ports system check a particular site first for all distfiles, regardless of the download site listed in the port. Perhaps you have a local mirror where you've stuck a whole bunch of distfiles, or you automatically load distfiles from your ports-building machines to a central location. Define this site with the variable MASTER_SITE_OVERRIDE in *network.conf*.

```
MASTER_SITE_OVERRIDE=ftp://ftp.mycompany.com/distfiles
```

**NOTE** *I've built local distfile mirrors many times, usually when starting a new job. I manage to update the mirror for about six months before some other task supersedes it and the mirror becomes obsolete, so I don't generally recommend this practice. But if maintaining a local distfile mirror reduces your workload instead of increasing it, enjoy.*

### Flavors

Some ports can create multiple but slightly different packages through *flavors*. The Apache 2.2 web server I keep dragging out as an example can be built with or without LDAP support, as can programs with optional X support. Shells can be built in dynamic or static versions. OpenBSD's official packages are built with the most common choices, but these alternatives are reasonable and occasionally necessary.

To identify the flavors that a port supports, go to the port directory and run **make show=FLAVORS**. Here's how to check the flavors of the popular text editor Vim:

```
# cd /usr/ports/editors/vim
# make show=FLAVORS
huge gtk2 athena motif no_x11 perl python ruby
```

You can guess what some of these eight flavors do, but how can you learn about the others? You can check the package's description file for brief descriptions of each flavor. Here are the descriptions for the Vim flavors, from *editors/vim/pkg/DESCR-main*:

```
...
Flavors:
        gtk2       - build using the Gtk+2 toolkit (default);
        motif      - build using the Motif toolkit;         athena     - build
using the Athena toolkit;
...
```

Motif? I remember Motif. And now I'm going to try really hard to forget it again. But if you want Motif support in your Vim version, go for it.

To fall back to my ongoing example, here are the flavors for Apache 2:

```
# cd /usr/ports/www/apache-httpd
# make show=FLAVORS
ldap
```

I use LDAP to attach websites to my central authentication system. If I can get LDAP authentication on my web server, I want it.

### Building a Flavored Port

Define any desired flavors with the `$FLAVOR` environment variable, but not in your *.profile* or *.cshrc* file, as a port will not build if you request an unrecognized flavor. Define it when you build the port. For example, while still in the *apache-httpd* directory, I run this command:

```
# env FLAVOR="ldap" make package
===>  Checking files for apache-httpd-2.2.20p1-ldap
>> Fetch http://www.reverse.net/pub/apache/httpd/httpd-2.2.20.tar.gz
...
===> apache-httpd-2.2.20p1-ldap depends on: openldap-client-* - not found
===>  Verifying install for openldap-client-* in databases/openldap
...
```

By your defining the flavor on the command line, the port knows to check for the OpenLDAP client needed to build Apache. When the build finishes, you should get a package file with the flavor appended—in this case, *apache-httpd-2.2.20p1-ldap.tgz*.

### Flavors and Dependencies

When you build a *flavored port*, the flavor does not propagate to dependencies. You need to check the flavored port's dependencies to see if they need flavoring as well. For example, my flavored Apache package calls in the OpenLDAP client, which has no flavors, but OpenLDAP calls in `cyrus-SASL`, and if I check that port, I see this:

```
# cd /usr/ports/security/cyrus-sasl2
# make show=FLAVORS
db4 ldap mysql pgsql sqlite3
```

Cyrus SASL comes in LDAP flavor, but defining that I want Apache built in LDAP flavor doesn't mean that `cyrus-SASL` will also be built with LDAP support. If I need LDAP support in this dependency, I must build it separately. I don't need it for my environment, so I won't bother, but check for potential issues like these when building your packages.

If you decide to rebuild a dependent port with a flavor, be sure to rebuild all the ports that depend on that port afterward. Be sure that your packages have correct dependencies using the targets `print-build-depends` and `print-run-depends`. Here, I see which ports I'll need to build for my flavored Apache 2:

```
# env FLAVOR="ldap" make print-build-depends
This port requires package(s) "metaauto-1.0 gperf-3.0.4 libiconv-1.14
gettext-0.18.1p1 gmake-3.82p1 groff-1.21p8 pcre-8.30 help2man-1.29p0
autoconf-2.65 autoconf-2.68 cyrus-sasl-2.1.25p3 icu4c-4.8.1.1p0 db-4.6.21v0
openldap-client-2.4.31 apr-1.4.6 apr-util-1.4.1-ldap" to build.
```

I can check the flavors of each of these ports.

#### Building Multiple Flavors

You can build multiple flavors of one port on the same system. Each package filename includes the flavor, so you can have packages for both the Motif and GTK2 versions of Vim. Carefully inspect the dependencies to verify that each is built with the correct flavoring. For packages with flavored dependencies, I recommend removing every flavored dependency and rebuilding them all again, so that everything gets the correct flavor.

#### Uninstalling and Reinstalling Flavored Ports

Flavoring a package changes its name. I can't run `pkg_delete apache-httpd` because it's not installed. Query the system for the packages you've manually installed, and you'll see this:

```
# pkg_info -m
apache-httpd-2.2.20p1-ldap apache HTTP server
...
```

When working with this package, you must specify the flavor.

```
# pkg_delete apache-httpd-2.2.20p1-ldap
apache-httpd-2.2.20p1-ldap: ok
...
```

Similarly, to reinstall a flavored package, specify the flavored package file.

## Subpackages

Some ports contain multiple wildly different packages. This isn't like adding LDAP support to Apache or Motif support to Vim—those are changes to the existing package, not wildly different. Some ports create two completely different packages, such as a database client and the associated

database server. I've drawn in OpenLDAP through this chapter's examples, and both the OpenLDAP server and client come from the same port: *databases/openldap*. Other applications might have plug-ins for accessing several different database engines. These are called *subpackages* or *multipackages*.

Unlike flavors, OpenBSD provides all subpackages of a port. You can install both the server and client versions of OpenLDAP from official packages. When the port is built, all the subpackages are built. The package is split into subpackages at the package-bundling stage.

To see all the subpackages supported by a port, run the following command:

```
# cd /usr/ports/databases/openldap
# make show=MULTI_PACKAGES
-main -server
```

This port has two subpackages: `openldap-main` and `openldap-server`.

How can you learn what each subpackage includes? As with flavors, you can check its description file, which is *pkg/DESCR*. OpenLDAP includes *pkg/DESCR-server* and *pkg/DESCR-main*. Reading these shows that the `main` package is the client, as you would expect.

If you run `make install` in the port directory, you get the main version of the port—in this case, the OpenLDAP client. OpenLDAP clients outnumber the servers, so that's also what you would expect. To build a different subpackage, set `SUBPACKAGE` in the environment on the command line, as you did for flavors.

```
# env SUBPACKAGE="-server" make package
```

This builds the `-server` version. Be sure to include the leading dash, as specifying a nonexistent subpackage makes the build fail.

## Packages and rc.d Scripts

Chapter 5 covered how to have OpenBSD start packaged software, but let's review it quickly. When you install a package that can be started at boot time, the package also installs a startup script in */etc/rc.d*. If I install the OpenLDAP server, the package installation will report:

```
...
The following new rcscripts were installed: /etc/rc.d/slapd
```

To start the `slapd(8)` OpenLDAP server at boot, add the script name to the `pkg_scripts` variable in */etc/rc.conf.local*.

```
pkg_scripts="slapd"
```

OpenBSD runs these scripts in order at boot, and in reverse order at shutdown.

To change a package's command-line arguments from the default, add a *command*_flags variable to */etc/rc.conf.local*. Do not edit the startup script.

```
slapd_flags="-u _openldap -6 -l local0"
```

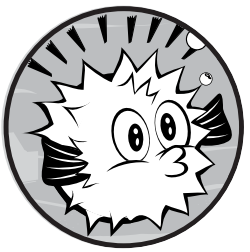
You can now manage your add-on software in any way you need.

Now let's move on to configuring OpenBSD's integrated software, through the files in */etc*.

# 14

# EVERYTHING /ETC

*You are in a maze*
*of twisty little configs;*
*no two are alike.*



When I get saddled with an unfamiliar server, the first thing I do is look for the previous sysadmin's documentation. When I discover there isn't any, I study the */etc* directory because it contains the basic configuration for a Unix-like system. The fastest way to go from a junior sysadmin to a mid-grade one is to read */etc* and the associated man pages—all of the documentation. Yes, that's a lot of reading.

Once you understand */etc*, you understand how the system hangs together. You must learn all this anyhow, but you might as well take the easier route and learn it up front rather than in an unscheduled series of desperate troubleshooting sessions. (I've already discussed many */etc* files in earlier chapters where relevant, such as */etc/fstab* in Chapter 8 and */etc/services* in Chapter 11.)

Some files that you'll find in */etc* are of only historical interest or are gradually dying out. I'll discuss briefly what they do, but I won't spend much time on obsolete files. I also won't spend much time on files useful only in

edge cases (where they relate to software that's not used too often or only in very peculiar circumstances). On the other hand, I will dive deeply into important */etc* files that haven't already found a place elsewhere in this book.

## /etc Across Unix Variants

Different Unix-like systems use different */etc* files. In many commercial variants, these files are simply renamed or restructured files from primordial BSD.

For example, the first time I had to manage an IBM AIX system, I needed to know which disks should be mounted where, but there was no */etc/fstab*. A little searching led me to */etc/filesystems*, which was IBM's */etc/fstab*. Apparently, the IBM folks felt that a file named for "filesystem table" was confusing, so they gave it a different name. Knowing that this information existed somewhere in */etc*, and knowing which files had an unrelated purpose, greatly shortened my search.

Changes to */etc* can dramatically alter how your system performs. While manually recovering a scrambled filesystem can push an adequate sysadmin toward becoming a pretty good one, it's one of the least pleasant ways to get there.

## The /etc Files

Now we will take a look at each of the */etc* files, going in alphabetical order. We'll start with */etc/adduser.conf* and end with */etc/ypldap.conf*.

### /etc/adduser.conf

The */etc/adduser.conf* file contains the persistent configuration for `adduser(8)`, which Chapter 6 covers in detail. To change `adduser`'s settings, edit this file. This file is self-documenting, and if you've read Chapter 6, you shouldn't have any trouble with it.

### /etc/amd

The automounter daemon automatically loads NFS filesystems upon request. If you're interested in this function, read the `amd(8)` man page.

The automounter daemon isn't as useful as you might think. As the documentation says, "A weird imagination is most useful to gain full advantage of all the features."

### /etc/authpf

The */etc/authpf* directory contains the authenticating packet filter configuration. If you're interested in having user authentication for firewall access, I recommend *The Book of PF, 2nd Edition*, by Peter Hansteen (No Starch Press, 2010).

### /etc/bgpd.conf

OpenBSD includes a BGP daemon, `bgpd(8)`. Most sysadmins will never go near BGP, but if you need it, see the `bgpd.conf(5)` man page.

### /etc/boot.conf

The */etc/boot.conf* file controls the system's booting process, as discussed in Chapter 5.

### /etc/changelist

*/etc/changelist* is a text file that contains the list of files to be checked by the daily security check script, */etc/security*. We cover these tasks in detail in Chapter 15.

### /etc/chio.conf

The `chio(1)` medium changer lets you manage jukebox-style media arrays, such as CD and tape changers. If you have a tape backup unit that can swap between multiple tapes all on its own, `chio` is your friend. Configure `chio` in */etc/chio.conf*. Most OpenBSD users don't have media changers, but if you're interested, see the man page for `chio(1)`.

### /etc/csh.*

The */etc/csh.** files contain system-wide defaults for `csh(1)` and `tcsh(1)`. When a user logs in with either of these shells, the shell executes any commands listed in */etc/csh.login*. Similarly, when the user logs out, the shell executes any commands in */etc/csh.logout*. Put general shell configuration in */etc/csh .cshrc*.

### /etc/daily and /etc/daily.local

The */etc/daily.local* script is run every day to maintain the system. See Chapter 15 for details.

### /etc/dhclient.conf

You can configure OpenBSD's DHCP client by using `dhclient(8)`, as discussed in Chapter 12.

### /etc/dhcpd.conf

OpenBSD includes a secure DHCP server. It started life as an Internet Systems Consortium (ISC) DHCP server, but has been repeatedly rewritten and simplified by the OpenBSD team. See Chapter 16 for details.

### /etc/disklabels/

The */etc/disklabels/* directory traditionally contains backup copies of disklabels, as discussed in Chapter 8. Very few system administrators actually

use it, because very few system administrators know it's there. OpenBSD copies the disklabels for all system disks as part of the daily backup of critical files (see Chapter 15).

### /etc/disktab

A couple of decades ago, hard drives were expensive and precious devices that came in only a few varieties. While modern disks can tell the computer about their geometry, older disks need manual configuration, as do older removable media such as 1.44MB floppy disks and Zip disks. If you want to access one of these ancient disks, you'll need the information in */etc/disktab*. (But if you need to use one of these old disks, you're almost certainly solving the wrong problem.)

### /etc/dumpdates

The */etc/dumpdates* file records the dates of the last successful `dump(8)` backup. The `dump` tool backs up a filesystem, rather than just the files on a filesystem, as `tar(1)` does. A dump includes file flags and other special characteristics of the filesystem.

### /etc/dvmrpd.conf

OpenBSD implements the Distance Vector Multicast Routing Protocol (DVMRP) with `dvmrpd(8)`, configured in *dvmrpd.conf*. This is another edge case where OpenBSD performs well, but is of interest only to a few users. If you're interested in DVMRP, see the `dvmrpd(8)` man pages.

### /etc/exports

NFS servers list the filesystems they export, and who may access them, in */etc/exports*. See Chapter 9 for information about using NFS as both a client and a server.

### /etc/fbtab

OpenBSD can change the ownership of system files and devices based on how a user has logged in. When a user logs in via the text console, `login(1)` changes the ownership of the console, as well as the keyboard and the mouse, to that user. This way, users can then configure the keyboard or mouse to suit their preferences. A user who logs in via an X session needs similar changes.

You could use */etc/fbtab* to change permissions on other devices or files for other special needs, but this is really tricky to get right, and usually means you're making something much more complicated than it needs to be. If you're considering this approach, rethink your problem.

### /etc/firmware

Some hardware needs software to run. In years past, this software would have been loaded onto programmable read-only memory (PROM) chips

on the device itself. Network cards often had boot PROMs that let them get configuration information from the network. PROMs are not expensive these days, but making millions of anything adds up quickly. Hardware vendors now often ask the operating system to load this software, called *firmware*, onto the hardware for them.

Firmware is usually a closed-source binary object, or *blob*. While the OpenBSD team members would never accept loading a blob into the kernel, they're willing to hand a file to a piece of hardware. It doesn't matter if the hardware gets the blob from the operating system or from a PROM chip attached to the hardware—it's still software that runs only on the device, not in the operating system.

For user convenience, OpenBSD distributes firmware that it's legally permitted to offer. If OpenBSD cannot distribute firmware on the installation media, the `fw_update` script uses the package system to fetch it over the Internet. Wherever the firmware comes from, it's stored in */etc/firmware*.

By default, `fw_update` runs at first boot after an OpenBSD install or upgrade, but you can run it any time you want (it's stored in */usr/sbin*).

### /etc/fonts/

The */etc/fonts/* directory contains the Xenocara X11 fonts. We'll discuss Xenocara and X11 in Chapter 17.

### /etc/fstab

The filesystem table lists all filesystems that the system knows about, whether they're automatically mounted at boot or kept in reserve. See Chapter 8 for details.

### /etc/ftpchroot

Users listed in */etc/ftpchroot* are automatically `chroot`ed into their home directory when they log in via FTP. See `ftpd(8)` for full details.

Try to avoid FTP, as it transmits usernames and passwords in cleartext. Use `scp(1)` or `sftp(1)` instead.

### /etc/ftpusers

The */etc/ftpusers* file does exactly the opposite of what the filename implies, but it has been this way for decades, so don't worry about it.

Any user listed in */etc/ftpusers* cannot log in via FTP. See `ftpd(8)` for details, but again, use `scp(1)` or `sftp(1)` instead—especially for administrative tasks!

### /etc/gettytab

The */etc/gettytab* file contains the configuration information for login terminals. Unix-like systems have been traditionally accessed by anything and everything, from innumerable slightly different serial consoles to Secure Shell (SSH) sessions over the network. If you ever need to use a nonstandard terminal type, explore */etc/gettytab*.

There's no reason to get rid of this file. After all, someone out there probably still uses a plugboard 1200-baud terminal. But there's no longer any reason to modify it either. In any case, the man page is worth reading, especially if you read it to the end.

### /etc/group

The */etc/group* file controls to which groups each user account belongs. User groups are covered in Chapters 6 and 7.

### /etc/hostapd.conf

OpenBSD can act as a wireless access point. The host access point daemon (`hostapd(8)`) lets OpenBSD perform some complicated access point tasks that are useful in larger environments. OpenBSD's wireless services are interesting if you use wireless; read `hostapd(8)` and `ifconfig(8)` for full details.

### /etc/hostname.*

The */etc/hostname.** files configure network interfaces, as discussed briefly in Chapter 4 and at length in Chapter 12.

### /etc/hosts

The */etc/hosts* file contains a hand-maintained map of IP addresses and hostnames. See Chapter 12 for details.

### /etc/hosts.equiv

The */etc/hosts.equiv* file is used by the various r-tools, such as `rcp(1)`, `rlogin(1)`, and `rsh(1)`. These tools, and the underlying protocols, are relics of an earlier age, when security on the Internet was not so great a concern. OpenBSD no longer includes an `rlogin(1)` client. The r-tools are largely replaced by SSH. Today, you should not use the r-protocols under any sensible circumstances.

The */etc/hosts.equiv* file should not contain any uncommented entries, unless you specifically put them there. This is the only system file I can reasonably say every sysadmin should verify is empty and marked immutable (see Chapter 10).

What did I mean by "sensible circumstances" and using the r-protocols? A few years ago, I worked on a network with ancient but mission-critical VMS servers manageable only by r-protocols, but those were not reasonable circumstances. If you find yourself similarly trapped, check out `hosts.equiv(5)`, `rshd(8)`, and `rsh(1)`. And do something about your circumstances.

### /etc/hosts.lpd

You can configure an OpenBSD system to accept print requests from other machines and feed them to a locally attached printer. This was vital when

printers were big, expensive beasts, but it's less important today. This file lists the hostnames or IP addresses of systems that may use the local system's line printer daemon, `lpd(8)`.

If you're really interested in having your OpenBSD system print, check out `lpd(8)` and */etc/printcap*.

### /etc/hotplug/

OpenBSD can automatically take action when a device is plugged into the system through `hotplugd(8)`. For example, if you attach your digital camera to a USB port, `hotplugd` can run a script that will attach the device node to a directory and make it readable by your user account.

`hotplugd` runs the script */etc/hotplug/attach* when a device is attached, and */etc/hotplug/detach* when a device is removed. These scripts must be carefully written to match the devices being attached and detached. For details on how this works, see `hotplugd(8)`.

### /etc/ifstated.conf

The interface state daemon `ifstated(8)` monitors network conditions and takes action when specified events occur. For example, you can configure `ifstated` to watch for another server to go down, and when that server fails, start up the local web server. For more information about using `ifstated`, see Hansteen's *The Book of PF*.

### /etc/iked/, /etc/iked.conf, /etc/ipsec.conf, and /etc/isakmpd

The */etc/iked/*, */etc/iked.conf*, */etc/ipsec.conf*, and */etc/isakmpd* files manage OpenBSD's implementation of the IPsec standard for VPNs. OpenBSD has a very robust IPsec implementation, and it is actually used for testing by various interoperability groups.

You can fill entire books with the acronyms used for VPN technologies, let alone instructions for actually configuring them. See the man pages for details.

### /etc/inetd.conf

The Internet small service listener `inetd(8)` attaches to multiple network ports for programs that don't need to run constantly. When a request on one of those ports comes in, `inetd` activates the correct program to handle the request. Chapter 16 discusses `inetd(8)` in more detail.

### /etc/kbdtype

The */etc/kbdtype* file contains a single line with your preferred terminal keyboard mapping. Test your keyboard mapping with `kdb(1)`, and then put that keyboard mapping in */etc/kbdtype*.

### /etc/kerberosV/

The */etc/kerberosV/* directory contains configuration for the Kerberos centralized authentication system. I recommend some kind of centralized logon for every network. Configuring Kerberos properly is a large subject. If you're interested, peruse `kerberos(1)`.

### /etc/ksh.kshrc

*/etc/ksh.kshrc* is the global configuration file for the public domain Korn shell included with OpenBSD. Users must include this file in their personal *.kshrc* for settings here to take effect. See the `ksh(1)` man page for details.

### /etc/ldap/ and /etc/ldapd.conf

OpenBSD includes a Lightweight Directory Access Protocol (LDAP) daemon. LDAP is commonly used for centralized authentication, address books, and other database operations that are read more than they write. As of this writing, the features of `ldapd(8)` are not complete, but it's good enough to provide a central authentication point.

### /etc/localtime

The */etc/localtime* file is a symlink to the actual time zone file. To change the time zone, change the symlink. Chapter 4 covers time zones.

### /etc/locate.rc

The */etc/locate.rc* file controls creation of the `locate(1)` database. OpenBSD updates the locate database every week, as discussed in Chapter 15.

### /etc/login.conf

With */etc/login.conf*, you can control user account login behavior, as discussed in Chapter 6.

### /etc/lynx.cfg

OpenBSD includes the `lynx(1)` text-mode web browser. Lynx is endlessly configurable, and settings in */etc/lynx.cfg* affect all Lynx users on the system. You can save yourself a lot of trouble by configuring your proxy server settings here.

### /etc/magic

Many files include a "magic number" and other characteristics specific to their type. `file(1)` uses these magic numbers to identify the file type, with */etc/magic* as an index of magic numbers. Do not manually edit */etc/magic*, as it's automatically generated by compiling `file(1)`.

## /etc/mail/

The */etc/mail/* directory contains the configuration files for OpenBSD's email software. OpenBSD includes two email packages: the old workhorse Sendmail and the OpenBSD-created `smptd(8)`. `smptd` isn't *quite* ready for production use, but it might be by the time this book hits the shelves.

This directory also contains */etc/mail/aliases*, a list of mail redirections. Be sure you set the email alias for your root account to somewhere you'll actually read your email, as discussed in Chapter 4.

## /etc/mail.rc

The */etc/mail.rc* file has nothing to do with sending or receiving email as a mail server. It's the global configuration file for the `mail(1)` email client. While more advanced email clients have almost completely superseded `mail`, it's worth exploring because almost any Unix-like system will have it installed.

## /etc/mailer.conf

Traditionally, the only mail server program available for any Unix-like operating system was Sendmail. As such, a huge amount of add-on software expects to find */usr/sbin/sendmail* and expects it to behave in a certain manner. It doesn't matter that, by modern standards, Sendmail and the whole Simple Mail Transfer Protocol (SMTP) are baroque and bizarre; software expects to find it.

Worse, `sendmail(8)` behaved differently depending on what name it was called with. Programs such as `send-mail`, `mailq`, and `newaliases` are all Sendmail wearing different hats. If you call the Sendmail program by running the `mailq` command, it runs differently than if you call it by running the `newaliases` command. They all point to the same binary on disk, however. Third-party software expects to find all these names as well, and that these commands behave as required.

Sendmail is such a standard that writers of newer mail server programs are forced to call them `sendmail` and to have them behave exactly as Sendmail does, just to maintain compatibility with this vast installed base. This makes using alternate mailers confusing. Also, OpenBSD includes Sendmail as part of the base system. You can't just remove Sendmail and go on. Upgrades reinstall brand-name Sendmail.

OpenBSD does an end run around all this confusion by eliminating */usr/sbin/sendmail* as an actual mail program. Instead, the `sendmail` program is just a wrapper that calls the real mail-handling software. The entries in */etc/mailer.conf* are just a list of classic Sendmail program names, along with the path to the actual program to be run. The mail-handling program `sendmail` is actually installed as */usr/libexec/sendmail/sendmail*, for example.

To run an alternate mail server, give */etc/mailer.conf* the expected command name and the full path to all of the appropriate programs. This happens automatically when you install a new mail transfer agent from a package.

## /etc/man.conf

The *etc/man.conf* file tells `man(1)` how to find and present man pages. If you install software in nonstandard locations, add the information on the software's man pages to *man.conf* so that you can call up those man pages transparently. This file has several types of entries, each of which is set off by keywords or section names.

Why would you do this? If you must install software from a source other than ports or packages, you could place it in a directory tree outside those managed by OpenBSD to reduce confusion when upgrading or adding software.

For example, I occasionally install Wireshark on an OpenBSD desktop. The OpenBSD team decided to remove OpenBSD's Wireshark package because it has such a shaky security history. If I installed Wireshark as */usr/local/bin*, it would be mingled with my packaged software. If I install Wireshark as */usr/local/wireshark/bin*, however, it's clearly distinct from packaged software. I can't access the man pages, however, as `man(1)` doesn't know about */usr/local/wireshark/man*.[1] Let's walk through how we would add man page access for Wireshark.

### Adding to the Search Index

The `_whatdb` keyword gives the full path to a `whatis(1)` database, used by `apropos(1)` and `whatis(1)`, allowing you to easily search and cross-index man pages. The file *man.conf* has entries for databases in */usr/local/man*, */usr/share/man*, and */usr/X11R6/man*. Here's how to add an entry for */usr/local/wireshark/man*:

```
_whatdb /usr/local/wireshark/man/whatis.db
```

Now we create a new database with `makewhatis(8)`. This job runs automatically when you install software and during weekly maintenance.

### Adding to Man Page Directories

Man pages are scattered in directories all over the system. The `_default` keyword tells `man(1)` which directories to search automatically. Use only one `_default` keyword, but list multiple directories if needed, and group directories using brackets.

Here's the standard directory list:

```
_default /usr/{share, X11R6,local,ports/infrastructure}/man/
```

This is a pretty massive group of directories, and the brackets combine multiple directories associatively. For example, this entry means that we

1. If Wireshark has a shaky security history, why would I install it? Because, sadly, it's still the easiest way to debug really complicated network problems, especially when you're working with an unfamiliar protocol.

check */usr/share/man/*, */usr/X11R6/man/*, */usr/local/man/*, and */usr/local/ports/infrastructure/man/*. (The entries end with a slash, which means that the final directories contain subdirectories.)

To add */usr/local/wireshark/man/* to the default locations, add `local/wireshark` into the associative array, like this:

```
_default /usr/{share, X11R6,local,ports/infrastructure,local/wireshark}/man/
```

The `_subdir` keyword lists subdirectories to be searched beneath the main directories, in order, with the first match returned first.

```
_subdir  man1 man8 man6 man2 man3 man5 man7 man4 man9 man3p man3f mann
```

You can use `_subdir` to change the order in which man pages are returned. For example, if your job is programming Perl on OpenBSD, you might want to see the Perl man pages by default. In that case, you could move the *man3p* subdirectory to the front of the list.

#### Displaying Man Pages

Software vendors distribute their manuals in the format they think best. As a sysadmin, this means you might as well get manuals in random formats, because each format needs a different command to display it. Fortunately, each format has a different filename suffix, which tells `man(1)` how to display the file. The `_build` keyword defines a filename suffix and the command used to display the file. (It's very unlikely that you'll have a man page that requires a new `_build` statement.)

#### Defining Man Sections

The final *man.conf* function is dividing the manual into sections. We saw in Chapter 1 that you can search the manual by particular sections to get specific man pages. These sections are nothing more than directories identified in */etc/man.conf*. Here's where we define the man pages included in section 1.

```
1 /usr/{share,X11R6,local}/man/man1
```

There's no trailing slash, because we're not adding any subdirectories. These are the actual directories containing section 1 of the manual.

You can define arbitrary section names in */etc/man.conf*. While you should avoid section names beginning with an underscore in order to prevent confusion with keywords, you can do just about anything else.

### */etc/master.passwd, /etc/passwd, /etc/spwd.db, and /etc/pwd.db*

The */etc/master.passwd*, */etc/passwd*, */etc/spwd.db*, and */etc/pwd.db* files contain usernames and passwords, along with a few other key items about

locally defined users. When you log in, the password you type is compared with the encrypted and salted hash of your password in this file. As such, */etc/master.passwd* is vital to system security.

### Editing /etc/master.passwd

If you're considering editing */etc/master.passwd* directly, ***stop***. Go back to Chapter 6. Reread it. See if there's another way to make your desired change. Damaging */etc/master.passwd* can prevent people from logging in at all, and might render your system unusable. To edit a single user account in */etc/master.passwd*, run `chpass(1)` as root.

If you must edit */etc/master.passwd* directly—say, to change everyone's home directory to point to a new filesystem—there's a program just for that. The program `vipw(8)` calls up the text editor in `$EDITOR`, loads the password file, lets you make changes, and checks the file syntax before saving it. `vipw` also updates */etc/passwd* and the password databases */etc/pwd.db* and */etc/spwd.db*.

Be absolutely sure that this file is synchronized with the password databases. Using `vipw` prevents many basic mistakes and helps ensure data consistency, but if you're really bent on corrupting */etc/master.passwd*, `vipw(8)` will make your task more difficult but won't stop you.

That said, only senior sysadmins should use `vipw`. How do you know if you qualify? If you've made enough horrible mistakes with `vipw` that you know in your bones not to use it, if your stomach churns at the mere thought of typing those four letters, you may use `vipw`.

### Controlling Account Information Access

Many programs need parts of the information stored in */etc/master.passwd*. For example, a program must be able to look up a user's shell and home directory to properly find the user's files. Rather than allowing anyone to read this file and the scrambled passwords therein, OpenBSD (and most other Unix-like systems) provide the account information everyone needs to see in */etc/passwd*.

Accessing and parsing a text file can be slow, especially if the computer has a slow processor and many user accounts. Text files are not meant for searching. If a program must search a text file for user account number 10631, the search can hold up the program's activity and even block other programs. Checking a database for an entry is much faster, as the program can just say "Give me account 10631" and get a response from a file store intended for searches.

All Unix-like systems create databases from the password files whenever the account information changes. The database of public account information, built from */etc/passwd*, is */etc/pwd.db*. The database file */etc/spwd.db* contains private account information built from */etc/master.passwd*.

Realistically, very few pieces of software actually use the password file directly. Most programs access *pwd.db*. I know people who delete */etc/passwd* without ill effect, but you do need to keep the password database.

### /etc/master.passwd Fields

Each account is a line in */etc/master.passwd* and */etc/passwd*. Each line has the following nine fields, separated by colons.

**Username**
: This field contains either an account created by the sysadmin and used by a human, or a nonprivileged user created for use by a program or service. Chapter 6 covers usernames.

**Hashed and Salted Password**
: This field contains the user's password, hashed and salted. (It's commonly called a hash, but you should know it's more than that.) You cannot derive the password from the hash, but if you have the hash, you can try passwords until you find one that matches the hash. That's why you must protect your */etc/master.passwd* file. In */etc/passwd*, the password field is blank.

**NOTE** *One simple way to temporarily disable a user account is to edit the password file with `chpass(1)` and put an asterisk (*) in front of the hash. While the account will still be active, no one will be able to log in to it. I've used this to great effect when a client is behind on a bill. While clients can ignore overdue payment notices, they call quite quickly when they cannot access their account. I can easily route that call to the billing department. Once the matter is resolved, I can re-enable their account by removing the asterisk.*

**User ID Number**
: The third field is the user ID number, or UID. Every user must have a unique UID.

**Group ID Number**
: This field is the group ID number, or GID. This is the user's primary group, as discussed in Chapter 6. Usually, this is the same as the UID, and the user's primary group has the same name as the username. Some sites prefer to use a single group for all unprivileged users.

**User Class**
: We discuss the user class in Chapter 6. Changing the class can increase or decrease the amount of system resources the user can access.

**Password Expiration Date**
: The expiration date is expressed in the number of seconds since midnight, January 1, 1970, the UNIX epoch. You can convert dates to seconds with `date(1)`. If you must manually set an expiration date for a password, use `chpass(1)` and specify a human-readable date.

**Gecos**
: This field contains the user's real name, office number, work phone number, and home phone number, all separated by commas. This information was much more important when computers were big systems with hundreds or thousands of users, and you might need to contact people when their process went completely insane. Today, it's basically ignored. (Do not use colons here; colons are reserved specifically for separating fields in */etc/master.passwd*.)

**User's Home Directory**
: This field is the user's home directory. While this defaults to a directory with the same name as the username, beneath */home*, you can move this directory anywhere you like. Editing the home directory in the password file does not move the actual directory; you need to do that yourself.

**User's Shell**
: The last field gives the user's shell. If this field is empty, the user gets boring old */bin/sh*.

## /etc/mixerctl.conf

OpenBSD includes solid audio abilities. You can listen to MP3s, mix music, or just about anything else you would like.

Control audio settings with `mixectl(8)`, and set boot-time `mixerctl` settings in */etc/mixerctl.conf*.

## /etc/mk.conf

Configure `make(1)` with */etc/mk.conf*. The most common use for special `make` settings is while you are building ports (covered in Chapter 13) or while building your own custom OpenBSD release (Chapter 20).

## /etc/moduli

The */etc/moduli* file contains prime numbers, used for Diffie-Hellman cryptography. Never edit this file. Some people may understand cryptography well enough to edit */etc/moduli*, but if you're reading this book, you're probably not one of them.[2]

## /etc/monthly and /etc/monthly.local

The */etc/monthly.local* shell script runs once per month as part of routine system maintenance. Chapter 15 discusses scheduled maintenance jobs.

2. Henning Brauer, OpenBSD developer and point man on packet filtering, comments, "I understand crypto somewhat well. . . . I don't muck with moduli either tho." Consider yourself warned.

### /etc/motd

The MOTD, or message of the day, is displayed to users upon login. In this file, you might put system notices or announcements that you hope users will notice. Many organizations put legal notices or acceptable use policies in */etc/motd*.

Note that the first line of */etc/motd* is overwritten at every boot. Start your legal warning in line 2 or below.

### /etc/mrouted.conf

In addition to `dvmrpd(8)`, OpenBSD supports multicast routing with `mrouted(8)`. The `dvmrpd` implementation is preferred, but for specific edge cases, you might need `mrouted` instead.

Configure `mrouted` in */etc/mrouted.conf*. Eventually, `mrouted` will be removed from OpenBSD.

### /etc/mtree/

The */etc/mtree/* directory contains a list of most directories on a stock OpenBSD system, with their ownership and permissions. The system upgrade process uses this. While you don't really need to edit these files, it's nice to know what the heck they're for.

### /etc/mygate

The */etc/mygate* script gives the address of the default gateway for both IPv4 and IPv6, as discussed in Chapter 12.

### /etc/myname

The */etc/myname* file contains the hostname of the system, as discussed in Chapter 4.

### /etc/netstart

The */etc/netstart* script starts the network, as discussed in Chapter 12.

### /etc/networks

*/etc/networks* is a list of subnets and their names. Use of a networks database has fallen out of favor, because it's not terribly useful.

### /etc/newsyslog.conf

The `newsyslog(8)` program rotates log files, as discussed in Chapter 15.

### /etc/nginx/

OpenBSD has imported the `nginx` web server (*http://www.nginx.org/*) as a replacement for the older Apache 1.3 server, but as of this writing, it's not

quite integrated with the rest of the system. You can find the `nginx` configuration files in this directory, and the server is quite usable, but it's not the official OpenBSD web server—yet.

### /etc/nsd.conf

OpenBSD has imported the name server daemon `nsd(8)` to eventually partially replace the old DNS workhorse server `named(8)`. It's usable, but as of this writing, it's not yet integrated with the system.

### /etc/ntpd.conf

The NTP daemon keeps the system time synchronized with other machines on your network and the Internet. We discuss `ntpd(8)` in Chapter 15.

### /etc/ospf6d.conf and /etc/ospfd.conf

OSPF is a routing protocol used inside autonomous networks. OpenBSD has two OSPF implementations: one for IPv4 and one for IPv6. If you want to know more about OSPF, read `ospfd(8)` and `ospf6d(8)`.

### /etc/pf.conf and /etc/pf.os

Configure the OpenBSD `pf(4)` packet filter in */etc/pf.conf*. Packet filtering uses */etc/pf.os* to fingerprint other operating systems. Chapters 21 and 22 cover packet filtering.

### /etc/ppp/

You can connect OpenBSD to the Internet via a dial-up modem, which is rarely done these days. If you need to configure a modem on your OpenBSD system, read the `ppp(8)` man page.

### /etc/printcap

The printer capability file describes all printers that this system can access. Making a Unix-like system work with a random printer was long considered to require some sort of sacrifice, a moon in the correct phase, and a team of chanting acolytes in robes. While complicated software such as CUPS has been written to simplify printing, configuring an OpenBSD machine to print to a print server or a network PostScript printer is pretty simple. See Chapter 16 for details on printing.

### /etc/protocols

The */etc/protocols* file contains protocol numbers for TCP/IP network protocols. Chapter 11 covers TCP/IP versions 4 and 6 in detail.

### /etc/rbootd.conf

`rbootd(8)` offers boot services for HP workstations—a very narrow subset of obsolete diskless clients. OpenBSD still supports the HP300 machines that need this service. If you're interested in diskless operations on modern hardware, read the `diskless(8)` man page instead, or look at Chapter 23.

### /etc/rc.*

The */etc/rc.** files are used for system booting, as discussed in tortuous detail in Chapter 5.

### /etc/relayd.conf

The load balancer daemon `relayd(8)` works with the OpenBSD Packet Filter (PF) system to act as a network load balancer. The `relayd` daemon requires a good understanding of PF, however, and a very specific network. If you're interested in load balancing, read Hansteen's *The Book of PF*.

### /etc/remote

Unix-like systems have extensive support for connecting into the system over serial lines, usually for serial consoles. Many network appliances have management serial ports, and you can use OpenBSD as a client to configure these devices. The */etc/remote* file contains serial connection configurations for most common modern serial connections (covered in Chapter 5).

### /etc/resolv.conf and /etc/resolv.conf.tail

The */etc/resolv.conf* and */etc/resolv.conf.tail* files configure the resolver (covered in Chapter 12), letting the host map names to IP addresses and vice versa.

### /etc/ripd.conf

RIP is an old way to broadcast routing instructions across a network. OpenBSD has a RIP daemon, `ripd(8)`, configured in */etc/ripd.conf*.

RIP is generally considered undesirable, like the r-services. Among other shortcomings, it doesn't even support netmasks, so it's restricted to old-style class A, B, and C networks. And as with the r-services, sometimes you're stuck with RIP because some obsolete device on your network can handle nothing else. Use `ripd` to scrape by until you can arrange a tragic accident for that device.

### /etc/rmt

The remote magnetic tape command (`rmt`) lets a host access a tape drive on another machine. It's most commonly used to restore a system from backup.

### /etc/rpc

RPC is a method for executing commands on a remote server. Much like TCP/IP, RPC has service and port numbers. The file */etc/rpc* contains a list of these services and port numbers. The most common RPC consumer in OpenBSD is NFS, as discussed in Chapter 9.

### /etc/sasyncd.conf

OpenBSD supports failover between IPsec gateways, using the security association synchronization daemon `sasyncd(8)`. This is not a common feature in operating systems, and its presence is a highlight in OpenBSD. To learn about IPsec failover, read `sasyncd(8)`.

### /etc/sensorsd.conf

Modern hardware has sensors for detecting items like fan speed, circuit voltage, temperature, and so on. OpenBSD's `sensord(8)` reads these sensors and presents the information to the user. Configure which sensors you want to pay attention to, as well as what you want to do when the sensors detect something, in */etc/sensorsd.conf*. See Chapter 15 for details on `sensorsd`.

### /etc/services

The */etc/services* file contains a list of network services and their associated TCP/IP ports. See Chapter 11 for details.

### /etc/shells

The */etc/shells* file contains a list of legitimate user shells, as discussed in Chapter 6.

### /etc/skel/

The */etc/skel/* directory contains standard user environment configuration files. When you create a user account, `adduser(8)` copies the files in this directory to the new user's home directory. This directory can be overwritten when you upgrade your system.

If you need to customize these files for your users, create a custom dotfile directory and tell `adduser(8)` to use it instead.

### /etc/sliphome/

The Serial Line Internet Protocol (SLIP) predated the Point-to-Point Protocol (PPP) commonly used for dial-up lines. OpenBSD still supports it, as someone might need it and there's no real reason to get rid of it.

### /etc/snmpd.conf

Simple Network Management Protocol (SNMP) is a method for accessing information about a device over the network. Unfortunately, it's not a terribly secure protocol (one common acronym for SNMP is "Security? Not My Problem!") The OpenBSD team has written a more secure SNMP daemon, `snmpd(8)`. Configure it in */etc/snmpd.conf*, as discussed in Chapter 16.

While OpenBSD's SNMP daemon might resist intrusions and abuse, it can't help the fact that SNMP itself, as commonly deployed, isn't terribly secure.

### /etc/ssh/

The SSH daemon `sshd(8)` offers a secure replacement for `telnet(1)` and the r-protocols. Chapter 16 includes a brief discussion of SSH.

### /etc/ssl/

The */etc/ssl/* directory is for Secure Sockets Layer (SSL) certificates, as well as the OpenSSL configuration file *openssl.cnf*. Store system SSL certificates here.

### /etc/sudoers

The */etc/sudoers* file controls `sudo(1)` configuration. See Chapter 7 for details about `sudo`.

### /etc/sysctl.conf

Set kernel runtime tunable options in */etc/sysctl.conf*. Sysctls are covered in Chapter 18.

### /etc/syslog.conf

The logging daemon `syslogd(8)` reads messages from programs and hosts, and then separates those messages into records based on the configuration in */etc/syslog.conf*. See Chapter 15 for details on `syslogd`.

### /etc/systrace/

The `systrace(4)` system call wrapper provides access controls to system calls. You could run a binary "under" `systrace(1)`, and if the program attempted to access any system call beyond those permitted in the application's `systrace` policy, `systrace` would block the access.

Flaws were found in `systrace`, however, that make it less than effective, and it's now considered only a partial solution. It still ships with OpenBSD, but its use is discouraged. Today, `systrace` is mostly used for package-building clusters to make sure that software built doesn't phone home or write outside the fake installation root.

If you need to use `systrace`, store policies in */etc/systrace*.

## /etc/termcap

The */etc/termcap* file describes all the different terminals that OpenBSD supports. Pretty much every console device now supports the standard VT220 terminal, however.

## /etc/ttys

Configure system terminals in */etc/ttys*. You can enable, disable, and change terminals here. A "terminal" could be the keyboard and monitor attached to the computer, a login over a serial line as with a serial console, or a virtual terminal as used by telnet or SSH.

A classic UNIX terminal device resembled a teletype; that's where the *tty* label comes from. All sorts of UNIX architectural details descend from this historical accident, and Unix-like systems inherited them.

### Terminal Types

*/etc/ttys* lists three different terminal types: the console, serial ports, and pseudo-terminals.

The console is where boot messages display, where single-user mode maintenance can happen, and where error messages directed at the console appear. While the console is usually the keyboard, monitor, and mouse attached to the computer, it doesn't need to be that. The "console" is an abstraction that usually happens to be aimed at your physical monitor and keyboard. You can direct the console at a serial port instead, for example. The console uses the device */dev/console*.

On some platforms, including i386 and amd64, OpenBSD supports multiple virtual consoles attached to your physical console. If you press CTRL-ALT-F2 on the physical keyboard, you'll see a brand-new login screen. CTRL-ALT-F1 returns you to the main console. You can have as many virtual consoles as you have function keys, but OpenBSD has five by default. These virtual consoles have device names beginning with */dev/ttyC* and ending in a hexadecimal number.

Serial ports can be used as login devices, once you attach either an old-fashioned serial terminal or a null-modem cable and another device with a serial port. They can also be used for outgoing serial connections. Serial ports used as incoming devices start with */dev/tty*, while ports used for outgoing connections start with */dev/cua*, and both end in hexadecimal numbers. Each serial port can have one terminal attached to it.

Pseudo-terminals support network connections. Even though your remote SSH window has no corresponding physical hardware on the server, OpenBSD treats it in some way as a `tty` device. Pseudo-terminals have device names beginning with */dev/tty*, a letter `p` through `z` (either lowercase or uppercase), and ending in a single letter or number. When a user connects over the network, such as via SSH, the login session is assigned one of these virtual terminal devices.

Whatever the terminal type is, configure it in */etc/ttys*, using the following procedure.

### Configuring Terminals

Each terminal has an */etc/ttys* entry, containing at least three entries and possibly up to five.

```
ttyC0 /usr/libexec/getty std.9600 vt220 on secure
```

The first entry is the device name, without the leading */dev*.

The second entry is the name of the program that spawns login requests on the terminal. Physical terminals and virtual consoles use `getty(8)`, while pseudo-terminals process login requests through whatever daemon the user logs in through.

The third entry is the terminal type. OpenBSD uses a `vt220` terminal on the monitor and the virtual consoles. Serial consoles use the `unknown` terminal type, as there's no way to know in advance what kind of hardware is on the other end of the terminal. (You can switch this to `vt220` without issue if you're using a reasonably modern serial client.) Pseudo-terminals use the `network` terminal type; the server daemon and client software determine the terminal's features.

The fourth field determines if the terminal is available for logins. Set this to `on` to accept login requests, or `off` to deny them. Pseudo-terminals are activated on demand, so you don't need to configure them in */etc/ttys*.

The root account can log on to only a secure console. The physical terminal and the console are the only devices defined as secure by default. You can log in as a regular user and use `su(1)` or `sudo(1)` on an insecure terminal; you just can't directly log on as straight `root`. This means that anyone who has the root password and physical access to the machine can just walk up to the keyboard and log in as root. To disallow logins directly to root, remove the `secure` keyword from the virtual console entries in */etc/ttys*. Also, on secure terminals, you won't be asked for the root password when you boot into single-user mode.

If you use serial consoles, you might want to log in to a running multiuser system over the serial cable. By default, you cannot log in on a serial line. Set the serial line with the serial console to `on`, and you'll be able to log in. This makes a serial line behave much like being at the physical console, where you can work in multiuser mode and while the machine is running normally.

While all of the defaults use `getty(8)`, there are alternatives. For example, the HylaFAX package lets you connect a fax machine to a serial line, but you need to reconfigure the terminal to support it.

```
ttyOe   "/usr/local/sbin/faxgetty"      dialup  on
```

The point is that you can use serial ports any way you like, once you get the right software tool for the job.

#### Making /etc/ttys Changes Take Effect

Offering terminals is a low-level system task handled directly by `init(8)`. Changes to */etc/ttys* do not take effect until you tell `init` to reread its configuration. (`init` is always process ID 1.)

```
# kill -HUP 1
```

If you don't tell `init` to reread its configuration, changes won't take effect until you reboot.

### /etc/weekly and /etc/weekly.local

The */etc/weekly.local* script runs once a week to perform weekly maintenance, as discussed in Chapter 15.

### /etc/wsconsctl.conf

OpenBSD includes hardware-independent access to the physical console through the `wscons(4)` driver. Configure this console via `wsconsctl(8)`. The boot-time `wsconsctl` settings are read from */etc/wsconsctl.conf*. See Chapter 17 for details on console configuration.

### /etc/X11

The */etc/X11* directory contains configuration for the X Window System. OpenBSD's Xenocara integrates X with the base system. Chapter 17 discusses desktop OpenBSD, including some X features.

### /etc/ypldap.conf

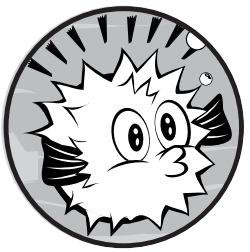
In addition to the LDAP daemon `ldapd(8)`, OpenBSD supports the YP database for centralizing passwords, groups, and host filesystems. YP is compatible with Sun's original Network Information System (NIS). OpenBSD uses YP as a gateway to LDAP authentication. If you're interested in this feature, see `yp(8)` and `ypldap(8)`.

This takes you through everything in */etc* not covered elsewhere. In the next chapter, we'll discuss how OpenBSD maintains itself, and how you can meddle with the maintenance processes.

# 15

# SYSTEM MAINTENANCE

*When hardware complains,*
*OpenBSD listens.*
*You should listen too.*



No computer runs itself. If it did, you would be out of a job. Even the best-configured server generates a constant low burn of maintenance needs.

OpenBSD includes a variety of tools to make maintenance easier, to alert you when maintenance is needed, and to tell you about the system's status. Every day, week, and month, OpenBSD performs maintenance tasks and notifies you of the results. OpenBSD takes daily backups of critical system features and files, and uses them to monitor system integrity. It can manage its own log files, keep its own time, and alert you when the hardware is failing.

All of this starts with scheduled maintenance.

## Scheduled Tasks

OpenBSD includes scheduled tasks that run once a day, week, and month. These jobs run as root and email the results to root. The daily maintenance script is the most complicated; the monthly script is the simplest.

If a server runs well, I might not log in to it for weeks or even months. In fact, I've had a few servers run for more than a year without a human being ever logging in to it. I read the daily reports from the machine and say "Yep, it's okay," and get on with my day, confident that what the regular status reports don't tell me the monitoring system will.

The scheduled maintenance jobs email their results to the local root user, but if no one ever logs in to the machine, no one will see those results. Always set an email alias for root in */etc/aliases*, so that these messages go to someone who will actually read them.

Reading every email message from every machine every day is annoying, but much less annoying than finding out that I have a bad service by a user telling me about it. These messages often alert me to system problems before anyone (including me) notices them. Sites with hundreds of machines often write scripts to parse incoming email messages and flag interesting details.

You should send maintenance email to the person ultimately responsible for the system—whoever is most interested in system changes and most likely to be aware of any day-to-day system changes. If you delegate the job of reading maintenance email to a minion who is less aware of the system, he will either annoy you with endless questions about what you did yesterday or learn to ignore anything actually in the status mail messages.

Here, we'll take a look at how the daily, weekly, and monthly routines work. Complete documentation of the maintenance jobs appears in `daily(8)`.

## Daily Maintenance

The daily maintenance job starts by running any custom maintenance jobs (covered at the end of this section) from */etc/daily.local*. Daily maintenance includes checking partitions, running the reminder service `calendar(1)`, running `rdist(1)`, removing scratch files, and a few other boring things.

OpenBSD can also do a few other interesting things as part of its daily maintenance:

- Create a backup root filesystem, */altroot*.
- Perform system security checks.
- Back up vital system files in */var/backup*.
- Check for changes in vital system files.
- Check filesystem integrity.
- Run `rdist(1)`.

I discussed */altroot* in Chapter 9 because it requires a dedicated filesystem partition. Each of the other tasks can be configured later.

### Security Checks

Some things that go wrong don't necessarily mean your system has experienced an intrusion, but are nonetheless suspicious. The daily security

check looks for a whole slew of misconfigurations and problems that arise from either malice or incompetence. You can read the list of checks in `security(8)`, but they break down into fairly broad categories:

**Device node changes and privileges**
: New device nodes, changed permissions on device nodes, new software packages, and new or altered disks or partitions might indicate malicious activity or might just be normal system management. The security script flags all of these. If you made such changes, you'll nod and go on with your day. If you requested a minion perform the change and the change doesn't appear, this is when you ask them what they did all day yesterday. If you didn't make a change that appears, you want to know about it.

**Insecure NFS exports**
: OpenBSD includes a lot of software to export filesystems and run commands remotely. These services, like printing and NFS, should not allow access from any host just anywhere, but only from hosts you approve. The security job checks for configurations that permit global access.

**Misconfigured accounts**
: Another popular attack route has been the password database and related files. Accounts without passwords, duplicate entries, improperly closed accounts, and so on could all be used to compromise a system. The script checks for these issues.

**Permissions**
: Poor permissions can lead to privilege escalation. For example, is there a new `setuid` or `setgid` file on the system? If so, the security script notifies you. If you installed that file with those privileges, you're okay. If it's unexpected, you should investigate.

**User environment**
: If you can change a user's environment, whether that's root or another account, you can trick him into giving away his authentication credentials or running suspect commands. If an intruder can edit a user's dotfiles, like *.cshrc* or *.login*, he can change which versions of a command he runs. Perhaps his shell is set to run a program that asks the user for his password and sends it to the intruder's anonymous email account. By having correct permissions on home directories, dotfiles, mail files, and so on, you make this class of attack more difficult. The security script verifies that permissions are set up correctly.

Note that the security check is *not* an intrusion-detection system. The changes it checks for are the sort that script kiddies and newbie intruders are most likely to make, but skilled intruders familiar with OpenBSD could get around it. They could even replace the security check with a shell script that sends a daily email message that looks like an innocuous security check.

Fortunately, competent intruders are relatively rare. Just keep in mind that receiving a security check with no mention of problems is encouraging, but it's not proof that your server is secure.

### Vital File Backup and Testing

The daily security check tests for changes in the files listed in */etc/changelist* and rotates their backups, since these files are generally critical system files, such as */etc/master.passwd*, */etc/boot.conf*, and */var/cron/tabs/root*. It also checks for changes to disk partitioning and mounted filesystems, as well as changes to device nodes.

Look in */var/backups*, and you'll see files like this:

```
...
etc_fstab.backup
etc_fstab.current
etc_ftpchroot.current
etc_ftpusers.current
...
```

The files ending in *.current* are copies of these files as they existed when the daily maintenance job was last run. The files ending in *.backup* are the previous version of those files.

The first time the security script runs, it copies all of these files to */var/backup*. Following that initial setup, the security script checks the original file against the current copy for changes. If the file changes, the previous version of the file is copied to the *.backup* filename, and the new version is copied to the *.current* file.

In the preceding example, the list shows that I edited my */etc/fstab* at some time, prompting the security script to move its copy of the old filesystem table to a *.backup* file. I have never edited */etc/ftpchroot* or */etc/ftpusers*, so there is no *.backup* version of these files, but only the *.current* one.

The security script doesn't copy all of the files that it watches. For example, files containing private keys or that might contain private keys are not copied, but the security script does take a checksum. (Files monitored by checksum have a plus sign before their name in */etc/changelist*.) There's no reason to manually edit */etc/ssh/ssh_host_ecdsa_key*, and if the file changes, either you know why or you need to restore from a trusted backup.

*/etc/changelist* is itself listed in */etc/changelist*. This seems recursive, but the system backs up the list of files you want backed up, and also notifies you when someone adds or removes a file in */etc/changelist*.

### Adding Vital Files

You can add files to the change list and even use wildcards to back up all the files in a directory. But note that if you did use wildcards in */etc/changelist*, you won't be notified when a file is removed.

Consider this example of using wildcards. In Chapter 13, I added the `apache2` port to one of my machines. I put the configuration files in */etc/apache2*. I could add a line like this to the change list:

```
/etc/apache2/*
```

This would automatically copy all files in the *apache2* configuration directory to */var/backup* and test them for changes. However, I would not be notified when files are removed from this directory. If you're using a configuration mechanism that says, "include all the *.conf* files in such-and-such directory," this might not be desirable. A better option would be to list each file individually and update the list when you add critical files.

One of the most convenient things about the file-integrity check is that it automatically creates a local backup of critical system files. That means that if you decide to learn how to use `vipw(8)` and utterly trash your user database in doing so, you can grab yesterday's copy out of */var/backups*, install it, and no one will be the wiser. The same applies to every other critical system file.

#### Filesystem Integrity Checks

You can't run a full-on Unix File System (UFS) check while a system is in multiuser mode, but you can have `fsck(8)` perform filesystem integrity checks to try to identify problems before they're serious. Doing so won't fix any problems, but it will notify you that they exist so you can schedule downtime for repairs.

To enable these checks, set `CHECKFILESYSTEMS` to `1` in */etc/daily.local*.

#### Copying Files with rdist

The `rdist(1)` program is used to copy files to other servers, letting you maintain identical copies of critical files on many servers. If you're interested in using it, see `rdistd(8)`.

#### Silencing /etc/daily

Some of us have monitoring systems that track a server's disk, network, and other basic information. If you don't need this sort of information to appear in your daily status mail, set `VERBOSESTATUS` to `0` in */etc/daily.local*. This turns off these parts of daily maintenance, reducing the amount you need to read.

If the remaining daily maintenance doesn't generate any output, the server should not send a status email that day. In environments where you don't trust the monitoring system, you could use the daily status messages to assure you that the system is running as expected. OpenBSD gives you the choice.

### Weekly Maintenance

The weekly script is simpler than the daily script with only three common functions:

- First, it runs the custom weekly script */etc/weekly.local*.
- Second, it updates the `locate(1)` database.
- Finally, it rebuilds the `whatis(1)` man page database.

### Monthly Maintenance

OpenBSD doesn't need any generic monthly maintenance, but for consistency, the */etc/monthly* script runs the custom script */etc/monthly.local*.

### Custom Maintenance Scripts

Each maintenance script runs a custom script before performing any other tasks. You can put any tasks you need in */etc/daily.local*, */etc/weekly.local*, and */etc/monthly.local*. These commands are run by root, so don't use them for tasks that should be performed by another user. If your database needs to be backed up, create a separate script, and have the unprivileged user running your database run that script via `cron(8)`.

Some sites use the scheduled maintenance jobs to run complex software that perform site-specific duties. For example, I know of one security firm that collects data from hundreds of machines, and uses the daily jobs to send that data to a central management system. Really, you can use the local scripts any way you choose.

If you have a maintenance task that can run under another user account, but you want to attach it to the scheduled maintenance jobs, you can have the local script call another script. Start that script by using `su(1)` to switch users and drop privileges.

Custom maintenance scripts may be most useful for altering the way the standard maintenance scripts perform their work. For example, say you have a system with many scratch directories containing temporary files. The weekly maintenance script updates the locate database, but you don't want these scratch files included in locate results. You could use a custom maintenance script to remove all the scratch files immediately before */etc/weekly* creates the new locate database, and schedule this as a separate task. By adding it to */etc/weekly.local*, you would know that it will finish before */etc/weekly* runs any other tasks.

## System Logs

The system log used by Unix-like operating systems has become the industry standard for logging, but that's not necessarily a good thing, because the log mechanism can be cantankerous. Once you properly configure log collection and rotation, however, OpenBSD's logging system mostly manages itself.

OpenBSD uses the standard logging system for Unix-like (and many embedded) systems, `syslog(3)`. The syslog protocol marks messages with a facility and a priority, and hands those messages to a daemon.

Any program can write to the local `syslogd(8)` server, but the key in log management is deciding how those messages are sorted and stored. OpenBSD's `syslogd` can sort messages based on facility, priority, and source program.

### Facilities

A *facility* indicates the source of a message. In most cases, each program that needs a separate log file uses a different facility. Many programs or protocols, such as FTP, have facilities dedicated to them. The syslog protocol also has a variety of generic facilities that you can use as you wish.

Table 15-1 lists the standard facilities and provides some notes on their usage.

**Table 15-1:** Standard OpenBSD Facilities

| Facility | Usage |
|---|---|
| `auth` | Public information about authentication, such as when someone logged on or when someone uses `su`. |
| `authpriv` | Private information about user authentication, normally accessible only to privileged users. |
| `cron` | Messages from the system scheduler `cron(8)`. |
| `daemon` | A catchall for processes that neither need nor require a dedicated facility. |
| `ftp` | Messages from FTP and Trivial File Transfer Protocol (TFTP) servers. |
| `kern` | Kernel-generated messages. |
| `local0` through `local7` | These facilities are provided for the sysadmin. Many programs let sysadmins configure their facility. Use these eight facilities for such programs. |
| `lpr` | Messages from the printing system. |
| `mail` | Messages from mail servers. |
| `mark` | This special facility writes a message every 20 minutes. |
| `news` | Messages from Usenet news servers. |
| `syslog` | Messages from the syslog server itself. |
| `user` | The catchall message facility. If a userland program doesn't specify a logging facility, the messages wind up here. |
| `uucp` | Messages from the Unix-to-Unix Copy Protocol (UUCP) servers. You will probably never encounter this pre-Internet email protocol. |

While most programs have sensible defaults, it's your job as the system administrator to manage which programs log to which facilities. If possible, use the local facilities for your server-specific daemons. While it's entirely

possible to use facilities for purposes other than originally intended, try not to reassign the `uucp` facility to some other daemon unless you really have no other option.

### Priority

A log message's priority represents its importance. Programs usually send their logging data to `syslogd`, but `syslogd` decides what to retain and what to discard. You get to decide how much detail you want in your logs. Use the following nine `syslog` levels to decide what to record and what to discard (in order from most to least important):

**`emerg`** System emergency. This message appears on every active terminal. The computer might be crashing, or it may have some other error that requires immediate attention.

**`alert`** An emergency. The system can continue to function, but attend to this error very soon.

**`critical`** Critical problems. These indicate serious errors, such as hard-drive failures.

**`err`** Errors. These are in regard to problems that require attention but won't destroy your system.

**`warning`** Miscellaneous warnings. These could be attended to, but will not prevent the process that generated them from running normally.

**`notice`** Important information, such as daemon startup and shutdown notifications.

**`info`** Basic information. This usually includes transactional data, such as individual messages in a mail server or individual queries to a web server.

**`debug`** Trivia. This level is usually of interest only to programmers, but occasionally useful to sysadmins trying to figure out why a program is behaving in a certain way. Debugging logs can contain anything, including information that violates user privacy, such as plaintext passwords.

**`none`** Don't log anything from this facility here. This is most commonly used to exclude information from log files, as discussed shortly.

By combining levels with priority, you can sort log messages into individual files or other targets.

### Sorting Messages via syslogd(8)

`syslogd` compares received messages to entries in */etc/syslog.conf*. This file has two columns: the first (the *selector*) describes a type of log message, and the second (the *action*) tells `syslogd` what to do when a message matches the description. Neither column can have whitespace; whitespace can appear only between the columns. For example, here's a line from the default *syslog.conf*:

```
daemon.info             /var/log/daemon
```

Any log message that has a facility of daemon and a priority of info or higher is appended to the file */var/log/daemon*. Of course, if all logs were so easily managed, this would be a short section.

syslogd compares all log messages to all *syslog.conf* entries. If a log message matches multiple selectors, it is sent to all matching destinations.

### Wildcards

You can use wildcards in either the facility or priority. For example, this line logs every message from the mail facility:

```
mail.*              /var/log/maillog
```

To capture messages of a given priority or higher from all facilities, use an asterisk (*). Here's how to send all priority err and higher messages to the console:

```
*.err    /dev/console
```

You can also use a double-wildcard to send all log messages to one place.

```
*.*    /var/log/all.log
```

Logging everything to one location isn't terribly useful or wise. You should *not* send authpriv debugging to a world-readable file.

### Excluding Information

Use the none level to exclude information from a log. For example, the following line excludes private authentication information from an otherwise all-inclusive log.

```
*.*;authpriv.none    /var/log/most.log
```

The semicolon (;) allows you to combine selection criteria on a single line.

**WARNING** *If you combine entries with a semicolon like this, do not put whitespace after the semicolon. The only whitespace can appear between the selector and the destination.*

### Combining Facilities

You can combine multiple facilities in a single entry by using commas. Here's how to capture all messages of info priority or higher from several facilities:

```
auth,daemon,syslog,user.info    @loghost
```

Any log message from the auth, daemon, syslog, and user facilities, and of priority info or higher, is sent across the network to the host loghost.

### Marking Time

While all log messages have a timestamp, you might want a marker in a log file to indicate that time has passed. The special facility `mark` creates a message every 20 minutes, letting you add an extra timestamp to a file. Here's how to add a timestamp to the mail log every 20 minutes:

```
mail.info;mark.info    /var/log/maillog
```

### Local Facilities

The eight facilities `local0` through `local7` are for your use. Many programs can be configured to use a specific facility, so you can aim them at a particular file. I've configured a daemon to use the facility `local7`. Here, I send messages from that facility to a file:

```
local7.*    /var/log/postgres.log
```

Some programs have a hard-coded preference for a specific facility. For example, the flow-tools package (see my book *Network Flow Analysis*, No Starch Press, 2010) has facility `local6` hard-wired into the code. Don't be shocked when you see something like this. Fortunately, OpenBSD's `syslogd` can filter based on program name, so you can easily filter your logs despite this sort of daftness.

### Selecting by Program Name

If you're out of facilities, you can use the name of the program generating the syslog messages as a selector. Using a program name requires two lines: The first contains the program name with a leading exclamation mark, and the second sets up logging. OpenBSD offers the following example of `sudo(8)` logging:

```
!sudo
*.*    /var/log/sudo
```

All log messages from `sudo` go to the specified log file.

You can also select by program name and stop all subsequent selections of matching messages by using two exclamation points (`!!`) before the program name. This example sends all messages from `sudo` to */var/log/sudo*, but prevents `sudo` messages from going to any other log.

```
!!sudo
   *.*    /var/log/sudo
!*
...
```

The !* after the end of the sudo entry is a way to say "all programs"—in other words, don't sort by program name anymore. You need this only if you use the double-exclamation-point "stop processing matching messages here" syntax.

## Log Actions

Now that you know how to sort your log messages into different buckets, let's see how to take different actions with those messages. Messages can be written to a file, piped to a program, sent to another host, or written to users.

### Logging to Files

Most of our examples so far send log messages to a file, giving the full path to the file as the action. Here's how to send all of the messages from facility local6 to a log file:

```
local6.*    /var/log/flowtools
```

You can also send the messages to a device by giving the full path to the device node, but this will make sense to very few devices, such as the console. This is because writing the log message to the disk device */dev/wd0d* will not store the message on disk.

### Logging to a Program

To send selected logs to a program, use a pipe (|) and the full path to the program, like this:

```
*.*    |/usr/local/bin/logsurfer
```

The logging system should start the destination program, and then feed log messages into the program's standard input.

### Notifying Users

You can also direct log messages to logged-in users by listing multiple users in a comma-separated list. For example, to send a message to all users, use an asterisk.

```
*.emerg    *
*.info    lasnyder
```

This example will notify all logged-in users of real emergencies, but deeply annoy lasnyder.[1]

1. Hey, I was running out of ways to annoy lasnyder—plausible ways, at least.

### Logging to a Remote Host

I usually have a logging host that collects log messages from everywhere—not only from my OpenBSD boxes, but from all my other Unix-like systems, as well as routers, switches, and anything else that speaks syslog. This reduces my maintenance needs and conserves disk space. And, since, every log message includes a hostname, I can easily sort them out later.

To send messages to another host, use the `@` symbol.

```
*.info    @loghost.blackhelicopters.org
```

This dumps everything of priority `info` and above to my logging host.

Your logging host must accept syslog messages from the network. If your host is an OpenBSD machine, run `syslogd` with the `-u` flag. And be sure to protect your log host with a packet filter, so random hosts can't write logs to it and fill up your disks.

## *Customizing syslogd*

OpenBSD runs `syslogd` by default, and you can customize how `syslogd` behaves. Common customizations include adding more log sockets and listening to the network.

### Adding Extra Log Sockets

Programs write log messages to the socket */dev/log*, but software inside a `chroot` won't be able to access that device. To have a program that's locked inside a `chroot` send messages to `syslogd`, you must put an additional log socket at */dev/log* inside the `chroot`.

For example, since the integrated BIND DNS server is `chroot`ed into */var/named*, the DNS server expects to find the log socket at */dev/log*, which means that the new log socket should be at */var/named/dev/log*. To create this log socket, use `syslogd`'s `-a` option, and give the full path to the log socket in */etc/rc.conf.local*.

```
syslogd_flags="-a /var/named/dev/log"
```

You can use about 20 additional logging sockets.

### Listening to the Network

If you want your OpenBSD box to act as a log host, accepting logs from remote hosts, use the `-u` flag.

```
syslogd_flags="-u"
```

Because the syslog protocol has no access control, anyone with access to port 514/UDP on the log host can write to your log files.

**NOTE** *Filling a host's logs with junk to fill the hard disk is an old attack. Use OpenBSD's packet filtering system (discussed in Chapters 21 and 22) to protect your logging host.*

### Syslog and Embedded Systems

OpenBSD supports writing log messages to an in-memory buffer, which allows logging on systems that have no writable disk, such as diskless systems and embedded routers and firewalls. `syslogd` retains these logs in a memory buffer, and clients can connect to `syslogd` through a reporting socket and read the logs. As you would expect, logs in memory disappear when `syslogd` is shut down.

To use `syslogd` for reporting, first provide a reporting socket with the `-s` option and give it a full path to a reporting socket. Here's an *rc.conf.local* entry for a reporting socket in */var/run/syslog*:

```
syslogd_flags="-s /var/run/syslog"
```

To log to the buffer, make a *syslog.conf* action. Specify logging to a buffer with a colon (`:`), the number of kilobytes to give the buffer, another colon, and the name of the memory buffer. (The maximum buffer size is 256KB.)

For example, here we capture all log messages of `err` priority or higher and write them to the 128KB memory buffer called `errors`:

```
*.err    :128:errors
```

Use `syslogc(8)` to read a memory buffer, and use the `-s` option to tell `syslogc` where to find `syslogd`'s reporting socket, and provide the name of the log buffer. Here's how to read the reporting socket */var/run/syslog* and read the `errors` buffer:

```
$ syslogc -s /var/run/syslog errors
```

If you've forgotten the name of the buffer you want to read, ask `syslogc` to query the list of available memory logs with `-q`. Be sure to provide the reporting socket.

**NOTE** *Even if you're not a programmer, you can still use real syslog features. Logging to syslog is available to shell scripts via the `logger(1)` program. See the `logger` man page for details.*

## Log File Maintenance

You can capture logs. Fantastic! Now just let the log files grow until they fill your hard disk and leave room for nothing else, right? Or you can discard old logs and have the system keep the logs to a manageable size. This is called *log rotation*.

Look at the system messages log, */var/log/messages*, and you should see six *messages* files: *messages*, *messages.0.gz*, *messages.1.gz*, *messages.2.gz*, *messages.3.gz*, and *messages.4.gz*. The plain *messages* file is the current log file. The other files are older logs; *messages.0.gz* is the newest, and *messages.4.gz* is the oldest.

When the current log file hits either a certain age or a specific size, log rotation discards the oldest log file (*messages.4.gz*), and the second-oldest file, *messages.3.gz*, is renamed to *messages.4.gz*; *messages.2.gz* is renamed to *messages.3.gz*; and so on. The existing *messages* file is renamed to *messages.0* and compressed, and a new *messages* file is created.

The `newsyslog(8)` program rotates log files, restarts daemons, runs commands, shuffles old files into other directories, and handles all routine tasks. `root` runs `newsyslog` once per hour via `cron(8)`. When `newsyslog` starts, it reads */etc/newsyslog.conf* and examines each log file listed. If the conditions for rotating the log file are met, the log is rotated and other configured actions are taken.

### *newsyslog.conf Fields*

*newsyslog.conf* uses one line per log file. Each line has seven fields, like this:

```
/var/log/authlog        root:wheel      640  7     *    168   Z
```

From left to right, the fields are log file, owner, permissions, number of files to retain, size, time, and flags. After the flags field, you might see a number of optional arguments. We'll look at each of the fields in order.

#### Log File

The first entry on each line is the full path to the log file to be processed (`/var/log/authlog` in this example). This must exactly match the current log file.

#### Owner

The second field (`root:wheel` in our example) lists the log file's owner and group, separated by a colon. This field is optional, and is not present in many of the default entries.

By default, log files are owned by the root user and the `wheel` group, but `newsyslog` can change the owner of log files. While changing ownership isn't common, you might want to explicitly declare it for specific files.

You can choose to change only the owner or only the group. In these cases, use a colon with a name on only one side of it, such as `:wheel` or `root:`. You must always include the colon if you're changing ownership.

#### Permissions

The third field (`640` in our example) gives the rotated file's permissions in standard octal notation, as discussed in `chmod(1)`. This field is optional, and it is not present in many default entries.

### Count

The fourth field specifies the number of archived log files that *newsyslog* keeps. In our example, */var/log/messages* has the current log file and five archives, numbered 0 through 4. *newsyslog.conf* has a count of `5` for */var/log/messages*.

### Size

The fifth field is a file size in kilobytes. When `newsyslog` runs, it checks the size of the log file. If the log is larger than the size given here, `newsyslog` rotates the log. If you don't want the file size to affect when `newsyslog` rotates the file, put an asterisk here.

### Time

To rotate the log based on time, use the sixth field, which has four possible values: an asterisk, a number, and a time in one of two standard formats. If you rotate the log based on size rather than age, put an asterisk here. If you put a number here, you are specifying a number of hours after which the log will rotate. Our example of */var/log/authlog* rotates every 168 hours.

The time formats—ISO 8601 restricted and `newsyslog`-specific—are a little more complicated.

**ISO 8601 restricted**

A time entry beginning with an `@` symbol is in the ISO 8601 restricted time format. The ISO 8601 restricted time format is used by `newsyslog` on most Unix-like systems, because it was the time format used in MIT's primordial `newsyslog`. The ISO 8601 format is a bit obtuse, but every Unix-like operating system I'm aware of supports it.

A full date in ISO 8601 format is 14 digits with a `T` in the middle. The first four digits are the year, the next two are the month, and the next two are the day of the month. (The `T` serves as a sort of decimal point, separating whole days from fractions of a day.) The next two digits are hours, the next two are minutes, and the last two are seconds. For example, the date September 13, 2013, at 3:18 and 58 seconds PM is expressed as `20130913T151858`. (Specifying a specific date and time to rotate a log wouldn't be terribly useful because the log would rotate only once.)

You can choose to specify only the fields near the `T`, leaving fields farther away blank. Again, if you think of the `T` as a decimal point, you don't need to write 5.87 as 005.8700; the leading and trailing zeros are irrelevant.

In the case of `newsyslog`, empty fields are wildcards. For example, `4T00` matches midnight on the fourth day of every month, and `T23` matches the twenty-third hour, or 11 PM, every day. If *newsyslog.conf* lists the time `@T2359`, the log rotates at 11:59 PM every day. (Of course, `newsyslog` runs once an hour, so the log won't rotate exactly then.)

As with cron(8), specify time units in detail. For example, @9T, the ninth day of the month, rotates the log once an hour, every hour, on the ninth day of the month, which would mean it rotates the log all day on that day. It would probably be better to specify a time of @9T01, which would rotate the log at 1 AM on the ninth day of the month. You don't need to specify times any more closely than the hour, as newsyslog runs only hourly.

**newsyslog times**

Because ISO 8601 time doesn't let you easily specify weekly jobs, and it's impossible to specify the last day of the month, OpenBSD includes a newsyslog-specific time format that lets you easily specify these common times.

Any entry with a leading dollar sign ($) is written in *month week day* format.

This particular format uses three identifiers: *M* (day of month), *W* (day of week), and *H* (hour of day). Each identifier is followed by a number indicating the unit you're using. Hours range from 0 to 23, and days run from 0 (Sunday) to 6 (Saturday). Days of the month start at 1 and go to 31, with L or l representing the last day of the month. For example, to rotate a log on the fifth of each month at noon, use $M5H12. To start the month-end accounting at 11 PM on the last day of the month, use $MLH23.

If you don't specify an hour, the time defaults to midnight on the chosen day. And if a *newsyslog.conf* entry lists both a time and a size for file rotation, newsyslog rotates the log if either requirement is met.

### Flags

The seventh field, which is optional, instructs newsyslog on special processing for the file itself. OpenBSD uses four flags:

**Z** Compress the file with gzip(1).

**B** Do not add a "log file turned over" message to the file (for binary files).

**F** Follow symlinks.

**M** A user is monitoring this log.

While the B and Z flags are not, strictly speaking, mutually incompatible, most log files need only one of them, and most binary files don't compress well anyway. (The default *newsyslog.conf* compresses the packet filtering log file, but that's something of an oddity.) If you see the Z flag with the M flag, the old log file will be sent to the user before the log is compressed.

### Monitoring Logs

OpenBSD's `newsyslog` can email logs to a user before rotating them. If you carefully control how you sort your logs, this feature can be useful. For example, `sudo(8)` logs successful uses at priority `notice`, but failed uses at priority `alert`. You might split these into separate log files in *syslog.conf*, like this:

```
!sudo
*.*         /var/log/sudo
*.alert    /var/log/sudofail
```

The file */var/log/sudofail* should now contain only `sudo` failures, such as users entering incorrect passwords or exceeding their privileges.

Now you could tell `newsyslog` to check for monitored logs by running it with the `-m` flag. (`newsyslog` runs as one of root's cron jobs.)

To have the `sudo` failure log emailed to you every time the log rotates, you can put your account in the monitor field.

```
/var/log/sudofail    root:wheel    640    30    *    $H06    ZM    mwlucas
```

This assumes that email to the account `mwlucas` on this machine reaches me. The simplest way to ensure that would be to forward the email in */etc/mail/aliases*.

**NOTE** *If you're serious about watching these kinds of failures, monitor logs on a logging host that end users cannot access. A user who becomes root on the local machine can edit logs before they are emailed and rotated.*

### Adding a PID File

If `newsyslog` tries to rotate and compress a file, but the process writing the file is still writing to the file, the file can become corrupted. Some programs need a right proper slapping before they will let go of their log files. How? Just list a PID file here, and `newsyslog` will send that process ID a `SIGHUP` (like a `kill -1`).

Note that PID files are not a terribly secure way to identify specific processes because they are subject to race conditions and other attacks. If the server has a command for rotating its logs, that's probably a wiser choice than signaling a process indicated in a PID file.

### Signal Name

To send a signal other than `SIGHUP` to a process with a PID file, use a different *signal name*. The signal name must begin with `SIG` and be specified by name. You can find a full list of signals in `signal(3)`, but the software

documentation should tell you which signal the process needs to release in order to restart its log file. This field is optional, but if you use it, you must enter a full path to a PID file immediately before it.

### Command to Execute

Rather than signaling a process, you can have `newsyslog` run a command when rotating logs by giving the full path to the command in double quotes. While this field is optional, it cannot be combined with a PID file. You can use a PID file or a command name, but not both.

## System Time

There's no excuse for a system having incorrect time. Once you set the time zone, having OpenBSD correct its own clock on an ongoing basis from any number of freely available network time servers is easy. Virtual machines in particular are notorious for skewing clocks, but time correction works on them as well, so as I said, no excuse.

OpenBSD includes its own NTP client, OpenNTPD, which is written to be safe and secure. Before `ntpd(8)` can do anything though, it needs some configuration.

### Configuring ntpd(8)

OpenBSD comes with a perfectly acceptable generic `ntpd` configuration that uses public time servers. If your host is on the public Internet and you only want to set your system time, not provide time to other hosts, use the defaults. Otherwise, you must customize */etc/ntpd.conf* by selecting time sources and deciding if `ntpd` will accept time requests from other machines.

#### Time Redundancy

NTP gets the time by querying remote servers. If you have a single server, that time is assumed to be correct. However, if you have multiple time servers, the times are not simply averaged. If one time server is wildly off from all of the other time servers, the results from that server are discarded, and a median from the remainder is selected. If you have only two time servers, and the times obtained from them differ, `ntpd` can't determine which one is correct. To help `ntpd` make sensible decisions, always list at least three time servers.

#### Time Sources

Choose your time sources with the `server`, `servers`, and `sensor` keywords.

The `server` option tells `ntpd` to get the time from a single server, which might have multiple IP addresses. If that's the case, `ntpd` tries to use the first

IP address. If the first address doesn't work, it tries the second, and so on, until it gets an answer. Use the `server` option if you have specific time servers to use, and be sure to list at least three time servers.

```
server time1.blackhelicopters.org
server time2.blackhelicopters.org
server time3.blackhelicopters.org
```

The `servers` option tells `ntpd` to get the time from multiple hosts that share a common hostname. The default *ntpd.conf* includes this entry:

```
servers pool.ntp.org
```

The host *pool.ntp.org* has four IP addresses, and `ntpd` will try to get time from all of those hosts.

If you have a hardware time sensor, you can tell `ntpd` to read time from it. Hardware time sensors include `nmea(4)`, `udcf(4)`, and `mbg(4)`. The `sensor` option tells `ntpd` to use a hardware sensor. If you've invested in a hardware time sensor, you might be sufficiently concerned about time to measure the distance between the transmitter and the receiver, and adjust the time based on the speed of light delay. The `correction` keyword lets you specify a number of microseconds that your sensor is behind.

As I wrote this, a 40-millisecond (ms) delay caused a furor in the scientific world when researchers thought they might have seen a neutrino go faster than light, so we'll put a 40 ms correction into our time sensor.

```
sensor nmea0 correction 40000
```

**NOTE** *Be warned that OpenBSD is not a real-time operating system. You should not be measuring neutrino speed with it anyway!*

### Serving Time

I run time servers on only closed networks, where very few hosts have access to the public Internet. I would also run time servers if I had hardware time sensors, but most of the time, I just use the public time servers.

To have `ntpd` answer time queries from other hosts, use the `listen on` directive. You can either specify an IP address or use an asterisk to say "every IP on the system."

```
listen on 192.0.2.87
listen on 2001:db8::aaaa
```

Because `ntpd` has no access controls, any host that can connect to port 123/UDP can get time from this server. If this worries you, use packet filtering (discussed in Chapters 21 and 22) to limit time checks to hosts on your

network. The author of OpenNTP served time to his entire company and to the public on a MicroVAX 3100 with 16MB (yes, that's an *M*) of RAM without the NTP process using more than 5 percent of the processor, so the load imposed by NTP is negligible on modern systems.

Now that `ntpd` is configured, let's use it.

### Using ntpd(8)

You can correct time slowly or do it in one fell swoop. I recommend fully correcting time at boot, and then letting `ntpd` slowly adjust the system clock as the system runs. This corrects time before anything relies on it, but keeps everything synchronized on an ongoing basis.

To correct time when starting `ntpd`, use the `-s` flag.

```
# ntpd -s
```

You'll get a command prompt back once `ntpd` receives a response from a time server and adjusts the clock. At boot, this delays other software starting so that it has the correct time, and when you check your clock, you should see the correct time. You can configure this at boot with `ntpd_flags` in */etc/rc.conf.local*.

```
ntpd_flags='-s'
```

If the clock is off on a running system and you're running software that would be corrupted by the clock moving backward or a time jump forward (as with many databases), you might need to tell `ntpd` to correct the clock more slowly. To do so, run `ntpd` without any flags, or set it in *rc.conf.local* to have it run in this mode at boot.

**NOTE** *Your starting time may be so far off that it will be impossible to make a gradual adjustment to the correct time in any reasonable period. To fix the clock, schedule a clock change when you can shut down your sensitive software, and make sure NTP runs afterwards so that the problem remains fixed. It's better to fix your clock right away and be done with it.*

## Hardware Sensors

Sensors are physical probes that check the health and status of hardware. Manufacturers have put more and more sensors in hardware, providing low-level hardware information to the operating systems. OpenBSD supports a wide variety of hardware sensors, and uses the `sensorsd` daemon to query them and act upon error states.

Resolving many hardware errors requires shutting down the machine, but advance warning that a component has stopped working changes a hardware failure from an unexpected middle-of-the-day catastrophe to an

after-hours annoyance. Some hardware, such as hot-swappable hard drives, can be replaced without interrupting service once you know the hardware has failed.

### Device Drivers

Each physical sensor has a device driver. The device driver extracts information from the hardware and publishes it in a sysctl (discussed in Chapter 18). `sensorsd` reads the sysctl values and can act when they change or cross critical values. For example, here are the sensor-related sysctl values from my laptop:

```
$ sysctl hw.sensors
hw.sensors.acpitz0.temp0=67.00 degC (zone temperature)
hw.sensors.acpiac0.indicator0=On (power supply)
hw.sensors.acpibat0.volt0=11.10 VDC (voltage)
hw.sensors.acpibat0.volt1=12.35 VDC (current voltage)
hw.sensors.acpibat0.power0=0.00 W (rate)
hw.sensors.acpibat0.watthour0=2.61 Wh (last full capacity)
hw.sensors.acpibat0.watthour1=0.30 Wh (warning capacity)
hw.sensors.acpibat0.watthour2=0.06 Wh (low capacity)
hw.sensors.acpibat0.watthour3=9.57 Wh (remaining capacity), OK
hw.sensors.acpibat0.raw0=2 (battery full), OK
hw.sensors.cpu0.temp0=81.00 degC
```

This comparatively simple and generic hardware has two temperature sensors and all kinds of power sensors. You can get hundreds of lines of sensor output, depending on your hardware.

Many RAID controllers have their own sensors, and will report when an array has failed. Here, we see three virtual disks provided by an AMI RAID controller:

```
hw.sensors.ami0.drive0=online (sd0), OK
hw.sensors.ami0.drive1=degraded (sd1), WARNING
hw.sensors.ami0.drive2=failed (sd2), CRITICAL
```

If you didn't have sensors, you would need to look at the blinking lights on the drive enclosure. Or you could listen for the really annoying "beep, beep, beep," which is *so* easy to hear over the roar of 5,000 server fans, the air conditioners, and someone else's hardware that has been beeping every time you've come in for the last six months.

**NOTE** *Some sensors require the Intelligent Platform Management Interface (IPMI). This is a kernel feature that's disabled by default in OpenBSD, because it makes some machines behave really badly. Chapter 18 discusses enabling IPMI.*

The device drivers attach to sensors automatically, and the values get into the kernel automatically, but to do anything with these results in any

automated manner, you need `sensorsd(8)`, or you need to configure an external SNMP-based management system and use `snmpd(8)`. We'll look at using `sensorsd(8)` here. Using `snmpd(8)` is discussed in Chapter 16.

## Sensor Configuration

The sensors daemon `sensorsd(8)` watches sensor monitoring data. It logs changes and can execute commands if needed. Because all hardware is different and all environments are different, by default, `sensorsd` notices changes only in sensor readings. To take action, you must configure `sensorsd` in */etc/sensorsd.conf*.

### Sensor Types

OpenBSD supports many types of sensors, as listed in Table 15-2.

**Table 15-2:** Supported Sensor Types

| Name | Function |
|---|---|
| temp | Temperature (C) |
| fan | Fan speed (RPM) |
| volt | DC voltage |
| acvolt | AC voltage |
| resistance | Ohms resistance |
| power | Wattage |
| current | Amperage |
| watthour | Power capacity |
| amphour | Power capacity |
| indicator | Device-dependent yes/no |
| raw | Device-dependent value |
| percentage | Device-dependent percentage |
| illuminance | Lighting |
| drive | Hard drives |
| timedelta | Time difference between operating system and hardware |
| humidity | Percent humidity |
| frequency | Microhertz |
| angle | Microdegrees |

You'll need to check your hardware manual in order to learn how to use some of these sensors effectively.

Some sensors appear to overlap. For example, why does OpenBSD have all those separate values for power, when you could probably do some math and get a common power gauge? The reason is that these are the values that the actual sensors report, and the developers would prefer to give you

the actual measurements. OpenBSD does perform some data rationalization, but only for simple data; all temperature sensors are normalized to degrees Celsius, for example.

Now let's see what you can do with these sensors.

### Settings in sensorsd.conf

The file *sensorsd.conf* has example entries, but because environments differ so widely, they're all commented out. It uses a `termcap`-style configuration syntax, much like */etc/remote* (see Chapter 5) or */etc/login.access* (see Chapter 6), with colons separating the terms in an entry. Each entry starts with the sensor to be measured, followed by attribute names and settings.

For example, here's an entry for a temperature sensor in the default *sensorsd.conf*:

```
hw.sensors.lm0.temp0:high=50C
```

For the sensor `lm0.temp0`, the attribute `high` is set to `50C`.

`sensorsd` supports four attributes:

**`high`** An upper limit

**`low`** A lower limit

**`command`** A command to run when a limit is crossed or a state changes

**`istatus`** Ignore this status

The values reported for a sensor type depend on what makes sense. Where high and low limits make sense for temperature and voltage, some sensors report specific values instead. The RAID controller shown earlier reports drives as degraded, failed, or healthy. A hard-drive sensor that reports a scalar value isn't useful, as you want to know if a RAID container is healthy or if drives have failed. There's no middle ground.

You can have both high and low values for a single sensor. For example, whereas temperature might not have a low value in most data centers, voltage certainly will. I work in all sorts of weird places, and not all of them have clean power.

```
hw.sensors.acpibat0.volt0:low=11.0V:high=13.0V
```

With a line like this, if the electricity supply to my laptop drops below 11 volts or goes above 13 volts, I will know.

Some systems might have dozens of sensors of a given type, which could make configuration tricky. If my motherboard has 15 temperature sensors, I don't want to configure each separately. Fortunately, you can configure sensors en masse by type, and since I don't care which temperature sensor goes above 80 degrees Celsius (if any of them do, I want an alarm), that works.

```
temp:high=80C
```

When this rule is applied, `sensorsd` first looks for a configuration item for a specific sensor. If it doesn't find that specific rule, it looks for a general rule. You can have one rule for most of your temperature sensors, and then override it for specific sensors, like this:

```
hw.sensors.lm0.temp5:high=90C
temp=80C
```

This rule says that most of my temperature sensors alarm at 80 degrees, but one specific sensor doesn't alarm until 90 degrees.

I care about temperature, but I don't care if my fancy keyboard sees that there's no light and wants to trigger its back lighting. You can ignore a sensor, or a type of sensor, with the `istatus` keyword.

```
illuminance:istatus
```

You should categorically ignore certain types of alarms based on your environment and gear. Make up your own mind.

### Sensors Triggering Action

Having an entry in */var/log/daemon* for when a hard drive fails is nice, but it would be better if the system would send email, page you, or trigger your monitoring system. It should do something—*anything*—that doesn't require you to log in and look at a log file. Fortunately, `sensorsd` can run arbitrary commands upon detecting a problem or crossing a threshold, using the `command` attribute.

Thanks to the wide variety of sensors and their possible error states and conditions, `sensorsd` doesn't have a fine-grained "run this command for an error, but run that other command for recovery." There are too many possible error states and conditions for this to make any sense. Instead, `sensorsd` runs a single command upon crossing any threshold or upon any state change, including when it starts up and the state of an individual sensor goes from "unknown" to whatever it starts at.

Consider this *sensorsd.conf* entry:

```
temp:high=80C:command=/sbin/reboot
```

At first glance, this reads "If the temperature is high, reboot the machine." You think that will unquestionably kill whatever runaway process is saturating your heat-generating CPU (completely setting aside the fact that other hardware besides CPUs generate heat), but `sensorsd` will run the command whenever the temperature state changes. The state changes at boot time, when the first temperature reading is taken, which means that your system will boot, and then immediately reboot. Your script needs intelligence.

To make scripting easier, `sensorsd` has a set of variables it can pass to a script:

**`%1`** Is the value within the limit set in *sensorsd.conf*? This can be one of `below`, `above`, `within`, `invalid`, or `uninitialized`.

**`%n`** Sensor number.

**`%s`** Sensor status.

**`%x`** Which device the sensor sits on.

**`%t`** Sensor type.

**`%2`** Sensor's current value.

**`%3`** Sensor's low limit

**`%4`** Sensor's high limit.

You might run a temperature command like this:

```
temp:high=80C:command=/usr/local/script/temp %1 %2 %n
```

Your script */usr/local/script/temp* would take three arguments: the error condition, the temperature, and the sensor name. Your script would check these values and see if a reboot is warranted.

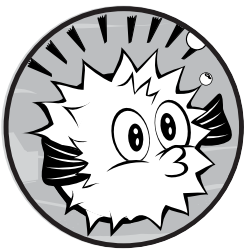
With `sensorsd`, proper timekeeping, and log file management, your OpenBSD system can largely look after itself.

In the next chapter, we'll look at how OpenBSD can take care of other hosts.

# 16

# NETWORK SERVERS

*Working behind scenes,*
*taking care of vital things,*
*the daemon is here.*



The OpenBSD base system includes several servers to support a network. This chapter covers the following network servers:

- Small-server handler `inetd`
- Printer daemon `lpd`
- DHCP daemon `dhcpd`
- TFTP daemon `tftpd`
- SNMP agent `snmpd`
- SSH server `sshd`

This miscellany of small daemons supports the features covered in upcoming chapters.

## The inetd Small-Server Handler

The inetd(8) "super-server" handles incoming network requests for network services that aren't used very often. After all, many systems don't have a steady stream of incoming FTP requests, so why have an FTP daemon running constantly? Instead, inetd listens for incoming network requests, and when an FTP request arrives, it starts the FTP server and feeds it the request. Other common services that frequently (but not always) run through inetd include ident, finger, and TFTP. Many of these services can also run standalone, if the application usage warrants it.

inetd also handles functions so small and rarely used that they're easier to implement within inetd itself, rather than by calling a separate program. These functions include discard (which dumps any data received into the bottomless pit of */dev/null*), chargen (which pours out a stream of characters), and echo (which repeats whatever you send to it). Most of these services are not needed on the modern Internet and are disabled by default, but you have access to them if necessary.

### Configuring inetd

You configure inetd in */etc/inetd.conf*. Here's the default inetd configuration for OpenBSD's FTP server:

```
#❶ftp ❷stream ❸tcp ❹nowait ❺root ❻/usr/libexec/ftpd ❼ftpd -US
#ftp    stream   tcp6  nowait   root   /usr/libexec/ftpd   ftpd -US
```

The first thing you'll notice is that these entries are commented out. OpenBSD's default inetd offers only the identity server identd(8) and two time services by default.

The first field is the service name (ftp in this case) ❶. The name in this field must match a name in */etc/services*. The inetd program uses the *services* file to perform a service lookup to identify which ports it must listen on. To change the TCP/IP port that your FTP server runs on, change the port for FTP in */etc/services*. (You could also change the first field to use the name of the service that usually runs on the desired port, but I find starting my FTP server entry with the wrong name just gives me a headache.)

The second field is the socket type (stream in this case) ❷. This field dictates what sort of connection this is. All TCP connections are of type stream, and UDP connections are of type dgram. The inetd program does support other types of connections, but they're rarely used. If you're considering using them, either you're reading the documentation for a piece of software that needs that type of connection or you're wrong (probably the latter).

The third field is the layer 4 network protocol, usually tcp ❸, udp, tcp6, or udp6. If you want to offer a service over both IPv4 and IPv6, you need a separate entry for each. That's why there are two otherwise identical configurations for the FTP server. The inetd program also supports RPC services, which have type rpc/udp or rpc/tcp.

The fourth field (`nowait` in this case) ❹ indicates whether `inetd` should wait for the server program to close the connection or just start the program and go away. As a general rule, TCP-based daemons use `nowait`, and UDP-based daemons use `wait`. (There are rare exceptions.)

The fifth field (`root` in this case) ❺ names the user that the server daemon runs as. Many `inetd`-using programs must run as root, as they can affect multiple users or accept more specific logins, but some smaller programs have dedicated unprivileged users.

The sixth field is the full path to the server program `inetd` runs when a connection request arrives ❻. Services implemented within `inetd` have a path of `internal`. The FTP server is at */usr/libexec/ftpd*.

Finally, the last field gives the command to start the server program, including any command-line arguments you want. This configuration runs the FTP server with the arguments `-US` ❼.

### Restricting Incoming Connections

Script kiddies occasionally try to knock a server off the Internet by sending it more connection requests than it can handle. The `inetd` program accepts up to 256 connections per minute per service. If a service receives too many connection requests, `inetd` logs the issue and stops answering requests for that service for 10 minutes.

**NOTE** *The IPv4 and IPv6 versions are limited separately, so you could accept 512 FTP connections per second if the requests are evenly divided between protocol families. You can override this globally with a command-line flag when starting* `inetd`*, or you can configure this on a per-service basis.*

The `-R` flag controls how many connections per minute and per service that `inetd` accepts. For example, to accept 1000 requests per minute, you would set the following in */etc/rc.conf.local*:

```
inetd_flags='-R 1000'
```

You can set per-service limits by editing the `wait/nowait` field in the service's *inetd.conf* entry. Add a dot to the `wait` or `nowait` entry, followed by the number of times per minute you want to allow the service to be called. For example, if you have an FTP server that should be used by only a few of your friends, you could limit the server to 10 requests per minute, as follows:

```
ftp   stream  tcp    nowait.10  root    /usr/libexec/ftpd       ftpd -US
ftp   stream  tcp6   nowait.10  root    /usr/libexec/ftpd       ftpd -US
```

Now, if more than 10 connection requests arrive in one minute, `inetd` stops servicing FTP requests for ten minutes. An attacker could still use this to knock your FTP service offline, but not to knock the entire server offline. At least this way you get to choose your failure mode and when you reach it.

## The lpd Printing Daemon

OpenBSD includes the `lpd(8)` printing daemon common on Unix-like operating systems. The `lpd` daemon has options to support thousands of different printers, but getting the right mix of options to support any one specific printer can be a challenge.

The simplest way to use a printer on OpenBSD is through a PostScript server, and that's the method I'll cover here. Many modern printers, particularly the popular multifunction fax/scanner/printer combinations, support PostScript, and you'll find that every office print server does, too.

Every printer your system knows about needs an entry in */etc/printcap*, the printer capability database. This is another `termcap(5)`-style configuration file. You don't need to know everything about the printer to change settings here. This entry just needs the hostname or IP address of the print server and the print server's name for the printer you want to access. Then use the following template:

```
lp|printername:\
  :sh=:\
  :rm=printservername:\
  :sd=/var/spool/output/printername:\
  :lf=/var/log/lpd-errs:\
  :rp=printername:
```

The first line gives the printer's names. Every printer can have any number of names, separated by the pipe (`|`) symbol. The default printer on a Unix-like system is named `lp`, so be sure that one of the printers has that name attached to it. Another name should be the one used by the print server for this printer (such as `Billing`). (Microsoft print servers frequently share one printer under several different names, and each name prints differently, so be sure to use the name that represents the PostScript facility.)

The other lines list attributes:

- By default, `lpd` precedes each print job with a page giving the job name, number, host, and other identifying information. This used to be important when people paid for printing by the page, but unless you're in an environment with a single, massive printer, this probably wastes paper. The `:sh:=\` entry suppresses this page.
- The `:rm=` attribute gives the hostname or IP address of the print server. You must be able to ping the print server by this name.
- Printing works best if each printer has a unique spool directory, given by the `:sd=` attribute. The printer daemon stores documents en route to the print server here. This directory must be owned by the user root and the group daemon.
- Several printers can share a common log file, shown by the `:lf=` attribute.
- Finally, specify the remote printer name with the `:rp=` attribute. This last attribute is the only one that doesn't end with a backslash.

Always end */etc/printcap* with a newline. I usually use an entire blank line, just to be certain.

Now that you have a printer configuration, you start `lpd` at boot with this *rc.conf.local* entry:

```
lpd_flags=""
```

Restart `lpd` with `/etc/rc.d/lpd restart` any time you edit */etc/printcap*.

Finally, view the print queue with `lpq(1)`, and watch */var/log/lpd-errs* for problems.

## The DHCP Server dhcpd

DHCP is the standard method for dynamically configuring clients on an IP network. You might know DHCP as a way to give computers basic IP information, but it can also hand out configuration files for embedded devices such as routers and phones, point diskless machines to their kernel and userland, and much more.

OpenBSD includes a heavily modified ISC DHCP server, `dhcpd(8)`. Here, we'll cover the basics of using `dhcpd` for configuring dynamic clients in a shared Ethernet system. In Chapter 23, we'll discuss the details of using DHCP to configure diskless workstations.

### How DHCP Works

A client seeking DHCP information broadcasts a request across the local network asking for someone—*anyone*—to give it a network configuration. If your DHCP server is on that Ethernet segment, it answers directly. If it's on another network segment, the router for that network segment can forward the DHCP request to your server, which will then offer a configuration to the client, maintaining a list of which clients have been assigned which unique configuration values (such as IP addresses). A configuration issued to a client is called a *lease*. Like all leases, DHCP leases expire and must be renewed in order to be valid.

Clients can request certain DHCP features to support their operations. For example, Microsoft clients request the IP addresses of the network Windows Internet Name Service (WINS) servers, Voice over IP (VoIP) desktop phones request their configuration file, and diskless systems (discussed in Chapter 23) ask where to find their kernel and userland. The DHCP server can offer this information, or not.

The DHCP server uniquely identifies each client by the MAC address of the network card it uses to connect to the network. To find out what information a client received from the DHCP server, get the client's MAC address and search for it in the */var/db/dhcpd.lease* file.

### Configuring dhcpd(8)

Configure `dhcpd` in */etc/dhcpd.conf*. The default *dhcpd.conf* file includes a sample configuration suitable for a small office environment, as well as a diskless client sample configuration.

I'm going to assume that you're running a single DHCP server on your network, and that this server is authoritative for DHCP services. (OpenBSD's DHCP server also supports clustering for fault tolerance.)

Before configuring `dhcpd` to configure clients dynamically, you'll need a few facts about your network:

- Domain name
- DNS servers
- IP network and netmask
- Range of IP addresses in the network used for DHCP clients
- Default router

Once you have this information, you can assemble a brief *dhcpd.conf*. Here's an example:

```
❶ option domain-name "blackhelicopters.org";
❷ option domain-name-servers 192.0.2.5 192.0.2.10;

❸ subnet 198.51.100.0 netmask 255.255.255.0 {
❹     option routers 198.51.100.1;
❺     range 198.51.100.51 198.51.100.100;
}
```

All hosts that get their configuration from this host are told that their domain name is *blackhelicopters.org* ❶, and that they should use the name servers 192.0.2.5 and 192.0.2.10 ❷. The client can be configured to ignore or override this DHCP configuration, but you can't prevent local sysadmins from hanging themselves.

Each subnet needs its own configuration. Even if you have only one subnet, you must still have a `subnet` statement defining the IP network for that subnet so that `dhcpd` can determine which clients get which configuration. This example defines the configuration for clients on the network at 198.51.100.0/24 ❸. Everything inside the brackets that follow applies only to hosts on this subnet.

The `routers` option at ❹ identifies the default gateway for this network. Because the `dhcpd` server won't let you define additional static routes to feed to clients, your local network router must have proper routes to reach the destination. If you have multiple gateways on your local network, your default router should send an ICMP redirect to the DHCP client to correct its routing. (You don't unilaterally block ICMP from your firewalls, do you?)

The `range` keyword gives the IP addresses that the DHCP server can assign to clients. In this example, the DHCP server controls the addresses 198.51.100.51 to 198.51.100.100, inclusive ❺. If 52 dynamic clients connect simultaneously, the last client won't get an address.

This configuration should get your clients on the network.

### Static IP Address Assignments

You can tell your DHCP server to assign a specific address to specific hosts by specifying the Ethernet address of the client in the configuration and using a stanza within the `subnet` statement. Here's the earlier DHCP configuration with a static entry added:

```
subnet 198.51.100.0 netmask 255.255.255.0 {
    option routers 198.51.100.1;
    host lucas-desktop {
        hardware ethernet 00:cf:01:b1:9b:07;
        fixed-address 192.0.2.254;
    }
}
```

I've found the MAC address of my workstation, and used it to assign a static IP address to that machine. This client machine inherits the default router from the subnet definition, as well as any default DHCP information.

### Enabling dhcpd

Enable `dhcpd` in *rc.conf.local*.

```
dhcpd_flags=""
```

If you have only one network-facing interface, `dhcpd` will automatically listen for DHCP requests on that interface. If you have multiple interfaces, give the interface name as an argument. For example, here's how to tell `dhcpd` to listen for requests only on the interface `fxp1`:

```
dhcpd_flags="fxp1"
```

The interface name must be the last `dhcpd` argument in *rc.conf.local*. If `dhcpd` needs to handle several interfaces, the list of interfaces must come after any other arguments in `dhcpd_flags`.

### dhcpd and Firewalls

The OpenBSD packet filtering system includes *tables*, which are lists of IP addresses that the packet filter applies rules to. Traffic from IP addresses in tables can be blocked, have its bandwidth throttled or prioritized, or be allowed to pass. Each table has a unique name.

The `dhcpd` server can add addresses to packet filter tables, thereby dynamically changing the firewall rules depending on whether an IP address is leased. Here, we'll look at configuring `dhcpd` to give addresses to the packet filter tables. Chapter 21 discusses how to configure the packet filter to handle addresses from `dhcpd`.

DHCP considers IP addresses in its address pool to be in one of three states: leased, abandoned, or changed. *Leased* addresses are addresses

assigned to a host attached to the network. Use `-L` to give `dhcpd` the name of the packet filter table for leased addresses, and then configure the packet filter to allow or deny those addresses access to the rest of the network.

*Abandoned* addresses are ones that have been assigned to a host, but that are not currently in use. In practice, that means that if you shut down your laptop, the DHCP server will consider the IP address assigned to it abandoned. The problem with that is that unauthorized users might try to get on the network by taking an unused address from the address pool, without going through the DHCP server. To address this problem, give the packet filter the list of addresses not in use, and give illicit network hosts their own special packet filter rules. Use the `-A` argument to tell `dhcpd` the name of the packet filter table for abandoned addresses.

If a host changes its address despite the DHCP server's configuration instructions, the DHCP server considers the address *changed*, and `dhcpd` can add its new address to the changed address table. Use the `-C` argument to tell `dhcpd` the name of the changed address table. (In Chapter 21, we'll do something interesting with these tables.)

```
dhcpd_enable="-A table1 -L table2 -C table3 fxp1"
```

**NOTE** *Static IP address assignments do not go into tables. If you assign a static address to a host, you must manually configure firewall rules for that address.*

## The TFTP Daemon tftpd

The Trivial File Transfer Protocol (TFTP) is used to transfer files across a network. Unlike FTP, TFTP doesn't include authentication. Anyone who can access the TFTP server can upload or download files from it.

TFTP is an inflexible protocol. It doesn't work through network address translation without a proxy or some kind of intelligence within the translation device, and there's no interactive session as there is with FTP and SFTP. TFTP is most commonly used to copy configuration files and operating system images for embedded devices such as routers.

OpenBSD uses TFTP to bootstrap diskless systems, as discussed in Chapter 23.

### Specifying a tftpd Directory

OpenBSD's `tftpd(8)` serves files from a directory, much like a web server. Traditionally, this directory is */tftpboot*, but don't follow tradition in this case (you don't want a TFTP user filling your server's root partition!). If you use */tftpboot* on your root partition, make sure that your TFTP clients can't write to the directory. (You could create a */tftpboot* partition.) Normally, I create */var/tftpboot* and tell `tftpd` to use that as its root directory. If your fingers are used to typing `/tftpboot`, create a symlink.

To enable `tftpd`, set `tftpd_flags` in *rc.conf.local* to the TFTP root directory.

```
tftpd_flags="/var/tftpboot"
```

`tftpd` chroots to the directory you specify, so `tftpd` cannot access files outside this directory.

### tftpd and Files

TFTP uses file permissions as an access control method. Because all files on the TFTP server can be read by anyone who can access the server port, TFTP will let clients read files in its root directory only if they are world-readable. To make them world-readable, do this:

```
# chmod +r /var/tftpboot/filename
```

Similarly, `tftpd` will not allow anyone to upload a file unless a file of that name already exists and is world-writable. This means that anyone who knows a file's name can overwrite it, so make vital files read-only. If an attacker can't write files, he can't fill your hard drive.

To create files via TFTP, so that you can upload files that don't already exist, run `tftpd` with the `-c` option.

`tftpd` starts as root in order to bind UDP port 69, but it then drops privileges and runs as the unprivileged user `_tftpd`. Any files `tftpd` created will be owned by its user. As a general rule, the files in the TFTP root directory should not be owned by `_tftpd` , in order to make sure that the server cannot affect the files it serves.

### tftpd Logging

You should log your TFTP transfers. Use the `-v` flag to send the transaction log to `syslogd`.

```
tftpd_flags="-v /var/tftpboot"
```

`tftpd` logs uses the FTP facility to log messages to */var/log/daemon*.

### Testing the TFTP Server

Use `tftp(1)` to test your TFTP server.

```
$ tftp caddis
tftp> get testboot.iso
Received 20879569 bytes in 10.4 seconds
```

You won't see any friendly hash marks as you download the file, and you can't change to another directory or list the contents of the TFTP server. Once the test is complete, use `quit` to end your TFTP session.

After you have a TFTP client and server set up, you'll be ready to serve diskless OpenBSD machines, router operating system images, or anything else you need.

## The SNMP Agent snmpd

SNMP is the de facto standard for gathering information from network devices. Many different devices from many different vendors support SNMP as a management protocol.

OpenBSD includes an SNMP agent, `snmpd(8)`, which supports all of the usual SNMP functions, and also offers visibility into OpenBSD-specific features such as packet filtering.

SNMP works according to the standard client/server model. The SNMP client (usually a server performing network management or monitoring) queries the SNMP server (or *agent*) running on a network device. The SNMP agent, `snmpd`, gathers information from the local system and returns it to the client.

In traditional SNMP, an SNMP client with the correct privileges can also request that the SNMP agent modify its device. Most Unix-like operating systems are designed to be configured at the command line and generally don't accept write requests from SNMP. OpenBSD follows this trend, and we will focus specifically on read-only SNMP.

In addition to having an SNMP agent answer requests from an SNMP client, the agent can transmit SNMP traps to a *trap receiver* somewhere on the network. SNMP traps are much like `syslogd(8)` messages, except that they follow a specific format required by SNMP.

**NOTE** *OpenBSD does not include an SNMP trap receiver. If you need one, check out `snmptrapd` in the `net-snmp` package.*

### SNMP MIBs

SNMP manages information via a Management Information Base (MIB), which is a tree-like structure that contains hierarchical information in ASN.1 format. Each SNMP agent has a list of information it can extract from the local system, arranged in a hierarchical SNMP MIB with very general main categories, such as network, physical, programs, and so on.

Think of the MIB tree as a well-organized filing cabinet, where individual drawers hold specific information, and files within drawers hold particular facts. Similarly, the uppermost MIB contains a list of MIBs beneath it.

#### MIB References

MIBs can be referred to by name or number. For example, here's a MIB pulled from an OpenBSD test machine:

```
interfaces.ifTable.ifEntry.ifDescr.1 = STRING: "em0"
```

The first term in this MIB, `interfaces`, tells us that we're looking at this machine's network interfaces. If this machine had no interfaces, this category would not even exist (although an OpenBSD machine will always

have at least a loopback interface). The `ifTable` is the *interface table*, which is a list of all network interfaces on the system. The field `ifEntry` shows one particular entry, and `ifDescr` means that we're looking at a description of this interface. This MIB could be expressed as "Interface number 1 on this machine is called `em0`."

MIBs can also be expressed as numbers, and most SNMP clients do their work natively in numerical MIBs. Your management tool should be able to translate between numbers and names, but just so you're not terribly surprised, here's the earlier example in numerical form:

```
.1.3.6.1.2.1.2.2.1.2.1 = STRING: "em0"
```

Expressed in words, this MIB has five parts separated by dots. Expressed in numbers, the MIB has 11 parts. Aren't they supposed to be the same thing? Well, the numerical MIB is longer because it includes the default address .1.3.6.1.2.1, which translates to *.iso.org.dod.internet.mgmt.mib-2*, the standard subset of MIBs used on the Internet. Most SNMP MIBs start with this string, so the management tools no longer bother printing out this name.

### MIB Definitions

OpenBSD supports two groups of MIBs:

- The standard host MIBs, which every network management system understands. This information includes network and disk space utilization, software running on the system, and so on.
- MIBs for OpenBSD-specific functions, such as the packet filter, network failover, bridging, and so on. Most network management systems will not understand the OpenBSD-specific MIBs out of the box, so you'll want to teach your management system about OpenBSD's MIBs.

MIBs are defined according to a very strict syntax documented in MIB files. For example, `snmpd` includes MIB files for the OpenBSD-specific functions in */usr/share/snmp/mibs*. These files are written in plaintext, in the very stilted and formal ASN.1 syntax. While you can read and interpret them with nothing more than your brain, I highly recommend copying them to your network management workstation and using an SNMP client to examine them.

MIB browsers interpret MIB files and present them in their full tree-like splendor, complete with definitions of each part of the tree and descriptions of each MIB, taken from the MIB files. Generally speaking, you enter a MIB in the MIB browser, which displays its numerical and word descriptions, and offers the ability to query an SNMP agent for that MIB.

If you don't already have a MIB browser on your OpenBSD workstation, use the `mbrowse` package. If you don't want a graphical interface, use the `net-snmp` package for a full assortment of command-line SNMP client tools, but be prepared to type some long command lines.

### SNMP Security

The most common alternate acronym for SNMP is "Security? Not My Problem!" This is unkind, but true. You should use SNMP only behind firewalls or on trusted networks. If you must use SNMP on the naked Internet, employ packet filtering to keep the public from querying your SNMP service. SNMP agents run on UDP port 161, so allow your management hosts access to that port on only your SNMP hosts.

SNMP provides basic security through *communities*. If you read the SNMP documentation, you'll see all kinds of explanations of why a community is not the same as a password, but as far as a sysadmin is concerned, a community is a password.

Most SNMP agents have two communities by default: `public` (read-only access) and `private` (read-write access). OpenBSD's `snmpd` daemon supports both of these communities by default. One of your first tasks will be to change these community names to something that the whole world doesn't know. Just like passwords, community names should be hard for intruders to guess and easy for you to remember.

As you might expect, there have been various versions of SNMP. Version 1 was the first attempt. Version 2c (SNMPv2c) is the more commonly deployed update. Version 3 (SNMPv3) uses encryption to protect data on the wire, and it includes strong authentication. In practice, few vendors actually use it because it's very complicated. The `snmpd` daemon has partial support for SNMPv3. Here, we'll focus on the completely supported SNMPv2c.

### Configuring snmpd

Configure `snmpd` in */etc/snmpd.conf*. The configuration format is a series of text statements. Defining new community strings overrides the defaults of `public` and `private`.

We start by defining new read-only and read-write community strings, as follows:

```
read-only community hansteen
read-write community henning
```

In general, most `snmpd` configuration statements look like these two. The `snmpd.conf(5)` man page lists all valid *snmpd.conf* configuration statements.

Every SNMP system is expected to list a contact, a description, and a location, as in this example:

```
system contact "mwlucas@michaelwlucas.com"
system description "Web server"
system location "Rack Row 9, Cabinet 6, Under the Meal Replacement Bars"
```

Many network management systems will automatically pull in this information to populate the database. Here, I've defined these values for my system. Make similar entries for your system.

The default *snmpd.conf* listens to only the localhost IP address, 127.0.0.1, so outside hosts cannot contact the SNMP daemon. If you want to listen on all available addresses, comment out the lines, like the following, that specify an address.

```
listen_addr="127.0.0.1"
listen on $listen_addr
```

Alternatively, you can give an interface IP address to have `snmpd` listen to a specific external IP address for those machines with many addresses.

```
listen_addr="192.0.2.5"
```

With this configuration, `snmpd` can provide information about your system. Enable it in */etc/rc.conf.local*.

```
snmpd_flags=""
```

This will start `snmpd` at boot, or you can run */etc/rc.d/snmpd*.

### Debugging snmpd

SNMP can be an annoying protocol to debug. For one, because it's UDP, there's no easy way to test connectivity to the agent. Also, it runs fairly silently, in that it doesn't log queries.

To verify that queries from your network management system are reaching your server, try running `snmpd` in verbose mode and with debugging.

```
# snmpd -vd
startup
snmpe_bind: binding to address 0.0.0.0:161
```

When an SNMP query reaches your server, you should see the server parse the requests. By the same token, `snmpd` is very good about telling you why it can't provide an answer.

```
snmpe_parse: 192.0.2.197: wrong read community
```

Errors, like the following, that arise from requests for a nonexistent MIB are a little more difficult to understand.

```
snmpe_parse: 192.0.2.197: SNMPv1 'henning' context 1 request 1141724535
snmpe_parse: 192.0.2.197: oid iso.org.dod.internet.private.enterprises.2041
snmpe_parse: 192.0.2.197: SNMPv1 'henning' context 0 request 1141724536
snmpe_parse: 192.0.2.197: oid iso.org.dod.internet.private.enterprises.2041
snmpe_parse: 192.0.2.197: invalid varbind element, error index 1
```

Here, the MIB request is trying to find the object identifier (OID) `iso.org.dod.internet.private.enterprises.2041`, but OpenBSD's `snmpd` does not support that. (It does support `2021`, part of the Net-SNMP MIB.) The SNMP client is requesting an invalid MIB.

This example shows a successful request and the MIB that `snmpd` sends in response:

```
snmpe_parse: 192.0.2.197: SNMPv1 'henning' context 1 request 1531862688
snmpe_parse: 192.0.2.197: oid iso.org.dod.internet.private.enterprises.ucDavis
```

By reading the output carefully, you should be able to see why `snmpd` is not answering requests as expected.

## *Getting snmpd Information*

The most important feature of SNMP is that it lets you read statistics from the operating system and/or software. In addition to the usual features supported by SNMP, such as resource utilization and processes, `snmpd` lets you grab OpenBSD-specific system information. You can get information about the packet filter, sensor data, interface memory, and Command Address Redundancy Protocol (CARP). All of this appears under the .1.3.6.1.4.1.30155 MIB, OpenBSD's private (enterprise) MIB tree.

### The PF SNMP MIB

The OpenBSD packet filtering feature keeps a lot of statistics, and everything I've ever wanted is available through the PF MIB. You'll find information such as the following:

- Whether PF is on, and how long has it been running (in hundredths of a second)
- The number of packets that have matched filter rules
- The number of fragments and reassembled packets
- The number of packets dropped because of memory problems, internal packet-filtering problems, overfilling the state tables, and so on
- The number of states added and removed from the state table
- The number of timeouts of various protocols
- The amount of traffic blocked on each interface
- Packet filtering table usage, number of addresses in each table

And there's more. The PF SNMP MIB gives you more useful visibility into packet filtering. Point your MIB browser at the .1.3.6.1.4.1.30155.1 MIB to see everything.

### Sensors

You can view the same kernel values processed by `sensorsd(8)` (see Chapter 15) via `snmpd`, including a list of sensors on this device, the value reported by the sensor, and whether each sensor is in an alarm state. This means you can use `snmpd` instead of `sensorsd` to monitor your hardware.

To view sensor data via SNMP, examine the MIB tree .1.3.6.1.4.1.30155.2.

### Interface Memory

You can view the amount of memory used by an interface, and how often (if ever) an interface was starved for memory as a result of system load. View the MIB tree .1.3.6.1.4.1.30155.5 to see these values.

### CARP

CARP is an OpenBSD invention for sharing one address between two or more machines. It was designed to provide highly available IP services. The `snmpd` daemon exposes CARP's innards, including these items:

- The name of each CARP interface
- CARP configuration values (preemption, `advskew`, and so on)
- The number of IPv4 and IPv6 packets received
- The number of packets discarded for various reasons
- The number of times the host has become master

To see the CARP MIB tree, view .1.3.6.1.4.1.30155.6.

### Other MIBs

The `snmpd` daemon is constantly being expanded. According to the MIB files, they've reserved space for IPsec and `relayd(8)`. Check */usr/share/snmp/mibs* for additional MIB files, and use your MIB browser to see what your specific version of OpenBSD supports. The OpenBSD team adds MIBs as they're needed and as code is contributed. If you need IPsec MIBs, feel free to write and submit the code.

## The SSH Server sshd

Secure Shell (SSH) is a protocol for building encrypted tunnels between hosts. SSH is most commonly used for remote command-line access to a system, but you can use it as a generic wrapper around other protocols or even to build virtual private networks. One common use for SSH is to support secure file transfer protocol service, or SFTP, which doesn't give you a shell prompt but does encrypt files and authentication information as they cross the network.

The OpenBSD project supports OpenSSH, a freely licensed client and server. OpenSSH is the most widely deployed SSH server in the world, with roughly 97 percent market share, and is generally considered the standard SSH server. Entire books have been written about OpenSSH, including mine (*SSH Mastery,* Tilted Windmill Press, 2012).

OpenBSD includes the OpenSSH server `sshd(8)`, the OpenSSH command-line client `ssh(1)`, and the SFTP client `sftp(1)`. We'll focus on `sshd` here, since you can use any number of SSH clients. The ones I use most commonly are `ssh` (for Unix-like systems) and PuTTY (for Windows). For SFTP, I commonly use `sftp` (for Unix-like systems) and WinSCP (for Windows).

### Disabling sshd

Unless you specified otherwise during installation, OpenBSD starts `sshd` by default. If you don't want `sshd` to run, disable it in */etc/rc.conf.local*.

```
sshd_flags=NO
```

### SSH Host Keys

The first time you start `sshd`, OpenBSD creates *host keys* in */etc/ssh*. These are sets of public and private keys that uniquely identify an SSH server. Each key file includes the word *key* in its name. When your client first connects to the SSH server, it presents a fingerprint summary of the server's host key. If you tell the client to accept the key, the client will cache the server's host key. If this key ever changes, the client warns the user that the server's unique identity has changed, and that the user might be offering his login credentials to a different server. (Anyone who gets copies of the host keys can have another server masquerade as yours.) Be sure to back up your host keys, and protect them from theft.

### sshd Network Options

You could change `sshd`'s behavior by adding command-line flags, but the most common way to reconfigure `sshd` is to edit the files in */etc/ssh*.

OpenSSH has many configuration options. The ones that are most commonly changed involve the network settings. You can control the port, IP address, and version of IP `sshd` listens to by editing the configuration file */etc/ssh/sshd_config*. Here's an example:

```
Port 22
AddressFamily any
ListenAddress 0.0.0.0
ListenAddress ::
```

The `Port` keyword specifies the TCP/IP port that `sshd` attaches to. The default is TCP port 22.

**NOTE** *Some people recommend using a port other than 22 to avoid password-guessing worms. Far better ways to protect your SSH server are to allow only public-key authentication or use a packet filter to allow logins from only selected hosts or networks.*

The `AddressFamily` keyword specifies the version of IP that `sshd` uses. The default is to use both IPv4 and IPv6, but you can restrict it to a specific protocol with the `inet` (IPv4) or `inet6` (IPv6) keyword.

Lastly, you can attach `sshd` to a specific IP address with the `ListenAddress` option.

### *chrooting Users*

Organizations commonly need to confine users to a particular directory or subset of directories. For example, many websites allow users command-line access over SSH so that they can edit their files and debug problems more easily, or even just SFTP access to their files. Those users should have access to their own directories, but not to other users' files, or any other part of the system. One solution is to `chroot` the user in his home directory. If you have several users who need to access a shared directory, you can `chroot` all of them in that directory.

Locking users in a directory involves three steps: choosing the directory to lock users into, populating that directory, and configuring `sshd` to `chroot` those users. To demonstrate, we'll walk through an example of `chroot`ing the user `lasnyder` in his home directory, and give him command-line access, so he will be able to access only the programs in his `chroot`.

#### Choosing the Directory

First, specify the `chroot` directory with the `ChrootDirectory` option.

```
ChrootDirectory /home/lasnyder
```

This works well if all of your users need to be locked into the same directory, but if you want users to have their own private directory, or if you want to specify a directory elsewhere on the filesystem, things get more complex.

OpenSSH supports the `%%`, `%h`, and `%u` macros to represent home directories. If your `chroot` directory includes a literal `%`, use the `%%` macro to represent it. The server in this example has home directories on */disk%3/home*, so the `%%` macro is needed to escape the percent sign.

```
ChrootDirectory /disk%%3/home/lasnyder
```

The %u macro expands to the user's username. You could use this to give users a chroot some place other than their home directory (though I don't know why you wouldn't just give them a home directory in the desired location). Here, each user has a directory under */var/www*:

```
ChrootDirectory /var/www/%u
```

Finally, you could lock each user in his home directory with the %h macro.

```
ChrootDirectory %h
```

Wherever you lock a user, you must give that directory everything the user needs to function, since the user won't be able to leave that directory to get a tool that he might need.

### Populating the chroot

Most programs, such as a shell, require at least a few device nodes, and the user must have a shell program to be able to run one. If a user has only SFTP access, you don't need to do any special preparation of the chroot. OpenSSH's SFTP server includes everything it needs. But if users have shell access, they need basic device nodes and a shell program.

For our example, to give lasnyder what he needs, go to the chroot directory, create a *dev* directory, and then make the standard device nodes using /dev/MAKEDEV. You can remove the console, klog, kmem, ksyms, mem, and xf86 devices.

```
# cd /home/lasnyder
# /dev/MAKEDEV std
# rm console klog kmem ksyms mem xf86
```

Now we need to get the user a shell. Since programs running inside the shell cannot access any files outside the chroot, including shared libraries, any shell copied into a chroot must be statically linked. The included system shells are statically linked, and most shells in the ports tree can be built in static flavors.

Verify that a shell is statically linked with file(1), and then create a *bin* directory inside the chroot and copy the shell there.

```
# file /bin/ksh
/bin/ksh: ELF 32-bit LSB executable, Intel 80386, version 1, for OpenBSD, statically linked, stripped
# cd /home/lasnyder
# mkdir bin
# cd bin
# cp /bin/ksh .
```

Lastly, although a chrooted user should not have write access to his own root directory, he needs a real home directory. The user's home directory in */etc/passwd* is relative to the chroot; in other words, if a user's home directory

in */etc/passwd* is */home/lasnyder*, and the user is chrooted to */home/lasnyder*, his personal files and dotfiles actually go in */home/lasnyder/home/lasnyder*.

```
# chown root:wheel /home/lasnyder
# mkdir -p /home/lasnyder/home/lasnyder
# chown lasnyder:lasnyder /home/lasnyder/home/lasnyder
```

The user now has a command-line friendly jail cell on the system. Now we need to tell sshd to lock the user in it.

### chrooting Specific Users

Applying this chroot strategy to all of your users probably isn't advisable—if nothing else, your sysadmins need unfettered system access to perform maintenance.

To tell sshd to chroot specific users, either by name or by group, use the Match keyword at the end of *sshd_config*. Match lets you change sshd's default behavior based on factors such as user and client IP address. (Match has many more functions; see sshd_config(5) for examples.)

For example, if you wanted to chroot only the user lasnyder, you could use Match to specify his username. Early in the configuration, you would have a ChrootDirectory statement that turns off chroot for most users. Then, at the end of the configuration, you would change the setting based on matching that username.

```
...
ChrootDirectory none
...
Match User lasnyder
      ChrootDirectory %h
```

You could also chroot all users in a group.

```
...
ChrootDirectory none
...
Match Group webcustomers
      ChrootDirectory %h
```

If you have multiple Match terms, separate them with commas.

```
...
ChrootDirectory none
...
Match User lasnyder, jgballard, pkdick
      ChrootDirectory %h
```

Or, if most of your users are chrooted, reverse the default and specifically dechroot your sysadmins.

```
...
ChrootDirectory %h
...
Match Group wheel
      ChrootDirectory none
```

With careful configuration, you can restrict access to only the desired users.

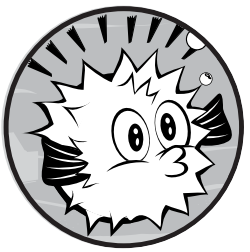
SSH can do a whole lot more, such as securely eliminate passwords from your network. It's worth your time to fully master this protocol.

OpenBSD's built-in services can help you hold your network together, and they provide all kinds of useful support infrastructure. Now that you know how to configure some of these built-in programs, let's see how to use OpenBSD as a desktop.

# 17

# DESKTOP OPENBSD

*Spend summer days with*
*blowfish at your fingertips:*
*no passwords stolen!*



OpenBSD is best known as a server operating system, but it can be a very effective and powerful desktop system. The X Window System is the standard graphic desktop software for Unix-like operating systems, and OpenBSD includes tools for using it. As this book assumes that you have some Unix experience, I won't cover all the applications that make X Windows comfortable. You'll need to experiment to find your preferred mail client, web browser, and text editors—most of which aren't OpenBSD-specific. Instead, this chapter covers items that are unique to OpenBSD, originated with OpenBSD, or require specific configuration.

OpenBSD includes the Xenocara framework for modifying and building X.Org in a manner tightly integrated with OpenBSD. We'll discuss making OpenBSD boot into a graphical desktop using the `cwm` desktop environment, as well as a text console using the `tmux` terminal multiplexer. But we'll start by customizing the console.

## Configuring Your Console with wscons

The `wscons(4)` hardware-independent console driver lets you configure your boring, black-and-white, nongraphical console in many ways.

Start by viewing the current console settings using `wsconsctl(8)`. Run the following on a text console, not in an X session (changes made in `wscons` can carry over to an X session, but once you start X, you're mostly stuck with X's configuration system).

```
$ wsconsctl
keyboard.type=pc-xt
keyboard.bell.pitch=400
keyboard.bell.period=100
keyboard.bell.volume=50
...
```

Each line contains a system variable and a setting, many of which you can change. The `keyboard.type` variable represents the type of keyboard on the system. Because this is an amd64 system, it uses the `pc-xt` keyboard common to consumer computers, but you'll see different keyboard types with different hardware.

You can also change these settings with `wsconsctl`. For example, in the previous listing, the variable `keyboard.bell.volume` sets the volume of the computer's beep. Now, I'm a `tcsh` user, and I frequently use tab completion (type a character or two, press TAB, and the shell fills in the name of the command or file you're about to type). Unfortunately, when tab completion hits an ambiguous spot, it stops. That's not a problem when I'm logged in over SSH, because I can just type a character or two and press TAB again. But when I'm on the local console, each ambiguity is accompanied by a beep (or bell) from the computer. When I'm trying to fix a problem, and the bell rings, shouting "*beep* WRONG! *beep* WRONG! *beep* WRONG!" I have only one thought:

The beep must die.

```
$ wsconsctl keyboard.bell.volume=0
keyboard.bell.volume=0
```

Now silence reigns and I can resolve the problem without the computer nagging me. (You could choose to turn up the volume, if you're a masochist. I won't judge you—at least not in public.)

Here, we'll look at a couple other things you can do with `wscons`.

### Screen Blanking

If you leave the system alone for a few minutes, the screen should go blank to reduce power usage. Modern monitors often do this on their own, but

you can also configure this behavior in the operating system, especially for older platforms. OpenBSD turns off the display only once it knows how to reactivate the display.

You have three choices:

**`display.kbdact`** Wake on keyboard activity

**`display.msact`** Wake on mouse activity

**`display.outact`** Wake on monitor output

Set one of these `wscons` variables to `on`, and OpenBSD will realize it should start blanking the monitor after the idle timeout. The variable `display.screen_off` gives the idle timeout in milliseconds; the default, `600000`, is 10 minutes.

You can also choose between turning the screen black and putting the monitor into "power-saver" mode, also known as *sleep*. A monitor showing a black screen reactivates immediately when triggered, but uses more power. A sleeping monitor really is off, and needs a few seconds to reactivate. To set power-saver mode, change the variable `display.vblank` to `on`. (Some old monitors don't believe in saving power, so this won't work on them.)

### *Setting wscons Variables at Boot*

Users can adjust console settings, but those settings will disappear at the next reboot. To set `wscons` variables at boot, add them to */etc/wsconsctl.conf*. The boot process reads this file and applies any variables it finds to the console.

## Running Virtual Terminals with tmux

The terminal multiplexer `tmux(1)` lets you run multiple virtual terminals inside one OpenBSD terminal window. While standard virtual terminals disappear when you disconnect from the system, `tmux` virtual terminals continue to run even after you disconnect. `tmux` is small, fast, easy to use, and written with the same care as the rest of OpenBSD.

Why would you need `tmux`? One example is for building programs. Just before I leave the office, I use my laptop to make an SSH connection into an OpenBSD server, create a virtual terminal, start building a huge program (such as OpenOffice.org), and shut down my laptop. Normally, the build on the server would terminate when my session is interrupted, but the `tmux` virtual terminal continues to run even when I log out. The build continues in the disconnected virtual terminal while I drive home, and when I reconnect to it later, I can see how the build has progressed. Virtual terminal sessions even survive accidental disconnections caused by network or client failures.

This section provides an introduction to `tmux`. For complete details on the features discussed here, as well as dozens of other features, read `tmux(1)`.

### The tmux Status Bar and Window Names

To start a virtual terminal session, run `tmux`. Your terminal window will show the command prompt and a green `tmux` status bar along the bottom, with information like the following:

```
[0] 0:ksh*        "caddis.blackhelicop" 11:55  26-Jun-13
```

This is a virtual terminal session. The left side of the status bar displays the `tmux` session number in brackets `[0]` and the list of `tmux` windows `0:ksh*` (beginning with window number 0). The right side shows the first part of your machine name (`caddis.blackhelicopters.org`), followed by the time and date. You'll learn how to customize things in "Setting tmux Options" and "Configuring tmux" on page 329.

The window name defaults to the name of the program running in that `tmux(1)` window. For example, if you start a command that continues until interrupted, such as `iostat -w 5`, the session name will change to match the command. Interrupt the command, return to a shell prompt, and the status bar should change its name to match your shell.

The status bar is normally green, but if it turns yellow, `tmux` is expecting input. When it's yellow, any typing is interpreted as a `tmux` command. If you reach this mode accidentally, press ENTER to return to a green status bar and normal operation.

### tmux Commands and Window Management

Pressing CTRL-B tells `tmux` that the next command is for `tmux`, not for the program running in the virtual terminal. (If pressing CTRL-B interferes with another program you use frequently, you can change this key combination, as you'll see in "Unmapping and Remapping Keys" on page 336.)

The most commonly used `tmux` commands are single characters. For example, to create a second terminal window in this `tmux` session, press CTRL-B-C. Your screen will display only a command prompt and a new status bar.

```
[0] 0:iostat-  1:ksh*          "caddis.blackhelicopte" 11:58 26-Jun-13
```

You have two windows: window 0 shows `iostat` output, and window 1 displays the `ksh` prompt. The asterisk next to window 1 means that you're currently looking at it. Run an ongoing command in your new window, such as `top`, and the window name should automatically change to the name of that command.

#### Changing the Current Window

To view another window, use one of the following key combinations:

- To see the next window, press CTRL-B-N.
- To switch to the previous window, press CTRL-B-P.

**NOTE** *Keep in mind that window ordering wraps. For example, if you are on the last window and press* CTRL*-B-N, you should see the first window.*

- To jump directly to a window by number, press CTRL-B followed by the window number.
- To open a menu of all windows, press CTRL-B-W, and then select a window with the arrow keys.

I find the next and previous sequences sufficient, but if you end up with a dozen windows in one terminal, you might think otherwise.

#### Renaming Windows

Terminal windows take the name of the currently running program, but that's not always useful. For example, if I'm compiling the newest source with `make build`, the window name will continually change to reflect the command running in the build at that moment. The only problem is that the constant flickering change in my status bar drives me nuts.

If you don't want to see the window name change with each command, use CTRL-B to assign a static name to the window. A yellow `[rename-window]` prompt will appear in the status bar. Enter your preferred window name, such as `upgrade`, and then press ENTER.

#### Terminating Windows

To kill a window and end any processes running in it, change to that window and press CTRL-B-&. You will get a confirmation prompt.

### Getting Online Help

Press CTRL-B-? to see a complete list of all `tmux` commands.

```
   C-b: send-prefix
   C-o: rotate-window
   C-z: suspend-client
  Space: next-layout
    !: break-pane
    ": split-window
    #: list-buffers
...
```

Now you can easily explore `tmux` without reading the manual page. You'll use this list to remap keys in "Unmapping and Remapping Keys" on page 336.

### Disconnecting, Reconnecting, and Managing Sessions

A collection of `tmux` windows is called a *session*. Conveniently, `tmux` can disconnect from a running session without interrupting its windows. Press

CTRL-B-D to disconnect your terminal from the current tmux session. Your terminal should now show what it held before starting tmux. To reconnect to your tmux session, run tmux attach.

You can have multiple tmux sessions simultaneously. The session number appears on the far left of the status bar. (In our sample status bars, the tmux session is 0.)

To start a new tmux session without attaching to your previous session, run tmux without any arguments. For example, I type tmux instead of tmux attach in order to spawn a new tmux session when I want to pick up where I left off. You can change your tmux session within tmux itself, using a tmux command, but I usually just end the session and enter the correct command.

If you can have all these tmux sessions, how can you be sure that you haven't left old, useless sessions lying around, with abandoned commands running in them? Use tmux list-sessions.

```
$ tmux list-sessions
0: 4 windows (created Sun Feb 13 12:17:14 2011) [80x23]
2: 1 windows (created Mon Feb 21 21:57:59 2011) [131x36] (attached)
```

I can see from the last line of this output that I left session 2 running on my other workstation, and am still attached to it.

To connect to session 2, use attach-session and option -t to choose a target session. Here, I attach to tmux session 2:

```
$ tmux attach-session -t 2
```

I'm now connected to the same session from two separate SSH sessions—in this case, from two separate client workstations. My typing in one screen is echoed on the other.

To destroy a session, use the kill-session command, specifying the session number with -t. Here, I kill tmux session 2:

```
$ tmux kill-session -t 2
```

Any programs running in windows in tmux session 2 will also be killed.

### Using tmux Commands

Command mode in tmux offers a prompt for entering more complicated commands. To enter command mode, press CTRL-B-:. The status bar will turn yellow, and a single colon replaces all window names. For example, to create a new window dedicated to running systat(1), press CTRL-B-: and enter **neww systat**. A window named systat will appear. Switch to that window, and then press CTRL-C to stop systat. That window will disappear.

You can do all sorts of things with tmux commands, including split windows into multiple panels, copy and paste text, and so on. (Read tmux(1) for the full list.) If you want to cut and paste from one window to another,

it's easiest if you use multiple terminal windows, but if you are working in a text-only console or another restricted environment, you might find these tmux features useful.

The tmux command mode is most commonly used to set options.

### Setting tmux Options

Options change how tmux windows, sessions, and the tmux server itself behave. The most common changes involve the appearance of windows, colors, or items displayed in the status bar. Some options affect the entire tmux session; others affect only a specific window. You can change options on the fly with the tmux command set-option.

Go ahead and open a tmux session to follow along. Press CTRL-B-: to enter command mode. When the colon appears, enter **set-option status-fg green**, and then press ENTER. Your status bar should now be solid green bar. Congratulations! You've set the status bar text color identical to the background color, making it unreadable. Return to command mode, and change the color to black to make it readable again. (If this bugs you, you can kill this tmux session and start a new one to reset all options.)

When making changes, use **set-option** (or just set) for options that affect the tmux server and the entire session. Use **set-window-option** (abbreviated setw) for options that affect only a single window.

Most people won't need many (if any) tmux options, but they can prove useful. For example, say you want the status bar clock to display time in 24-hour format, or you want a visual bell instead of a beep. Options let you control these behaviors, as well as run commands in the status bar. To change basic tmux appearance and behavior, see the options in tmux(1).

Be sure to try any interesting options interactively. Once you have a tmux session running the way you like, enter **show-options** for an accurate list of the current options. Copy that list because we'll use it to build a configuration file.

### Configuring tmux

Modify *$HOME/.tmux.conf* in your home directory to configure your tmux sessions, or use */etc/tmux.conf* to inflict your tmux preferences on every system user. Personal tmux configurations override global settings.

As a simple example, I've set the left side of my status bar (containing the session number) to blue, and the right side (the hostname, time, and date) to red. If I decide I like this, I can make this change permanent by entering the following in *tmux.conf*:

```
set -g status-left-bg blue
set -g status-right-bg red
```

The -g flag sets an option globally, so it takes effect for all sessions and windows.

This should get you comfortable with using tmux. If you need multiple terminal windows simultaneously, use a graphical desktop. Stay tuned.

## Setting Up X

The OpenBSD developers modified the industry-standard X graphic interface provided by X.Org to better fit with OpenBSD. The combination of X.Org and OpenBSD-specific patches is called Xenocara.

In most cases, Xenocara works exactly like X.Org, and X.Org documentation is applicable to OpenBSD. Most of Xenocara is there for security and for the convenience of developers building X, but there are a few additions. In my opinion, OpenBSD's best enhancement to X.Org is the `cwm(1)` window manager. Here, we'll cover configuring and starting X. The next section provides details about using the window manager.

### *Configuring X*

Configuring X can be simple or agonizing, depending on your hardware.

Most video cards require special access to system memory, though some new Intel video cards can work without this access. For other cards, you must adjust the `machdep.allowaperture=2` sysctl in */etc/sysctl.conf* and reboot.

Most amd64 and i386 systems need `machdep.allowaperture` set to `2`, but other platforms might require `1` or `2`. Without this sysctl setting, the kernel will not permit X to communicate with the graphics card. If you're in doubt, try X without changing the sysctl, and when you find out your hardware is too old or the wrong model to work that way, set it to `2`.

After rebooting, see if X.Org can automatically set up your graphics interface by running `startx`. If it works, you should see the `fvwm(1)` desktop and a very bland gray background with a couple of terminal windows.

**NOTE** *If X doesn't start, see the OpenBSD FAQ, the X.Org documentation, and* /var/log/Xorg.0.log. *Many things can go wrong with X autoconfiguration. Read your error log and search the Internet for solutions.*

Once you know that X works, it's time to decide whether you want to start X manually each time you need it or if you want OpenBSD to boot in to X automatically.

### *Starting X Manually*

After logging into the text console, run `startx(1)`. This command starts the commands in *$HOME/.xinitrc* and starts X.

### *Booting into X*

OpenBSD includes an */etc/rc.conf* hook for starting the X Display Manager, `xdm(1)`, at boot time with a login prompt, but the default is to not use `xdm`. Here's the line to add to your *rc.conf.local* to have `xdm` without any flags start X at boot:

```
xdm_flags=""
```

After booting, the console will show a graphical login prompt. Once a user logs in, xdm runs any commands in *$HOME/.xsession*.

**NOTE** *Because this is a chapter about using OpenBSD as a desktop, I assume that you're using xdm(1). Examples refer to* $HOME/.xsession. *If you use startx(1) instead, substitute* .xinitrc.

### Emulating a Three-Button Mouse

A lot of X software expects you to have a mouse with three or more buttons, but many have only two buttons. Xenocara lets you pretend that you have a third mouse button, and when you press both mouse buttons simultaneously, it interprets that as pressing the nonexistent third button.

Of course, the best solution is to buy a real mouse with three or more buttons. They're much easier to get than they used to be.

Now that you have X ready to use, let's explore that cwm window manager I mentioned earlier.

## Using the cwm Window Manager

While X provides operating system support for a graphical interface, management of that interface falls to the window manager. OpenBSD has packages for button-heavy, pointy-clicky window managers such as KDE, Gnome, and Xfce. These window managers might provide a comfortable bridge between consumer-friendly operating systems and OpenBSD, but they're not designed for the more hard-core Unix user.

Xenocara includes three window managers: the classic fvwm(1) and twm(1) window managers that have shipped with X since the last millennium, and the OpenBSD-specific cwm(1). OpenBSD developers wrote cwm specifically as a modern, fast, keyboard-friendly interface.

To start cwm at login, invoke it in *$HOME/.xsession*:

```
/usr/X11R6/bin/cwm
```

When your cwm session ends, xdm returns you to the login screen.

### Configuring cwm

Rather than using mouse-driven configuration menus, cwm uses a single configuration file, *$HOME/.cwmrc*. You can read the complete documentation in cwmrc(5). Here, as I discuss various cwm features, I'll mention how each can be configured or changed in *.cwmrc*.

#### Modifier Keys

Most cwm operations require you to press a configurable combination of keys. For example, CTRL-ALT-DEL locks the screen. The cwm documentation lists the modifier keys shown in Table 17-1.

**Table 17-1:** cwm Modifier Keys

| Symbol | Key |
|---|---|
| C | CTRL |
| S | SHIFT |
| M | META/ALT |

For example, `CS-r` in *.cwmrc* means CTRL-SHIFT-R. `CM-W` represents CTRL-ALT-W.

### Choosing a New Window Manager

The default `cwm` configuration allows you to choose a new window manager with CTRL-ALT-W from any command on the system. Enter **`cwm`**, and `cwm` should restart without losing any of your windows.

**NOTE** *You can also enter a command that isn't a window manager, such as `grep`. If you do, OpenBSD will silently log you out. It won't say, "Please step away from the keyboard before I hurt you." Not threatening you passes for user-friendly in OpenBSD.*

### Binding a Key Sequence to a Command

You can also bind a key sequence to any `cwm` command listed in `cwmrc(5)`. For example, suppose you want to use the key sequence CTRL-ALT-R to delete your current window. Add the following to *.cwmrc*:

```
bind CM-r                delete
```

The change will take effect only once you use CTRL-ALT-W to restart `cwm` or you log out and back in again. After you've done one or the other, use CTRL-ALT-R to delete the current window.

**WARNING** *If you make an entry in* .cwmrc *that `cwm` cannot parse, `cwm` will not process the configuration file, and you will lose all of your custom `cwm` settings as soon as you load the configuration file. If your custom settings vanish, your most recent changes to* .cwmrc *are wrong. If you make an error that* `cwm` can *parse, `cwm` will accept it. No one except the user will have trouble in this case.*

## Creating cwm Windows

When you are running the graphical desktop, everything on screen is a *window*. A terminal runs in a window, as do web browsers and games. Managing windows—raising, hiding, resizing, naming, and so on—is the core task of a window manager.

A default `cwm` session starts with a plain gray screen and a small `xconsole(1)` window. Create a new terminal window with CTRL-SHIFT-ENTER. The window

manager should focus on whatever window your mouse is over. (Press SHIFT-+ to increase the font size of the terminal windows.)

If you press CTRL-SHIFT-ENTER repeatedly, you won't see additional terminal windows. Oh, the new windows will be created, but on top of one another. Press ALT and the left mouse button to move the currently active window, and you should expose another terminal window beneath that one.

I find the default terminal size too small; I want wider terminals with more rows. To resize the terminal window, press ALT and the center mouse button (or both buttons simultaneously). The mouse will move to the lower-right corner of the window and change to a right angle bracket. The window will continue to resize as long as you hold down the mouse button.

To maximize windows vertically, press CTRL-ALT-=. To maximize windows horizontally, press CTRL-ALT- SHIFT-=. To destroy a window, focus on it and press CTRL-ALT-X. You will not be asked to confirm your decision; `cwm` will obey and exterminate the window immediately.

To exit `cwm` and return to the login screen, press CTRL-ALT-Q.

### Managing Windows

Now that you can create windows, let's look at ways to manage them.

First, switch between visible windows with ALT-TAB. The newly active window should rise to the foreground.

To assign a name to a window, press CTRL-ALT-N to access the label prompt, and then enter the window's desired name. Names are useful when you choose to hide a window without destroying it.

To hide a window, focus on it, and then press ALT-ENTER to make it disappear. Pressing ALT-TAB won't bring it back because it's hidden. Press the left mouse button for a list of all hidden windows, arranged by name. Any windows you didn't name will show up as the program name. All terminals show up as `xterm`. Click the name to unhide the window.

**NOTE** *It's a good idea to name windows that have a specific purpose, such as a long-running software build. That way, you can minimize the window when it's not interesting, and quickly find it again when necessary. I name windows created by SSH sessions after the connected server.*

You can search for windows by name. Press CTRL-ALT-/ to get a `window>>` prompt, and then start typing the name of the window. `cwm` will list all matching windows. Hidden windows have an ampersand (`&`) before their name. Exclamation points indicate the window with focus.

### Locking the Screen

Don't walk away from an active workstation without locking it, especially if you're logged on to sensitive systems or as root. Press CTRL-ALT-DEL to lock your desktop, and the screen will go blank. Press another key, and `cwm` will request your password to unlock the workstation.

The default screensaver is a blank screen, provided with `xlock(1)`. To use a different screensaver, set a path to it in *.cwmrc*, as follows:

```
command lock path-to-command
```

For example, to use `xlock`'s flow mode as a screensaver, add the following to *.cwmrc*:

```
command lock '/usr/X11R6/bin/xlock -mode flow'
```

If you don't like any of the screensavers in Xenocara's `xlock(1)`, try the `xscreensaver` package.

**NOTE** *`xlock` is easily bypassed by anyone with console access. You can't count on it for security, but it does make a decent reminder for your coworkers.*

### Connecting to Other Machines with SSH

One common task is to connect to remote machines with SSH. To do so, press ALT-. to display an `ssh>>` prompt, and then enter the name of the machine to which you want to make the connection. Conveniently, `cwm` supports autocompletion, based on entries in *known_hosts*. As you type a hostname at the `ssh` prompt, `cwm` checks for matching names in the system's and users' *known_hosts*. Press the down-arrow key to find your desired hosts, or keep typing the hostname to connect to a new host. (Autocompletion won't work if you hash *known_hosts* entries.)

And by the way, if you open multiple SSH sessions, name them, because sorting through multiple sessions labeled `ssh` is annoying.

### Creating an Application Menu

Click the right mouse button on the background to bring up the application menu. The `cwm` developers have no idea which programs are important to you, so they don't even try to provide a default application menu. You need to build that yourself with *.cwmrc* entries. Each command has the following format:

```
command name path-to-command
```

Yes, this is exactly the same as the format for setting the screensaver. The `lock` command is actually one of two special command keywords. Here, I've created an application menu with two choices, which are my web browser and my PDF reader:

```
command firefox /usr/local/bin/firefox
command xpdf /usr/local/bin/xpdf
```

When I right-click the desktop background, I'll see a menu with these two choices.

### Using Keyboard Navigation

Almost everyone has a mouse these days, but sometimes you're in a situation where it's best to ignore that mouse. Perhaps your desk is too small, your mouse is broken, repeatedly removing your hands from the keyboard slows you down (as in you don't have a sensible mouse-in-keyboard), or you just hate your mouse today (which is both valid and respectable).

To control the mouse cursor with the keyboard, use CTRL and the arrow keys to move the pointer a small amount, or press CTRL-SHIFT and an arrow key to make larger pointer movements. On my system CTRL-SHIFT-up arrow moves the mouse pointer up about a terminal line, but that varies with font size.

You can also use keyboard commands to shift window placement and size, as shown in Table 17-2.

**Table 17-2:** cwm Window Movement Direction Keys

| Key Combination | Direction |
|---|---|
| ALT-SHIFT–H | Left |
| ALT-SHIFT–J | Down |
| ALT-SHIFT–K | Up |
| ALT-SHIFT–I | Right |

Use ALT and a direction key to move a window a small amount, or ALT-SHIFT to move the window a larger amount. To resize a window by a small amount, use CTRL-ALT and a direction key. CTRL-ALT-SHIFT and a direction key resizes the window a larger amount. Just as if you were resizing with the mouse, the size change occurs from the lower-right corner of the window. Place a window's upper-left corner where you want it, and then resize the window.

### Decorating cwm

The default `cwm` desktop is rather bland, but a few adjustments make it easier on the eyes. One of the first things I set is a background color: black. Use `xsetroot(1)` to set your background color.

```
$ xsetroot -solid black
```

You can include this command in *.xsession* or run it in a terminal. The file */usr/X11R6/share/X11/rgb.txt* lists the colors X recognizes. If a color name is two words, either remove the spaces in the name or put the name in single quotes, like this:

```
$ xsetroot -solid 'hot pink'
```

If you want an image in the background, use `feh` (*/usr/ports/graphics/feh*).

```
$ feh --bg-scale /home/mwlucas/galaxies.jpg
```

To make window edges easier to identify, put borders around them. The default border is 1 pixel wide, in your choice of colors. I prefer 3-pixel borders, blue for the active window and dark blue for the inactive windows. That requires the following entries in *.cwmrc*:

```
borderwidth 3
color activeborder blue
color inactiveborder darkblue
```

As you grow more accustomed to `cwm`, you might find that you want particular applications—perhaps an MP3 player, a clock, and a fancy graphic system load indicator—to always be visible. Maximizing a window can bury these applications. To address this, define a gap in *.cwmrc*, which sets the number of pixels to be kept clear even when you maximize a window.

```
gap top bottom left right
```

For example, when I must keep track of time, I run `xclock(1)` on the right side of my screen. Experimentation has shown that my clock is about 175 pixels wide. I leave a gap of 180 pixels, so that even when I maximize a window, it doesn't cover the clock. Here's my `gap` entry in *.cwmrc*:

```
gap 0 0 0 180
```

Now I can no longer use the excuse that I missed work because I lost my clock on my desktop. Fortunately, I have many other handy excuses.

### Unmapping and Remapping Keys

While the `cwm` authors did their best to choose keyboard shortcuts that wouldn't conflict with those used by other programs, they could not avoid every possible conflict. If you run into such a conflict, you can solve the problem by modifying entries in *.cwmrc* to replace conflicting `cwm` key bindings.

For example, `cwm` uses CTRL and CTRL-SHIFT with the arrow keys to move the pointer, but OpenOffice also uses these key combinations to move the pointer and highlight within a text document. I've used OpenOffice for more than 10 years, and have written millions of words in it. My fingers have been well-trained, and I'm not going to try to retrain them. The `cwm` key assignments must change.

Use the `bind` command to remap keys. Start by disconnecting the CTRL and CTRL-SHIFT and arrow key combinations from `cwm` with the `unmap` option. Remember that *.cwmrc* uses `C` to represent CTRL and `S` to represent SHIFT (as shown earlier in Table 17-1).

```
bind CS-Left unmap
bind CS-Right unmap
bind CS-Up unmap
bind CS-Down unmap
bind C-Left unmap
bind C-Right unmap
bind C-Up unmap
bind C-Down unmap
```

These keystrokes will now pass through to applications, such as OpenOffice.

To determine how to move the pointer with the keyboard, I check `cwmrc(5)` for the list of commands that can be bound to a key. The manual defines commands with a brief name and a description of their functionality. The pointer movement commands begin with `ptrmove` and `bigptrmove`, plus a direction. I find them and use the Windows key (also known as modifier 4) to replace the functions I removed from the CTRL key.

```
bind 4-Left ptrmoveleft
bind 4-Right ptrmoveright
bind 4-Up ptrmoveup
bind 4-Down ptrmovedown
bind 4S-Left bigptrmoveleft
bind 4S-Right bigptrmoveright
bind 4S-Up bigptrmoveup
bind 4S-Down bigptrmovedown
```

I can now use both OpenOffice and `cwm`'s keyboard functions.

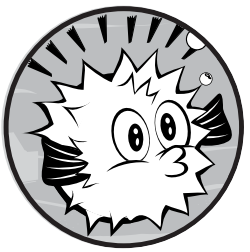
At this point, I've covered everything I've used since OpenBSD introduced `cwm`, which should get you started. For more information, read `cwm(1)` and `cwmrc(5)`. You'll see that `cwm` supports many more features.

Now that we've covered OpenBSD's appearance, let's dive deep into the operating system core.

# 18

# KERNEL CONFIGURATION

*Kernel, not colonel!*
*This is blowfish, not chicken.*
*Less grease, more function.*



Depending on your systems administration experience and background, the kernel is a subject of great mystery and speculation. It might be something you reconfigure when the whim strikes you, or something you know to leave alone.

Most commercial operating systems provide only a few basic hooks for configuring the kernel. Many open source operating systems tell you to rebuild the kernel from source code whenever you change anything.

OpenBSD falls somewhere in the middle.

The standard OpenBSD kernel is intended to be perfectly usable without modifications, but you have the tools to perform any tweaks or adjustments necessary for your environment. Additionally, you have the complete source code and kernel-building tools in case you decide to perform wholesale kernel surgery.

OpenBSD lets you adjust kernel behavior even as the system is running, via `sysctl(8)`. Some hardware or protocols require special OpenBSD kernel tweaks to run in specific environments. This chapter will cover both kinds of changes, but first, let's talk about the kernel in general.

## What Is the Kernel?

"The file */bsd* is OpenBSD's kernel. Next question?"

That's technically correct, but not exactly useful. A more general description is that "The kernel is the interface that links applications and the hardware." That's not a complete definition, but it's good enough.

The kernel allows programs to write data to disk drives and to the network, and it gives instructions to the CPU and shuffles bits into memory. When you open a web page, the browser application asks the kernel to fetch the data it displays.

Some kernel responsibilities exceed this definition. For example, the kernel handles network connectivity, including forwarding packets from one interface to another if needed. The packet-filtering rules run in the kernel (although the rules are managed by applications). The kernel handles disk redundancy. And the kernel also handles all sorts of things that don't impact applications but are integral to a functioning system.

A simplified view is to think of the kernel as the program that handles all the low-level functions, which is close enough to give you an idea of what the kernel does.

Along with *kernel*, you'll also hear the term *userland*. Userland is everything in the system that isn't the kernel. Your shells, libraries, and applications are all part of userland.

### Kernel Messages

The kernel issues messages to userland. These include hardware attaching and detaching alerts, warnings from device drivers, and system boot messages. If you're logged on to the system console in text mode, you might notice these messages.

To review kernel messages, you can watch the console, check the system logs (as discussed in Chapter 15), or use `dmesg(8)`.

OpenBSD has a system message buffer, where it sends messages from the kernel. These messages are usually copied to the system logger, but they're also accessible via `dmesg`.

The system message buffer is circular. As it fills up, the oldest messages are deleted to make room for new ones. Run `dmesg` to view it.

### Startup Messages

One common question is "What hardware did your kernel find?" If the kernel handles all the device drivers and other hardware support, the list of devices found should include all the supported hardware in the system.

While the system message buffer is circular, OpenBSD copies the boot-time system messages into */var/run/dmesg.boot*. Here are the boot messages from one of my test systems.

```
OpenBSD 5.2-current (GENERIC) #287: Tue Aug 21 18:15:00 MDT 2013
    deraadt@i386.openbsd.org:/usr/src/sys/arch/i386/compile/GENERIC
cpu0: AMD Opteron(tm) Processor 4184 ("AuthenticAMD" 686-class, 512KB L2 cache)
2.80 GHz
cpu0:FPU,V86,DE,PSE,TSC,MSR,PAE,MCE,CX8,APIC,SEP,MTRR,PGE,MCA,CMOV,PAT,
PSE36,CFLUSH,MMX,FXSR,SSE,SSE2,NXE,MMXX,FFXSR,LONG,3DNOW2,3DNOW,SSE3,CX16,
POPCNT,LAHF,ABM,SSE4A
real mem  = 267907072 (255MB)
avail mem = 252616704 (240MB)
...
```

The first line lists the version of OpenBSD, the kernel name and version, the date the kernel was built, as well as the machine and directory where the kernel was built and who built it. This machine runs an official OpenBSD i386 snapshot, built by Theo de Raadt.

We then see some specifics on the processor. Those familiar with AMD will note that this is a 64-bit amd64 processor. I chose to run the 32-bit i386 version of OpenBSD, because that's the installation disk I had handy.

This system came with 256MB of RAM, but 1MB is lost due to hardware-level weirdness. OpenBSD sees 255MB, and 240MB are available to programs other than the kernel at this moment. The kernel might use some of that memory later.

### Device Attachments

The kernel then explores the hardware. When it finds hardware that matches a device driver, it attaches the device driver to the hardware.

```
mainbus0 at root
bios0 at mainbus0: AT/286+ BIOS, date 10/13/09, BIOS32 rev. 0 @ 0xfd780,
SMBIOS rev. 2.4 @ 0xe0010 (98 entries)
bios0: vendor Phoenix Technologies LTD version "6.00" date 10/13/2009
bios0: VMware, Inc. VMware Virtual Platform
acpi0 at bios0: rev 2
```

OpenBSD found the main system bus, `mainbus0`, which is a bit odd because it's not actually a piece of hardware. The kernel creates this logical device as a point for all other devices to attach to. It's not the only logical device driver, but it's present on every machine.

The `bios0` device, for the hardware BIOS, isn't terribly interesting either. You know the hardware has some kind of BIOS. We covered configuring your system BIOS back in Chapter 3, and you haven't needed to look at it since. Similarly, the `acpi0` device represents the Advanced Configuration and Power Interface (ACPI). If it needed any configuration, you took care of that after unpacking the system from the shipping box.

### Connections and Numbering

Now we get into real hardware.

```
pci0 at mainbus0 bus 0: configuration mode 1 (bios)
pchb0 at pci0 dev 0 function 0 "Intel 82443BX AGP" rev 0x01
ppb0 at pci0 dev 1 function 0 "Intel 82443BX AGP" rev 0x01
pci1 at ppb0 bus 1
piixpcib0 at pci0 dev 7 function 0 "Intel 82371AB PIIX4 ISA" rev 0x08
pciide0 at pci0 dev 7 function 1 "Intel 82371AB IDE" rev 0x01: DMA, channel 0
configured to compatibility, channel 1 configured to compatibility
```

The first PCI bus, device `pci0`, is attached to `mainbus0` in the slot bus 0. The kernel then finds a device it identifies as `pchb0`, and attaches it to the PCI bus as device 0. Don't know what `pchb0` is? Use `man pchb` to identify this as a PCI host bridge. `dmesg` gives you the part number.

Next is the device `ppb0` (a PCI/PCI bridge, per `ppb(4)`), attached to PCI bus 0 as device 1. This is followed by another PCI bus, `pci1`, attached to the `ppb` device. Each instance of a device is assigned a number, starting with zero. Our tenth PCI bus would be device `pci9`. (There's no technical requirement for sequential numbering, but the kernel follows this rule unless you tell it otherwise.)

If you dig through *dmesg.boot*, you'll see that every device is plugged into another device somewhere. For example, here's my keyboard.

```
wskbd0 at pckbd0: console keyboard, using wsdisplay0
```

The keyboard `wskbd0` is attached to device `pckbd0`.

```
pckbc0 at isa0 port 0x60/5
pckbd0 at pckbc0 (kbd slot)
```

Device `pckbd0` is attached to device `pckbc0`, which, in turn, is plugged into the `isa0` device, which is the ISA bus.

```
isa0 at piixpcib0
```

The ISA bus is connected to the Intel PIIX4 ISA bridge.

```
piixpcib0 at pci0 dev 7 function 0 "Intel 82371AB PIIX4 ISA" rev 0x08
```

And this bridge is then hooked to PCI bus 0.

OpenBSD finds devices from the root outward, which means that everything is listed in the reverse order from what you've just seen. You get a list of which devices are attached to a device, and then the devices attached to those devices. You can backtrack starting with the end device, but that's kind of annoying.

### Using dmassage to View Installed Devices

I find the `dmassage` package most useful for identifying exactly what's attached to what devices, although that's not its only function. Install `dmassage` like any other package, and then run it with `-t` to display installed devices as a tree, like this:

```
root
 |-mainbus0
 |  |-bios0
 |  |-cpu0
 |  |-ioapic0
 |  |-pci0
 |  |  |-mpi0
 |  |  |  \-scsibus1
 |  |  |     \-sd0
 |  |  |-pchb0
 |  |  |-pciide0
 |  |  |  \-atapiscsi0
 |  |  |     \-scsibus0
 |  |  |        \-cd0
...
```

While this information may not be immediately useful, `dmassage` illustrates how devices are interconnected on your system, which may become important later.

## Viewing and Adjusting Sysctls

As noted in earlier chapters, the OpenBSD kernel includes a variety of parameters known as *system controls*, or *sysctls*. Some sysctls are static and can be viewed but not changed. The root account can change others, either at runtime or at boot.

Sysctls allow an application to retrieve information from the kernel. They also let a sysadmin change system behavior without reconfiguring applications, recompiling the kernel, or rebooting. You can view sysctl values and adjust those that can be changed with `sysctl(8)`.

That said, just because you *can* change sysctls doesn't mean you *should* change them. The OpenBSD developers set the sysctls to default values that work well for most environments. You might need to change one or two for your system, but if you find yourself changing sysctls all over the place, you're probably sending yourself down the sysadmin rabbit hole.

### Sysctl MIBs

The kernel presents sysctls in a MIB tree. As you learned in Chapter 16, MIB trees organize information into hierarchical categories. The top-level categories include `kern` (kernel), `vm` (virtual memory), `net` (networking), `hw` (hardware), `machdep` (machine-dependent values), and so on. Each of these categories has additional subcategories. For example, `net` has the categories

inet (IPv4) and inet6 (IPv6). The inet6 MIBs have subcategories ip6 (general IPv6 characteristics) and icmp6 (ICMP for IPv6). When you reach the end of categories, you'll find individual MIBs like these:

```
net.inet6.ip6.forwarding=0
```

This MIB configures forwarding IPv6 packets between interfaces, turning the host into the router. How do I know? I've read it in the documentation, and it's a commented example in */etc/sysctl.conf*. OpenBSD doesn't maintain a central list of sysctl values, but the man pages refer to any related sysctls.

If you want to explore sysctls, get a list from your system, as described next.

### Viewing Sysctls

Use sysctl(8) to view the sysctls available on a system.

```
$ sysctl
kern.ostype=OpenBSD
kern.osrelease=5.2
kern.osrevision=201211
kern.version=OpenBSD 5.2-current (GENERIC) #287: Tue Aug 21 18:15:00 MDT 2013
    deraadt@i386.openbsd.org:/usr/src/sys/arch/i386/compile/GENERIC
...
```

This particular system has more than 400 sysctls. Interpreting the kern.ostype and kern.osrelease sysctls is fairly straightforward, but why would an OpenBSD system have a sysctl to report the operating system?

The sysctl(3) interface appears in all BSD-derived operating systems and even in Linux, so checking the kern.ostype sysctl, or checking for its existence, is a good way for third-party software to identify the operating system. kern.osrevision is just the year and month this particular snapshot was built. kern.version is the kernel compilation information displayed at boot. That's not hard, is it? Let's look at the next few sysctls:

```
kern.maxvnodes=5926
kern.maxproc=1310
kern.maxfiles=7030
kern.argmax=262144
```

Figuring out what these do is a little harder than interpreting the previous sysctl names. An experienced sysadmin could make really good guesses about these, but guessing isn't system administration. Always research sysctls before changing them.

When you know the name of a sysctl and you want to view its current value, give the sysctl name as an argument to sysctl. For example, to view the current securelevel (discussed in Chapter 10), check the kern.securelevel sysctl.

```
$ sysctl kern.securelevel
kern.securelevel=1
```

The current value of `kern.securelevel` is 1.

You can view subsets of the sysctl tree by giving just the part of the tree you're interested in. For example, to view only the sysctls related to ICMP, check the `sysctl net.inet.icmp` subcategory.

```
$ sysctl net.inet.icmp
net.inet.icmp.maskrepl=0
net.inet.icmp.bmcastecho=0
net.inet.icmp.errppslimit=100
net.inet.icmp.rediraccept=0
net.inet.icmp.redirtimeout=600
net.inet.icmp.tstamprepl=1
```

OpenBSD has six sysctls for IPv4 ICMP networking. You can view any portion of the sysctl tree this way, going as deep or as shallow as you like.

### Changing Sysctl Values

Some sysctls are read-only. For example, the `hw.ncpufound` sysctl shows how many processors the system has.

```
$ sysctl hw.ncpufound
hw.ncpufound=1
```

This system has one processor. You cannot change the number of hardware processors through software (duh).

On the other hand, a system decides whether or not to forward packets in software. OpenBSD performs packet forwarding entirely in the kernel, like embedded firewalls and routers. The sysctl `net.inet.ip.forwarding` controls this feature. If this is set to `0`, packets are not forwarded. If it's set to 1, the system routes packets.

```
$ sysctl net.inet.ip.forwarding
net.inet.ip.forwarding=0
```

To change this, use the equal sign to assign a new value.

```
# sysctl net.inet.ip.forwarding=1
net.inet.ip.forwarding: 0 -> 1
```

If you need to stop forwarding packets, set this sysctl to `0`.

Changes take effect immediately. Remember that only root can change sysctl values.

### Types of Sysctl Values

Most sysctls have a numerical value, but the interpretation of that number depends on the sysctl. A few sysctls are words, and some generate tables.

### Numerical Sysctls

Some sysctls are Boolean—either on or off. For example, IP forwarding is either on or off. You can't have 50 percent packet forwarding on a properly functioning system.

Other numerical sysctls have a range of valid numbers. For example the `kern.securelevel` sysctl can range from `-1` to `2`, as discussed in Chapter 10. While you could assign a value outside this range, it wouldn't have any effect beyond the closest valid value.

Some sysctls have numerical values that map directly to some kernel value. For example, the `kern.maxproc` sysctl gives the maximum number of processes that the system can run. You can adjust this value as needed to support your applications. While there's no maximum value, increasing `kern.maxproc` increases the memory used by various in-kernel tables. By the same token, there's no minimum size, but if you reduce this setting too far, the system won't run correctly.

### Word Sysctls

A few sysctls are words, such as the `kern.ostype` sysctl examined earlier. Most of these sysctls cannot be changed with `sysctl`, but some can be changed with other programs. For example, the sysctl `kern.hostname` gives the system's hostname. You cannot change `kern.hostname` with `sysctl`, but you can change it with `hostname(8)`.

### Table Sysctls

In addition to words and numbers, some sysctls generate output in the form of tables. These sysctls are not intended for direct human consumption, but are meant for processing by dedicated userland programs. For example, `netstat(1)` reads table sysctls to create its output.

To view all sysctls, including tables, pass the `-A` option to `sysctl`.

```
$ sysctl -A
```

Many table sysctls still won't print (they will generate warnings that you should use program such-and-such to view that data), but you'll get a few tables amid the regular output.

And by the way, tabular sysctls are read-only.

## *Setting Sysctls at Boot*

Sysctl changes are not permanent; they revert when you reboot. To make sysctl changes permanent, set them in */etc/sysctl.conf*.

Changes specified in *sysctl.conf* take place early in the booting process, before any server software starts. For example, if you need to customize the network stack, those changes should take place before the system opens any network connections. List the sysctls you need to change, an equal sign, and the desired value in *sysctl.conf*.

The default *sysctl.conf* contains commonly changed sysctls (those that the OpenBSD team expects you might reasonably want to change). Each is commented out with a pound sign (#) and set to the most common nondefault setting. If you want to change the sysctl, uncomment the entry.

The following are some commonly changed entries from *sysctl.conf*. (You might have different entries in your system, depending on your OpenBSD version.)

**net.inet.ip.forwarding**
: This controls forwarding of IPv4 packets between interfaces. When set to 1, the system forwards packets received on any interface according to the internal routing table. When set to 0 (the default), packets are not forwarded.

**net.inet.icmp.rediraccept**
: This determines whether the host will accept ICMP redirects. Routers send ICMP redirects to direct hosts to use different local gateways for more specific routes. While the router can forward the packets for the clients, using redirects reduces network load. Accepting ICMP redirects means the host could be redirected to an invalid gateway, however, so they can be a security issue. Set this to 1 to accept ICMP redirects. The default of 0 ignores ICMP redirects.

**net.inet6.ip6.forwarding**
: This controls the forwarding of IPv6 packets, much like net.inet.ip.forwarding does for IPv4 packets. You can control IPv4 and IPv6 forwarding separately. Set this to 1 to forward IPv6 packets.

**net.inet6.icmp6.rediraccept**
: By default, OpenBSD ICMPv6 ignores redirects, just as it ignores IPv4 ICMP redirects. Set this to 1 to accept ICMPv6 redirects.

**net.inet6.ip6.accept_rtadv**
: IPv6 autoconfiguration listens for router advertisements, much as IPv4 autoconfiguration listens for configurations from DHCP servers. To autoconfigure IPv6, a host must accept router advertisements. Set this to 0 to disable accepting router advertisements.

**net.inet.tcp.always_keepalive**
: The TCP keep-alive feature sends packets over otherwise idle connections so that intermediate devices will recognize that a connection is still in use. Proper firewalls recognize live but idle TCP connections even without keep-alives. If you have a broken firewall or NAT device, TCP keep-alives can help hold a connection alive. Set this to 1 to enable keep-alives.

**net.inet.tcp.ecn**
: By default, OpenBSD's TCP stack does not use Explicit Congestion Notification (ECN). Set this to 1 to enable ECN.

**ddb.panic**
: OpenBSD uses the ddb(4) kernel debugger. If you want the system to drop into the debugger in the unlikely event of a kernel panic, leave this at 1. If you want the system to reboot as soon as possible, set this to 0.

**ddb.console**
: When set to 1, this enables entering the ddb(4) debugger from the console when someone presses CTRL-ALT-ESC. This option is primarily of interest to developers.

**vm.swapencrypt.enable**
: By default, OpenBSD encrypts all data written to swap. To disable encrypting swap, set this to 0. There's really no reason to disable swap encryption, because encrypting swap space induces minimal system load.

**machdep.allowaperture**
: This controls userland program access to the memory that userland really shouldn't be able to access. The X Windows System needs access to this memory to display a graphical console. (Chapter 17 covers this sysctl and X.)

**machdep.kbdreset**
: On amd64 and i386 systems, setting this to 1 allows you to press CTRL-ALT-DEL on the console to do a clean shutdown and reboot. When set to 0 (the default), pressing CTRL-ALT-DEL has no effect.

As a rule, if you don't understand the thing that a sysctl affects, don't change it. You won't learn about RFC 3390 by playing with a sysctl related to it; you'll learn about RFC 3390 by actually *reading* RFC 3390 and spending quality time with a packet sniffer watching traffic with RFC 3390 disabled and enabled.

And if you want to change a sysctl that's not listed here, think twice. If the OpenBSD guys wanted you to change it, they would list it in *sysctl.conf*.

## Altering the Kernel with config(8)

While sysctl lets you tweak the kernel, it won't let you change values that are hard-coded into the kernel binary. Some of these values are used to initialize kernel data structures, and they can't be changed once the kernel is running. Others relate to device drivers. Once the kernel has finished probing devices, it won't go back and reprobe just because you change where a device driver checks for its hardware. To change hard-coded values like these, you must edit the existing kernel file and reboot, allowing the system to set things as you like from initialization. That's where config(8) comes in.

The config command has two completely separate functions. The first creates a kernel compilation directory from a text configuration file, as

discussed in Chapter 19. The function we're most interested in now is editing an existing kernel binary, which lets you tweak a kernel to better suit your needs.

**NOTE** *The modern OpenBSD kernel is largely dynamic. If you call for additional virtual interfaces, the kernel creates them. If you need to change the amount of memory for the buffer cache, use a sysctl. Editing the kernel is rarely necessary.*

### Making a Backup of the Default Kernel

Before making any changes to a working kernel, no matter how minor, back up the original kernel! If your minor changes make your machine unbootable, you want to be able to easily fall back to a working kernel.

The kernel is just a file, */bsd*. To back it up, copy it to another file. I recommend naming your backup of the default kernel */bsd.GENERIC*, for reasons that will become apparent in Chapter 19.

Always keep a known-good kernel on your system. A bad kernel can prevent a computer from booting, and if you don't have a reliable kernel that's easily bootable, you will need to boot from installation media. (Boot your backup kernel using the instructions in Chapter 5.) And remember that subtle kernel bugs can take weeks or months to show up, so plan to keep your backup kernel forever.

### Device Drivers and the Kernel

Much of the hard-coded information in the kernel relates to device drivers, especially drivers for ancient ISA cards.

Some of you may remember manually configuring the interrupt request (IRQ) and memory port addresses on a network or SCSI card. The kernel uses the IRQ to identify cards. Essentially, it consults an internal list of IRQs and port numbers, compares it to what it finds on the hardware probe, and assigns the drivers appropriately. "This card answers at IRQ 10 and memory port 0x300? It must be a NE2000-compatible network card. I will assign that driver to it." The process is more complicated than this, of course, but this probe is a vital part of the process. If you want OpenBSD to recognize such a card, and the card is set to an IRQ and memory port other than what OpenBSD expects, you must tell the kernel the IRQ and memory port the card is using.

Realistically, the best way to deal with ISA cards is to feed them to the recycling plant. Running OpenBSD on a 25-year-old VAX is interesting and educational. Running OpenBSD on 15-year-old Sparc hardware is realistic for very specific applications, and can also be educational and interesting. Running OpenBSD on 10-year-old consumer-grade i386 hardware is either a waste of time or an exercise in masochism—probably both.

**NOTE** *Modern PCI-descended hardware includes hooks for the kernel to identify the hardware and assign the proper device driver. You shouldn't need to edit the kernel to support hardware.*

### Enabling Drivers

Rather than changing driver IRQs, more realistically, you might need to enable a device driver that's disabled by default or disable a device that's on by default.

The kernel includes some device drivers that are disabled because they react badly with certain hardware, such as the IPMI driver. The `ipmi(4)` driver is known to be buggy, and as I write this, it is badly broken in some use cases. It's included in the default kernel, but disabled by default.

You can choose to enable `ipmi(4)`. If it works for you, great. If it doesn't, feel free to submit bug reports, preferably with patches, or at least proper `dmesg` output and crash dumps.

### Editing the Kernel with config

When using `config` as a kernel editor, use the command-line options `-e` and `-o`. The `-e` flag tells `config` you're editing a kernel binary. The `-o` flag lets you specify a new file for the edited version of the kernel.

Give the original kernel file path as an argument. For example, here's how to edit */bsd* and write the result to the file */bsd.test*:

```
# config -e -o /bsd.test /bsd
```

You could use the `-f` flag instead of `-o` and a filename. The `-f` flag tells `config` to edit the kernel file in place, not to create a new file.

**NOTE** *If you're editing /*bsd *and you specified the -f option, your changes are written directly to /*bsd. *I recommend* not *doing this. (Unless, of course, you're absolutely certain you know what you're doing. You get to keep all the parts.)*

Running `config` will open the kernel editor, which should look much like this:

```
OpenBSD 5.2-current (GENERIC) #287: Tue Aug 21 18:15:00 MDT 2013
    deraadt@i386.openbsd.org:/usr/src/sys/arch/i386/compile/GENERIC
Enter 'help' for information
ukc>
```

At this point, you need to use kernel editor commands to make changes.

#### Using the help and list Commands

Start with the two editor commands `help` and `list`. The `help` command shows all the commands available within `config` and comes in particularly handy at stupid-o'clock AM to remind you of the necessary syntax.

The `list` command displays a complete list of all the devices the kernel supports, one screen at a time.

```
ukc> list
  0 video* at uvideo* flags 0x0
  1 audio* at uaudio*|sb0|sb*|gus0|gus*|pas0|ess*|wss0|wss*|ym*|eap*|envy*|
eso*|sv*|neo*|cmpci*|clcs*|clct*|auacer*|auglx*|auich*|auixp*|autri*|auvia*|
azalia*|fms*|maestro*|esa*|yds*|emu* flags 0x0
  2 midi* at umidi*|sb0|sb*|ym*|mpu*|mpu*|autri*|eap*|envy* flags 0x0
...
```

On an OpenBSD 5.2 system, the default kernel has 538 entries, most for hardware that isn't on any particular system but that OpenBSD supports out of the box. Let's take a closer look at the devices shown.

Line 0 says that this kernel supports the `video` device. The kernel will look for a video device attached to the `uvideo` device. The `uvideo(4)` man page tells us that `uvideo` is USB video, mainly for webcams and the like, and `video(4)` says that the `video` driver is a device-independent video driver. The `flags` statement gives settings to feed to this device driver. (This kernel supports webcams.)

Line 1 says that this kernel supports an `audio` device, and it can be attached to any of a long list of device drivers. The online manual says that `uaudio`, `sb0`, `gus0`, and so on are sound cards. We get sound with our video? Truly we live in an age of wonders.

Entries for older ISA gear are more complex.

```
278 ne0 at isa0 port 0x240 size 0 iomem -1 iosiz 0 irq 9 drq -1 drq2 -1 flags 0x0
```

This entry for supporting the old-fashioned NE2000 ISA network card includes an IRQ, DRQ, memory port, and a few other settings that I've (thankfully) forgotten about. The kernel will check ISA bus number 0 at the stated port and IRQ, in the hope of finding such a device.

```
504 pflog count 1 (pseudo device)
```

This is a *pseudo-device*—a software creation that acts much like an actual device but has no underlying hardware. The `pflog(4)` pseudo-device is where the packet filter dumps its logs. This kernel creates one instance of the `pflog` device at boot, but thanks to OpenBSD's cloneable interfaces, the kernel can create more `pflog` interfaces as needed.

Finally, notice that several lines declare themselves "free." You can copy an existing device and add it to the kernel. For example, if you wanted a kernel that supported 10 NE2000 cards, and needed 10 instances of the device driver in the kernel, you could copy and add the devices here. The kernel will autoconfigure any number of device driver instances for modern hardware; it will find 10 PCI Express network cards and give them their own instances of the device without any prodding from you.

### Finding and Enabling Devices

One of the disadvantages to the `list` command is that it shows everything in the kernel. You can't interrupt it; you must scroll through to the end. It's also difficult to search through several hundred devices by eye. If you know the device you want, use `find` to search for it. Here, we'll use `ipmi` as an example.

```
ukc> find ipmi
493 ipmi0 at mainbus0 disable bus -1 flags 0x0
```

The IPMI device is device number 493, and it is attached to the device `mainbus0`. But note the word `disable` in the device entry. The `ipmi` device is disabled. Let's turn it on.

```
ukc> enable ipmi
493 ipmi0 enabled
```

The kernel now has an active IPMI driver. Yippee!

### Changing Kernel Constants

In addition to the device drivers, the kernel has a few hard-coded values for internal data structures. If you run `help` in the kernel editor, you'll see these values as options.

```
ukc> help
...
        bufcachepercent [number]            Show/change BUFCACHEPERCENT
        nkmempg         [number]            Show/change NKMEMPAGES
```

As you can see there are only two values: `BUFCACHEPERCENT` and `NKMEMPAGES`. Unless you have a compelling reason to touch these values, leave them alone.

`NKMEMPAGES` is the number of pages of memory dedicated to the kernel. If your machine starts panicking with error messages of `out of space in kmem_map`, you can increase this value. If the system boots successfully, however, you're better off setting the `vm.nkmempages` sysctl rather than editing the kernel.

`BUFCACHEPERCENT` is the percentage of physical memory dedicated to the buffer cache. In some fairly rare circumstances, increasing the size of the buffer cache can improve filesystem performance. You could set the sysctl `kern.bufcachepercent` instead of editing this kernel value, however.

To view a current value, enter its name.

```
ukc> bufcachepercent
bufcachepercent = 20
```

To change the value, enter its name and the desired value.

```
ukc> bufcachepercent 50
bufcachepercent = 50
```

Again, don't muck with these numbers arbitrarily. The OpenBSD developers set them to the default values for very good reasons.

#### Completing Configuration

Once you've made all of your changes, enter **`quit`** to save your changes and write them to a kernel file. The `exit` command discards all changes and leaves the editor, making it easy to start over. Do not mix `quit` and `exit` unless you like being annoyed and confused.

#### Installing Your Edited Kernel

Your edited kernel is just a file. Verify that you have a backup of your working kernel, copy your new kernel to */bsd*, and reboot.

## Boot-Time Kernel Configuration

The `config` kernel editor is great when you know what you're doing, but many of us aren't that lucky or educated. When I'm trying to figure out how to fix a problem, I'll frequently make a change, reboot to test the change, and see if things work.

OpenBSD lets you edit the kernel at boot time. You can try one boot with a kernel change, see if it works, and write your changes to the kernel. At the boot loader prompt, run **`boot -c`**.

```
boot > boot -c
```

You'll get a couple lines of boot output, and then the kernel editor prompt.

```
ukc>
```

This works just like the `config` kernel configuration editor. Make any changes you want here, exactly as you would with `config`. When you `quit` the editor, the kernel should boot with the changes you've chosen.

The nice thing about boot-time edits is that they're not permanent unless you later declare them so. If your changes don't result in the desired behavior, reboot and try again. If your changes do solve your issue, however, you can write them to a kernel file.

The kernel remembers the changes you made in it. You can "replay" those changes in `config` by using the `-u` flag. Run `config` as if you were editing the kernel, but add the `-u` flag to replicate your boot-time changes.

```
# config -u -e -o /bsd.test /bsd
```

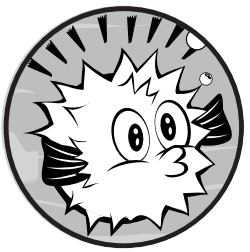
When you get your command prompt, enter **`quit`** to save your changes to your new kernel file.

Between `sysctl` and `config`, you should be able to make any OpenBSD-supported changes to the kernel. In the next chapter, we'll cover how to make wildly unsupported kernel changes by rebuilding the kernel from source.

# 19

# BUILDING CUSTOM KERNELS

*Rewiring the brain?*
*Knowing where the parts plug in*
*makes it possible.*



The OpenBSD team works very hard to provide a high-quality kernel that requires no tweaking beyond setting the occasional sysctl or perhaps enabling a feature. But if you want to use an experimental feature or add a device driver to the kernel, or you want to squeeze OpenBSD into tiny hardware or embedded systems, you'll need to build a custom kernel from source code. The OpenBSD people won't support you if you venture into custom kernels, but they'll provide you with everything you need to shoot yourself in the foot, as you'll learn in this chapter.

## Kernel Cautions

Before we get into the details of building custom kernels, we'll look at why that's usually a bad idea.

### Don't Build Custom Kernels

Many open source operating systems encourage sysadmins to build custom kernels. Mailing lists for these operating systems are full of suggestions on rebuilding, tweaking, and modifying the kernel. Those user communities will walk new users through rebuilding the kernel.

OpenBSD developers take a different approach to rebuilding the kernel. They ship a default kernel, called GENERIC, which you will almost never need to rebuild.

Building a kernel from source doesn't prove that you're an alpha geek, and rebuilding the kernel is never a recommended way to solve a problem. The people who build custom kernels are either kernel developers or ignorant newbies. The OpenBSD Project members feel no particular obligation to help users with customized kernels. If your custom kernel crashes, destroys your filesystem, or starts making threatening calls to the local constabulary, they won't care. Why? Adding, moving, or changing one kernel option might seem trivial, but each option might represent tens of thousands of lines of source code that you've just casually gutted.

That said, the OpenBSD Project is much friendlier than closed source operating systems, in that it provides the source code for the kernel, and gives you the tools and instructions needed to build it. The territory might be dangerous, with rattlesnakes and bears and the occasional bottomless pit, but they give you a map and a flashlight. If you can carve out some new territory for yourself, good for you! If you get eaten by coyotes, well, that's pretty much what happens.

**NOTE** *These warnings apply only to custom kernels. The OpenBSD team is extremely interested in problems in a provided kernel, whether that's the GENERIC kernel, the installer kernel, or any other.*

When working with kernels, keep in mind that some platforms have multiple GENERIC kernels. For example, the i386 platform has the standard GENERIC kernel, but it provides GENERIC.MP for multiprocessor machines, and it supports both versions. By the same token, the SGI platform has several GENERIC kernels—one for each supported hardware variety. These kernels are all GENERIC, and all supported.

### Why Build Custom Kernels?

People build custom kernels for various reasons. For example, if you're a kernel developer, or aspire to be one, you will need to build customized kernels to test new features and new code.

Some people who play with kernels are interested in using experimental features. For example, OpenBSD supports the newly developed but not well-tested multipath SCSI, which is not supported by GENERIC. Not many people have the hardware to use multipath SCSI, but those who do have the hardware, along with programming skills, are encouraged to help improve

this feature. (When running experimental features, be sure that you understand that *experimental* is the Siamese twin of *unstable*.)

Rarely, remediating a security flaw will require a patch to the kernel source code. But rather than build your own, get the patch from OpenBSD's stable branch or a snapshot (discussed in Chapter 20).

Finally, some people will build custom kernels to save RAM on a machine with very low memory. Removing features from the kernel reduces its size.

### Problems Building Custom Kernels

When building a custom kernel, you are likely to run into trouble. For one, the interdependencies between kernel modules are quite complex and not thoroughly documented. The developers generally assume that people building custom kernels will read kernel source code and man pages. You are expected to read error messages and sort them out yourself.

OpenBSD's cross-platform design slightly complicates kernel configuration. Some devices run on some architectures, but they fail to run or behave weirdly on others. If you include the wrong device in your kernel or tell the kernel a card is attached to the wrong bus, you'll be building a busted kernel. Be sure that you understand how your hardware actually fits together.

When mucking around in the source tree, you can corrupt the source code in various ways, such as by applying a patch incorrectly, scrambling a file, or forgetting that you edited a file that is now causing you grief. To test your source code, compile GENERIC. If GENERIC won't compile, you've either mucked up the source code or your system has some deeper problem.

Building a custom kernel usually means including or removing kernel options and features from the configuration file. If you're trying to use fancy compiler flags, however, stop. Custom compiler options are great for exposing compiler bugs, but the OpenBSD team members make no effort to have their code comply with the demands from these compiler options. Many of these options and higher optimizations break if you're not running very specific operating systems on very specific architectures. The kernel code assumes that you are using the specified compiler options; if you change them, you'll get nothing but pain.

If you've checked everything, and you still can't get your kernel to build, you might don your flameproof suit and ask for help on *misc@OpenBSD.org*. State up front that you're trying to build a custom kernel, and include the following information:

- Your kernel configuration
- OpenBSD version
- Unedited boot-time messages from booting a GENERIC kernel on your computer
- A full description of the problem

Someone might take pity and try to help you.

### *Problems Running Custom Kernels*

Custom kernels can have any number of problems, such as the following:

- Programs might not run as expected.
- The system might not boot.
- The system might crash randomly.
- The kernel might not find all of your hardware.
- The kernel might eat your hard drives or your motherboard (without mustard or even a shot of malt vinegar).

If you have customized your kernel narrowly—say, by adding only the multipath SCSI driver to the GENERIC kernel—the developers working on that feature will probably be interested in your bug reports on that feature.

If you can reproduce that problem when the same system boots with the GENERIC kernel, the OpenBSD team is definitely interested. Report your problem as occurring on the GENERIC kernel, and include debugging output only from GENERIC, not from your custom kernel. If you manage to identify, debug, and create a patch for a problem with a custom kernel, send your patch and a problem description to the mailing list. Your problem may be due to running on a custom kernel, but you may also have found a bug that could be triggered in GENERIC.

But most important, if you have a problem running a custom kernel, reboot with GENERIC and get on with your day.

## Preparing for Kernel Customization

Before customizing the kernel, back up the known-good GENERIC kernel on your system by copying */bsd* to */bsd.GENERIC*. That way, if your custom kernel doesn't boot, you can recover by booting the backup kernel.

You'll need the kernel source code in order to build a custom kernel. You can just grab *sys.tar.gz* from your OpenBSD installation media. If you installed from an Internet mirror, make sure to get the source code for your version of OpenBSD. The OpenBSD mirror root directory usually contains a snapshot of fairly recent source code, but check the directory for your release for its source code. Expand this directory under */usr/src*.

```
# cd /usr/src
# tar -xzvpf sys.tar.gz
```

Now that you have a backup (you *did* make a backup of your working kernel when I told you to, right?) and the source code, let's look at kernel configuration.

## Kernel Configuration

You configure the OpenBSD kernel via text files. Like 4.4BSD, OpenBSD doesn't offer a fancy graphical kernel configuration utility or menu-driven system. Each kernel configuration is on a single line, along with a label indicating the type of entry and a description. Pound signs (#) mark comments.

### *Configuration Entries*

Kernel configuration entries fall into four general categories: options, device drivers, pseudo-devices, and keywords.

#### Options

*Options* are hardware-independent kernel functions. Options handle things like filesystems, networking protocols, and compatibility layers.

Option entries look like this:

```
option      FFS         # UFS
option      INET        # IP + ICMP + TCP + UDP
option      CRYPTO      # Cryptographic framework
```

To learn more about options, read the `options(4)` man page.

#### Device Drivers

Device drivers give the kernel the necessary software to interact with a piece of hardware. If you want your kernel to support a piece of hardware, it must include the appropriate device driver.

Device driver kernel configuration entries can be quite long. They might include flags or settings that tell the kernel where to find the device and how to initialize it. (ISA cards usually have a hard-coded IRQ and/or memory address.)

Device drivers have no common label, but their entry starts with the device name.

```
mainbus0 at root
cpu0     at mainbus?
fxp*     at pci?                          # EtherExpress 10/100B ethernet
wd*      at wdc? flags 0x0000
ec0      at isa? port 0x250 iomem 0xd8000 irq 9  # 3C503 ethernet
```

#### Pseudo-Devices

*Pseudo-devices* behave much like devices, but have no real hardware attached to them. Pseudo-devices are frequently abstractions that can be opened, read from, written to, and closed in the same way as real hardware.

For example, the loopback interface is a pseudo-device used for network connections to the local machine. (Your computer has no loopback network card, but the loopback interface behaves just like a real network card with an unusual MTU value.)

Pseudo-devices are labeled with `pseudo-device`.

```
pseudo-device   loop    # network loopback
pseudo-device   pf      # packet filter
pseudo-device   gre     # GRE encapsulation interface
```

#### Keywords

Finally, a handful of other keywords appear only once or rarely. These one-offs change how the kernel runs or how it's built, and defy easy categorization. The following keywords may appear:

- The `machine` keyword tells the kernel which architecture it should run on.
- The `makeoptions` keyword tells the compiler how to build the kernel.
- The `include` keyword means pull in another configuration file.
- The `maxusers` value sets the size of some in-kernel tables.

You'll find even less common keywords scattered in different kernel configurations.

```
machine         amd64
makeoptions     DEBUG="-g"  # compile full symbol table
include         "../../../conf/GENERIC"
maxusers        80          # estimated number of users
```

All of these affect the kernel in wildly different ways. You'll find several of these keywords in any kernel, even GENERIC.

### *Configuring GENERIC*

Let's look at an actual kernel configuration. OpenBSD divides kernel configuration into machine-independent and machine-dependent files.

#### Machine-Independent Configuration

The machine-independent kernel configuration files are in */usr/src/sys/conf*. The file */usr/src/sys/conf/GENERIC* contains the machine-independent kernel configuration, which describes all of the features that OpenBSD supports on all hardware platforms. Every GENERIC kernel contains the configuration in this file. If you change this file, it will affect every kernel built that includes this file.

The machine-independent configuration file doesn't contain device drivers; instead, devices are tied to particular hardware. This file won't contain any special building instructions, because they vary from platform to platform. Nor will it include hard-coded system limits, data structure sizes, and so on, as OpenBSD running on a 25-year-old VAX has considerably fewer resources than a brand-new amd64 system. The */usr/src/sys/conf/GENERIC* file contains mostly options and pseudo-devices. Every OpenBSD kernel must support a filesystem, or it won't be able to write to disk or anything disk-like.

A kernel based on this file doesn't yet know what sort of hardware the filesystem will run on, but it knows how to make a filesystem. It doesn't know what kind of network card it will have, but once you give it a network card, it can create a TCP data stream and serve your web pages. You'll need the machine-dependent configuration to make a kernel that can function in the real world.

### Machine-Dependent Configuration

Each platform has its own machine-dependent kernel directory under */usr/src/sys/arch*. Here's where you'll find a subdirectory for every platform OpenBSD supports, as well as a directory for any platforms under development. Separate directories contain platform-specific code, as well as further *conf* subdirectories for the kernel configuration file.

I'm using amd64 as an example, so the kernel configuration directory is */usr/src/sys/arch/amd64/conf*. While we'll focus on the common i386 and amd64 architectures, the kernel-building process is the same across all hardware platforms.

A traditional kernel configuration filename is in all capital letters. You'll see the *GENERIC* configuration, as well as the *RAMDISK** files used for the installation disks. (The *GENERIC.MP* kernel is the multiprocessor kernel.) We'll start with the *GENERIC* kernel configuration file:

```
machine         amd64
include         "../../../conf/GENERIC"
```

The first entry in this kernel configuration defines the machine. The machine definition tells the kernel configuration parser the kind of hardware you're running, and defines core hardware characteristics and constraints, such as how many bits are in an integer and how much memory the system can support.

The second entry pulls in the machine-independent kernel configuration (described in the previous section), defining all of the protocols and tools that make OpenBSD OpenBSD. The amd64 kernel inherits the filesystems and network stacks from this entry.

Following these two lines you'll see the devices OpenBSD supports on amd64 hardware. Take a moment and skim the file. It's the same mix of devices and attachments as described earlier in this chapter.

## *Your Kernel Configuration*

In order to build your own kernel, you'll need a configuration file. Here, we'll look at how to create your configuration file. (Do not just edit either GENERIC kernel file.)

### Minor Changes

If your kernel adds only a couple of items to the GENERIC kernel, use the GENERIC configuration as a basis for your new one. For example, here's the multiprocessor kernel configuration, GENERIC.MP:

```
include  "arch/amd64/conf/GENERIC"
option          MULTIPROCESSOR  # Multiple processor support
cpu*            at mainbus?
```

The multiprocessor kernel builds on GENERIC, adding only one option and one device attachment. You can use this model to define your own kernel configuration.

For example, suppose you want to enable the experimental SCSI multipathing feature on a kernel. You could create a kernel configuration file in your platform directory, and simply copy the commented-out multipathing entries from the machine-independent GENERIC kernel, like this:

```
include    "arch/amd64/conf/GENERIC"
mpath0     at root
scsibus*   at mpath?
```

This creates a custom kernel that closely resembles GENERIC, with these two extra devices.

### Removing Options

To strip options from your kernel, use the `rmoption` keyword. For example, to create a minimal kernel based on GENERIC, you could use the `rmoption` keyword to remove some kernel options, as in this example:

```
include "arch/amd64/conf/GENERIC"
rmoption    NTFS
rmoption    HIBERNATE
...
```

One advantage to creating a configuration by including the default kernel is that when you update your source code, your custom kernel configuration will probably still be valid. However, the more options you remove from the kernel, the greater the chance that the kernel will fail to compile, or if it compiles, that it might not boot. And if it boots, it might eat your hard drive.

When removing options, keep in mind that some options are more important than you might think. For example, removing the `INET6` option (aka IPv6) can create a nonfunctional system. Removing options doesn't save you much memory, and it might cripple any number of programs.

### Removing Devices

If you want to remove a lot of stuff from a machine-dependent kernel configuration, while retaining the options for base OpenBSD functions, copy the machine-dependent GENERIC configuration file to a new text file and make your changes in that file.

### Wholesale Butchery

If you want to commit wholesale butchery on the kernel, you'll want a configuration that includes both the machine-independent and machine-dependent parts. Start by copying the existing GENERIC kernel configurations into one file, in the platform's kernel configuration. Here, I call my new kernel TREBLE, after the hostname:

```
# cd /usr/src/sys/arch/amd64/conf
# cp ../../../conf/GENERIC TREBLE
# cat GENERIC >> TREBLE
```

Before making any other changes, remove the line that includes the machine-independent kernel configuration file. Then slice out everything that makes the system functional, and try to build the new kernel. Next, add stuff back in until the kernel builds. (Although removing drivers won't save much memory, doing so will make booting a tiny bit faster.)

**NOTE** *You might be tempted to use the man pages to create your own kernel configuration from scratch. You're certainly free to do that, if you're either a Kernel Lord or an irremediable doofus. Feel free to try it. Every sysadmin can use such a valuable lesson in humility.*

### Stripping Down the Kernel

Every device driver and option in the kernel uses memory. If you're trying to cram OpenBSD onto a tiny computer, or you're doing any sort of embedded development, you might want to build a custom kernel that includes as few device drivers as possible by editing */var/run/dmesg.boot*, where every entry matches a line in the kernel configuration.

The simplest way to trim out unnecessary device drivers is to remove everything that's not in your computer. The kernel includes dozens of network card drivers, but you need only one or two. If you're unsure about a device, keep it in the configuration. (The ACPI and BIOS devices in particular are tightly interrelated, and you'll probably have a really hard time building a bootable custom kernel without the complete set of ACPI and BIOS devices.)

### Gutting the Kernel

If removing device drivers doesn't create a sufficiently small kernel for you, try removing machine-independent options. Many of these options are interdependent, however, and removing them can create a kernel you can't compile. If you can compile the kernel, it might not boot, and if it boots, it might not function correctly.

## *Testing Your Kernel Configuration with config(8)*

Is your custom kernel configuration internally consistent? To test your kernel and prepare the files needed to compile it, use `config(8)`.

While still in the kernel configuration directory, give `config` the kernel configuration filename as an argument, like this:

```
# config TREBLE
```

If you get any error messages, read them. For example, `config` might tell you that you need to run `make clean` before building your new kernel, or that your kernel configuration is internally inconsistent and will not compile. If there's a problem, `config` will often give a line number where you made an error. Follow any advice `config` offers.

The following are some of the more common types of errors.

### Orphaned Devices

One common way that `config` fails is if you're missing a device that's needed by another device. Here's an example:

```
# config TREBLE
TREBLE:36: cpu0 at mainbus? is orphaned
 (nothing matching mainbus? declared)
TREBLE:37: bios0 at mainbus0 is orphaned
 (no mainbus0 declared)
TREBLE:38: ioapic* at mainbus? is orphaned
 (nothing matching mainbus? declared)
TREBLE:82: pci* at mainbus0 is orphaned
 (no mainbus0 declared)
*** Stop.
```

Your configuration attaches various devices to `mainbus0`, but there's no `mainbus0` entry in your configuration. Kernels that include devices that aren't attached don't make sense and cannot compile.

To address this, examine your hardware again. Figure out how these devices are supposed to attach to the system, and fix your kernel configuration.

### Bogus Hardware

Another common problem is including nonexistent device drivers, which generates the following error.

```
# config TREBLE
TREBLE:36: cpe0: unknown device `cpe'
*** Stop.
```

`config` shows me the error and the line number where it occurs. There is no `cpe` device, but there is a `cpu` device. My bad.

The error checking performed by `config` does not guarantee that your kernel will compile or run as expected. The only errors it catches are ones where the configuration is either internally inconsistent or flat-out wrong. The first real test comes when you try to actually build your configured kernel.

## Building a Kernel

If `config` ran successfully, you will have a kernel compilation directory including a makefile and a whole slew of header files. The traditional place for the *compile* directory is under the platform directory, which is */usr/src/sys/arch/amd64* for amd64 hardware.

The compile directory contains a subdirectory for each kernel configuration processed by `config`. My amd64 kernel called TREBLE is in the */usr/src/sys/arch/amd64/compile/TREBLE* directory, which contains a makefile, as well as all the header files for all included devices and options.

```
# cd ../compile/TREBLE
# make
```

Now it's time to wait. A successful compilation will create a kernel file *bsd* without generating any error messages.

### Kernel Build Errors

If your kernel fails to build, you probably have a perfectly explicable error. First, read the error message given by the compilation. Most of the time, the error message will explain what the kernel is missing. Generally, you will need to change your kernel configuration in some manner because of an error that `config` could not catch. A broken kernel compilation will end something like this:

```
../../../../arch/amd64/pci/pci_machdep.c: In function ❶'pci_intr_map':
../../../../arch/amd64/pci/pci_machdep.c:641: error: ❷'PCI_INT_VIA_ISA'
undeclared (first use in this function)
../../../../arch/amd64/pci/pci_machdep.c:641: error: (Each undeclared
identifier is reported only once
❸ ../../../../arch/amd64/pci/pci_machdep.c:641: error: for each function it
appears in.)
*** Error code 1

❹ Stop in /usr/src/sys/arch/amd64/compile/ENVY (line 89 of /usr/share/mk/sys.mk).
```

This kernel cannot be built because something is missing. When a build fails with statements that something "is undeclared" (as shown in bold), that's a hint that the kernel is missing a necessary entry.

The name of where it failed might offer you a hint as to what's missing. In this case, at ❶, I have a function name where the compilation failed, and then a specific undeclared variable ❷ that caused the compilation to fail.

I would start by figuring out where the `pci_intr_map` function comes from and what it's supposed to do. Search the source code and man pages for references to the missing function. Failing that, try the mailing list archives. Be sure to include the function and variable names in any web search. Generic output that says that "there was an error" ❸ or "the compile has stopped" ❹ is less unique, and hence it could be useful. If all else fails, fall back to the GENERIC configuration.

## Installing Your Kernel

Your completed kernel is the file *bsd* in the compile directory. Before you use your new kernel, verify that you have your current, working, well-behaved kernel backed up to a separate file on the root filesystem, and then copy your new kernel to */bsd*. That's it! The next time you reboot, you'll come up on your new kernel.

**NOTE** *Some people do not like to copy their custom kernel to /*bsd *until they're certain that the kernel will boot. If you're one of these people, copy your new kernel to the root directory under a different name, such as /*bsd.test. *Boot into this alternate kernel. Test your system. If everything works, properly install your new kernel.*

## Identifying the Running Kernel

If you build several custom kernels, you might forget which kernel you're running. The `uname(1)` command will tell you the name of the kernel configuration file used to build the running kernel. The `-v` flag will tell you the name of your kernel configuration and the number of times you have compiled it.

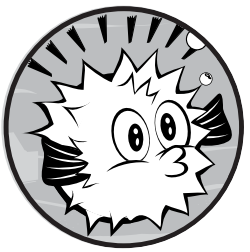
```
# uname -v
GENERIC.MP#348
```

This output does not mean that I've built a multiprocessor GENERIC kernel 348 times. I use the GENERIC kernel, and I let the OpenBSD release engineers build my kernels for me. They have built 348 official snapshot multiprocessor kernels without wiping the kernel build directory. Remember that building custom kernels is for advanced programmers and ignorant newbies. I'm neither.

# 20

# UPGRADING

*The latest source code?*
*Fugu extraordinary!*
*Be brave and swallow.*



Here's an ugly truth: If upgrades are hard, sysadmins try their best to avoid them. And that can cause security problems. Operating system upgrades can cause software that has worked well for years to develop nervous tics or stop working altogether. Fixing add-on packages that don't work on the new operating system version can require days of troubleshooting. Server upgrades can make even seasoned sysadmins wish that they had a simpler job, such as performing as a carnival sideshow, stuffing weasels into their trousers.

While you can probably deal with a bit of odd behavior in a desktop after an upgrade, your servers and firewalls must behave exactly as expected. It's common to delay upgrades until the system is so old that it can be replaced with a new machine running the new release, but that's both terrible system administration practice and completely unacceptable security practice. Computers connected to the Internet must be patched, maintained, and upgraded, or an intruder will almost certainly compromise them.

Fortunately, the OpenBSD upgrade process is simpler than those used by many other Unix-like operating systems. With proper preparation, you can upgrade OpenBSD with a minimum of difficulty.

## Why Upgrade?

Because you don't have a choice.

Security researchers, programmers, and skilled intruders continuously discover new ways to penetrate previously secure systems. Although OpenBSD has suffered only two vulnerabilities in a default installation that permitted an intruder to compromise the system, that doesn't mean that a two-year-old OpenBSD version is secure.

The OpenBSD Project provides security updates for only the two most recent releases. For example, when OpenBSD 5.3 comes out, OpenBSD 5.1 will be "end-of-lifed" and lose support from developers. If someone figures out how to break into a default OpenBSD 5.1 installation after 5.3 comes out, the developers might not provide fixes. You might adjust new security patches to work on older versions of the code, but you will find that backporting fixes becomes increasingly difficult.

Software not enabled in the default installation can also have problems. For example, in November 2011, the OpenBSD Project released a patch for a problem in the included BIND `named(8)` name server. OpenBSD does not ship with `named` enabled, so this wasn't a problem in the default installation, but it was certainly a security problem in a function that you might have chosen to enable.

In order to protect your system, you must understand how to apply security patches, either by applying the patch or by upgrading the entire system. But before we get to the upgrade process itself, let's look at your choices for OpenBSD versions.

## OpenBSD Versions

Developers all over the world continually make minor changes to OpenBSD's source code. If you download the source code in the morning and again in the afternoon, you'll get two slightly different versions. In fact, at any given time, you can get a few different versions of OpenBSD: *-current*, *snapshots*, *releases*, and *-stable*.

### OpenBSD-current

OpenBSD-current is the most recent development version of OpenBSD, containing code that is making its public debut. Developers test each other's work and then get approval to commit code to the tree. Eventually, they must put their work out for the public to test, review, and debug.

OpenBSD-current is where the public can access the newest code. If a change would temporarily break web servers, games, database servers, or whatever is running on -current, but the change is for the long-term good,

the change will go into -current. Those programs will probably work again before the next OpenBSD release, but there's no requirement that every third-party program work perfectly at all times on -current.

**NOTE** *The developers expect -current itself to work at all times, and they consider breaks serious problems. You might need to recompile Firefox, or the port maintainer might need to rewrite a makefile, but the core operating system is expected to run at all times.*

With these caveats, why would you possibly want to run -current? One excellent reason is to test the new OpenBSD in your environment. If today's -current panics under certain conditions, but last week's didn't, the OpenBSD folks want to know that.

(All the OpenBSD folks run -current on their laptops, and they run firewalls on -current.) If you can exercise -current in the real world, with a real workload, they want you to do so. Having real users run -current is the only way that OpenBSD can be tested before the official releases come out.

### OpenBSD Snapshots

Every few days, the OpenBSD team uploads a release from the latest -current code to the mirror servers. This is an interim release called a *snapshot*, which is identified only by the date of its release. A snapshot is simply the state of -current at a particular time. While the developers try not to build a snapshot on a day that -current is notably fouled up, guess who's in charge of the snapshot quality-assurance process. That's you.

Snapshots are provided for installation and testing convenience. Installing and testing a snapshot is easier than building -current on your own. Also, if you can reproduce a bug on a specific snapshot, the developers know exactly which version of the code you are running. It's much easier to identify a problem as appeared "in the July 15 2013 snapshot" than in a -current you built yourself from "code downloaded from server X at about 3:17 PM EST on July 15, 2013."

**NOTE** *Snapshots can contain uncommitted code not in -current. The patches for the changes are not usually available.*

You can get snapshots installation media from any mirror site, in the */pub/OpenBSD/snapshots* directory. If you want to run -current, the recommended way to start is by installing the most recent snapshot you can get your hands on and upgrading from there.

### OpenBSD Releases

Every six months, the pace of OpenBSD development is deliberately slowed. Developers spend time polishing new features, and Theo makes increasingly forceful requests for beta testers of the newest snapshots. When the OpenBSD team is satisfied that the software is of adequate quality, the source code tree is tagged, and a high-quality snapshot is built. This

snapshot is called a *release* and is issued a number like 5.2, 5.3, and so on. This is almost certainly what you installed on your first OpenBSD machine. A new release appears every May and November.

OpenBSD numbers releases sequentially, starting with 2.0 and incrementing .1 with every release. Unlike most software products, a .0 release has no special meaning. It's just another spot along a long path—a milestone hit every five years.

The release is the best-supported version of OpenBSD. Everything is expected to work, and the development team stands behind its releases. If a serious security problem is discovered in a release, OpenBSD will release a patch, or *errata*, for it.

### OpenBSD-stable

OpenBSD-stable is an OpenBSD release with all errata and very minor patches included. The developers deliberately hold the number of changes to each -stable version to the absolute bare minimum. A stable version is referred to as its base release plus -stable, such as 5.4-stable, 5.5-stable, and so on.

What sort of changes are merged back into -stable? Security fixes and errata go in automatically. Other than security issues, any patches added to -stable must be simple, short, and obviously correct. Patches that dramatically affect a small number of users might go in. For example, if all systems with a specific network card panic at random intervals, a patch might go into -stable (accompanied by various developers asking why no one with that network card ran snapshots before the release).

You won't get new functions in -stable. It won't come with any new device drivers or packet-filtering features. The API will not change. In general, -stable is expected to never get worse.

The only way to get OpenBSD-stable is to update the system from source.

### Which Version Should You Use?

OpenBSD's release system combines the best features of open source development and commercial releases. Users have access to both the bleeding-edge experimental code and the stable, polished releases. Look at your requirements and choose your poison.

- If you're running OpenBSD in a production environment, either use a release with the applicable security errata or track -stable. The developers encourage more experienced users to use snapshots or -current, but that choice is up to you.
- If you are evaluating OpenBSD for use in a production environment, install the version you intend to use.
- If you're just learning about Unix-like systems, or if you want a quiet OpenBSD experience, use a release and apply applicable errata.

- If you're an operating system developer or experienced sysadmin, feel free to jump right in to -current or snapshots. You can either handle any problems you encounter or use those problems as an excuse to expand your knowledge. Many people find that they can use -current in production, if they do not need packages. These are usually more experienced users who want firewalls.
- Hobbyists can run anything they want!

Remember the limitations of your chosen branch. A release is a good place to start, but you can gradually upgrade your system to -stable, and then to -current, as your understanding expands. Many developers started out as interested hobbyists.

## The OpenBSD Upgrade Process

An OpenBSD upgrade has three distinct phases: installing the newer versions of the operating system files, updating the local configuration, and updating obsolete add-on software packages. Each is a separate part that requires independent handling.

An upgrade requires installation media. The best upgrade media is the new release CD or an Internet mirror. You can also upgrade OpenBSD by building and installing the source code directly on the machine to be upgraded, but doing so is more difficult and risky than upgrading from the official release. Much of the information for upgrading from a network or CD applies to upgrading via source code.

**NOTE** *OpenBSD supports upgrading only one major release at a time. You cannot upgrade directly from, say, 5.3 to 5.5; you must upgrade from 5.3 to 5.4, and then to 5.5. The more releases you need to upgrade through, the more reason to reinstall. You would spend more time serially upgrading three or four releases than you would reinstalling.*

Before upgrading, back up any data you actually care about. The upgrade process extracts new files over the existing operating system, and could overwrite something important. The installer generally works, but human beings are fallible. Back up!

### Following the Upgrade Guide

As OpenBSD evolves, basic system features change. This wouldn't be a big issue, except when interdependent changes create a chicken-and-egg or bootstrap problem. If you just blindly run the upgrade process and don't handle any other required changes, you'll find that your new system fails in unpredictable ways.[1] If you're building the system from source, these problems might prevent the build from completing.

1. Henning Brauer tells me that many upgrade failures aren't really unpredictable; they're merely "unsupported and untested" code paths. To most of us, that's "unpredictable," but you're welcome to predict them yourself.

All of these potential problems should be solvable by anyone building the system from source, but it's nice to have them documented. Conveniently, OpenBSD provides an *Upgrade Guide* for each release, documenting the steps needed to take a system from one release to the next.

The *Upgrade Guide* is divided into chunks by the type of upgrade you are performing. The simplest upgrade is for people using official OpenBSD files, such as a network or CD upgrade. If you're building from source, the instructions quickly grow in complexity. Follow the instructions in the order in which they appear. Most upgrade prerequisites are typical system administration tasks. The following are the most common requirements.

**NOTE** *Instructions in the* Upgrade Guide *supersede anything I say in this chapter. I could just sprinkle the words "unless specified otherwise in the* Upgrade Guide*" in every paragraph for the rest of this section, but then my editor would slap me. The OpenBSD documentation is the final word in OpenBSD system administration, including the upgrade process.*

### Install Programs

Especially when you are building from source, bootstrap tools such as `gcc(1)` and `perl(1)` might need to be built with the upgraded tool. When upgrading from source, you might need to install these bootstrap tools before beginning to compile the new version of OpenBSD. The *Upgrade Guide* notes these requirements.

If your attempt to build OpenBSD from source fails, reread the *Upgrade Guide* before troubleshooting. Starting from the closest available binary release or snapshot will probably solve your problem.

### Remove Programs and Files

OpenBSD removes programs from the base system when they become obsolete or dangerous, or when their functions are integrated into other programs. When you upgrade, you must manually remove these programs. This is necessary because old software left on an upgraded system can pose a security risk. Also, some files and directories might become superfluous in a new OpenBSD version. You can remove these programs, files, or directories once the upgrade is complete.

### Prepare Package Upgrades

When you upgrade OpenBSD, you must upgrade the installed packages as well, because you can't reliably run packages built for old versions of OpenBSD on newer versions. (Doing so *might* work, but there's no guarantee.) The *Upgrade Guide* includes notes on upgrading specific installed packages, and you should take some of those actions before beginning the upgrade.

For example, the *Upgrade Guide* for the newest OpenBSD version says that the PostgreSQL port had a major version upgrade. You must do a database

dump and restore as part of the upgrade. The old version of PostgreSQL might not run well on the new OpenBSD, so perform the database dump before starting the system upgrade.

Your packages might not require any pre-upgrade work, but it's much easier to check beforehand than to finish the operating system upgrade, and then need to fall back because you didn't prepare some third-party package.

#### System Configuration

The preceding tasks are the most common requirements for upgrading, but you might need to change other system files before or after the upgrade process itself. Read the *Upgrade Guide*, or your programs might not run as expected.

### *Customizing Upgrades*

The upgrade script supports the *siteXX.tgz* file discussed in Chapter 23. If the file exists in the installation media, you can choose to install it during the upgrade.

You can also run a custom post-upgrade script as part of the upgrade. When the upgrade completes, the script checks for the file */upgrade.site*. If the upgrader finds this file, it executes this script as the last step of the upgrade. Copy */upgrade.site* to the system before starting the upgrade. Chapter 23 discusses *upgrade.site* in more detail.

## Upgrading from Official Media

After reading the *Upgrade Guide*, get your installation media for the new version of OpenBSD and boot from it. If you plan to upgrade over a network, you should need only the new installation kernel *bsd.rd*. You can just grab this via FTP (or you could grab the entire directory along with it and run the upgrade from your local disk). Here, I grab the newest snapshot kernel from my root directory:

```
# cd /
# ftp ftp://ftp3.usa.openbsd.org/pub/OpenBSD/snapshots/amd64/bsd.rd
Connected to plier.ucar.edu.
...
```

After you get the snapshot kernel, go to your console and boot into the new kernel.

```
>> OpenBSD/amd64 BOOT 3.18
boot>  boot bsd.rd
booting hd0a:bsd.rd: 2993636+916428+2864232+0+531344
[89+320016+207017]=0xb799f0
entry point at 0x1001e0 [7205c766, 34000004, 24448b12, a608a304]
...
```

```
root on rd0a swap on rd0b dump on rd0b
erase ^?, werase ^W, kill ^U, intr ^C, status ^T

Welcome to the OpenBSD/amd64 5.3 installation program.
(I)nstall, (U)pgrade or (S)hell? U
```

Enter `U` to upgrade. The upgrade process looks much like the installation process covered in Chapter 3. Defaults appear inside square brackets. Accept the defaults by pressing ENTER.

```
Terminal type? [vt220] ❶
Available disks are: sd0 sd1 sd2.
Which one is the root disk? (or 'done') [sd0] ❷
Root filesystem? [sd0a] ❸
Checking root filesystem (fsck -fp /dev/sd0a)...OK.
Mounting root filesystem (mount -o ro /dev/sd0a /mnt)...OK.
Do you want to do any manual network configuration? [no] ❹
Force checking of clean non-root filesystems? [no] ❺
fsck -p e4bf0318329fe596.a...OK.
...
```

Always use the default terminal, unless you know exactly when you shouldn't. Commodity hardware usually uses vt220, as shown here at ❶, but the default terminal is platform-specific.

The upgrade needs to read your root partition to learn where to install files. It can't conclusively identify your actual root disk ❷ and partition ❸ unless you tell it to do that.

The upgrade script will configure your network according to the existing settings that you should hope are correct. If you need to adjust the network at every boot, the upgrade script gives you a chance to reconfigure the network at ❹.

If you shut down the machine via `reboot` or `shutdown`, your filesystems should be clean. If you unceremoniously pulled the power plug because you were going to upgrade the machine and no longer cared about your filesystems, OpenBSD will notice and clean your filesystems. To deep-check clean filesystems, you can force running `fsck(8)` at ❺. The upgrade script preens clean filesystems to check for obvious errors before proceeding.

### Upgrading Over the Network

The default upgrade method is CD. I want to do this upgrade over the network, so here's how I continue:

```
Location of sets? (cd disk ftp http or 'done') [cd] ftp ❶
HTTP/FTP proxy URL? (e.g. 'http://proxy:8080', or 'none') [none] ❷
Server? (hostname, list#, 'done' or '?') [ftp5.usa.openbsd.org] ftp3.usa.openbsd.org ❸
Server directory? [pub/OpenBSD/snapshots/amd64] ❹
Login? [anonymous] ❺
```

I choose `ftp` as the location of the sets at ❶. I don't need to go through a proxy server to access the FTP server, so I leave that space blank at ❷.

The default OpenBSD FTP server is perfectly fine, but if you've identified a really fast mirror, you might use that. I use my preferred mirror site at ❸.

Every *bsd.rd* installer knows the server directory to install from at ❹. I change the server directory only if I have set up a local mirror. Similarly, every OpenBSD mirror permits anonymous FTP. I change the username and enter a password only if I'm using a local mirror at ❺.

### Choosing File Sets

Next comes a chance to choose which sets to upgrade.

```
Select sets by entering a set name, a file name pattern or 'all'. De-select
sets by prepending a '-' to the set name, file name pattern or 'all'. Selected
sets are labelled '[X]'.
    [X] bsd           [X] base51.tgz    [X] game51.tgz    [X] xfont51.tgz
    [X] bsd.rd        [X] comp51.tgz    [X] xbase51.tgz   [X] xserv51.tgz
    [X] bsd.mp        [X] man51.tgz     [X] xshare51.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

You must upgrade every file set installed on your machine, or the machine will behave unpredictably. If you didn't install some sets during your original installation, you don't need to install them now. For most machines, I recommend installing all sets.

**NOTE** *Notice that two sets are missing:* etcXX.tgz *and* xetcXX.tgz. *These files belong in* /etc *and are legitimately edited by system administrators. The upgrade script cannot know if a file should be replaced, edited, or ignored. You must update* /etc *yourself.*

The upgrade script downloads and extracts the selected file sets, and then asks you to verify that you're finished selecting file sets. If so, it remakes all your device nodes to fit with the new kernel.

At this point, you can reboot into your new OpenBSD userland except that userland might not work quite right because you haven't updated */etc* yet.

## Updating /etc

The */etc* directory contains system and program configuration information. When a program changes, its configuration file might also change. If you try to run a new program with an obsolete configuration file, the program will not run correctly.

You absolutely must update */etc* before running your system—arguably the most annoying part of an upgrade. No automated process can possible know how your system should behave. Only you can know that, which means that you must compare the contents of your existing */etc* to the same files in a new, stock */etc*. OpenBSD provides tools to make the process less annoying.

Before you begin, if your system performs complicated functions, such as a database or packet filtering, boot into single-user mode. (Although

single-user mode is not strictly necessary, I've had software behave badly during a half-completed upgrade, so I now routinely update */etc* in single-user mode.)

```
 >> OpenBSD/amd64 BOOT 3.19
boot> boot -s
booting hd0a:/bsd: 5687720+1608588+939456+0+644288 [80+502320+325975]=0xd43b98
...
Enter pathname of shell or RETURN for sh:
#
```

While I'm a long-time `tcsh` user,[2] I always use the default shell in single-user mode. If you want to use an alternate shell, it must be statically linked and available on the root partition.

### Mounting Filesystems

Now mount all your filesystems. If you upgraded via the network, start the network now.

```
# mount -a
# /bin/sh /etc/netstart
WARNING: inconsistent config - check /etc/sysctl.conf for IPv6 autoconf
#
```

I've hardly begun, and here's a warning already. How fantastic! Perhaps this IPv6 error is from the upgrade, or maybe it's a lingering misconfiguration I never noticed before. Either way, this is a good time to identify and fix the problem.

Verify that you're on the network by pinging a couple of hosts.

You need the files *etcXX.tgz* and *xetcXX.tgz* for your new release. If you have the CD, the files are in the release directory. If not, fetch them over the network. (I always get these file sets from the same server I upgraded from, just to eliminate any chance of a difference in the files.)

```
# cd /tmp
# ftp ftp://ftp3.usa.openbsd.org/pub/OpenBSD/snapshots/amd64/etc51.tgz
# ftp ftp://ftp3.usa.openbsd.org/pub/OpenBSD/snapshots/amd64/xetc51.tgz
```

You are now ready to update */etc*.

### Using sysmerge(8) to Compare /etc Files

The `sysmerge(8)` program compares your existing */etc* to the */etc* in the installation set, points out differences, and lets you replace your installed file with the new one, keep your file, or merge the two.

2. I know, I know, your shell is superior to mine. I was given `tcsh` as my first shell almost 30 years ago, and my fingers are too habituated to it to change. I'll concede your superiority if you'll stop telling me about it.

Use -s to tell sysmerge where the new *etcXX.tgz* file is, and -x to point to the new *xetcXX.tgz*. I put both of these files in */tmp*.

```
# sysmerge -s /tmp/etc51.tgz -x /tmp/xetc51.tgz
```

sysmerge will handle the easy changes itself, but leave you to take care of files that need your intervention.

### Easy sysmerge Updates

If your system is only lightly modified, you should see something like this:

```
===> Populating temporary root under /var/tmp/sysmerge.daiHKukKfE/temproot
===> Starting comparison
===> Updating /etc/inetd.conf
===> Updating /etc/login.conf
...
```

I haven't changed these files, so sysmerge automatically updates them for me.

```
...
===> Installing /etc/nginx/fastcgi_params
===> Installing /etc/nginx/koi-utf
...
```

I didn't have these files on my system, so sysmerge installs them for me.

These examples are easy cases. In cases where you've edited an */etc* file, sysmerge will need your help.

### sysmerge and Edited Files

Say you've edited a file, and the file version has changed. Does your local change reflect the update, does it conflict, or can the two coexist? sysmerge can't tell if it should overwrite the installed file with a new version, leave it unchanged, or merge the two, so it displays the differences between the old and new files.

```
===> Displaying differences between ./etc/mail/aliases and installed version:

❶ --- /etc/mail/aliases   Sun Jun  9 04:50:04 2013
❷ +++ ./etc/mail/aliases  Wed Oct 23 17:06:02 2013
@@ -1,5 +1,5 @@
 #
❸ -#      $OpenBSD: aliases,v 1.36 2010/09/22 13:01:10 deraadt Exp $
❹ +#      $OpenBSD: aliases,v 1.37 2012/10/13 07:42:39 dcoppa Exp $
 #
 #  Aliases in this file will NOT be expanded in the header from
 #  Mail, but WILL be visible over networks or from /usr/libexec/mail.local.
@@ -32,6 +32,7 @@
 _identd: /dev/null
 _iked: /dev/null
```

```
    _isakmpd: /dev/null
❺ +_iscsid: /dev/null
    _kadmin: /dev/null
    _kdc: /dev/null
    _ldapd: /dev/null
   @@ -69,7 +70,7 @@
    sshd:   /dev/null

    # Well-known aliases -- these should be filled in!
❻ -root: mwlucas@blackhelicopters.org
❼ +# root:
    # manager:
    # dumper:
```

If you've changed the file, `sysmerge` presents the differences between the old and new files with a few surrounding lines of context. In this example, the */etc/mail/aliases* file on my system is dated June 9 at ❶, and the new version is from October 23 at ❷. Lines that exist in the new version of the file but not in the installed one are prefaced with a plus sign (+). Lines that exist in the installed file but not in the new one are prefaced with a minus sign (-).

This example shows that the OpenBSD version of this file changed from 1.36 at ❸ to 1.37 at ❹. That's not terribly surprising, and for system administration purposes, not a terribly vital piece of information. But the new version has a new alias, directing email addressed to the user `_iscsid` to */dev/null* at ❺. This could be important, so I want the new alias on my system.

Next, we see a difference between the files, where I've forwarded email addressed to root to my personal email at ❻, but the new version of the file has no such redirection at ❼. I want the old version of this line but the new version of another line, and while I don't particularly care about the OpenBSD version numbers, I would prefer the newer one. I could hand assemble an aliases file, but after `sysmerge` prints out the differences, it offers to help.

```
❶ Use 'd' to delete the temporary ./etc/mail/aliases
❷ Use 'i' to install the temporary ./etc/mail/aliases
❸ Use 'm' to merge the temporary and installed versions
❹ Use 'v' to view the diff results again

  Default is to leave the temporary file to deal with by hand

How should I deal with this? [Leave it for later] m
```

`sysmerge` offers the following choices:

- If I delete the temporary aliases file, `sysmerge` throws away the new file ❶. This is fine if my existing aliases file is adequate, but in this case, I want part of the new file.
- If I install the temporary aliases file, I overwrite my changes ❷. Unless I go back in and change the aliases file again, my custom mail forwarding will stop working. I don't want this to happen.

- I can merge the old and new files ❸, choosing the best fit from each file, which is the option I'll pick.
- I could look at the differences again ❹. This has the advantage of putting off an actual decision.

To merge the old and new files, I enter `m`. Note that the merge function requires close attention to detail. A mistake here can make your system hang as it tries to go into multiuser mode.

When you merge, `sysmerge` takes your input and builds a combined file. Lines that are identical in both versions are automatically added to the new file. When lines differ, `sysmerge` walks you through the differences and lets you choose a version.

The new version of the line appears on the right, and the installed version is on the left. Enter **`l`** or **`1`** to choose the version on the left side, or **`r`** or **`2`** to choose the version on the right.

```
# $OpenBSD: aliases,v 1.36 2010/09/22 13:01:10 de | # $OpenBSD: aliases,v 1.37 2012/10/13
07:42:39 dc
%r
```

The version number has updated, though it's in a comment, which won't affect how the alias file updates. Still, as I'm merging the files anyway, I might as well get the new version number. I enter **`r`** to choose the version on the right.

```
                                > _iscsid: /dev/null
%r
```

There is no equivalent to this line in the installed file, as this alias exists only in the new file. Again, I choose **`r`** to include this line in my file.

```
root: mwlucas@blackhelicopters.org    | # root:
%l
```

Here, I want the entry from the installed file, on the left-hand side. I choose **`l`**.

Once I've gone through all of the entries, `sysmerge` offers me more choices. These include comparing the merged and installed files, comparing the merged and new files, starting over, viewing the merged file, redoing the merge, and installing the merged file.

```
  Use 'e' to edit the merged file
  Use 'i' to install the merged file
  Use 'n' to view a diff between the merged and new files
  Use 'o' to view a diff between the old and merged files
  Use 'r' to re-do the merge
  Use 'v' to view the merged file
  Use 'x' to delete the merged file and go back to previous menu
  Default is to leave the temporary file to deal with by hand
===> How should I deal with the merged file? [Leave it for later] i
```

I did everything correctly, so I install the merged file (although I should probably view the merged file first, and then install it).

My biggest difficulty with `sysmerge` comes in differentiating my left and my right. Worse, the L key is on the right side, and the R key is on the left. (Go ahead now, laugh, but just wait until you mix that up.)

#### Finishing sysmerge

When `sysmerge` finishes installing the files, it checks the permissions on the */etc* files, and tells you where to find the log and that the system might need a reboot. A purist might tell you that you don't need to reboot, but usually you should go ahead and do it. Rebooting after changing core system files prevents a variety of problems, and rebooting as part of an upgrade isn't unreasonable. You can wait to reboot until after you upgrade your packages, as long as everything works.

```
...
===> Comparison complete
===> Checking directory hierarchy permissions (running mtree(8))
===> Output log available at /var/tmp/sysmerge.daiHKukKfE/sysmerge.log
        *** WARNING: some new/updated file(s) may require a reboot
# reboot
```

You now have an updated OpenBSD base system. Be aware that new or changed files can change system behavior, but usually you won't notice. The *Upgrade Guide* usually notes any changes average users are likely to notice. Still, only you know what your system does and how you want it to behave.

Upgrading your installed packages is a separate task.

## Updating Installed Packages

Packages run reliably only on the version of OpenBSD for which they're compiled. If you're using packages, then updating your third-party software is very easy. (If you build your own software from the ports collection, you can still update but it won't be as easy.)

First, check the *Upgrade Guide* again. It describes any intrusive changes to major software. Take any actions it recommends before continuing.

### *Updating the Package Repository*

Before upgrading your packages, check your `$PKG_PATH` environment variable. It almost certainly references the package directory for your previous version of OpenBSD.

```
# echo $PKG_PATH
ftp://ftp11.usa.openbsd.org/pub/OpenBSD/5.2/packages/i386/
```

Find the package repository for your new version of OpenBSD. You can probably just update the release number in your shell's dotfile, but go to the mirror site and make sure that the packages for that release are present.

If you upgrade from release to release, you can use the `uname(1)` command to set your `PKG_PATH` in your dotfile. For example, if *ftp11.usa.openbsd.org* is your favorite mirror site, use a line like this for `sh`-based dotfiles.

```
export PKG_PATH=ftp://ftp11.usa.openbsd.org/pub/OpenBSD/`uname -r`/packages/`uname -m`/
```

### *Using the Upgrade Command*

To upgrade your installed packages, use `pkg_add` with the `-i` and `-u` flags.

```
# pkg_add -iu
quirks-1.73->1.77: ok
apr-1.4.6->1.4.6p0: ok
apr-util-1.4.1-ldap:cyrus-sasl-2.1.25p3->2.1.25p3: ok
apr-util-1.4.1-ldap:openldap-client-2.4.31->2.4.31: ok
apr-util-1.4.1-ldap:libiconv-1.14->1.14: ok
...
```

The `-i` flag tells `pkg_add` to work in interactive mode and ask you about any ambiguities. The `-u` flag means "update."

This upgrader recurses through each of your add-on software packages and its dependencies, uninstalling the old version and installing the new. If you want to see more verbose and detailed messages about the package-updating process, add the `-v` flag.

#### Package Options

If the dependencies for a package have changed and you now have multiple options, `pkg_add` presents your choices.

```
Ambiguous: choose dependency for foomatic-db-engine-4.0.8p2:
 a       0: curl-7.26.0
         1: wget-1.13.4
Your choice: 1
```

The package `foomatic-db-engine` can use either `curl` or `wget`. Of the two, I prefer `wget`, so I enter `1`. Pressing ENTER tells `pkg_add` to use the default.

#### Package Messages

Once all of the packages have been updated, `pkg_add` displays any messages from the upgraded packages.

```
Read shared items: ok
You may wish to update your font path for /usr/local/share/ghostscript/fonts
Look in /usr/local/share/doc/pkg-readmes for extra documentation.
...
```

Some of the installation instructions will tell you to clear out cached files from the older version of the software, as in this CUPS example.

```
--- -cups-1.5.3p4 -------------------
You should also run rm -rf /var/log/cups/*
You should also run rm -rf /var/cache/cups
You should also run rm -rf /var/spool/cups
...
```

Other times, software might jump versions. For example, OpenBSD lets you install multiple versions of PHP, Python, and other scripting languages, but after upgrading, you must decide which is your preferred default.

```
--- +python-2.7.3p1 -------------------
If you want to use this package as your default system python, as root
create symbolic links like so (overwriting any previous default):
 ln -sf /usr/local/bin/python2.7 /usr/local/bin/python
 ln -sf /usr/local/bin/python2.7-2to3 /usr/local/bin/2to3
 ln -sf /usr/local/bin/python2.7-config /usr/local/bin/python-config
 ln -sf /usr/local/bin/pydoc2.7  /usr/local/bin/pydoc
...
```

You may also need to change some system configuration after an upgrade.

```
--- +tk-8.5.12 -------------------
You may wish to add /usr/local/lib/tcl/tk8.5/man to /etc/man.conf
...
```

The package maintainers put these messages into the package for your benefit. Read them, and if you're in doubt, follow their instructions.

If all of your software is installed via packages, the upgrade process should be painless and transparent. I would like to tell you about all the problems and edge cases, except I've never been able to trigger any. Upgrading packages from the official release media just works. Packages built from the ports tree, however, are more complicated to upgrade, as I discuss in "Upgrading Ports" on page 368.

## Why Build Your Own OpenBSD?

Building your own upgrade from OpenBSD's source is intended only for advanced users and those interested in developing OpenBSD and advanced users. You must be comfortable reading and compiling source code, debugging problems, and restoring from backup before even trying to build OpenBSD from source. In OpenBSD's earlier days, I found upgrading from source to be the easiest way to move forward, but now upgrading via snapshot is much easier and much less error-prone. If there's any way you can use an official binary release to install what you're looking for, do so.

When you build OpenBSD from source, you are building the distribution sets that you installed via FTP or CD. The files might not be bundled up in distributions, but their contents will be the same. You still must merge your configuration files with `sysmerge`, and you will still need to update your installed software. The only thing building OpenBSD gets you is the latest version of the branch you're following.

I know of three reasons to build your own OpenBSD from source: to get OpenBSD-stable, to get the latest OpenBSD-current, or to highly customize OpenBSD. OpenBSD-stable is available only as source code. No official installation media is available for -stable, so if you want to go from 5.4-release to 5.4-stable, you must build it from source. If you want the absolutely latest OpenBSD code—newer than the latest snapshot—you must build it. And if you want to highly customize OpenBSD, you must build it from source.

## Preparations for Building Your Own OpenBSD

Building OpenBSD takes up about 4GB of disk, 2GB in */usr/src* and 2GB in */usr/obj*. OpenBSD creates these directories as separate partitions by default, but if you designed your own disk-partition scheme, make sure you have enough space.

You must build on your target platform. Don't try to cross-compile by, for example, building VAX binaries on an amd64 box. OpenBSD developers use cross-compiling to bring up a new hardware platform, but once the platform is up and running, all development happens on the native hardware. Code produced by cross-compiling might not be identical to code produced by the compiler running on the native platform.

### *Preparing the Base Operating System*

Your first step is to prepare the base operating system. You can build OpenBSD on only an OpenBSD installation similar to what you're trying to build, which means you need to install the closest binary set to your target platform on your build machine. If you're trying to build OpenBSD 5.4-stable, start by installing 5.4-release on your build machine. If you're trying to build the latest OpenBSD-current, upgrade your build machine to the newest snapshot first.

Why start from the closest available binary release? For one, that's how the OpenBSD developers do it; the code is meant to be built from a very recent OpenBSD. Although the system changes only slowly, those changes can add up. OpenBSD-stable is built only on the OpenBSD release it's based on, or on a -stable release following that base release.

Also, OpenBSD-current occasionally has "flag days," where a critical system change makes building the source code difficult. These might be compiler or linker upgrades, library or kernel changes, or just about anything else. While the OpenBSD team documents what you need to do to get over these humps, those documents are more like notes for people who know what they're doing than user-friendly instructions.

These flag days are announced on the OpenBSD mailing lists. You can try to follow those notes and build OpenBSD over these barriers, but when you get sick of beating your head against a flag-day change, upgrade to a snapshot to get over the hump. (Many OpenBSD developers also use snapshots to get over flag-day changes; inability to compile OpenBSD through a flag day is not a threat to your manhood or womanhood.)

### Getting Source Code

Now get the OpenBSD source code. If you have already installed these files, and you need to upgrade to a more recent version, see "Updating Source Code" on page 385.

For those installing the source code for the first time, the OpenBSD project provides recent code snapshots in four compressed tar files: the userland (*src.tar.gz*), kernel (*sys.tar.gz*), X Windows (*xenocara.tar.gz*), and ports (*ports.tar.gz*). All must be kept synchronized, which means that you cannot use a -current ports tree atop a -stable userland and kernel. Get the file that's closest to what you want to build.

If you're building -stable, you can grab all four files from the release directory of the binary you installed. For example, if you're building OpenBSD 5.4-stable, you'll find *src.tar.gz*, *sys.tar.gz*, *xenocara.tar.gz*, and *ports.tar.gz* on your CD or on an OpenBSD mirror under */pub/OpenBSD/5.4/*.

If you're building -current, you're better off starting with a newer snapshot of the source code. On the OpenBSD mirror sites, under */pub/OpenBSD*, you'll find recent copies of *src.tar.gz* and *sys.tar.gz*. Grab the most recent ones of those. You still need the *xenocara.tar.gz* and *ports.tar.gz* files from the most recent OpenBSD release, as those files are not updated as frequently.

Verify that the directories */usr/src*, */usr/obj*, */usr/xenocara*, */usr/xobj*, and */usr/ports* are empty. Then extract *src.tar.gz* and *sys.tar.gz* under */usr/src*, and Xenocara and *ports* directly under */usr*. Here, I've copied all the tarballs to my home directory:

```
# cd /usr/src
# tar -xzpf $HOME/src.tar.gz
# tar -xzpf $HOME/sys.tar.gz
# cd /usr
# tar -xzpf $HOME/ports.tar.gz
# tar -xzpf $HOME/xenocara.tar.gz
```

This gives you a known good base to start from. If you're looking to build your own OpenBSD, you probably don't want to build a version that's available for installation now; you want to build a version that's not available for installation. This means you want to update the source code to either -current or -stable.

## Updating Source Code

OpenBSD uses Concurrent Versions System (CVS) for source code management. CVS is an older, somewhat traditional version control system. While many projects have moved from CVS to newer, shinier, and perhaps more glamorous systems, CVS meets the OpenBSD Project's needs.

OpenBSD has a single central source-code repository: the master CVS server. Only developers and mirror sites have access to this server. When a developer wants to make new OpenBSD code available, he *commits* the changes to this central repository, and other developers can see his changes at this point.

The master CVS server tracks all changes ever made to the OpenBSD source, as well as who made those changes. Mirror sites capture these changes and make them available to the users in a matter of hours. As a user, you can use CVS to update your local source code to the latest version from a mirror site.

### Source Code Repositories and Tags

OpenBSD's source code is divided into *repositories*, or collections of code for particular subsystems. You need to download and synchronize only the collections that you want to use.

The OpenBSD CVS repository includes four collections: `src` (userland and kernel source), `ports` (the ports collection), `xenocara` (X Windows), `www` (the website), and the obsolete `X11` and `XF4` X Windows collections. While X11 and XF4 are still kept for historical purposes, you should never need to use that code. The `www` repository is of interest to the website editors and contributors. In order to build a recent OpenBSD, you must update your `src`, `ports`, and `xenocara` collections to the latest versions of your chosen branch.

A *tag* is a label for a particular version of a repository. OpenBSD uses tags to differentiate between -stable, -release, and -current. For example, the source code of every single OpenBSD release ever made includes the file */usr/src/etc/master.passwd*. But the version of *master.passwd* shipped with OpenBSD 2.0 differs wildly from that shipped with OpenBSD 5.3! CVS uses tags to differentiate the various versions of this and every other file. By using tags, you can ask CVS for the version of any file that shipped with any OpenBSD release.

The tag for any -stable version of OpenBSD is the string `OPENBSD` and the version number, separated by underscores. For example, the tag for OpenBSD 5.4 is `OpenBSD_5_4`. Note the two underscores: there is no `OPENBSD_54` or `OPENBSD5_4`. If you use a tag that does not exist, rather than updating your local source code files, you'll delete them. (While you should download the source code for a release, rather than updating to it via CVS, an OpenBSD release appends the string `_BASE` to the tag, as in `OPENBSD-5_4_BASE`.) That said, OpenBSD-current is special in that it has no tag and it includes the latest version of all source code in all repositories.

All of the repositories are designed to be updated synchronously. If, for example, you update the source code repository to -current and leave your ports and Xenocara at their -release or -stable versions, your system will behave unpredictably. As with learning to juggle chainsaws, you're welcome to try it, but don't whine.

### CVS Mirrors

You can use anonymous CVS to update your source code to the latest version. Start by choosing a convenient anonymous CVS server from the list at *http://www.OpenBSD.org/anoncvs.html*. There are mirrors all over the world, but choose one on your continent for better performance. (I use *anoncvs13.usa.openbsd.org*[3] in my examples.)

Tracking OpenBSD-current is slightly different than tracking OpenBSD-stable. We'll start with -stable, and then see how -current differs.

### Updating to -stable

The first time you update your source code, you must specify the anonymous CVS server on the command line.

```
# cd /usr
# cvs -qd anonymous@server:/cvs get -rOPENBSD_tag -P src
```

CVS is very picky about the order of its command-line arguments, and many flags are position-dependent. Don't change the order of arguments unless you know what you're doing.

Substitute your preferred server and the release tag you want to get into this command. For example, to update my OpenBSD 5.1 source tree to the latest stable version from *anoncvs13.openbsd.org*, I would run the following:

```
# cd /usr
# cvs -qd anonymous@anoncvs13.openbsd.org:/cvs get -rOPENBSD_5_1 -P src
The authenticity of host 'anoncvs13.usa.openbsd.org (192.0.2.217)' can't be
established.
❶ ECDSA key fingerprint is d3:b2:b5:68:87:3b:f6:93:21:fd:28:ea:cc:b6:e1:13.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'anoncvs1.usa.openbsd.org,149.20.54.217' (ECDSA) to
the list of known hosts.
```

Because OpenBSD runs CVS over SSH the first time you run `cvs`, it asks you to verify the CVS mirror's host key. Compare the ❶ key fingerprint given by your client to the fingerprint listed on the CVS mirror list. If they match, you're talking to the actual CVS server. If the fingerprints don't match, something is wrong, which could be a problem at the server, a skipped website update, or an actual security problem at the mirror. If the key fingerprints

3. Again, there is no *anoncvs13.usa.openbsd.org*. Find a server close to you. Stop blindly copying my examples. It's like you think I know what I'm doing or something!

don't match, choose a different CVS mirror. (SSH will cache this key, and future updates won't ask you to verify the key unless it changes.)

There's a pause when CVS starts comparing the source code on your disk to the source code on the server, and just about when you think that something has gone wrong, you'll probably see actual source code updates, like this:

```
U bin/systrace/intercept-translate.c
U lib/libssl/src/crypto/mem.c
U lib/libssl/src/crypto/asn1/a_d2i_fp.c
U lib/libssl/src/crypto/buffer/buffer.c
U sys/conf/newvers.sh
U sys/netinet6/ip6_output.c
U usr.sbin/nsd/query.c
```

This is complete CVS update output for updating OpenBSD 5.1 release to -stable. In all, there were seven changes. When the OpenBSD guys say "minimal changes in -stable," they mean it.

Repeat this for */usr/ports* and */usr/xenocara*.

```
# cd /usr
# cvs -qd anonymous@anoncvs13.openbsd.org:/cvs get -rOPENBSD_5_1 -P ports
# cvs -qd anonymous@anoncvs13.openbsd.org:/cvs get -rOPENBSD_5_1 -P xenocara
```

A source tree records the last server updated from, and on subsequent updates, you can drop the server from the command line. The source tree also knows which repository within the server it's supposed to update from, so you don't need to specify it.

```
# cd /usr/src
# cvs -q up -rOPENBSD_5_1 -Pd
```

Run this same command any time you want the latest -stable source code.

### Updating to -current

The process for updating your source code to -current is much the same as updating to -stable, but the command line differs slightly. The first time you update your source tree, you must specify the server name.

```
# cd /usr
# cvs -qd anonymous@server:/cvs get -P src
```

This cvs command gives you the latest -current source code. For example, if I want to update my source code from *anoncvs13.openbsd.org*, I run this:

```
# cd /usr
# cvs -qd anonymous@anoncvs13.openbsd.org:/cvs get -P src
```

You should get the SSH key fingerprint verification message, and see the same type of messages that you would get updating to -stable.

The first time you run CVS to update a specific set of source code, cvs records which server the source code came from. For subsequent updates to the latest -current source code, you can skip the server name and shorten the command, as follows:

```
# cd /usr/src
# cvs -q up -Pd
```

Now you need to build the new source code into program code.

You build -stable and -current in the same way, but -current has more potential issues, so we'll start by building -stable.

## Building OpenBSD-stable

Building OpenBSD-stable requires building and installing a new kernel, building and installing a new userland, and building and installing the new Xenocara.

### *Upgrading the Kernel*

Building an upgraded kernel is like building a custom kernel, as discussed in Chapter 19. Basically, the process boils down to this:

```
# cd /usr/src/sys/arch/platform/conf/
# config GENERIC
# cd ../compile/GENERIC
# make clean && make
# make install
```

(If I planned to build OpenBSD regularly on this machine, I would script this.)

**NOTE** *Chapter 19 is full of warnings about difficulties compiling a custom kernel. These don't apply to building the GENERIC kernel on -stable. Remember that -stable includes only security fixes and obviously correct small changes. ABI, API, configuration, and syntax changes are absolutely forbidden. If this kernel build fails, you probably corrupted your source tree somehow. Remove everything in* /usr/src *and start over.*

After building and installing the new kernel, reboot. You must run the new kernel to build the new userland.

### Building the Userland

To build and install everything outside the kernel, remove any old builds and re-create the object directories. Also, make sure that the installed OpenBSD system has all of the necessary directories. Skipping this step will make the build fail and corrupt your source tree.

```
# rm -rf /usr/obj/*
# cd /usr/src
# make obj
# cd /usr/src/etc
# env DESTDIR=/ make distrib-dirs
```

Now you can build and install the userland.

```
# cd /usr/src
# make build
```

Building userland can take several days on an antique system, but should take only an hour or two on more modern hardware. When the process finishes, you should have the new userland installed on the local system.

**NOTE** *Installing -stable simplifies the userland part of the upgrade. There's no need to merge any new /*etc*/ files with* `sysmerge` *(but there's no harm in running* `sysmerge` *either, just to check that your configuration is indeed valid), or to re-create your device nodes, as they won't change. OpenBSD-stable contains very minor changes from the release on which it's based.*

### Building Xenocara

The X Window System might or might not change during -stable. If your CVS update shows no changes in -stable, you don't need to rebuild it, but if any of the files in */usr/xenocara* have changed, you're better off rebuilding X. The build process is completely routine for Xenocara-stable.

```
# cd /usr/xenocara
# rm -rf /usr/xobj/*
# make bootstrap
# make obj
# make build
```

This builds and installs the new X on your system.

### Building a Release

This is all very nice if you want to upgrade only one machine. But what if you have several machines to upgrade to your custom OpenBSD build? You don't want to go building -stable on your firewalls or your web server.

If you need to upgrade multiple machines, build your OpenBSD on one machine, and install that build on multiple machines by building your own *release*. This will take less time than you needed to build your upgrade and use under a gigabyte of disk space.

A release is what the OpenBSD Project puts on the mirror sites for you to install. It's a few kernels, tarballs containing the userland files, the index file, and so on. Using these files, you can upgrade your other hosts just as you would perform the official media upgrade discussed earlier this chapter. Building a release is the easiest way to upgrade several OpenBSD hosts to identical versions.

Before you can build a release, you must build both the base OpenBSD system and Xenocara. You could skip Xenocara if you don't want any X on any of your hosts, but a surprising number of third-party programs need the X libraries. It's easier to build X and not install it on selected hosts than to go back and rebuild the whole release because you didn't build Xenocara the first time.

The release process installs OpenBSD in a temporary root directory and then bundles that installation into the release tarballs and related files. Next, it repeats the process with the X software. It assumes that you have the OpenBSD source code in */usr/src* and a completed build in */usr/obj*, as well as the Xenocara source in */usr/xenocara* and a completed build in */usr/xobj*. You can change the build process to get around these requirements, as documented in `release(8)`, but you should accept the defaults.

You'll need to define three directories: one to store your release, one for your temporary OpenBSD root directory, and one for your temporary Xenocara root directory. You can reuse the temporary root directories, but I keep them for reference. I use */home/releasedir* as my release directory, */home/destdir* as my temporary OpenBSD root, and */home/xdestdir* as the Xenocara temporary root.

**WARNING** *You can use any partition with sufficient free space, except for* /mnt *because the release process uses this partition. Similarly, building a release builds ISO and floppy images using the first* `vnode` *device,* /dev/vnd0. *If you have any disk images mounted using that device (see Chapter 9), the release process will fail. If you must mount a disk image while building a release, use a* `vnode` *device other than* /dev/vnd0.

The release process has three steps: bundling the base system, bundling Xenocara, and indexing the results.

### Bundling the Base System

OpenBSD's build system includes all of the glue that you need to build a release. First, do a `make build` of your new OpenBSD so that you're running the same version you want to build a release for. Next, define the temporary OpenBSD root and the release directory in your environment as `$DESTDIR` and `$RELEASEDIR`, respectively.

**NOTE** *Verify that the temporary OpenBSD root and the release directories are empty before you start. While the release process can overwrite files from an old build, the directories might have obsolete files that you don't want included in the new release.*

```
# echo $DESTDIR
/home/destdir
# echo $RELEASEDIR
/home/releasedir
```

Once you have this ready, building the release involves only a few commands.

```
# cd /usr/src/etc && make release
# cd /usr/src/distrib/sets && sh checkflist
```

Take a look in your release directory. You should see the following items:

- Three kernels (*bsd*, *bsd.mp*, and *bsd.rd*)
- Three floppy boot images if you're building for i386, or one if it's for amd64 (other architectures vary)
- Two ISO images
- Five file sets for the OpenBSD base system

These files are functionally identical to those distributed by the OpenBSD project, except they're based on your custom build.

Once you've finished building releases, be sure to remove the `$RELEASEDIR` and `$DESTDIR` variables from your environment because they can mess up other software builds. You can't successfully build Xenocara with them still set.

### Bundling Xenocara

As with bundling the base system, you must first complete a Xenocara build. Confirm that your system has the same version of Xenocara installed that you want included in your release, and then set the `RELEASEDIR` and `DESTDIR` environment variables. `RELEASEDIR` should be identical to that used to bundle the base system, but `DESTDIR` should differ.

**NOTE** *You could reuse `DESTDIR`, but that will erase everything from your temporary base system installation. Leave those files around until you're sure you have a solid release.*

```
# echo $DESTDIR
/home/xdestdir
# echo $RELEASEDIR
/home/releasedir
```

Now go into the Xenocara source and bundle the release.

```
# cd /usr/xenocara
# make release
```

Xenocara isn't much smaller than the base system. It takes a while to bundle up, so this is a good time to go to lunch. When you get back, you should find five new files in your release directory, all tarballs beginning with *x*.

Before you quit for the day, remove `RELEASEDIR` and `DESTDIR` from your environment.

#### Indexing the Release

Copy your release to your local FTP or web server, and create an index of the contents. (Only HTTP installs and upgrades need an index file.) The OpenBSD installer and upgrade software will use this index during the installation.

```
# /bin/ls -l > index.txt
```

Make the web or FTP site accessible from the machines you want to upgrade.

### *Using the Release*

Upgrade or install using this release just as you would use an official release. Copy *bsd.rd* to a machine to be upgraded, and then boot into that kernel. When the installer asks where to get the file sets, give the location of your release. Extract and reboot!

## Building OpenBSD-current

Building OpenBSD-current is exactly like building -stable, except when it isn't. OpenBSD-current can change wildly, and building it from source is considered an advanced activity. The only time I actually build -current is if I need to test some new functionality or a patch offered by an OpenBSD developer.

The two big problems are the radical changes in -current and merging */etc*.

### *Following -current*

When you follow -current, keep a close eye on OpenBSD's changes by tracking the Following -current web page at *http://www.OpenBSD.org/faq/current.html*. This is where the OpenBSD developers list all of the changes likely to impact people trying to build -current. Not all changes apply to all systems, but any change listed that applies to your system requires special handling.

The entries are chronological, and include everything since the last release. Just concern yourself with entries dated on or after the date of the source code used to build your snapshot. For example, if you built a snapshot dated January 30, and you want to build -current on the following February 5, check the web page for any entries between those two dates, inclusive. Earlier changes are already incorporated in the installed snapshot.

Some changes will require your intervention before you even try to build the system. For example, if you have new unprivileged usernames, they will need to be in place before a `make build` can succeed—after all, a program owned by user `_fdisk` can't be installed unless that user is in place.

If you don't understand an entry on this page, do not upgrade!

### *Merging /etc*

When you upgrade to a new -stable, you can be sure that the files in */etc/* haven't changed. When you track -current, those critical system files might well change. Any critical changes are usually noted in the Following -current website, but it's best to use `sysmerge(8)` to merge in all */etc* changes. You can give `sysmerge` the path to the system source instead of the *etc.tgz* file set.

```
# sysmerge -s /usr/src
```

See the section about `sysmerge` earlier in this chapter for detailed information.

## Upgrading Ports

If you use OpenBSD-provided packages, upgrading your system is as easy as running `pkg_add -ui`. If you built your third-party packages from source using the ports collection, however, there's no easy way to upgrade. You must rebuild those packages. There is no automated way to do this, but the `make update` command in a port can rebuild a specific port.

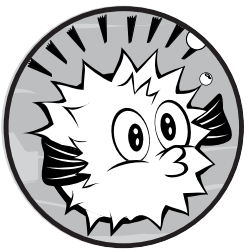
Presumably, you built your own packages because the OpenBSD-provided packages lacked some option or flavor you needed. In that case, you probably only needed to build one or two packages from source. All of the software required by that package could be installed from official OpenBSD sources. You should upgrade everything possible via packages and rebuild only what is strictly necessary.

Now that you can upgrade OpenBSD any way you want, let's look at OpenBSD's packet filter.

# 21

## PACKET FILTERING

*The name's Pond, James Pond.*
*My x86 loaded,*
*licensed to filter.*



Packet filtering and traffic manipulation are among the most basic tools in network security. OpenBSD includes a very powerful in-kernel packet filter, `pf(4)`, or PF. This tool not only performs standard filtering, but it can also inspect, reassemble, redirect, and otherwise abuse packets in several ways; translate addresses in several different directions simultaneously; authenticate users; and manage bandwidth. Along with PF, OpenBSD includes programs that let you turn your system into a load balancer, transparent proxy, or any number of other network devices.

PF is one of the high points of OpenBSD and deserves its own book. That book is *The Book of PF, 2nd edition*, by Peter Hansteen (No Starch Press, 2010), which goes into detail on many different PF use cases. This chapter covers the basics of PF so that you can protect a small network or an individual server. If you want to protect a web farm and transparently relay traffic to only the active servers with sufficient free capacity to handle the load, get Peter's book.

That said, not even Peter's book covers PF in its entirety. OpenBSD lets you fold, spindle, and mutilate TCP/IP far beyond anything any reasonable person could ever expect to support in the real world. For complete details on PF, read the `pf(4)`, `pfctl(8)`, and `pf.conf(5)` man pages, and the OpenBSD PF FAQ at *http://www.OpenBSD.org/faq/pf/*.

**NOTE** *PF is still undergoing active development. While the configuration syntax doesn't change as often as it used to, check `pf.conf(5)` for the latest information on your version of OpenBSD.*

## Firewalls

The word *firewall* has been tortured beyond recognition over the past 20 or so years, until it has ceased to mean much of anything in particular. In general, a firewall sits between a private and public network, and controls the traffic between the two.

You can buy a firewall for your cable modem for under $100, and you can purchase an enterprise firewall cluster for $1 million. What's the difference? They're all firewalls, much as rats and cats and elephants are all mammals, but some are welcome in your home and most are not.[1] Which you permit, of course, is your personal preference. And firewalls are much the same.

Some firewalls filter application-level traffic. Some only filter based on protocol or ports. Some firewalls inspect protocol flags and ensure traffic sanity. Others just pass packets. And some firewalls just translate network addresses and claim that provides security. Worse, the price tag bears no relationship to the feature set.

At their most basic, all firewalls filter packets and can perform network address translation (NAT). OpenBSD can perform those tasks as well or better than most commercial firewalls. If you want application proxies, however, they don't come with the core OpenBSD system (with the exception of FTP and TFTP proxies, which are necessary for those protocols to function with NAT). Several popular application proxies run quite well on OpenBSD, but they are not part of OpenBSD. For example, I've used Squid (*/usr/ports/www/squid*) and several related packages to build a web proxy and filter on OpenBSD that is comparable to anything the big companies offer, and an assortment of other proxies to manage just about everything else. If you are interested in firewalls, I highly recommend that you assemble your own highly featured firewall from available components at least once, for the sake of education if nothing else.

A firewall is what you make it. You can send all your traffic through a simple OpenBSD packet filter and honestly declare that you have a firewall, or you can set up application proxies, authentication, and so on, and still

1. Sorry, cats and elephants, find your own place to live.

say you have a firewall. A plain packet filter is a firewall just as much as one of those umpteen-integrated-application-proxy, six-figure-price-tag devices. Remember this the next time someone says he has a firewall.

Realistically, a firewall is not a security device. It is a point of policy enforcement.[2] The firewall doesn't secure anything; it prevents access to certain services. But blocking access doesn't secure inherently insecure services—it just means you can't access them. If your firewall permits access to a service, the firewall doesn't add any security to that service.

In order to build an effective firewall, you must understand TCP/IP. If Chapter 11 was a revelation to you, get a copy of *The TCP/IP Guide* (No Starch Press, 2005). Read it. Mark it up. Highlight it. And read it again.

Many of the examples in this chapter assume that you are building a firewall. This means that your host has two or more network interfaces (including VLAN interfaces) and that you want to protect the network on one side from the network on the other side. While this is a popular application for OpenBSD, everything covered here works just as well on individual hosts. I filter packets on lone web servers, on desktops, and on any host sitting naked on the Internet.

## Enabling and Configuring PF

OpenBSD enables PF by default at system boot with these *rc.conf* variables:

```
pf=YES
pf_rules=/etc/pf.conf
```

To disable PF at boot, set `pf` to `NO` in *rc.conf.local*.

The default configuration file for PF is */etc/pf.conf*. There's nothing special about this file—it's just a standard location. The `pf(4)` kernel interface doesn't read the file directly; the PF control program `pfctl(8)` reads the file and sends the configuration to the kernel.

The default PF configuration (hard-coded in */etc/rc*) blocks all network traffic except for ICMP and SSH. During boot, PF replaces those defaults with rules from */etc/pf.conf*. If an error in *pf.conf* renders the file unparsable when the system boots, PF can't load those rules; instead, it retains the default configuration. You'll be able to connect to your machine to correct your rules, but that's about it. (And, as anyone who administers remote firewalls can tell you, this ability can save you a lot of driving and phone calls.)

Running PF by default, even with a permissive ruleset, cleans up incoming traffic before the rest of the kernel has to deal with it. PF reassembles packets before handing them to the kernel, and obviously bogus traffic, such as packets too short to be legitimate, is discarded.

2. Blatantly stolen from Henning Brauer. Thankfully, he's so sick of this book by now, he won't notice.

If you want to forward packets between interfaces (that is, act like a "firewall"), tell the kernel to forward packets with the `net.inet.ip.forwarding` and `net.inet6.ip6.forwarding` sysctls. (See */etc/sysctl.conf* for commented-out examples.)

```
#net.inet.ip.forwarding=1
#net.inet6.ip6.forwarding=1
```

Remove the pound signs and reboot, or use `sysctl(8)` to enable and disable packet forwarding on the fly.

## Packet-Filtering Basics

Packet filtering is comparing packets to a list of rules and accepting, rejecting, or altering them as those rules dictate. As a network administrator, you get to decide which packets are naughty and which are nice. When you filter packets for a single host, you can legitimately call that host *hardened*. (The word *hardened* means almost exactly what *firewall* means: nothing.) When you send all packets on your network through a single host that filters packets, you have a basic firewall.

A basic packet filter might allow you to filter based on only the TCP or UDP protocol number. Some don't even allow you to filter by ICMP type or cannot cope with protocols other than those enumerated in the GUI. PF, however, can cope with almost anything you throw at it. If you need a machine to communicate with another over IP protocol 184, PF will support you. Many commercial firewalls won't let you pass such traffic, or claim that they do but throw a tantrum if you actually try it.

### Packet-Filtering Concepts

Chapter 11 described how TCP connections can be in a variety of states. A TCP connection that is just starting goes through a three-way handshake process. A client requests a connection by sending a synchronization request, or SYN, packet to the server. The server responds by sending the client an acknowledgment of the SYN, as well as its own SYN request, or a SYN+ACK packet. The client responds with its own ACK.

Every part of this three-way handshake must complete for any actual data to transfer between the two machines. Your packet-filtering rules must permit each part of the three-way handshake and the subsequent data transmission. PF automatically recognizes these three-way handshakes and tracks them through *stateful inspection*.

#### Stateful Inspection

PF maintains a list of permitted connections that have completed connection setup, which is called a *state table*. When a client sends out a SYN packet, PF records that packet in a table and waits for a corresponding SYN+ACK packet. If a SYN+ACK packet arrives at PF, but PF has no record of a corresponding SYN request, the SYN+ACK packet is rejected.

PF has a series of built-in timeouts that dictate how long idle connections remain in the state table, how long to wait for each stage of the three-way handshake, and so on. The state table is self-maintaining, and I've never had to adjust any of these timeouts. (On occasion, I have needed to increase the maximum size of the state table.)

UDP is technically stateless, but some applications expect a certain amount of state. When your system transmits a UDP packet, the application might well expect a UDP packet or 10 in response, or no packets, depending on the application.

DNS queries are a common example of UDP packets flowing back and forth, and while UDP has no state, DNS certainly does. (ICMP behaves similarly.) You can have PF either expect this back-and-forth or not, by adding these flows to the state table as your protocol dictates.

**NOTE** *PF can also operate without stateful inspection, allowing traffic to and from hosts and ports based on individual packet characteristics.* Stateless filtering *is slower than stateful inspection, harder to correctly configure, and generally considered less secure and less useful than stateful inspection.*

### Packet Reassembly

Packets can be mangled during transit, usually by *fragmentation*. Part of a packet filter's job is to sensibly *reassemble* those packets. PF can reassemble and rationalize packets in a variety of ways. (Old versions of PF called this *scrubbing*.)

### Default Accept vs. Default Deny

One of the essential concepts in packet filtering is the question of default accept versus default deny:

- A *default accept* stance means that you allow any type of connection except what you specifically deny. The default PF rules are an example of a default accept stance.
- A *default deny* stance means that you allow only explicitly permitted connections. All other connections are refused.

Once you have chosen your default, you can adjust your rules to hide or reveal network services as needed. In today's world, I recommend default deny on all systems, because this stance protects new services as they are added to a system. In most environments where I've seen a default accept stance used in the past decade, it's because the system administrators did not understand the network protocol they were using. This is particularly common in VoIP installations (yes, you *can* packet filter VoIP servers!)

In addition to packet filtering and reassembly, PF offers several other important features, including NAT, connection redirection, and bandwidth management, to name a few. We'll consider each separately. All are configured in *pf.conf* and managed with `pfctl(8)`.

### *"My Network Can Do No Wrong"*

Many network administrators who build a firewall carefully filter and restrict incoming traffic, but only apply minimal restrictions on outgoing traffic. While control of incoming traffic is among the most in-your-face issues of network management, control of outgoing traffic is also important.

Even if you trust your users, malware can convert a skilled engineer's workstation into a garbage-spewing pest. Do not assume that your network can do no wrong. It can be malicious, and one day it will be, but careful traffic control can minimize the damage you inflict on your neighbors, clients, customers, and reputation.

Is there any reason for your staff desktops to connect to any random remote mail server? If not, block it, and even if a workstation is infected with a spambot, the rest of the world won't blacklist you. Is there any reason for your users to connect to remote DNS servers, or should they use your company's? Block outbound DNS, and prevent your users from becoming unwitting amplifiers of denial-of-service attacks. I strongly recommend a default deny stance for outbound as well as inbound traffic, and explicitly allowing desirable traffic.

Some networks might be exceptions, of course. If every system on your network runs OpenBSD, you're pretty safe from routine malware, but already we see malware targeting televisions, Blu-ray, streaming media players, and other appliances with network connectivity. Protect yourself now.

Anytime that you catch yourself thinking that your network can do no wrong, stop and remind yourself that you are not as smart as the combination of every malware author in the world.

### *What Packet Filtering Doesn't Do*

Packet filtering controls network connections based entirely on TCP/IP protocols and related characteristics, such as port numbers. If you want to block all traffic from certain IP addresses, packet filtering is your friend. If you want to allow only connections to a particular TCP/IP port, packet filtering will work for you. If you want to allow entrance only to packets with the ECN flag set, but no other flags, PF will support you (even though that's a pretty daft thing to do).

You can filter protocols that operate at a logical protocol layer such as IPsec, SKIP, VINES, and so on, but only on the network protocol. If it's a different protocol layer, PF can't help.

**NOTE** *PF can even filter by MAC address. There's special support for this specific media layer protocol via tags added on* `bridge(4)` *interfaces, as documented in* `ifconfig(4)`.

Similarly, PF doesn't know anything about applications or application protocols. If you allow TCP/IP connections to port 25 on a server within your network, you might think that you're allowing connections to the mail server on that host. Actually, you're allowing connections to whatever daemon happens to be running on port 25 on that host! PF doesn't recognize

an SMTP data stream; it sees only that the connection goes to port 25. (I have a system that offers SSH on many ports commonly assigned to other services, just so I can saunter past whatever naïve packet filter I happen to be stuck behind.)

## PF Components

Before we dive into PF, let's look at the basic components of packet filtering on OpenBSD. In addition to the `pf(4)` kernel module, we'll look at the packet filter control program and the configuration file */etc/pf.conf*. Knowledge of interface groups also helps.

### Packet Filter Control and Configuration

Use the packet filter control program `pfctl(8)` to manage, configure, and extract information from PF. You can see the current packet filter rules and settings, connections being processed, the state of the TCP/IP transactions, debugging information, and all kinds of other details. You can also parse rules files and install them in the actual packet filter.

You'll see many different options for `pfctl`, addressing every aspect of packet-filter management. Many of these are rather lengthy, but you need to type only as much of the word arguments to make a command unique. For example, instead of typing `pfctl -s rules`, you can get away with `pfctl -sr` because no other argument to `pfctl -s` begins with an `r`. That said, I give all examples in their full form, as it's impossible to guarantee that OpenBSD won't add some other argument that begins with `r` in the future.

I focus on using `pfctl` for viewing PF output, but OpenBSD also includes PF views in `systat(1)`. For a dynamic display of PF activity, somewhat like `top(1)` for the network, look at `systat`. Run `systat` by giving the name of the view as an argument, such as `systat pf`. And, as always, any time you want more detail from `pfctl`, add one or two `-v` arguments for verbose mode.

You configure PF in */etc/pf.conf*. The *pf.conf* file contains statements and rules, whose format varies with the features they configure. You'll be very good friends with this file before we're through.

### Interface Groups

OpenBSD lets you put interfaces in named groups, which you can refer to in PF rules. This abstracts away the actual physical interface, and lets you build policy-based rulesets. Take a look at this interface:

```
# ifconfig em0
em0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
...
        groups: egress
...
```

This interface is in the `egress` group. An interface is assigned to the `egress` group if a default route is reached over it.

To move this interface to a new group, `dmz`, remove it from the `egress` group and add it to the `dmz` group. An interface group is created when you assign the first interface to it, and one interface can be in any number of groups.

```
# ifconfig em0 -group egress
# ifconfig em0 group dmz
# ifconfig em0
em0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
...
        groups: dmz
...
```

You can now write rules that reference interface groups instead of specific interfaces.

### PF Configuration

Let's dismantle the default *pf.conf* from an OpenBSD system and identify some parts. Many of the default entries are commented out, but identifying them will help you understand how the components fit together.

It begins with an *option*:

```
set skip on lo
```

Options turn features on and off, or set general rules on how other features behave. The `skip` option disables PF on a per-interface basis.

Next comes the `anchor` setting:

```
anchor "ftp-proxy/*",
```

An *anchor* is a set of dynamic sub-rules for packet filtering. If a packet hits an anchor as it's processed through the filter rules, it's dropped into this sub-ruleset for further processing. `pfctl` can change the rules running in the kernel, and an anchor is a way of saying, "Add new rules here."

Anchors are generally used for letting outside software add rules to the firewall. For example, FTP is a complicated protocol that requires all sorts of firewall rules. OpenBSD includes an FTP proxy that dynamically adds the necessary rules for permitted FTP connections.

Then come two *packet-filtering* rules:

```
pass in quick inet proto tcp to port ftp divert-to 127.0.0.1 port 8021
pass
```

The first is a rule to support FTP traffic, in combination with the FTP anchor. We'll look at anchors and FTP handling in more detail in the next chapter. The other is a much simpler packet-filtering rule, which permits all traffic.

Up next are two *tables*, which are lists of IP addresses:

```
table <spamd-white> persist
table <nospamd> persist file "/etc/mail/nospamd"
```

External programs can dynamically alter tables, and you can add addresses to tables directly within *pf.conf* or in an external file. These two tables are used by the antispam software `spamd(8)`.

After the tables is another packet-filtering rule:

```
pass in on egress proto tcp from any port smtp \
    rdr-to 127.0.0.1 port spamd
```

This rule is interesting in that it refers to an interface group. Traffic is permitted in, as long as it arrives on an interface in the `egress` group.

And the final rule is as follows:

```
block in on ! lo0 proto tcp to port 6000:6010
```

This packet-filtering rule stops traffic. If a packet arrives on any interface except the loopback interface, and the packet is a TCP protocol going to port 6000 through 6010 inclusive, it is blocked.

This is the sort of thing you'll see in *pf.conf*. Let's dive into some specifics of filtering rules.

## Filtering Rules

Filtering rules are the heart of PF. You can use PF without doing any of the fancy redirection, address translation, load balancing, or redundancy, but packet filtering is the bedrock on which most of these features are based. To start with, however, basic packet filtering is defined as access control for network packets by source, destination, protocol, and protocol characteristics.

PF processes filtering rules in order. The last rule that matches a packet is acted on. A typical packet-filtering rule looks like this:

```
❶pass ❷in ❸on egress ❹proto tcp ❺from any ❻to 192.0.2.12 ❼port 80
```

The first word of the filter rule is a keyword that describes the results of this rule ❶. PF will either `pass` or `block` packets that match a rule. (There's also `match`, which we'll look at in the next chapter.) The rest of the line is a description of matching packets. If the packet matches the description, the rule is applied.

The second statement is the direction the packet is going. Packets are either going in or out. In this rule, the packet is going `in` ❷—it is entering the system. Not only do we define a direction, but we also define an interface group. Packets must be entering this system on an interface in the `egress` group to match this rule ❸.

We then have several statements that define traffic characteristics. (This rule is almost like a regular expression for TCP/IP.) This rule applies to TCP connections ❹, coming from any IP address ❺, if the connection is made to the IP address 192.0.2.12 ❻ on port 80 ❼.

If a packet matches all of these characteristics, it can pass. If any of these characteristics isn't matched, the packet does not match this rule, and PF continues processing the rules, looking for a matching one.

TCP and UDP rules implicitly check connection state. A TCP packet that matches this rule needs to be a SYN packet, the start of a standard TCP/IP connection. PF uses the state table to manage follow-up packets in the same connection (see "Filtering Rules and the State Table" on page 411).

### Default Permit or Default Deny

I touched earlier on the idea of default accept versus default deny. Set this stance at the beginning of your packet-filtering rules with one of the following two statements:

```
pass
block
```

The default *pf.conf* has a default pass stance, but it's for people who haven't yet configured a firewall. I recommend starting your filter rules with a lone `block` statement, and then adding rules to explicitly permit desirable traffic. Remember that the last matching rule wins.

### Packet Pattern Matching

One of the most intensive parts of PF is the syntax used to describe packets. Most filter rules describe packets by protocol, port, direction, and other characteristics. PF compares each arriving packet to the state table, and if the packet isn't part of the state table, it compares the packet to the filter rules. If the rule matches the packet description, the packet is passed or blocked as desired.

Once you define whether you're in a default accept or default deny stance, the filter rules describe exceptions to your default. So if you block packets by default, most of your filter rules will be `pass` statements that describe particular desirable connections.

#### Direction

The keywords `in` and `out` describe the direction the packets are going. In many commercial firewalls, the word `in` means traffic entering the protected network, and `out` refers to traffic leaving the protected network. OpenBSD does not magically know which side of the network is protected and which is not. As far as PF knows, it's managing traffic between two interfaces. The keyword `in` means traffic flowing into the machine from the network, and `out` means traffic leaving the machine and entering the network.

When you see `in` or `out` in a PF rule, do not think about your network as a whole. Instead, imagine that you're very small and sitting on your CPU, grilling steaks over the heat sink and watching packets enter and leave the computer. You cannot see what lies beyond the case, just the packets as they come and go. Packets coming in are approaching you, and packets going out are receding.

### Interface Matching

The `on` keyword describes an interface or interface group to which this rule applies. You must specify an interface.

If you want a rule to match every interface on the system, use the interface name `all`. This example stops all traffic entering the machine on the interface `fxp0`, but allows all traffic leaving the system on the interface group `egress`:

```
block in on fxp0
pass out on egress
```

This ruleset implies that interface `fxp0` is special for some reason, so it's not treated like the rest of the `egress` group.

### Address Families

Rules can apply to specific address families, either `inet` for IPv4 or `inet6` for IPv6. Here's how to prohibit IPv4 but permit IPv6:

```
block in on egress inet
pass in on egress inet6
```

Presumably, you have later rules that more tightly restrict IPv6.

### Network Protocol

PF can recognize almost any network protocol by number or name. The `proto` keyword tells PF to match a protocol. Network protocols can be given by name from */etc/protocols*, protocol number, or even a list (see "Using Lists" on page 413).

```
block in on egress proto tcp
pass in on egress proto udp
```

You can use this to pass protocols other than IP and IPv6. Here's how to allow the protocols necessary for IPsec:

```
pass in on egress proto esp
pass in on egress proto ah
```

This functionality somewhat overlaps the `inet` and `inet6` statements. If you prefer, you could explicitly allow IP, ICMP, TCP, UDP, and all the various IPv6 protocols.

### Source and Destination Address

Almost every filter rule specifies a source and/or destination address.

```
pass in on egress from 198.51.100.0/24 to 192.0.2.0/24
```

IP addresses can appear either as individual addresses or as an address with a netmask (as shown in the preceding example). The keyword `any` means any IP address. The keyword `all` is shorthand for "from any to any."

You can also use hostnames instead of IP addresses. `pfctl` will check the IP address of the host when loading the rules, and insert the actual IP address into the rules.

```
pass in on egress from www.michaelwlucas.com
```

If the IP address of the host changes, PF won't notice until you reload the rules with `pfctl`. If the hostname cannot be found, the rules won't parse, and `pfctl` will not be able to load them. I recommend not using hostnames in filter rules, much as I recommend not wearing medieval plate armor while swimming, but it is an available option.

To say "anything but this address," use the exclamation point as a negation character.

```
block in from !192.0.2.0/24
```

This says "block everything except the addresses 192.0.2.0/24." That's not the same as saying "pass 192.0.2.0/24," but it can help simplify your rules.

You can also use lists, macros, and tables as IP addresses. Lists and macros are discussed later in this chapter, and tables are covered in the next chapter.

### Source and Destination Variants

You can use the name of an interface or interface group instead of an IP address.

```
pass out on egress from egress
```

This lets traffic leave via the `egress` interface group, from any IP address on any interface in that group, to any IP address.

If you put the interface name or group in parentheses, PF updates its rules whenever the IP address on the interface changes. This is useful for dial-up connections, or if you add and remove IP addresses from an interface.

```
pass out on egress from (egress)
```

You can specify a network that is directly attached to an interface or an interface group by following the name with `:network`.

```
pass in on egress from egress:network
```

Suppose the `egress` group has only one interface, and that interface has an IP address of 192.0.2.88/25. This rule would translate to the following:

```
pass in on egress from 192.0.2.0/25
```

This rule means that any host on the local network to an `egress` interface can communicate anywhere. When you add another interface to the `egress` group, the rules automatically update to accommodate the new interface's network.

To filter on broadcast traffic for an interface or group, use the `:broadcast` modifier.

```
block in on egress from egress:broadcast
```

Again, suppose that the `egress` group has only one interface, and that interface has an IP address of 192.0.2.88/25. This rule would translate to the following, blocking broadcast traffic on the local subnet:

```
block in on egress from 192.0.2.127
```

Use the `:peer` modifier to indicate the IP address of the far side of a point-to-point link, such as a dial-up connection.

```
pass in on egress from egress:peer
```

Here, we completely trust our dial-up provider.

#### Interface Main Address

To use only the first IP address on an interface, add the `:0` modifier with an interface or group name.

```
pass out on egress from (egress:0)
```

The `egress` interface group might have 98 IP addresses scattered across three interfaces, but only one address on each interface is the first address. This host can communicate out through the `egress` interface group, but only from primary IP addresses. The aliased IP addresses cannot initiate outbound connections.

The problem with the `:0` modifier is that the kernel has a very weak idea of what is the "first" address on an interface. The kernel has a list of addresses associated with an interface. The address at the top of this list is the "first" or "main" address at the moment, but this address can change. If this might cause problems, specify an IP address in your rule rather than rely on `:0`.

You can attach `:0` to any of the other interface modifiers, that is, to IP addresses other than the first from the rule. OpenBSD can't tell if IP addresses on remote machines are aliases or actual IP addresses, but you can prohibit traffic to or from aliases on the local machine.

Note that the first address on an interface is either an IPv4 address *or* an IPv6 address. If you want to allow the first address of each protocol, specify the address family in the rule.

```
pass out on egress inet from egress:0
pass out on egress inet6 from egress:0
```

Otherwise, PF will use only the first address it sees, regardless of address family.

#### Source and Destination Port

Filter rules can describe TCP and UDP ports.

```
pass in on egress proto tcp from any to 192.0.2.12 port 80
```

This example permits access to TCP port 80 on the server 192.0.2.12. Presumably, this is a web server.

You could use a service name from */etc/services* instead of a port number, or even use a list (as described later in this chapter). You can also use ranges, as shown in Table 21-1.

**Table 21-1:** Port Ranges

| Symbol | Meaning |
|---|---|
| != | Not equal |
| < | Less than |
| > | Greater than |
| <= | Less than or equal to |
| >= | Greater than or equal to |
| >< | Range |
| <> | Inverse range |

For example, to specify all ports over 1024, you could use the greater-than operator (>).

```
pass in on egress proto tcp from any to 192.0.2.12 port > 1024
```

To specify all ports between 1000 and 2000, excluding both 1000 and 2000, use the range operator (><).

```
pass in on egress proto tcp from any to 192.0.2.12 port 1000 >< 2000
```

To include ports 1000 and 2000 in your range, use the inclusive range operator (:). (Note that you cannot have space on either side of the colon.)

```
pass in on egress proto tcp from any to 192.0.2.12 port 1000:2000
```

To pass traffic on all ports less than 1000 and greater than 2000, use the inverse range operator (<>).

```
pass in on egress proto tcp from any to 192.0.2.12 port 1000 <> 2000
```

Ranges let you express large numbers of ports in very few rules.

### A Complete Ruleset

The following is a complete ruleset for a desktop machine, using many of the features described previously. We'll look at some more complicated rulesets later, but this illustrates many basic principles of PF rules.

Interface group egress is attached to the public network, and interface group inside is connected to my private network.

```
❶ set skip on lo
❷ block
❸ pass in on egress from egress:network
❹ pass in on inside from inside:network
❺ pass in on egress proto tcp from any to egress:0 port 22
❻ pass out all
```

The first rule disables packet filtering on the loopback interface ❶, and the second defines a default deny stance ❷. The second and third rules permit all connections from IP addresses directly connected to the external ❸ and internal interfaces ❹. If I install a web server on my desktop, I want to be able to view it from any machine on the network I control. Then I permit inbound SSH connections from anywhere in the world to the primary IP address on any egress interface ❺. Finally, I permit all outbound traffic, so my desktop can freely access the outside world ❻.

I've said before that PF rules are processed in order, and these rules illustrate that. I establish a default, blocking all traffic, and then use individual rules to carve out exceptions to that global block.

### Activating Rules

For your PF rules to take effect, you must load them into the kernel using pfctl -f.

```
# pfctl -f /etc/pf.conf
```

First, pfctl reads and parses the rules file. If the file parses correctly, pfctl expands any variables in the file, performs any necessary DNS lookups to transform hostnames into IP addresses, and feeds the complete rules into the kernel. The kernel reads the new rules, and then swaps between

the old and new rules in one operation. At no time are the packet-filtering rules missing, scrambled, or a hybrid of the two rulesets. Also note that `pfctl -f` won't enable PF if it's disabled.

Personally, I like to know that my edited packet-filter configuration parses before the scheduled change time. It's embarrassing to announce to your team that "the new firewall configuration will be active at noon" and spend the whole time tracking down a misplaced comma or a parenthesis where you should have put in a curly brace. To test your syntax without installing the rules, use the `-n` flag with `-f`. Add `-v` for verbose mode, to see how `pfctl` expands your macros, groups, and so on.

```
# pfctl -nvf /etc/pf.conf
```

The rules might still have errors, but only errors of comprehension rather than syntax.

Loading new rules doesn't remove any existing open connections or state entries. If my old ruleset allowed outbound SSH connections, and I remove that permission from the newly installed rules, existing SSH connections remain open. I can either specifically kill those connections with `pfctl -k` or flush the state table.

### Viewing Active Rules

To see how these rules are interpreted inside PF, view the currently installed ruleset with `pfctl -s rules`. Here are the rules generated by the configuration in "A Complete Ruleset" on page 409:

```
# pfctl -s rules
❶ block drop all
❷ pass in on egress inet6 from 2001:db8:4::/64 flags S/SA
❸ pass in on egress inet from 192.0.2.0/28 flags S/SA
❹ pass in on inside inet from 192.168.1.0/24 flags S/SA
❺ pass in on egress inet proto tcp to 192.0.2.5 port = 22 flags S/SA
❻ pass out all flags S/SA
```

The first rule establishes a default deny stance ❶. I then specifically allow connections from hosts on the networks local to interfaces in the `egress` group, for both IPv6 ❷ and IPv4 ❸. This desktop also accepts connections from my private network ❹.

The private network permits connections only from IPv4 addresses because the interface in the private group has only an IPv4 address. (I really should add an IPv6 address, but it hasn't caused me any trouble, so I'll probably forget all about it once again.) Then there's a rule permitting inbound SSH traffic ❺, followed by a final rule to pass all outbound traffic ❻.

If I change any IP address on my desktop, my firewall rules update to accommodate them. That's a really nice feature of interface groups. If I moved my desktop regularly, I would put the interface group names in parentheses so PF would watch for IP address changes.

**NOTE** *One thing you'll probably notice is that the pass rules end with* `flags S/SA`*. This means that out of the SYN and ACK flags, matching packets can have only the SYN flag set, indicating that these are requests to establish a connection. You can filter on TCP flags, but doing so requires in-depth understanding of TCP, and most people should never do it. To see how SYN and SYN+ACK packets affect connections, you need to understand the state table.*

To see how often a packet triggers each rule, add `-v` to the `pfctl` command.

To see how the rules impact traffic in a constantly updating display, run `systat rules`.

## Filtering Rules and the State Table

OpenBSD tracks approved connections in the state table. Packets that are part of an approved connection are allowed to pass. Consider this rule from an earlier example:

```
pass in on egress proto tcp from any to 192.0.2.12 port 80
```

If a packet matches this rule, and it has the TCP/IP flags that indicate this is the start of a TCP connection, PF permits the connection. PF also makes an entry in the state table. If a packet arrives that matches the state table, PF passes the packet without consulting the rules.

### TCP States

First, we'll look at a state table entry for a TCP connection. To view the state table, enter **`pfctl -s states`**.

```
# pfctl -s states
❶all ❷tcp ❸192.0.2.12:80 <- ❹198.51.100.227:55635 ❺ESTABLISHED:ESTABLISHED
...
```

This state table entry represents one specific connection that the packet filter approved. This state applies to all interfaces ❶. If a state applies to only one interface, you'll see the interface name here.

This TCP connection ❷ was bound for 192.0.2.12 port 80 ❸, and came from the host 198.51.100.227 port 55635 ❹. When the first SYN packet arrived from 198.51.100.227 port 55635, PF added this entry to the state table. When 192.0.2.12 sent a SYN+ACK packet back to 198.51.100.227 port 55635, PF consulted the state table. This was clearly a match to the permitted SYN packet, so PF permitted that packet, even though no explicit rule in *pf.conf* permitted that connection. Data exchange between these two hosts and these two ports proceeded.

PF knows what an actual TCP/IP data exchange looks like. There's a three-way handshake in the beginning, and a similar dance when the connection is finished and PF tracks the state of the connection. This particular connection is established on both sides ❺, meaning that the initial setup negotiation succeeded, and data can flow back and forth freely.

If your server is busy enough, and you keep refreshing the state table view, you'll catch connections in other states. Here's the same connection as the data exchange ends and is being torn down:

```
all tcp 192.0.2.12:80 <- 198.51.100.227:55635  FIN_WAIT_2:FIN_WAIT_2
```

**NOTE** *One possible problem with viewing the state table is that* `pfctl` *displays a snapshot. By the time your eyes scroll down the screen, the table has changed. Personally, I find that's the only way I can cope with the information. If you need to view states in a constantly updating display, in near real time, run* `systat states`.

The state table is very specific. A state table entry permitting 198.51.100.227 port 55635 to 192.0.2.12 port 80 does not permit traffic between other hosts and ports. PF knows how traffic should flow, and it won't allow traffic that isn't obviously part of an existing TCP/IP exchange. If a packet arrives from 198.51.100.227 that looks like it's part of this data exchange, except that it comes from port 55634 instead of 55635, the state table entry won't match. Similarly, if PF knows that the connection is in a `FIN_WAIT_2` state, or almost finished, a subsequent data packet with an ACK flag set won't match and will be discarded. This is because a SYN request from the same host, from the same port, should not arrive—the client should know that the port is busy closing the previous connection. A new connection should come from a different port on the client and create a new state table entry.

Without stateful inspection, you would need to write firewall rules that not only permitted incoming traffic, but also permitted the responses. Your firewall rules would need to permit outbound connections to thousands of high-numbered ports, instead of just the single ports attached to desirable connections. Filtering based on TCP flags would be nearly impossible.

**NOTE** *As a consultant in the 1990s, I made a couple of rent payments dismantling such rules that had been shoehorned into stateless packet filters because they just aren't realistic without stateful inspection. Plus, carefully tracking data exchanges not only simplifies rules, but also prevents a whole slew of TCP/IP-based attacks. You don't hear much about these attacks anymore, thanks to stateful inspection.*

### UDP States

The state entries for UDP connections are similar to those for TCP connections.

```
all udp 192.0.2.12:53 <- 198.51.100.227:38469       SINGLE:MULTIPLE
```

This is a DNS query, bound for 192.0.2.12 port 53 from 198.51.100.227 port 38469. The client sent a single packet, and the destination replied with multiple packets. While stateful inspection cannot identify the state of this connection by flags, it can track the source and destination addresses and ports. You would need to write only a single rule permitting access to 192.0.2.12 port 53, and stateful inspection would permit the matching reply packets.

### ICMP States

ICMP falls somewhere in between TCP and UDP. PF is aware of ICMP types and knows legitimate responses to ICMP packets, and by using stateful inspection, you get all of these benefits automatically. Much as you could write rules that permit specific TCP flags, you can write rules that permit certain ICMP types and codes. Most of us cannot manage that, and those of us who can know better. (ICMP errors referring to an existing TCP or UDP state are matched to the state, and don't need to be allowed separately.)

**NOTE** *OpenBSD's stateful inspection actually tracks more detail than source and destination addresses and ports. Add* `-v` *to the* `pfctl` *command to see more information, including timing, the number of packets passed as a result of the state, and more.*

## Packet Filtering with Lists and Macros

PF includes many ways to have one rule reference several similar items, or symbolically represent something with a variable. The basic ways are lists and macros.

### Using Lists

A *list* is a way to represent several similar items in one rule. You might want to use a list if, for example, you want a particular group of TCP ports open on a certain group of hosts, and your rule entries would be repetitions of one rule with minor changes. Opening ports 80 and 443 to one host requires two rules: one for each port. If you have 30 web servers, you would need 60 rules. This is a pain to maintain and error-prone, but lists let you express these common elements more easily.

A list is represented in curly braces within a rule. To make the rule more readable, you can put a comma between items.

```
pass in on egress proto tcp from any to 192.0.2.12 port {80, 443}
```

This one *pf.conf* statement creates two rules, opening both TCP ports 80 and 443 to the target host.

```
pass in on egress from any to 192.0.2.12 port = 80 flags S/SA
pass in on egress from any to 192.0.2.12 port = 443 flags S/SA
```

You could also use a list to have this rule cover multiple web servers.

```
pass in on egress proto tcp from any to {192.0.2.12, 192.0.2.13} port {80, 443}
```

This expands to four rules: one for each combination of server and port.

Remember that each entry in the list creates its own rules. The list entries do not combine to create a single rule.

### Using Macros

A macro is a variable that you create and define for use within PF rules. Macros keep *pf.conf* more readable, maintainable, and manageable.

Macro names must begin with a letter, but can include letters, numbers, and underscores. You cannot give a macro a name that's used elsewhere in PF, like `pass`, `block`, or `proto`. Frequent uses of macros include interface names, network addresses, and ports.

Earlier, we saw a list that included the popular web ports 80 and 443. You could make these a macro, as follows:

```
web_ports="{80, 443}"
```

Our sample rule would then become this:

```
pass in on egress proto tcp from any to 192.0.2.12 port $web_ports
```

When combined with braces, macros can simplify your *pf.conf* file. Consider the following *pf.conf* snippet:

```
webservers="{192.0.2.12, 192.0.2.13, 192.0.2.14, 192.0.2.15}"
web_ports="{80, 443}"
pass in on egress proto tcp from any to $webservers port $web_ports
```

This expands to eight rules, but requires only three easy-to-understand configuration statements. When you add a new web server, add its IP address to the list in the `webservers` macro. What's more, you might use the `webservers` macro in dozens of places throughout your rules. Changing the IP address list once is much easier and more likely to be correct than doing so in each rule.

While you probably use interface groups to represent IP addresses local to your machine, you might have other IP addresses that you need to represent. Macros are great for this, too.

```
internal_ip="10.10.0.0/16"
```

Or if you have multiple disparate blocks, you could use a list inside the macro.

```
internal_ip="{10.0.0.0/24, 10.0.5.0/24, 10.0.10.0/24}"
```

You don't see macros or lists when viewing the running PF rules with `pfctl`; instead, you see the rules that they expand to.

### A Common Error: List Exclusions and Negations

Lists can be counterintuitive, and it's easy to write lists that negate other rules. For example, this seems like it should work:

```
clients = "{192.0.2.0/24, !192.0.2.128/29}"
pass in on egress from $clients
```

The idea here is that our clients have the IP addresses 192.0.2.0/24. We want to permit all of those addresses except for the small chunk in the middle, 192.0.2.128/29. That seems reasonable, right? But much like excluding commands from `sudo(8)`, this breaks. Remember that each entry in a list expands into another rule. This creates two rules.

```
pass in on egress inet from 192.0.2.0/24 flags S/SA
pass in on egress inet from ! 192.0.2.128/29 flags S/SA
```

The first rule passes in everything from the 192.0.2.0/24 subnet. That's what we wanted. The second rule, however, passes in *everything* that's not in the subnet 192.0.2.128/29, also known as "everyone in the world"—not what we were hoping to achieve.

Similarly, negating an entire list expands to negating each individual item in the list. If you need to do this sort of exclusion, use a table, as described in the next chapter.

## Sanitizing Traffic

All sorts of weird traffic arrives at Internet hosts. Some of that traffic is broken garbage. Other parts tell you that someone else is running broken garbage.

PF tries to sanitize and normalize traffic before otherwise processing it. The normalizations include discarding illegal packets, packet reassembly, and packet modification.

### Illegal Packets

Some of the random stuff that arrives at a host is garbage. If a packet is shorter than the IP header, it can't be a real IP packet, and if a TCP packet is too short to include a full TCP header, it can't be a real packet.

If the packet length doesn't match the length given in the header, it's somehow corrupt. PF has no way to figure out where these packets came from, or if they're maliciously damaged or just corrupted in transit. Since the kernel can't do anything with them, PF automatically drops them.

### Packet Reassembly

Before the packet filter can decide how to handle a packet, the packet should be free of ambiguities and random weirdness. Reassembly cleans up these ambiguities, and the default reassembly settings are suitable for most environments. You get reassembly when you enable PF.

### Packet Modification

Sometimes you need to modify packets. These days, PF handles everything for most environments. If you need to modify packets, such as clearing the "do not fragment" bit on fragmented UDP packets, see the `scrub` keyword in `pf.conf(5)`.

### Blocking Spoofed Packets

Another classic IP attack is sending packets that appear to come from the private network to a firewall, in an attempt to evade the packet filter. Most firewalls today block this type of attack, so attackers rarely bother, but you should still protect against spoofed attacks. Just because everyone else has had their measles shot doesn't mean you should go without one.

For an antispoofing rule, use `antispoof for` and an interface name.

```
antispoof for fxp0
```

When fed into the packet filter, the rules would look something like this:

```
block drop in on ! fxp0 inet from 192.0.2.5/28
block drop in inet from 192.0.2.5 set ( prio 0 )
```

The first rule drops any traffic that arrives from an address local to interface `fxp0` on any interface other than `fxp0`. Packets from an address local to interface `fxp0` should always arrive on your system via `fxp0`.

The second rule drops any traffic that comes from the address of interface `fxp0`. Packets with that source address should never arrive from the outside world. If the system needs to communicate with itself, it uses interface `lo0`.

You could use interface groups instead of interface names, but I don't recommend doing so. If you have multiple `egress` interfaces, using antispoofing rules on the egress group won't block outside packets that arrive at the wrong egress interface. Take the time to enumerate your interfaces in your antispoofing rules.

Instead of listing a single interface, you can also use a list or a macro.

```
antispoof for {lo0, fxp0, em0}
```

Antispoofing rules can mess with packets passed over the loopback interface. I recommend skipping filtering on `lo0`, although PF includes special built-in protection for 127.0.0.0/8 addresses.

Now that you have basic packet filtering, let's consider some of PF's core settings.

## PF Options

Options are basic settings that affect core PF functions. Options answer questions like these:

- Do we reassemble fragments into packets?
- How many entries should the state table support?
- Is logging on?

All options start with the `set` keyword. Because options affect how all other parts of PF operate, I recommend placing them at the very top of *pf.conf*.

Here, we'll look at some of the more commonly used options.

### The set block-policy Option

Will your firewall silently drop forbidden packets, or respond to the client with "sorry, not allowed?" The block policy determines which approach it takes. By default, PF drops blocked packets, but you can override the global block policy on individual filter rules.

Strictly speaking, when PF drops packets, it should return an error to the client, so that legitimate clients can immediately recognize that they cannot connect. Using `set block-policy return` tells PF to return these polite errors: an RST for TCP connections and an ICMP unreachable message for other types of connections.

Unfortunately, politeness has largely been overwhelmed by the modern Internet. PF's default, `set block-policy drop`, tells PF to not return any kind of error on blocked packets. Client applications such as web browsers, vulnerability scanners, worms, and other malware must wait for the network protocol to time out before realizing that they cannot connect.

I recommend dropping blocked packets silently.[3]

### The set limit Option

PF includes limits on the size of various internal tables used to track fragments, states, address tables, and other memory-consuming items. I have needed to adjust these limits on very rare occasions. The existing limits are chosen because they are sufficient for most users in most environments.

View the existing limits with `pfctl`.

```
# pfctl -s memory
states        hard limit    10000
src-nodes     hard limit    10000
frags         hard limit     1536
tables        hard limit     1000
table-entries hard limit   200000
```

Let's take a look at what each limit represents.

3. Mind you, if PF included an option to insult the client when a packet is dropped, somewhat like `sudo`, I would need to change my recommendation. But that's a fault in the underlying network protocol, not PF.

### frags Limit

When PF receives a fragmented packet, it holds onto that fragment and waits for other fragments of that packet to arrive. Once it has all the pieces, it reassembles the fragment and processes it. The `frags` limit controls the number of packet fragments awaiting reassembly at one time. (You shouldn't need to change this.)

To see the total number of fragments PF has processed, and how many arrive per second, use `pfctl -s info` and look at the Counters section.

```
# pfctl -s info
...
  fragment                               368          0.0/s
...
```

This host has been sitting on the naked Internet for three months in an Internet colocation site, and has received only 368 fragments. I do not need to increase PF's memory for fragments, and I certainly don't want to reduce the limit in case I receive a sudden barrage of fragments.

If you suspect that fragments are flowing in, run `systat pf` for constantly updating counters of PF statistics.

### The src-nodes Limit

PF can track a number of states per source address. You might want to limit each client to, say, 10 connections to a specific server. This connection limit includes connections being set up and those still waiting to finish. Here's an example of this sort of rule:

```
pass in proto tcp to $webserver port 80 keep state(max-src-states 10)
```

PF's load balancer features use `src-nodes` to help track which clients are attached to which servers, through the `sticky-address` and `source-track` options.

If you use these features, and think you might be out of source nodes, check usage with `pfctl -s Sources`.

### The states Limit

The `states` limit controls how many entries can be in the stateful inspection list. The default of 10,000 is adequate for most environments.

You can view the current usage with `pfctl -s info`.

```
# pfctl -s info
Status: Enabled for 1 days 18:01:06             Debug: err

State Table                          Total             Rate
  current entries                       30
  searches                         54510751          6.3/s
  inserts                           2459724          0.3/s
  removals                          2459694          0.3/s
...
```

**NOTE** *I have needed to change the state table more than once. Each time, it was because of a strangely written application that required clients to make dozens of connections to a single TCP/IP port. I'm certain that the application developers had their reasons for doing so (possible reasons do include ignorance and malice). Multiplied by thousands of simultaneous users, that became a lot of states. As I wasn't in a position to tell the developers to write their application like normal people, I had to adjust the state table.*

If you suspect that the state table is having trouble, use `systat pf` and/or `systat states` to view state activity in real time.

#### The tables and table-entries Limits

The `tables` and `table-entries` limits control how many tables PF can create, and how many entries can go into a single table. I have never had to adjust these, and I would suggest that if your filter rules need more than 1000 tables, you should probably reconsider how you've designed it. A table might need to hold more than 100,000 addresses, but that's very much the exception these days.

#### Setting Limits

To change a limit, use `set limit`, the name of the limit, and the new value. Here's how to double the size of the default state table:

```
set limit states 20000
```

Again, don't change these defaults lightly. Increase them only if existing limits cause a specific problem. And don't decrease them, or you won't be prepared for problems and spikes.

### The set optimization Option

PF includes a variety of timeouts, which default to values reasonable for the modern Internet. Some environments, such as satellite uplinks, do require slightly different timeouts.

You can adjust PF's timeouts with `set optimization`. (The name is a leftover from the early days of PF, but has stuck around.) This has four values:

`normal`
: The `normal` optimization is the default. If you don't specify an optimization, the standard timeouts are used.

`conservative`
: The `conservative` optimization is for environments where you want to be absolutely sure you don't time out connections. (State table entries will stick around longer.) This setting uses more memory and processor time—possibly much more on a busy network. I use it to ease the minds

of managers of industrial networks who are less concerned about buying more hardware and more concerned about the possibility of a meeting caused by some executive's idle connection timing out.

**high-latency**
If you connect over a satellite uplink or carrier pigeon, use the `high-latency` optimization.

**aggressive**
If you have a busy firewall, with many connections coming and going, you might try the `aggressive` optimization. This times out idle connections more quickly, reducing memory and processor use. Many people report that `aggressive` timeouts work perfectly well in their environments, but if low timeouts cause trouble for you, turn them off.

Configure any of these by using `set optimization` and the optimization name.

```
set optimization conservative
```

### The set skip Option

You can tell PF to not manage an interface. By default, it watches all interfaces, but some interfaces don't really require filtering. Your loopback interface, `lo0`, passes traffic only from the local machine to itself. Packet filtering on `lo0` is an interesting educational exercise, but not terribly useful in production.

```
set skip on lo0
```

You can also specify multiple interfaces to skip.

```
set skip on {lo0 fxp0 fxp1}
```

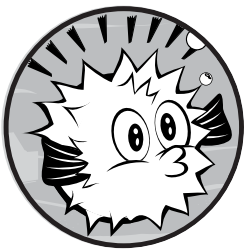
It's fairly common to skip filtering on the physical interfaces beneath a trunk in favor of filtering on the trunk itself.

This will get you started with packet filtering. If you have a single server with simple functions, you can protect it quite nicely using the techniques covered in this chapter. But PF can do a lot more than what we've talked about here, such as control bandwidth and have applications dynamically change rules. In the next chapter, we'll touch on a few of PF's more advanced functions.

# 22

# ADVANCED PF

*Office net seems slow*
*thanks to bootleg film swapping.*
*Let's stop that right quick!*



The previous chapter covered the basics of the OpenBSD packet filter `pf(4)`. But, as I mentioned, PF can manipulate packets in all kinds of ways beyond just permitting or denying them, including the following:

- You can dynamically change the list of addresses to pass or block through outside software, such as `dhcpd(8)` or `spamd(8)`.
- You can dynamically create sub-rulesets that let you set up very specific rules for troublesome protocols without allowing more access than necessary.
- PF can provide NAT, letting you offer an entire network Internet access without public IP addresses.
- You can redirect incoming traffic arbitrarily, and control how much bandwidth you will let a service use.
- You can use PF logging.

This chapter covers each of these topics.

## Packet Filtering with Tables

A *table* is a list of IPv4 and/or IPv6 addresses, much like a list. A table is faster than a list, however, and uses less memory. If you have only a few addresses, using a list is fine, but once you have more than a few, use a table.

Interestingly, you can edit tables without reloading the filter rules, and several programs use this feature to dynamically change how a server behaves. Some people load lists of malware-laden computers into a table to block those hosts, or use external programs to generate such lists. ("You've tried to send us four invalid emails in a row? Good-bye!") Tables can be kept permanently in external files, or you can treat them as ephemera. It's your choice.

### *Defining Tables*

You can create and manipulate tables entirely with `pfctl`, but that's not as common as defining the table within *pf.conf*. Give the table name in angle brackets, and provide the initial members delimited by commas inside braces.

```
table <management> {192.0.2.5, 192.0.2.8, 192.0.2.81}
```

In this case, the `management` table contains three IP addresses.

If you want to define a table that `pfctl` cannot change, use the `const` keyword. The following example defines a table for private (RFC 1918) address space. This address space has been well defined for many years, so no one should alter it.

```
table <private> const {10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16}
```

If no rules reference a table, PF drops it. This makes sense for static rules, but if you're using anchors (discussed later this chapter), you might want to retain the table for when rules reappear. Use the `persist` keyword to make a table stick around even if it's not used in a rule.

```
table <scumbags> persist
```

Some tables contain enough addresses that you wouldn't want to list them in your configuration. For convenience, you can populate a table from a file, like this:

```
table <fullbogons> persist file "/etc/fullbogons.txt"
```

I have a script that updates the *fullbogons.txt* file every day. (*Bogons* are addresses that should never appear in the global Internet routing table.)

The bogons list includes private address space, addresses reserved for experimentation or documentation, addresses not assigned to any network, and addresses assigned to other exotic purposes. Several organizations

produce and update full bogon lists. I use the bogons list at my border to weed out obvious garbage. The file looks like this:

```
# last updated 1352220481 (Tue Nov  6 16:48:01 2012 GMT)
0.0.0.0/8
10.0.0.0/8
14.1.96.0/19
...
```

You can include individual addresses, but not dotted-quad netmasks. You can use hostnames, but before `pfctl` feeds the rules to the kernel, it checks the IP address or addresses of the host. This means that if a host changes its IP address after you load the rules, PF will not know about the new IP address.

### Using Tables

Use the table in your firewall rules exactly as you would use an address or list.

```
block in on egress from <fullbogons> to any
```

You can put multiple tables in a list.

```
block in on egress from {<fullbogons>, <scumbags>} to any
```

Yes, a list is slower than a table. But if you maintain two different tables in different ways, you probably want those tables separated. And if a list of two items triggers firewall exhaustion, you really need more hardware.

### Viewing Tables

Tables have their own subset of `pfctl` commands. To see which tables are in the kernel, use `pfctl -s Tables`. (Note that `Tables` begins with a capital `T`.)

```
# pfctl -s Tables
fullbogons
scumbags
```

Why would you need to ask the kernel what tables it has? Because dynamic rules can add and remove tables, as discussed in “Anchors” on page 434.

If you already know the table name, and you want to view the addresses within the table, use the `-t` argument to specify a table name. The `-T` argument has several subcommands, much like `-s`, but is for table operations. Here’s how to examine the contents of the `scumbags` table:

```
# pfctl -t scumbags -T show
   157.166.248.10
   157.166.248.11
```

```
157.166.249.10
157.166.249.11
```

For many table operations (`add`, `delete`, `replace`, and `test` as of right now), you can add one or two `-v` options before the `-T` to increase verbosity. If you work on multiple addresses simultaneously, adding verbosity shows details of what the command did.

### Searching Tables

You can eyeball a table with four entries pretty easily, but if a table has thousands of entries, you won't want to page through it searching for an address. You could use `grep(1)`, but that can fail because an address might be part of a network that looks completely different. (I'm sure I *could* write a `grep` expression that matches 10.0.0.0/8 if I enter 10.99.61.4, but I don't want to try it.) You can test an address to see if it's in a table.

```
# pfctl -t fullbogons -T test 192.0.2.88
1/1 addresses match.
```

This address appears in the `fullbogons` table.

If you test multiple addresses in one command, use `-v` or `-vv` before `-T` to see which addresses match and which don't.

```
# pfctl -t scumbags -vvT test 192.0.2.88 198.51.100.90
1/2 addresses match.
M  192.0.2.88    192.0.0.0/22
198.51.100.90    nomatch
```

Using a single `-v` shows only matching addresses.

### Changing Tables

One important feature of tables is that you can dynamically alter them without reloading the firewall rules. If you must add an address to a table, use `-T`'s `add` command.

```
# pfctl -t scumbags -T add 192.0.2.88
1/1 addresses added.
```

Add networks by specifying a netmask and multiple addresses in a single command.

```
# pfctl -t scumbags -T add 198.51.100.0/24 2001:db8::/32
2/2 addresses added.
```

If you add addresses to a nonexistent table, PF automatically creates the table (so now you know where that `scumbags` table came from).

Add all the addresses in a file to a table with the `-f` argument.

```
# pfctl -t scumbags -T add -f scumbags.txt
1/1 addresses added.
```

To remove addresses, use the `delete` command.

```
# pfctl -t scumbags -T delete  198.51.100.0/24
1/1 addresses deleted.
```

To completely remove all entries from a table, use `flush`.

```
# pfctl -t scumbags -T flush
6 addresses deleted.
```

If emptying the table is not enough, and you want to completely remove it from the rules, use `kill`.

```
# pfctl -t scumbags -T kill
1 table deleted.
```

### *Tables and Automation*

OpenBSD includes software that can adjust tables algorithmically. In Chapter 16, I mentioned the DHCP server's ability to assign leased, abandoned, and changed addresses to tables. You can use PF to assign different rules to each group of addresses.

Assume you have `dhcpd(8)` add all leased IP addresses to the `leased` table, abandoned addresses to the `abandoned` table, and changed addresses to the `changed` table. Hosts with properly leased addresses can access the network, but hosts with abandoned and changed addresses cannot. Here, interfaces in the office group face the local network:

```
table <leased> persist
table <abandoned> persist
table <changed> persist
pass in on lan from <leased> to any
block in on lan from {<abandoned>, <changed>} to any
```

If someone decides to configure an address from the DHCP server as a static address for their computer, they automatically lose access to the rest of the network—problem solved. Other OpenBSD software, such as `spamd(8)`, has similar features.

At first glance, it might seem like this feature is ready for integration with other programs. It's fairly simple to write a script that parses a log, grabs the IP addresses, and feeds those addresses to a table. Several years ago, I wrote a script to take alerts from the Snort intrusion detection system and automatically block attackers from the network. Without careful and skilled

attention though, Snort generates many false positives. My autoblocking script very effectively created a denial-of-service attack against my own development team.

Be careful with automatically feeding PF tables to block traffic. It's very easy to harm desirable connectivity.

## Using NAT

One of the critical functions of a firewall is NAT. Use NAT to provide IPv4 network access to multiple machines but show only one public IPv4 address. Some companies provide Internet access to thousands and thousands of machines via NAT.

NAT is like making soup out of a bone—it stretches what you have so that it covers more. Some protocols won't work well with NAT. It really confuses anyone who is trying to restrict access by IP address. And it can cause nightmares for network forensics and troubleshooters. But NAT is the chosen solution for the IPv4 address shortage.

NAT is *not* intended as a security mechanism. There are minor security benefits, but they are inadequate against today's network threats. Relying on NAT for security is chasing 10 boilermakers with a cup of black coffee before staggering out of the pub to drive home. You might get away with it, but only by luck.

IPv6 was designed without NAT, but it was shoehorned in several years later by popular demand. (IPv4 was originally designed without NAT as well, so IPv6 is just following tradition.) Note that an IPv6 address—even a globally unique IPv6 address—does not mean or even imply "reachable from the world." You can have solid network separation without NAT. Avoiding NAT means using your packet filter to protect your machines, with additional application proxies as needed.

### *Private NAT Addresses*

In theory, you can use any addresses behind your NAT device. If you use some random IP addresses, though, you cannot exchange packets with whoever uses those IP addresses out in the real world. It's highly advisable to use some of the IP addresses reserved for private use, generally referred to as "RFC 1918 addresses." These include the following IP addresses:

- 10.0.0.0/8 (10.0.0.0-10.255.255.255)
- 172.16.0.0/12 (172.16.0.0-172.31.255.255)
- 192.168.0.0/16 (192.168.0.0-192.168.255.255)

You can subnet and rearrange those addresses any way you like, as long as you don't try to route them on the public Internet.

You can use other IP addresses behind your NAT if you have a really good reason for doing so. For example, RFC 5737 defines IPv4 addresses for use in documentation. Like RFC 1918 addresses, RFC 5737 addresses should never appear on the public Internet. I write documentation, so

I use those addresses on my home and test networks. It saves me from doing search and replace as I write books.[1] There's still no chance of those addresses appearing on other networks.

### Configuring NAT

Perhaps the most common form of NAT is for use in hiding a small network behind a single IP address. You'll find this in many homes and small businesses. Very few home offices have internal routing and multiple subnets. For this example, I have two interface groups: the Internet-facing `egress` group and the `lan` group attached to my office.

```
pass out on egress from ❶lan:network to any ❷nat-to egress
```

The first part of this rule looks just like any other firewall rule permitting the addresses on the `lan` interface access to everywhere, but the last two words additionally configure NAT. The `nat-to` keyword tells PF to translate addresses ❷. The `egress` that follows tells PF to hide the internal addresses behind the addresses of the `egress` interfaces ❶. You could use an interface name or a specific IP address here, but if you do, you must change your filter rules when you change your server.

In order to have PF recognize IP address changes from DHCP, put the interface group name in parentheses.

```
pass out on egress from lan:network to any nat-to (egress)
```

Now load your firewall rules, enable IP forwarding, and suddenly, hosts on your LAN will have access to the Internet through the firewall's public address.

### How NAT Works

The easiest way to understand how address translation works is to look at the state table (discussed in the previous chapter) after PF passes translated packets back and forth. On the office network from machine 192.0.2.2, I ran this command:

```
$ ping www.michaelwlucas.com
```

Several pings later, I checked the state table and found entries like this:

```
# pfctl -ss | grep 192.0.2.2
all udp ❶203.0.113.5:55797 ❷(192.0.2.2:10853) -> ❸203.0.113.15:53    MULTIPLE:SINGLE
all icmp 203.0.113.5:8813 (192.0.2.2:41584) -> 198.22.63.8:8       0:0
```

1. Can Lucas configure a highly available firewall cluster in a day? Yep. Can he search and replace IP addresses in a text file without screwing everything up? Nope.

The first state represents a UDP connection from the firewall's public address ❶ to the local DNS server ❸. This state entry includes the client's private IP address ❷, as well as the actual ports used by the client, the firewall, and the DNS server.

The client initiated this state by sending a request from port 10853 on its IP address to port 53 on the DNS server. When the packet passed through PF, OpenBSD rewrote the packet so that it appeared to come from the address 203.0.113.5 on port 55797 and sent it on to the DNS server. The DNS server sent its response to the firewall's public IP on port 55797. When the reply arrived, the firewall checked the state table, and found that UDP packets on port 55797 were part of the state for the client. PF rewrote the packet's destination address and forwarded it to the client.

The second state represents an ICMP connection. The state table encodes the various ICMP codes used for a ping request as port numbers, and forwards responses back to the client based on that information. Otherwise, it's very similar to the DNS example above it.

In other words, NAT works by lying. PF lies to the client, telling it that it has direct access to the public Internet. It lies to the external servers, giving a false source address and port for client connections. PF uses the state table to track its lies and keep everything consistent. These lies are convenient for IPv4 address conservation, but they're exactly why address translation complicates troubleshooting and intrusion forensics.

Now that you understand the basics of NAT, let's tell the network even more complicated and interesting lies.

### Multiple or Specific Public Addresses

You can use several public IP addresses for address translation. If you use an interface group for the external address in your NAT rule, any addresses in that interface group can become the public address of any connection. If you want to be specific, list particular addresses.

```
pass out on egress from lan:network to any ❶nat-to 203.0.113.5
```

I use this configuration when my firewall's external interface has multiple IP addresses and I want to conceal my desktop clients behind a single address (although I probably would define and use a macro for the external address ❶).

But how many public addresses do you need? The answer depends on your clients.

Port numbers range from 0 to 65535. The bottom 1024 ports are generally used for services on the localhost. Not all of those ports will be used on the localhost, but a packet filter generally won't use those ports for translated connections. I'm lazy, so I'll round off to 64,000 free ports.

Even the most heavily loaded desktop client rarely can use as many as 100 outbound connections simultaneously. Most will use far fewer, but again, I'm lazy, and I want a worst-case scenario, so I'll call it 100.

One IP address can support 64,000 / 100 = 640 machines being pathological simultaneously. Realistically, each client might have 10 simultaneous outbound connections, so a public address could support 6,400 simultaneous clients. How many of your users browse the Internet at the same time? The answer probably is not many. And if you have thousands of users, you would probably benefit from implementing a caching proxy, which would greatly reduce the number of connections.

If you're concerned about overflowing the number of client machines for one address, watch your state table. Until you have multiple tens of thousands of states for one public IP address, don't worry.

Specifying individual addresses in a NAT rule is most useful for bi directional NAT.

### Bidirectional NAT

Some applications work better if you dedicate a public IP address as the NAT address for a specific private IP address. For example, if you have a server that offers several different services on different ports, and you want to put it behind your firewall, you might want to dedicate a single address to it. This is called *bidirectional*, *one-to-one*, or *static* NAT. OpenBSD docs use "bidirectional," but the terms all mean the same thing.

Configure bidirectional NAT with the `binat-to` keyword.

```
pass on lan from 192.0.2.65 to any binat-to 203.0.113.6
```

PF dedicates the public IP address 203.0.113.6 for NAT services for the private IP address 192.0.2.65.

If you use bidirectional NAT, be sure to specify a specific IP address for your general NAT and consider using the following NAT rules:

```
pass out log on egress from lan:network to any nat-to egress
pass on lan from 192.0.2.2 to any binat-to 203.0.113.6
```

The IP addresses on this LAN are hidden behind the IP addresses on the `egress` interface. If 203.0.113.6 is an address on an `egress` interface, outbound packets from the LAN might use it as a source address.

When I need bidirectional NAT, I usually write my NAT rules like this:

```
mainnat="203.0.113.5"
servernat="203.0.113.6"
pass out log on egress from lan:network to any nat-to $mainnat
pass on lan from 192.0.2.2 to any binat-to $servernat
```

In this way, packets leaving my network are unambiguously translated. Only the one specific server uses the IP address 203.0.113.6; all other hosts on my local network use 203.0.113.5. If I change IP addresses, I must reconfigure *pf.conf*, but that's a minor annoyance compared to troubleshooting network ambiguity.

### Bidirectional NAT and Security

The use of bidirectional NAT, and allowing the redirection of connections, lets you give people outside your network access to servers behind your firewall, and every one of these gaps is a potential security hole. If you allow the world access to your web servers, and an intruder compromises one of your servers, you have a compromised machine inside your firewall. The firewall doesn't really secure the web servers; it just controls who can try to break into them and limits the available attack vectors.

### Packet Filtering, Bidirectional NAT, and Rule Order

When writing packet-filtering rules for bidirectional NAT, the order in which you list rules is important. Consider the following rules:

```
pass on lan from 192.0.2.2 to any binat-to 203.0.113.6
pass in on egress proto tcp from any to 192.0.2.2 port 80
```

The first rule establishes static NAT for the host 192.0.2.2 on the LAN, hiding it behind the public IP address 203.0.113.6. All is well and good. The second line permits connections to port 80 on the same host, or does it? Packets meant for this server that arrive on the firewall's egress interface won't be addressed to 192.0.2.2; they'll be addressed to the public NAT address, or 203.0.113.6. They won't match this rule, so they are discarded.

In order to permit connections from the world to the web server behind this firewall, permit packets sent to the proper port on the public address.

```
pass on lan from 192.0.2.2 to any binat-to 203.0.113.6
pass in on egress proto tcp from any to 203.0.113.6 port 80
```

This translates 192.0.2.2 to the public address 203.0.113.6, and then allows packets with a destination of port 80 on 203.0.113.6 to pass. You'll see this in the state table, like this:

```
all tcp 203.0.113.6:80 <- 198.22.63.8:64791       ESTABLISHED:ESTABLISHED
```

The host 198.22.63.8 has connected to the server's public IP address on port 80.

Why doesn't this state entry have the hidden IP address in it? Because this is a bidirectional NAT. PF can send port numbers through unaltered, so it can track a little less information in the state table.

The tricky thing here is that the rule order impacts how you filter, and you must read your filtering rules carefully to see how address translation interacts with packet filtering. I *always* write my rules so that I do address translation before I filter. I consistently use the public IP address in the filter rules, but sometimes that's not practical. PF lets you write arbitrarily complex rules mainly because the real world is arbitrarily complex. If you have trouble passing traffic through NAT, read your rules very carefully.

To see a bidirectional NAT, look at the loaded rules.

```
# pfctl -sr
...
pass out on lan inet from 192.0.2.2 to any flags S/SA nat-to 203.0.113.6 static-port
pass in on lan inet from any to 203.0.113.6 flags S/SA rdr-to 192.0.2.2
pass on egress inet proto tcp from any to 203.0.113.6 port = 80 flags S/SA
```

The first rule gives the private IP address access to the public Internet, translated to the specific IP address. The third rule passes traffic to the translated address.

But what about the second rule, with that `rdr-to` stuff? That's a redirection, which is how PF implements static NAT.

### Redirection

Bidirectional NAT is actually a combination of address translation and *redirection*; in other words, it twists a connection intended for one IP or port to another. In bidirectional NAT, all connections to the designated public IP address are redirected to a different IP address. Sometimes you don't want to twist all traffic for an IP address—only a few ports. Sometimes you want to redirect one port one way, but a different port elsewhere. Do this with redirection rules.

Suppose you have one public IP address: 203.0.113.5. You want port 80 on that IP address routed to your web server at 192.0.2.2, ports 25 and 110 to your mail server at 192.0.2.3, and port 443 to your e-commerce server at 192.0.2.4. PF lets you choose where to send each port via redirection by using a standard packet-filtering rule and adding the `rdr-to` redirection keyword.

```
pass in on egress proto tcp from any to egress port 80 rdr-to 192.0.2.2
pass in on egress proto tcp from any to egress port {25, 110} rdr-to 192.0.2.3
pass in on egress proto tcp from any to egress port 443 rdr-to 192.0.2.4
```

These rules declare that any connection coming to the `egress` interface group (the interface facing the public Internet, with a default route going over it) can be redirected in three different ways. The first rule directs port 80 requests to one internal server. The second rule directs requests for ports 25 and 110 to the second server. The last rule redirects requests for port 443 to the third server. One public IP address is now providing services to the world from three different servers.

All port redirection rules must include a protocol, because specifying a TCP/IP port works only if you're forwarding a protocol that includes port numbers, such as TCP or UDP. If you want to forward both TCP and UDP ports, you must specify both protocols. For example, DNS uses port 53 on both TCP and UDP. Here's a rule that forwards both of these protocols' port 53 to the internal server 192.0.2.5:

```
pass in on egress proto {tcp, udp} from any to egress port 53 rdr-to 192.0.2.5
```

Pick a port, say where you want it to go, and PF will redirect it as you please.

**NOTE** *You've learned how bidirectional NAT combines redirection and address translation. The in-kernel PF engine doesn't actually know anything about this beastie called "bidirectional NAT." `pfctl(8)` translates the `binat` rule into two separate rules: one for translation and one for redirection.*

### Multiple Addresses and Interface Groups

All of the preceding discussion makes sense when you have only one public IP address. But what happens when you have multiple addresses?

Remember that using an interface group in *pf.conf* tells `pfctl` to create a matching rule for every IP address in the interface group. Suppose you have three IP addresses on your `egress` interface: 203.0.113.5, 203.0.113.6, and 203.0.113.7. You write this *pf.conf* rule:

```
pass in on egress proto tcp from any to egress port 80 rdr-to 192.0.2.2
```

Load this rule into the kernel with `pfctl`, and what do you get?

```
# pfctl -sr
...
pass in on egress inet proto tcp from any to 203.0.113.5 port = 80 flags S/SA rdr-to 192.0.2.2
pass in on egress inet proto tcp from any to 203.0.113.6 port = 80 flags S/SA rdr-to 192.0.2.2
pass in on egress inet proto tcp from any to 203.0.113.7 port = 80 flags S/SA rdr-to 192.0.2.2
```

Any connection to port 80 on any of these IP addresses is directed to port 80 on the same server. This might be useful in some environments, but that's not what most of us want. If you have multiple IP addresses, and you want to redirect a port on only one IP address, you must specify the interface name and the public IP address.

```
pass in on em0 proto tcp from any to 203.0.113.5 port 80 rdr-to 192.0.2.2
```

This doesn't expand; it doesn't have any interface groups, lists of addresses, variables, or macros. When `pfctl` parses this, it loads only one PF rule into the kernel.

### Port Manipulation and Ranges

As you redirect ports from one machine to another, you can change the port. The following example takes requests to TCP port 2222 on the firewall and redirects them to port 22 on a machine inside the firewall.

```
pass in on egress proto tcp from any to egress port 2222 rdr-to 192.0.2.2 port 22
```

This is a reasonable way to offer SSH services to several machines inside the firewall on only one IP address, and to give each machine its own port.

If you have specific source addresses that you want to abuse, you can give them special port redirections by source IP address.

```
pass in on egress proto tcp from 198.51.100.0/24 to egress port 80 rdr-to 192.0.2.2
pass in on egress proto tcp from ! 198.51.100.0/24 to egress port 80 rdr-to 192.0.2.3
```

Every HTTP connection from the IP addresses in 198.51.100.0/24 will be redirected to one server, while every other connection will be directed elsewhere. (To redirect connections for many source addresses, use a table for the source address.)

PF can also redirect entire ranges of ports using the same logical operators used for filtering ports. One obvious thing to do is to redirect a range of ports to a single machine. NFS is a prime example, as it requires TCP port 111, as well as all TCP and UDP ports from 1024 to 65535.

```
pass in on egress proto {tcp, udp} from any to egress port {111, 1024:65535} rdr-to 192.0.2.15
```

Recall from Chapter 21 that a colon between port numbers indicates a range of ports. This rule passes ports 1024 through 65535, inclusive. Admittedly, certain NFS implementations can be restricted to use either TCP or UDP, and that's a great big gaping hole in your packet filter. But NFS uses random high-numbered ports that come and go very quickly, and cannot be effectively filtered or restricted at the packet level.

You can also funnel an entire range of ports to one port on one machine.

```
pass in on egress proto tcp from any to egress port {1024:65535} rdr-to 192.0.2.15 port 80
```

I've used this to point random traffic at a web page that says "Go away. You cannot use this service."

### Transparent Interception

Traffic interception is similar to redirection in that PF intercepts traffic bound for one port and steers it to a port on the local machine. Traffic interception is one way to implement a transparent proxy. Use the `divert-to` keyword to tell PF to steer any matching packets to a local server.

```
pass in inet proto tcp from lan:network to any port 80 divert-to 127.0.0.1 port 3129
```

Any traffic from the local LAN to port 80 will be diverted to port 3129 on the firewall. Port 3129 is usually used by the Squid caching proxy (*/usr/ports/www/squid*). If you choose to implement a caching proxy like Squid, you'll probably want to redirect several ports to the cache. (We'll take a closer look at diverting connections in "FTP and PF" on page 437.)

## Anchors

In PF, an *anchor* is a sub-ruleset at a specific point in the filter rules that you can change without reloading the rules. It's a spot marked "insert rules here," letting you dynamically add and remove filter rules, tables, and other PF configurations.

The most common users of anchors are software programs. Human beings or sysadmins should probably just edit *pf.conf* and reload the rules.

OpenBSD includes several programs that take advantage of anchors, however, including the FTP proxy `ftp-proxy(8)`, the authenticated firewall access system `authpf(8)`, and the load balancer `relayd(8)`. You could also use anchors to trigger conditional evaluation of rules.

A ruleset with an anchor might look something like the following, where the interface group `egress` faces the Internet, and the interface group `lan` faces a small office with the addresses 192.0.2.0/24.

```
block
pass in on egress from any to 192.0.2.45 port {25, 80}
anchor "antivirus/*"
pass in on lan from 192.0.2.0/27 to any
```

These rules block all traffic by default. Incoming traffic is allowed to a specific address on ports 25 and 80 because those are the mail and web servers. There's an anchor in the middle of the rules. I don't yet know what's in the `antivirus` anchor, but any rules in it are processed next. Finally, a small subnet of the addresses is allowed out.

Now let's add some rules to the anchor.

### Adding Rules to Anchors

You can insert rules into anchors from a file, within *pf.conf* itself, or via `pfctl`.

#### Anchor Rules from Files

Adding rules to an anchor from a file is a good way to initialize your anchor when first starting the packet filter. You can set base rules here that you can expand later. Give the filename in *pf.conf*.

```
anchor dhcp
load anchor dhcp from "/etc/pf/dhcp-anchor.conf"
```

I created an */etc/pf/* directory because I didn't want to have a whole bunch of PF configuration files scattered throughout */etc*. I'm easily confused, after all. This file contains PF rules like this:

```
block from 192.0.2.192/26 to any
```

This is one way to load basic rules into an anchor when you start PF.

If you were paying attention, you probably noticed that my first example anchor had a /* after its name. This example doesn't. I'll explain why in "Nested Anchors: /*" on page 436.

### Anchor Rules in pf.conf

You can place anchor rules directly inside *pf.conf*. If you don't intend to dynamically alter the rules, you don't even need to name the anchor. Just use curly braces to define the beginning and end of the anchor.

```
anchor "smtp" on egress {
    pass proto tcp from 192.0.2.12 to any port 25
    }
```

This is just slightly more complicated than the anchors in the default *pf.conf*.

Why would you want to do this? Read "Conditional Filtering" on page 436.

### Anchor Rules via pfctl

To dynamically alter anchor rules with `pfctl`, you need the name of the anchor and the rule you want to put in its place. For example, suppose I want to add a rule to the `antivirus` anchor in the first anchor example.

```
# ❶echo "block in from 203.0.113.8 to any" ❷| pfctl ❸-a antivirus ❹-f -
```

Let's look at this command slightly backwards. The `-a` argument to `pfctl` specifies an anchor name—in this case, the `antivirus` anchor ❸. The `-f` argument normally gives a filename that contains the new anchor rule, much like `-f` when loading a PF ruleset, but rather than a path to a file, I use a single dash that tells `pfctl` to read the new rule from standard input, or the command line ❹. I start everything by echoing the rule to be added ❶, and then piping that into `pfctl` ❷.

Taken as a whole, this adds the rule `block in from 203.0.113.8 to any` to the anchor `antivirus`.

You could also write the new rule to a file, and tell `pfctl` to load the rules from that file into the anchor.

```
# pfctl -a antivirus -f newrule.conf
```

If you're writing rules to a file to load them into an anchor, however, chances are you're better off editing *pf.conf*.

**NOTE** *Adding a rule to an anchor erases any rules already in the anchor. If you have a software package that updates anchor rules, your software needs to handle this behavior. If your desired behavior can be accomplished using a list of IP addresses, consider using a table instead of an anchor.*

### Viewing and Flushing Anchors

Use the `pfctl` view (`-s`), flush (`-F`), and load (`-f`) commands on anchors by specifying the anchor name with `-a`.

```
# pfctl -a antivirus -s rules
block drop in inet from 203.0.113.8 to any
```

To erase the rules from an anchor, flush the rules in the anchor.

```
# pfctl -a antivirus -F rules
rules cleared
```

Your anchor is now empty.

Rulesets within anchors are completely separate from each other, and also from the main ruleset. Flushing all the rules in a specific anchor does not affect the rules in any other anchor, or the rules in the main ruleset. For that matter, flushing the rules in the main ruleset does not impact the rules in the anchor. To destroy an anchor, you must remove everything in the anchor, including any child anchors.

"Child anchors?" I hear you cry. "What are you babbling about *now*, dude?"

### Conditional Filtering

Consider the following *pf.conf* snippet:

```
...
anchor "office/*" in from lan to any {
    pass out proto tcp from any to {80, 443}
    }
...
```

The `office/*` anchor has a filter condition after it, and only traffic that matches the filter condition will pass through the anchor. In this case, only packets that come from the `lan` interface group will pass through the rules within the anchor. Your rules within the anchor might be easier to write, simply because everything in the anchor is already known to be originating from the `lan` interfaces.

If your packet filter is very heavily loaded, you might be able to reduce the amount of time it spends processing packets by careful conditional filtering.

### Nested Anchors: /*

Anchors can contain other anchors.

```
anchor "office" in from lan to any{
    ...
    anchor "ftp-proxy/*"
    pass in quick inet proto tcp to port ftp divert-to 127.0.0.1 port 8021
}
...
```

Only traffic that passes into the `office` anchor can pass through the `ftp-proxy` anchor. The FTP proxy can have its own sub-anchors as well. In fact, you might have several layers of anchors to support a complicated protocol, such as FTP.

This is where the `/*` after some anchor names comes in. An anchor name without this is executed all by itself. By adding the `/*`, you tell PF to evaluate all sub-anchors within this anchor, in alphabetical order.

Anchors and sub-anchors deliberately resemble a filesystem. You can have a file */office* or a directory */office/* containing more files. If you list the files in a directory, they appear in alphabetical order. Anchors work much the same way.

All of this anchor stuff is very theoretical. How about a practical example? Read on to see how PF uses anchors to handle that most annoying of network protocols: FTP.

## FTP and PF

Most modern application protocols run over a single network connection. If you make a web request, your browser opens a connection to the server on port 80, requests information, and receives the answer, all on the same connection. SSH opens a single connection on port 22 and exchanges all information over that port, even if you tunnel a hundred other protocols inside it. Experience and experiments with older protocols taught the wisdom of this approach. FTP is an older protocol, and it provides a wealth of experience on how not to do things.

The original version of FTP (today called *active FTP*) required the client to connect to the server on port 21. The server would then open a connection back to the client, from port 20 to some random high-numbered port on the client for sending information. The connection from server to client is called the *data connection*, or the *back channel*. The FTP client and server agree on the ports to be used and how the second connection will be used. On a network protocol level, however, no connection exists between the client's connection to port 21 and the server's connection from port 20, so there's no way for a firewall to use stateful inspection to sort out if such a connection is allowed. Worse, if the client is behind a NAT device, there's no way to determine to which private IP address the firewall should route an incoming FTP data request.

*Passive FTP* is an updated version of the FTP protocol where the client initiates both TCP connections. All modern clients and servers support passive FTP. The differences between active and passive FTP spark endless rounds of user education and increased help-desk load, especially if you're trying to use FTP through a web browser. (And if anyone is going to break my help desk staff, it's going to be me!) Active FTP simplified firewall rules, because the firewall didn't need to allow the back channel. Unfortunately, the creators of passive FTP called the modified protocol FTP. Clients don't care about active or passive, they just want "this FTP thing" to work, regardless of the actual protocol underlying it.

To complicate things, some FTP servers and clients implement something between active and passive FTP. The FTP protocol has been around for decades (it predates TCP/IP), and people have tweaked and "improved" it for years. Getting a random combination of FTP server and client through a random NAT device and a packet filter can cause nightmares, or at least require opening a wide range of TCP ports.

OpenBSD and PF get around this problem by including an FTP application proxy, `ftp-proxy(8)`. When a client makes an FTP request, PF intercepts the request and reroutes it to the application proxy. The proxy tracks the FTP protocol transactions, uses anchors to insert the appropriate rules into the firewall, and removes the rules when the transfer finishes. Strictly speaking, `ftp-proxy` isn't a traditional proxy. Data doesn't actually go through `ftp-proxy`; the "proxy" adjusts the firewall rules so that traffic can pass. The proxy requires two parts: a running `ftp-proxy` instance and the redirect rules.

### Configuring ftp-proxy(8)

Like any other OpenBSD daemon, `ftp-proxy` is enabled in */etc/rc.conf.local*. There's no configuration file—only command-line arguments. By default, `ftp-proxy` automatically listens on port 8021 on the loopback interface. It's very rare for me to add any command-line arguments for `ftp-proxy` for routine use.

```
ftpproxy_flags=""
```

If I'm debugging a problem, however, I might run `ftp-proxy` in the foreground, in debugging mode. Doing this shows me all FTP transactions as they occur.

```
# ftp-proxy -dD7
```

This displays everything that passes through the FTP proxy, including the ports used for the data channel back to the client. Press CTRL-C to stop `ftp-proxy`.

The most common problem I have with `ftp-proxy` is that nothing appears in the debugging terminal. That means that the firewall isn't diverting any traffic to the proxy. Check your *pf.conf* file to verify that you have the necessary rules to support the FTP proxy.

### PF Configuration and the FTP Proxy

PF must know to send FTP requests to `ftp-proxy`. There's a good example configuration in the default *pf.conf* file:

```
anchor "ftp-proxy/*"
pass in quick inet proto tcp to port ftp divert-to 127.0.0.1 port 8021
pass out inet proto tcp from (self) to any port ftp
```

Here's where we use anchors. The `ftp-proxy/*` anchor can contain subrulesets. The `ftp-proxy` daemon modifies these anchors on the fly to configure the necessary traffic or data connections. The second rule declares that PF will divert any traffic addressed to the FTP port (21 as per */etc/services*) to port 8021 on the localhost. The third rule says that the firewall host can send TCP port 21 traffic to any other host. This rule contains a new term, (`self`), which is PF shorthand for "all IP addresses on the localhost."

How can you be sure this works? First, find an FTP server that supports active FTP. Open your FTP client and log in to the server, going through the firewall. Once you log in, use the `pasv` command at the FTP prompt. This command turns passive mode on and off. If the server doesn't recognize `pasv`, it supports only passive FTP. Find another FTP server for this test. Once the FTP server reports that "passive mode is off," list the contents of a directory. Directory listings, like data files, come over the data channel.

During the data transfer of an active FTP connection, you should see rules in the `ftp-proxy/*` anchor.

```
# pfctl -a "ftp-proxy/*" -sr
anchor "6837.2" all {
  pass in log (all) quick on rdomain 0 inet proto tcp from 129.128.5.191 to
139.171.202.34 port = 62323 flags S/SA keep state (max 1) rtable 0 rdr-to
192.0.2.2 port 64280
  pass out log (all) quick on rdomain 0 inet proto tcp from 129.128.5.191 to
192.0.2.2 port = 64280 flags S/SA keep state (max 1) nat-to 129.128.5.191
}
```

The rules created by `ftp-proxy` are very specific. They permit only one connection, from a particular server to a particular client, with address translation rules to make each side think it's actually talking to the proper client or server.

**NOTE** *To learn how to restrict your clients to using only anonymous FTP, or how to use `ftp-proxy` to permit inbound FTP access to a server inside your firewall, read the `ftp-proxy(8)` man page.*

## Bandwidth Management

One common task for a network perimeter device is bandwidth management. Network managers must control how much bandwidth is used for certain tasks, and must also reserve bandwidth for vital functions. If one of your minions loads the latest blockbuster comic book movie on the web server, you must be able to make an SSH connection to the server, find out why your server is overloaded, and fix the problem. PF includes the ALTQ bandwidth management system.

The most important thing to remember about bandwidth management is that you cannot control how much traffic other people send you. You can stop traffic at the point it enters your network. You can send hints that the

bandwidth is saturated. You can arbitrarily restrict bandwidth *from* your servers. But nothing you do can stop 10,000 people a second from clicking a link to that server. You cannot prevent a distributed denial-of-service attack from saturating your inbound bandwidth. The best you can do is control how you respond to those requests.

When I run content farms, I usually put dedicated bandwidth control machines in front of my servers. This setup controls how much traffic actually reaches my server network, reduces load on the servers in case of a sudden spike, and prevents one overly busy customer from taking down other customers on the same server.

### Queues for Bandwidth Management

ALTQ manages bandwidth by *queues*. A queue is a list of packets waiting to be processed.

By dividing your bandwidth into separate queues, and processing those queues as you configure, you can manage server bandwidth. Queues are somewhat like the checkout lines at the grocery store; some lines are for 10 packets or less and get you out quickly, and others are for people who shop once a month and fill up three carts. You can define just about any characteristics for queues, as if you could create a "meats only" or "white wine with fish" register.

Engineers have defined many different queuing algorithms, and the most proper queue method for a given situation is a topic that sparks heated discussions. TCP/IP quality-of-service queue handling is one of those topics that make angelic children cry. By default, all BSD-based systems use first-in, first-out (FIFO) queuing, where packets are processed in the order in which they are received. Newer packets wait in a queue until older packets move on.

OpenBSD also supports priority queuing (PRIQ or prio), where the kernel considers packets of certain types to have "priority" and processes them first. This means that if you assign web packets highest priority, all web packets jump to the head of the queue. Packets of lower priority might never be processed at all under this scheme. These days, just about everything supports priority queuing, especially switches. The goal of priority queuing is to reduce latency for specific traffic, such as voice or video, paying for that reduced latency by increasing the latency of less urgent traffic.

However, in most operational settings where you must regulate bandwidth, class-based queuing (CBQ) is appropriate. CBQ allows the network administrator to allocate a certain amount of bandwidth to different types of traffic through hierarchical classes. Each class has its own queue, with its own bandwidth characteristics. You can assign different sorts of traffic to different classes: SSH to one class, HTTP and HTTPS to another, and so on. One of the nice features of CBQ is that its hierarchical nature allows lower classes to borrow available bandwidth from classes above them.

As I find CBQ appropriate for most environments, I focus on it here. Once you master CBQ, if you need PRIQ, you'll find it easy to understand.

### Parent Queue Definitions

Queuing starts with defining the parent queue. All other queues are children of the parent queue. The parent queue is attached to a network interface, most commonly the Internet-facing interface. Place your queue definitions in *pf.conf*. I put queues at the top of the file, before any packet-filtering rules.

Here's how you define a parent queue on an interface:

```
❶altq on ❷interface ❸cbq bandwidth ❹bw qlimit ❺qlim tbrsize ❻size ❼queue { ❽queue1, ❾queue2}
```

Start all ALTQ parent queue definitions with the `altq` keyword ❶, and then give the interface to which this queue is attached ❷. (Each interface can have no more than one parent queue.) Then give the queue type you're using ❸. For CBQ queuing, the queue type is always `cbq`.

Now define the total amount of bandwidth in the parent queue ❹. This is not the same as the amount of bandwidth the interface can pass, but the amount of bandwidth you reasonably expect to pass upstream. If your OpenBSD machine has a gigabit network card, but you have only 10 megabits of bandwidth to the Internet, use `10Mb` as your bandwidth (or fiddle with the bandwidth value until you hit your actually usable allocation). You can use the following case-sensitive abbreviations for bandwidth:

- **`b`** bits per second
- **`Kb`** kilobits per second
- **`Mb`** megabits per second
- **`Gb`** gigabits per second

The optional `qlimit` parameter gives the number of packets the queue can hold ❺. The default value is `50`, which suffices for almost all cases. I recommend not setting `qlimit` unless specific debugging shows that you need a larger queue size.

This example includes the token bucket regulator size configuration because `tbrsize` lets you dictate how quickly packets can be transmitted ❻. ALTQ defaults to transmitting packets as fast as the wire permits. As with `qlimit`, I recommend not setting `tbrsize` unless you encounter a problem.

Next, identify this as a parent queue ❼, and define child queues `queue1` ❽ and `queue2` ❾.

Here's how to configure a parent queue with a 50-megabit uplink, with the child queues `ssh`, `web`, and `mgmt`:

```
altq on em0 bandwidth 50Mb queue {ssh, web, mgmt}
```

The `tbrsize` and `qlim` keywords are not set, so they're at their defaults.

### Child Queue Definitions

Once you have a parent queue, you can define child queues. Define CBQ queues with the following syntax:

```
queue ❶name on ❷interface bandwidth ❸bw [priority ❹pri] [qlimit ❺qlim] cbq
❻(options) ❼{child_queues}
```

Each queue needs a name ❶, defined in the parent queue definition, of 15 characters or less. The names don't need to be unique—you could use a queue of the same name on a different interface—but I recommend that you use unique names.

The interface is the specific interface to which this queue is applied ❷. If you don't define an interface, traffic that passes through any interface can be assigned to this queue.

The `bandwidth` term uses the same bandwidth labels that the parent queue uses, but the total bandwidth assigned to all child queues cannot exceed the total amount of bandwidth available on the parent queue ❸. You can also use a percentage value for bandwidth, indicating the percentage of the parent queue that this queue can consume. Bandwidth and queue are the only mandatory terms in a child queue description.

The following defines the `ssh` child queue and gives it a bandwidth of 2 megabits:

```
queue ssh bandwidth 2Mb
```

Here's a child queue called `web`, which is allowed to use three-quarters of the parent queue bandwidth:

```
queue web bandwidth 75%
```

You can assign a priority to a queue ❹. CBQ priorities run from `0` to `7`, with `7` being the highest. The default priority is `1`. A CBQ queue with a higher priority does not run to the exclusion of other queues, but PF processes it more quickly than other queues.

As with a parent queue, you can assign a `qlimit` to a child queue ❺, but don't do this unless you have a specific problem that can be solved with this value.

You can assign options to a CBQ child queue ❻. We'll look at these options in the next section.

Finally, child queues can have their own children. Define a queue's children in the queue ❼. You'll see an example of this in "A CBQ Ruleset" on page 443.

### Queue Options

Modify how a child queue processes packets by assigning options to a queue. Options let you decide how the queue should respond to a variety of network conditions and bandwidth availability.

#### Default

Every parent queue must have one and only one default child. If a packet crossing a queued interface is assigned to no other queue, it is assigned to the default queue.

#### Random Early Detection

Random early detection (RED) is a method for handling packet loss when a queue starts to fill up. As the queue fills up, more and more packets are dropped. RED randomly chooses packets to drop. The net effect is that short transfers, such as HTTP requests and interactive SSH sessions, respond more quickly, while large data transfers become slower.

TCP clients and servers react to dropped packets by reducing their throughput. UDP, ICMP, and other protocols don't have any built-in reaction to packet loss. Using RED on queues expected to carry TCP is sensible, but not on queues for other protocols.

#### Explicit Congestion Notification

Explicit Congestion Notification (ECN) is a modification to RED that sets flags in the packet rather than dropping the packet. If a device recognizes the ECN flag, it will reduce transmission rates.

Not all platforms understand ECN, however, and many that can recognize ECN disable it by default. Microsoft's Windows Vista and newer, Apple OS X, FreeBSD, and OpenBSD can support ECN, but disable it by default. Newer Linux versions support ECN if the other host requests it. I have successfully used ECN, in corporate environments where I could make the support guys enable ECN on the desktops.

Unless you know the operating systems in use and can control their settings, stick with standard RED.

#### borrow

The `borrow` option is available only in CBQ. A queue with borrow set may borrow bandwidth from its parent queue, if the bandwidth is available. For example, you might have a queue that reserves 20 percent of your bandwidth for VoIP. If you don't have that much VoIP traffic at any particular moment, the parent will have excess bandwidth. Other queues could borrow bandwidth from that allocation. When your VoIP traffic spikes, however, PF revokes the bandwidth loan, and the VoIP traffic gets what's reserved for it.

Use the `borrow` option on the queues that you want to permit to borrow bandwidth, not on the queues whose bandwidth might be borrowed.

### *A CBQ Ruleset*

Before configuring queues, figure out how you want to divide your bandwidth. While you could use bits per second to manage bandwidth, for most of us, percentages are easier to deal with. Here's how you might divide Internet bandwidth for a company with a 10-megabit link. Start by making

a list of your desired bandwidth reservations, and then assign a name to each category, like this:

- 5 percent for SSH (`ssh`)
- 50 percent for inbound traffic to our e-commerce server, with RED (`web`)
- 5 percent for inbound VoIP, high priority (`voip`)
- 40 percent for other traffic, including DNS, SMTP, and so on

All of these queues can borrow from the parent queue.
Start by defining the parent queue.

```
altq on em0 cbq bandwidth 10Mb queue {ssh, web, voip, other}
```

This parent queue is attached to interface `em0`, and has 10 megabits of bandwidth and four child queues. Leave all the other options alone.
Now define the first child queue.

```
queue ssh bandwidth 5% cbq (borrow)
```

Start with the queue name and the bandwidth percentage you've chosen. This percentage is calculated from the parent of this particular queue, so it's about 5 percent of 10 megabits, or 500 kilobits per second. That should be plenty to log in remotely and fix any problems. Adding the `borrow` option lets you use more bandwidth for SSH if it's available.
Building from this example, you can define the other child queues.

```
queue web bandwidth 50% cbq (borrow, red)
queue voip bandwidth 5% cbq (borrow)
queue other bandwidth 5% cbq (borrow, default)
```

The other queue is your default. Any traffic that isn't assigned its own queue is assigned to this queue.

### Assigning Traffic to Queues

Assign traffic to a queue with the `queue` keyword at the end of a packet-filtering rule. To allow all SSH (port 22) traffic into the network and assign it to the queue named `ssh`, use a rule like this:

```
pass in on egress proto tcp from any to lan:network port 22 queue ssh
```

### Using the match Keyword

Sometimes you must classify traffic without filtering it. The previous example let you assign inbound SSH traffic to the `ssh` queue, but what if you want to capture outbound SSH as well? Consider the following rule snippet:

```
pass in on egress proto tcp from <customers> to <sshservers> port 22
pass out on egress from lan:network to any
```

This allows hosts in the customers table to connect to hosts in the sshservers table on port 22. The second rule allows the local network to send any traffic, or any protocol. Some of that outbound traffic will be SSH traffic. Should you write a separate rule just for queuing traffic?

This is where the match keyword comes in. Using match, you can change how PF classifies traffic without changing how it filters traffic. Here's how to send all TCP port 22 traffic to the ssh queue, without changing any filtering characteristics:

```
match proto tcp from any to any port 22 queue ssh
pass in on egress proto tcp from <customers> to <sshservers> port 22
pass out on egress from lan:network to any
```

The first rule matches all traffic on TCP port 22 and assigns it to the ssh queue. The rules that follow control who can send and receive SSH connections.

### Viewing Queues

To view the queues currently in the packet filter, run pfctl -s queues.

```
# pfctl -sq
queue root_em0 on em0 bandwidth 10Mb priority 0 cbq( wrr root ) {ssh, web, voip, other}
queue  ssh on em0 bandwidth 500Kb cbq( borrow )
queue  web on em0 bandwidth 5Mb cbq( red borrow )
queue  voip on em0 bandwidth 500Kb priority 7 cbq( borrow )
queue  other on em0 bandwidth 500Kb cbq( borrow default )
```

Adding -v gives you a brief snapshot of the state of each queue. For a constantly updating view of all queues, including how much traffic is borrowed from each, what gets dropped, and so on, use -vvsq or systat queues instead.

## PF Edges

This section covers a couple tidbits of PF configuration that don't quite fit anywhere else: include files and the quick keyword.

### Using Include Files

Sometimes splitting a configuration file into multiple pieces simplifies your work. Do this with an include statement in *pf.conf*.

```
include "/etc/pf/management-addresses"
```

I do this when I need to manage several PF machines with unique configurations, but certain pieces are identical. The *management-addresses* file defines a table listing all hosts and networks that can connect via SSH, make SNMP queries, as so on. When one of those addresses change, I copy this file to all of my PF hosts and reload the packet-filtering rules.

### Skipping Matches with quick

PF processes packet-filtering rules in order, and the last matching rule wins, which can complicate designing a ruleset that supports exactly the access you desire. If you find yourself stuck, use the `quick` keyword to abort processing the rest of the rules for matching packets. Here's an example:

```
...
pass in quick proto tcp from any to $sshserver port 22
...
block in proto tcp from any to any port 22
...
```

The first rule permits traffic to the host(s) in the macro `$sshserver` on port 22. The second rule drops all TCP port 22 traffic. The `quick` keyword in the first rule says, "When a packet matches this rule, follow this rule and do not process any more rules." In this case, the SSH connection will be permitted.

The `quick` keyword is especially useful in anchors, where rules added for a special purpose by an automated process like `ftp-proxy(8)` might be overridden by later rules meant for unrelated purposes.

The purist in me wants to insist that all static rulesets be written without using `quick`. While strictly speaking that's true, sometimes avoiding `quick` creates rulesets that are difficult to interpret. A ruleset you can easily understand is more secure than something baroque but syntactically pure.

## Logging PF

Tell PF to log packets with the `log` keyword in a rule.

```
pass out log on egress from lan:network to any
```

Without additional setup, however, those logs just go to the PF log device `pflog0`. To successfully log PF messages, you must run the packet filter logger `pflogd(8)`. If you start PF at boot, `pflogd` is automatically started with it. Otherwise, you must start it on the command line.

One thing to remember is that if you're using stateful inspection, only the first packet that triggers a rule is logged. Other packets that are part of the same state are not logged. To log all packets in a stateful connection, give the `all` modifier to the `log` keyword, but beware because this can generate very large logs.

```
pass out log (all) on egress from lan:network to any
```

Logging is especially useful when troubleshooting connection problems. If packets are being blocked when you think they should be passed, add logging to your `block` statements to see which rule is stopping the traffic.

I don't recommend logging everything, especially because logs can grow quite large. Log selectively. For example, perhaps you don't care which

websites your local users visit, but do want to know about incoming traffic. And be sure to exclude your firewall logging traffic from your packet filter logs, or you'll quickly find that PF is logging the transmission of the logs of the log transmissions, which are logs of transmitting the logs, from when you transmitted the logs . . . yadda yadda yadda.

### Reading PF Logs

PF logs in the `tcpdump(8)` binary format. Use `tcpdump` to examine the data. To just dump everything in the log, tell `tcpdump` to read the log file.

```
# tcpdump -r /var/log/pflog
```

This can generate a huge amount of output. See "Filtering tcpdump" on page 447 for some hints.

### Real-Time Log Access

The entries in */var/log/pflog* are not added in real time; `pflogd(8)` buffers its records until writing a log message is worthwhile. To see PF logs in real time, attach `tcpdump` to the `pflog0` interface with the `-i` flag.

```
# tcpdump -i pflog0
```

Depending on how much traffic you're logging, this might also produce an overwhelming amount of information. You must filter `tcpdump` to make it useful. Or if you pretend you missed my earlier warning about log sizes, you can devise a one-liner that uses `logger` to send your PF logs as text to `syslog`.

### Filtering tcpdump

Every system administrator should know how to use `tcpdump`. Here's your motivation for doing so.

When troubleshooting a problem with a particular connection, you probably don't care about every packet passing through the filter. You care about traffic to or from a particular host. Specify an IP address with the `ip` or `ip6` expression.

```
# tcpdump -i pflog0 ip host 192.0.2.2
```

This will display only traffic to and from this particular host.

To narrow things further and see only the traffic between two hosts, combine the hosts with the `and` keyword.

```
# tcpdump -i pflog0 ip host 192.0.2.2 and ip host 203.0.113.88
```

Maybe you're interested in only a specific port, on a specific address. Use the `tcp` or `udp` keyword and the port number to filter on that.

```
# tcpdump -i pflog0 ip host 139.171.199.254 and tcp port 80
```

Read the tcpdump(8) man page for an exhaustive list of innumerable other filtering options.

If using tcpdump doesn't appeal to you, consider the pflow(4) NetFlow exporter. Network flow is a complicated topic, but the book *Network Flow Analysis* (No Starch Press, 2010) might help you.

### Ruleset Tracing

Sometimes, knowing whether a packet passed or failed isn't enough. You know that a packet was blocked, but not why. You want to watch the packet pass through the rules and see which rules affect it.

Suppose an internal host 192.0.2.226 cannot connect to the external host 203.0.113.34. The log would show that the packet is blocked, but not why. You can specifically have PF log matching rules. Add a line like this to the top of your *pf.conf* file:

```
match log (matches) from 192.0.2.226 to 203.0.113.34
```

This is a standard packet-filtering rule. You could use an individual IP address, a port number, or any other legal packet filter terms. Reload your packet-filtering rules.

Turn on tcpdump, and filter based on one of the IP addresses in your match statement. If you're using NAT, filter on the IP address that doesn't change.

```
# tcpdump -n -e -ttt -i pflog0 ip host 203.0.113.34
Dec 17 18:05:07.773703 rule 0/(match) match out on fxp0: 192.0.2.226.24916
> 203.0.113.34.22: S 1730871963:1730871963(0) win 16384 <mss 1460,nop,nop,
sackOK,nop,wscale 3,nop,nop,timestamp 597858150[|tcp]> (DF)
Dec 17 18:05:07.773708 rule 2/(match) block out on fxp0: 192.0.2.226.24916
> 203.0.113.34.22: S 1730871963:1730871963(0) win 16384 <mss 1460,nop,nop,
sackOK,nop,wscale 3,nop,nop,timestamp 597858150[|tcp]> (DF)
Dec 17 18:05:07.773712 rule 5/(match) pass out on fxp0: 192.0.2.226.24916
> 203.0.113.34.22: S 1730871963:1730871963(0) win 16384 <mss 1460,nop,nop,
sackOK,nop,wscale 3,nop,nop,timestamp 597858150[|tcp]> (DF)
```

While I won't go through all the annoying details of reading tcpdump output, you can see that PF logs the rule numbers that this data connection matches, and whether the rule passes or blocks the connection. If the connection involves NAT, you'll see the actual and translated IP addresses.

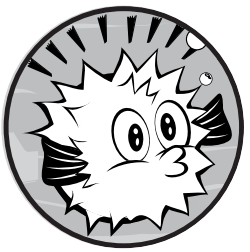
At this point, you know enough about PF to protect a small network. If you need more, definitely check out *The Book of PF, 2nd edition* (No Starch Press, 2010).

Now let's look at some of the more exotic edges of OpenBSD.

# 23

## CUSTOMIZING OPENBSD

*Customize installs*
*with files and DHCP,*
*then run without disk.*



This chapter covers different ways to use OpenBSD to customize itself, as well as how to install OpenBSD in nonstandard situations and debug problems with your system. The first task we'll address is diskless installation. Diskless systems are usually used to install OpenBSD without attaching any installation media, but they can also be used to run a system without a hard drive. Next, we'll create a USB flash drive for use as OpenBSD installation media. Finally, we'll cover various ways to customize the OpenBSD installation and upgrade processes.

All of these tasks assume that you already have an OpenBSD machine running the version you want to customize. You can accomplish some of these tasks using a virtual machine, as long as the virtual machine software has the necessary support. Because virtualization is such a common choice, let's tackle it first.

## Virtualizing OpenBSD

The OpenBSD developers are pretty clear on virtualization. OpenBSD is written for real hardware. Virtual hardware is not real hardware. While it can be very similar, it's not exactly the same.

This approach has a number of implications, the most problematic of which is that not all virtualization software can run OpenBSD. As I write this, Oracle's VirtualBox can't cleanly run either i386 or amd64 OpenBSD. (Some people report being able to boot some versions of VirtualBox and/or OpenBSD, but OpenBSD software crashes all over the place.) This is not an OpenBSD bug. VirtualBox doesn't sufficiently emulate real hardware.

That said, OpenBSD does run well on some virtual machines. VMware works well enough that OpenBSD includes specific drivers for VMware integration, including a VMware Tools driver in the kernel. KVM virtualization also works, although KVM requires some tweaks depending on the exact combination of KVM and OpenBSD you're using. Microsoft's virtualization mostly works, although Virtual PC has some commercially motivated limitations.

The main problem with virtualization is that a compromise of the virtualization platform automatically gives an intruder hardware-level access to all virtual machines, and OpenBSD cannot possibly secure you against that kind of attack. In fact, no operating system can. And it does you no good to run your database on OpenBSD when any script kiddie can compromise the underlying virtualization server.

In my experience, OpenBSD virtual machines are excellent for experimentation and reference. I used them to document the installation process for this book, and I always test software configurations on virtual machines before rolling them out to production. (The real benefit of virtualization might be that there's no longer any excuse for not testing changes.) But when I want a server that's actually secure, I put OpenBSD on real hardware.

**NOTE** *If you want to run virtual machines on OpenBSD, you can find* `qemu`, `bochs`, `dosbox`, *and other packages in the packages collection. Check* /usr/ports/emulators *for other options.*

## Diskless Installation

Booting a blank system into the OpenBSD installer without using local media can save you time and energy. A lot of modern hardware doesn't come with CD or floppy drives. Of course, you could temporarily add a CD drive, but if you have a whole bunch of OpenBSD machines to install, that's just an annoyance.

You can also use network booting to boot OpenBSD on hardware that lacks an installed operating system, or with a different operating system that you plan to overwrite. This process is called *pxebooting*, or *diskless*, operation. Diskless systems can have disks—they just don't use them to boot the operating system.

If you've never worked with diskless systems before, your first attempts will probably give you a headache. Setting up your first diskless environment can be tricky, and will teach you all sorts of things you didn't know about your operating system and hardware. But test everything along the way, read the error messages carefully, and soon you'll wonder why you thought this was hard.

**NOTE** *I'll cover diskless installations on amd64 and i386 hardware. Other platforms have different requirements that may be very different. Read the* `diskless(8)` *man page for your particular architecture to get an overview of your platform.*

Diskless systems work because a computer doesn't need a hard disk to run. It needs an operating system. The easiest way to store a computer's operating system is on the local hard drive, but a sufficiently smart network card can use information provided by DHCP to find an initial boot loader.

All amd64 and modern i386 hardware use Intel's Preboot Execution Environment (PXE, pronounced "pixie"). The DHCP server tells the network card the name of a file and the IP address where the file can be found, and the server fetches the file via TFTP. This file is usually called *pxeboot*, but *pxeboot* files can vary widely among operating systems. A *pxeboot* file for OpenBSD probably won't boot a FreeBSD system, let alone anything from Microsoft. It's specific to each operating system.

Once the computer has loaded *pxeboot*, it goes back to the TFTP server to look for the appropriate kernel. An OpenBSD *pxeboot* looks for a file called *bsd*, assumes that it's a kernel, loads the kernel into memory, and boots it. To install OpenBSD, you'll load the install kernel file *bsd.rd* instead, which you can do automatically.

### Diskless Hardware

OpenBSD systems installed over diskless systems must have enough smarts to find their boot loader and operating system over the network or they won't boot. Any machine built in the past several years uses PXE.

You've probably seen a computer try to boot from the network more than once, and for most people, those BIOS messages are just an annoyance that they keep forgetting to disable. For diskless installation, you need to make sure that feature is on.

To enable PXE, boot the hardware and go into the BIOS setup. Somewhere in the BIOS, you should find an option to set the device boot order. If the machine supports PXE, one of those options will be to boot over a network. Enable that option and see if it works. While you're in the BIOS, make a note of the MAC address of your network card. Your DHCP server will need it. If your BIOS uses the Unified Extensible Firmware Interface (UEFI) by default, disable that.

Save your changes and exit. Your hardware should now be prepared. Let's ready the server.

### DHCP Server Setup

DHCP is not just a way to hand out IP addresses and network configurations. A DHCP server can tell network-aware phones where to find their configuration, server hardware where to find its operating system, printers where to find their print server, and so on. Diskless installations use DHCP to feed diskless servers the location of the *pxeboot* file.

#### Per-Host or Per-Network Configuration

DHCP expects to configure hosts either by the network or by the host. When a DHCP server receives a DHCP request, it knows the address of the network that the host is on and the host's MAC address. The DHCP server must decide which configuration to give the host based on this information. This means you can configure your DHCP server so that any host on a given network is told to install OpenBSD, or you can give it the MAC address of the machine you're going to install and tell the DHCP server to start the installation only on that machine.

Because I install machines frequently, I usually set up a small VLAN where any machine plugged onto the network is told to install OpenBSD. That way, workers who plug their laptops into random Ethernet cables in my office get a free operating system upgrade. If you only occasionally install machines, and have control over the DHCP server, it's pretty easy to configure the DHCP server to tell a host with a specific MAC address to install OpenBSD.

The DHCP server needs to tell the client the location of a PXE boot file, which gives the client just enough brains to find a bootable kernel. This is just like the on-disk boot loader, except that the PXE boot file talks to the network. OpenBSD's i386 and amd64 platforms include the file */usr/mdec/pxeboot* for just this purpose.

Give the name of the PXE boot file with the `filename` option, and then use the `next-server` option to specify the IP address of the TFTP server where the client can get the file. This example tells DHCP clients to load the file *pxeboot* from the server at 192.0.2.34:

```
filename "pxeboot";
next-server 192.0.2.34;
```

Place these statements according to whether you have an installation network or your DHCP server is set for a specific MAC address.

#### Per-Network Configuration

If you want all the hosts on your network to receive the OpenBSD installation PXE boot file, put the `filename` and `next-server` options in the `subnet` stanza, like this:

```
option  domain-name "michaelwlucas.com";
option  domain-name-servers 192.0.2.1;
subnet 192.0.2.0 netmask 255.255.255.0 {
        option routers 192.0.2.1;
        range 192.0.2.10 192.0.2.15;
```

```
        filename "pxeboot";
        next-server 192.0.2.34;
}
```

Any host on this network that makes a DHCP request at boot will learn where to get the PXE boot file.

#### Per-Machine Configuration

If you've hard-coded a machine's MAC address into your DHCP configuration, as discussed in Chapter 16, you can feed the PXE boot information to that host.

```
subnet 192.0.2.0 netmask 255.255.255.0 {
...
    host installationtarget {
        hardware ethernet 02:03:04:05:06:07;
        filename "pxeboot";
        next-server 192.0.2.34; }
    }
```

Machines on this subnet that make a PXE request at boot will get the location of the PXE boot file only if they have MAC address 02:03:04:05:06:07.

Decide how you want your DHCP server to behave and make similar configuration changes.

Now let's look at the TFTP server.

### TFTP Server Setup

The next task is to make the OpenBSD-specific boot files available on your TFTP server. As a minimum, you need the *pxeboot* file and a kernel, but adding a *boot.conf* file will simplify your life.

OpenBSD includes an architecture-specific *pxeboot* file in */usr/mdec/*. If you're installing an i386 machine, grab this file and */bsd.rd* from an existing i386 installation. If you're installing amd64 hardware, get *pxeboot* and */bsd.rd* from an existing amd64 system. Copy them to the TFTP server root directory, and verify that they're world-readable.

*pxeboot* tells the machine to look for the standard kernel */bsd*, not the installation kernel */bsd.rd*. When *pxeboot* finishes loading, it looks exactly like the standard OpenBSD boot loader. You could interrupt the boot, as described in Chapter 5, and choose a different kernel, but *pxeboot* also recognizes */etc/boot.conf*.

To tell *pxeboot* to load a different kernel, create an *etc* directory in your TFTP server's root directory, and then create the file *boot.conf* inside that. This new *boot.conf* file has exactly the same syntax as */etc/boot.conf*, so you can do a one-line entry like this:

```
boot bsd.rd
```

You can include additional boot options, such as setting a serial console.

### Completing Diskless Installation

Once you have DHCP and TFTP, power on the installation target. You should see the network card make a DHCP request, get an IP address, and grab *pxeboot* via TFTP. You should then see the OpenBSD boot loader load the installation *bsd.rd*. Finally, you should get the OpenBSD install script.

If you don't get the installer, take a step back. Does the network card get an address from DHCP? If not, check your wiring and DHCP server configuration. If you get an IP address, but can't fetch *pxeboot*, check that you put the `filename` and `next-server` statements in the correct part of your DHCP configuration, and verify that you don't have a packet filter blocking access to the TFTP server. Try to fetch those files from a different TFTP client to make sure that the TFTP server works. If the installation target partially boots OpenBSD, but doesn't activate the installer, make sure you have an *etc/boot.conf* entry pointing the client at *bsd.rd* rather than *bsd*.

At this point, you should be able to install OpenBSD normally, as described in Chapters 2 and 3. But what if you want to run a full OpenBSD system without a hard drive? That's where diskless operation comes in.

## Running Diskless

If you manage many computers, you probably understand that moving parts cause trouble. Spinning hard drives, in particular, are just a very bad idea.

Try this: If you have a roomful of identical machines, try simplifying maintenance by running them without hard drives. Each machine in this group will use a root directory and filesystem mounted via NFS rather than stored locally. You'll still need data storage, but you can use a central high-availability disk array, flash drives, or some other mechanism with better reliability than lowest-common-denominator hard drives.

You can extend the diskless installation process to run OpenBSD in full multiuser mode without a local hard drive. Your server will need three additional services to support fully diskless clients: `rarpd(8)`, `bootparamd(8)`, and NFS. (Only diskless clients need `rarpd` and `bootparamd`.)

### Using rarpd(8) for Reverse ARP

In a standard ARP request, a client knows an IP address and wants to get the corresponding MAC address. For reverse ARP, a client knows a MAC address and wants to know the corresponding IP address. OpenBSD needs to get reverse ARP during the diskless boot process, and it uses `rarpd(8)` to provide reverse ARP services to other hosts.

`rarpd` uses */etc/ethers* as a table of Ethernet addresses and hostnames. Each diskless client needs an */etc/ethers* entry much like this:

```
00:50:56:00:01:01       gill.blackhelicopters.org
```

This entry means that the host with MAC address 00:50:56:00:01:01 has the hostname *gill.blackhelicopters.org*. The `rarpd` server must be able to resolve the hostname to an IP address, either in DNS or in */etc/hosts*.

Now decide which network interfaces you want to run `rarpd` on. If your server has only one network interface, that's the one to use. If you have multiple network interfaces, however, it might make sense to listen on only a single interface.

To use a specific interface, use the interface name as a command-line argument; otherwise, use `-a` to listen on all network interfaces. For example, this *rc.conf.local* entry tells `rarpd` to listen on only interface `em0`:

```
rarpd_flags="em0"
```

Start `rarpd` with */etc/rc.d/rarpd*, and go on to `bootparamd`.

### Running bootparamd(8)

The boot parameter daemon `bootparamd` tells a diskless OpenBSD machine where to find its root filesystem. When a boot parameter request arrives at the server, `bootparamd` checks the file */etc/bootparams* for a matching configuration and returns that to the client.

Entries in */etc/bootparams* give a hostname, followed by the string `root=`, an NFS server, and the directory where the client's root directory is stored.

```
gill.blackhelicopters.org root=192.0.2.34:/var/diskless/client1
```

In this example, the host *gill.blackhelicopters.org* will use an NFS root directory from a server at 192.0.2.34, in the directory */var/diskless/client1*.

For almost all environments, you can run `bootparamd` without any command-line options. Enable it in *rc.conf.local* like so:

```
bootparamd_flags=""
```

Start `bootparamd`. Now it's time to deal with your NFS server.

### Setting Up the NFS Root Directory

A multiuser OpenBSD system needs a userland. Without a local disk, you'll need to create an OpenBSD userland. It is possible to export the NFS server's root directory for use as the diskless client's root directory, but this isn't merely insecure, it's also a good way to damage the NFS server itself. Create a separate userland for your diskless machine.

#### Exporting the Root Directory

You must export the userland's root directory to the diskless machine. For example, here's an */etc/exports* line that shares the directory */var/diskless/client1* to the IP address 192.0.2.37:

```
/var/diskless/client1 -maproot=root 192.0.2.37
```

Note the `-maproot` option here. The diskless client will expect to be able to write and own files as the root user. This `-maproot` entry maps UID 0

(root) on the client to the root account on the NFS server. You can also set up a separate user for the diskless client's root account, map the client's root account to that new account, and change the ownership of all files in the diskless userland to that root account. As this is your first diskless host, however, we'll start off basic.

### Populating the Diskless Userland

The easy way to install a minimal userland is to extract the *etcXX.tgz* and *baseXX.tgz* file sets from your chosen OpenBSD release into the NFS root directory. In the following example, I've copied these file sets into */tmp*, and I'm using them to create a userland in */var/diskless/client1*.

```
# cd /var/diskless/client1
# tar -xzpf /tmp/etc53.tgz
# tar -xzpf /tmp/base53.tgz
```

Note the use of the `-p` flag in the `tar` command, preserving the original permissions on extracted files.

The diskless client also needs device nodes. Go into the new userland's *dev* directory and create them.

```
# cd dev
# ./MAKEDEV all
```

While `bootparamd` told the kernel where to find the root of the filesystem, userland programs expect to read */etc/fstab* for that information. Create an */etc/fstab* file that points the root directory to your NFS share.

```
192.0.2.34:/var/diskless/client1 / nfs rw 0 0
```

You can also add any other NFS-mounted directories you desire here. This should be everything you need.

## Power On!

Once you have a basic userland, device nodes, and a filesystem table, you can power on your diskless node, and it should boot. If it doesn't boot to a login prompt, read the console error messages. Usually, they're pretty clear.

Because you've bypassed the OpenBSD installer, there are no root password or user accounts yet. Immediately, log in as root and change the root password, and then set up a regular user account.

For your first diskless setup, once you have a working userland, back it up right away. Even a tar file containing the entire userland will prove useful. You'll muck up the diskless userland more than once as you're trying to get things working exactly as you wish, and being able to blow the entire userland away and restore it from the backup file is invaluable.

Once you have a basic system working, expand it. Add additional file sets as needed, set up more users, add packages, and deploy for your users.

Congratulations, you're now on the cutting edge of OpenBSD users.

## USB Installation Media

For many people, burning a CD to install an operating system seems like a waste. They prefer to write an image to a USB flash drive and install from that. OpenBSD doesn't provide such an image, but if you're willing to do some extra work, you can create a bootable USB device that you can use to install on your target hardware.

The official recommendation is to install OpenBSD on the USB device, copy *bsd.rd* and the file sets to that device, and use that to install your new hardware. The OpenBSD installer lets you choose the target hard drive. You select the USB device in the installer, and OpenBSD installs to the USB just as it would any other data-storage device. But how do you install OpenBSD on the USB device without burning a CD in the first place? There are a few ways around this, including a couple of approaches already covered in this chapter.

### Using a Virtual Machine

Your first choice is to perform the USB installation in a virtual machine. Many desktop virtual machine software packages let you attach a physical USB port to a guest virtual machine. (OpenBSD's virtualization options are discussed in "Virtualizing OpenBSD" on page 450.)

If you have virtualization software that runs OpenBSD and supports USB, choose this option.

### Running a Diskless Installation

Your second choice is to run a diskless installation. Most DHCP servers embedded in cheap home hardware will let you send a filename and a TFTP server address to a client. If yours won't, you can get suitable DHCP servers for any platform. You can find freely available TFTP servers for just about any operating system.

Boot your install target with the USB drive, but load the *bsd.rd* kernel. You now have the OpenBSD installer running on the target system, and an OpenBSD system that fits in your pocket and that you can run almost anywhere. If you're already running OpenBSD on something with the right architecture and a USB socket, it's even easier: You boot the system from the appropriate *bsd.rd*, choose the `disk` option, and point the installer to sets in a local directory.

### Converting ISO Images

As a less official method, you can find software to convert ISO images to bootable USB images. I've used Rufus (*http://rufus.akeo.ie/*) on Windows and UNetbootin (*http://unetbootin.sourceforge.net/*) on other Unix-like systems. This approach might work, but it's certainly not OpenBSD-approved.

## Customizing OpenBSD Installations

Many of us follow a set of steps when installing a machine. All freshly installed hosts of a specific operating system revision have a common SSH server configuration. My machines all have `tcsh` installed and attach to the central authentication system. You probably have your own list. These tasks can be done by hand after installation, but it's much easier to let OpenBSD do them for you during the installation process.

Installations can be customized by adding files during installation or by running commands after the installation.

### Custom File Sets

A custom file set includes files that you want copied to your new installation. I use custom file sets to install the default */etc/sudoers*, a SSH server configuration, my company's default *pf.conf*, and similar files. As I'm the lead sysadmin, I also include dotfiles in my home directory and other personal touches to make my life easier. Some people include several home directories, including *authorized_keys* files for SSH.

Bundle these files together as a *siteXX.tgz* file, which the installer can extract in the root directory of the new installation. (Be sure to replace the *XX* with the OpenBSD version you're installing on; for example, name a *siteXX.tgz* file for OpenBSD 5.4 *site54.tgz*.)

Start by installing an OpenBSD machine of the exact same version and platform that you want to customize. Make your changes and add your files to this system, verify that this template system works exactly as you desire, and then copy the changed files to a tar file.

**NOTE** *You could make a directory hierarchy and copy the files you want to it, but I find that to be more error-prone. A small virtual machine will let you build a* siteXX.tgz *file more reliably.*

The following example creates a *site54.tar* file containing one file, */etc/ssh/sshd_config*. Note that I start by creating a plain tar file. Since I can't easily add files to a compressed tar file, I'll need to compress the file after it's complete.

```
# cd /
# tar -cf site54.tar etc/ssh/sshd_config
```

Now that I have the initial file, I can add additional files. I've customized a few files on the system, as well as added new ones, all of which I add to the *site54.tar* file. The `-r` flag tells `tar` to add a file to an archive.

```
# tar -rf site54.tar etc/sudoers
# tar -rf site54.tar etc/pf/mgmt-hosts.conf
# tar -rf site54.tar etc/pf.conf
```

Here's how to compress the tar file:

```
# gzip site54.tar
# mv site54.tar.gz site54.tgz
```

I've built my own custom release of OpenBSD, so I have a local FTP server that contains all of the release files. If you're using the official OpenBSD release, but you're installing enough OpenBSD machines to warrant making a *siteXX.tgz* file, you can copy the official release to a local FTP or HTTP mirror. Copy your *siteXX.tgz* file to this directory and update the *index.txt* file.

```
# ls -l > index.txt
```

Now start your installation. Tell the installer to use your local release mirror rather than an official OpenBSD mirror. You should see the following sets:

```
Select sets by entering a set name, a file name pattern or 'all'. De-select
sets by prepending a '-' to the set name, file name pattern or 'all'. Selected
sets are labelled '[X]'.
    [X] bsd           [X] etc54.tgz     [X] xbase54.tgz   [X] xserv54.tgz
    [X] bsd.rd        [X] comp54.tgz    [X] xetc54.tgz    [ ] site54.tgz
    [ ] bsd.mp        [X] man54.tgz     [X] xshare54.tgz
    [X] base54.tgz    [X] game54.tgz    [X] xfont54.tgz
Set name(s)? (or 'abort' or 'done') [done] site52.tgz
```

Your *site54.tgz* file should now be available as a file set. Add it because the installer won't automatically include it. Once the installation finishes, you should find your customized and added files on the new system.

### Post-Install Shell Scripts

Some tasks can be accomplished by copying files, but that's annoying. For example, I want the shell `tcsh` installed on all of my OpenBSD servers. I could put all the files in the `tcsh` package, as well as the contents of */var/db/pkg/tcsh*, in *siteXX.tgz*, but I know I'm likely to mess that up somehow. It would be much easier to run `pkg_add tcsh` after the installation, and let OpenBSD do what it's supposed to do. That's where the `install.site` script comes in.

After completing the installation, but before giving you the final command prompt, OpenBSD checks for */install.site*. If this file exists, the installer runs it. The script is run `chroot`ed into the new installed system, so you don't need to worry about changing any paths. The script does need to run on a minimal kernel, however, so it's best to wait for low-level kernel twiddling until the first real boot.

Here's a sample `install.site` script that installs the two packages `tcsh` and `python`:

```
#/bin/sh
export PKG_PATH=ftp://ftp13.usa.openbsd.org/pub/OpenBSD/snapshots/packages/i386/
```

```
pkg_add -v tcsh
pkg_add -v python-2.7.3p1
```

When working with `install.site` scripts, if a package's name could be ambiguous, be sure to give the full package name. There's only one `tcsh` package, but Python comes in several versions. I specify the full package name, rather than using plain `python`.

Also note that while you're running in a `chroot` that contains a full userland, that userland isn't fully initialized. When dropping into the `chroot`, OpenBSD doesn't do a full multiuser startup of that `chroot`. The environment is roughly equivalent to single-user mode. The `install.site` script is not where you initialize your database.

When you have a real userland ready to go, to automatically run commands on the system's first real boot, append the commands to */etc/rc.firsttime*. This file runs once, at the system's first boot after installation, and then deletes itself.

## Customizing Upgrades

OpenBSD lets you use custom file sets and shell scripts during binary upgrades. If you have a lot of machines to upgrade, run these to ensure that your systems are as identical after the upgrade as they were before. I highly recommend automating known changes during an upgrade.

The *siteXX.tgz* file works for upgrades exactly as for installations. Put the files you want on this system in *siteXX.tgz*, and the install program should copy those files to the system as it installs the upgraded files. Rather than `install.site`, however, the upgrade software looks for the script `upgrade.site`. Any *install.site* file is ignored during an upgrade, so you can use the same *siteXX.tgz* for upgrades and for new installations.

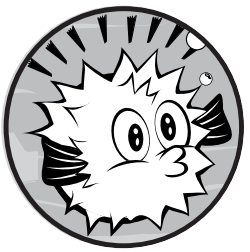
I find the `upgrade.site` script especially useful in conjunction with the *OpenBSD Upgrade Guide* for that release. The *Upgrade Guide* includes tasks that must be performed during an upgrade, many of which are very suitable for scripting. For example, the common tasks of deleting files, programs, and libraries removed from the new OpenBSD release are easily added to `upgrade.site`.

One convenient thing about `upgrade.site` is that you can copy the script to the target machine before running the upgrade. It doesn't need to be part of *siteXX.tgz*. That said, I don't recommend running `pkg_add -u` in `upgrade.site`. While the idea of automatically upgrading all your packages sounds good, remember that you're running on a limited kernel with a less than completely initialized userland. Have your `upgrade.site` script add any commands that need to run on a fully multiuser system to */etc/rc.firsttime*, so that they run when the system boots the first time.

With the hints in this chapter, you can customize OpenBSD any way you need. And with the information throughout this book, you should know where OpenBSD fits into your network. Remember that they really are out to get you, and you'll achieve practical paranoia.

# AFTERWORD

*Failure's bad enough;*
*add the human element*
*and things really suck.*



Back around 2000, my employer's main business was designing web applications, but once those applications were built, our clients would turn around and ask, "Where should we host this?" That's where I came in, building and running a small but professional-grade datacenter for custom applications.

As with any new business, our hosting operation needed to make the most of existing resources. Hardware was strictly limited to cast-off equipment from the web developers, and we used only software that was free. The only major expense was a big-name commercial firewall, purchased for marketing rather than technical reasons.

With a whole mess of open source software, we built a reliable network management system that provided our clients with more insight into their equipment than their in-house people could offer. The clients paid for their own hardware, and so had fancy high-end rackmount servers with

their chosen applications, platforms, and operating systems. As the business grew, we upgraded the hardware (it's nice to have disk drives that are less than five years old), but we saw no need to replace the software.

One Monday morning, a customer who had expected to use very little bandwidth found that he had sufficient requests to devour twice the bandwidth we had for the entire datacenter. This affected every customer. If your $9.95 per month web page is slow, you have little to complain about; if your $50,000 per month web application is slow, you pick up the phone and scream until the problem stops.

To make life worse, my grandmother had died only a couple days before. Visitation was on Tuesday, and the funeral was Wednesday morning. I handed the problem to a minion and said, "Here, do something about this." I knew the network could manage bandwidth at many points. The web servers themselves, the load balancer in front of them, the commercial firewall, and even the router claimed to have traffic-management capacity.

Tuesday, after visitation, my cell phone voicemail was full. Our version of Internet Information Server (IIS) could manage bandwidth—in 8MB increments, and only if the content was static HTML and JPEG files. With several web servers behind the load balancer, that fell somewhere between useless and laughable. The load balancer *would* support traffic shaping, if we bought the new feature set. If we plopped down a credit card, we could have that feature set installed by next Sunday. Our big-name commercial firewall also had traffic-shaping features available, *if* we upgraded our service level and paid an additional (and quite hefty) fee for the feature set. That left the router, which I had previously investigated and found would support traffic shaping with only an IOS upgrade.

I was on the phone until midnight Tuesday night, making arrangements to do an emergency router IOS upgrade on Wednesday night. I had planned to go to the funeral Wednesday morning, give a eulogy, go home and take a nap, and arrive at work at midnight ready to rock.

Unfortunately, the funeral was more dramatic than I had expected, and I showed up at work at midnight sleepless, bleary-eyed, and upright only courtesy of the twin blessings of caffeine and adrenaline. In my email, I found a note that several big clients had threatened to leave unless the problems were resolved by Thursday morning. If I hadn't already been stressed out, the prospect of choosing a minion to lay off would have done the trick. (I work hard training my minions, and prefer not to replace them once they are beaten into shape.)

Still, only a simple router flash upgrade and some basic configuration stood between me and relief. What could possibly go wrong?

The upgrade went smoothly, but the router behaved oddly when I enabled traffic shaping. Over the next few hours, I discovered that the router didn't have enough memory to simultaneously support all of our BGP feeds and the traffic-shaping functionality. Worse, it wouldn't accept more memory. At about 6:00 AM, I finally got an admission from the router vendor that it could not help me.

I hung up the phone. The first client who had threatened departure would be checking in at 7:30 AM. I had slept 4 hours of the last 48, and had spent most of that time under fiendish levels of emotional stress. I had already emptied my stash of quarters for the soda machine, and had pillaged my coworkers' desks for more change. The caffeine and adrenaline that had gotten me to the office had long since worn off, and further doses of each merely slowed my collapse. We had support contracts on every piece of equipment, and they were all useless. All the hours of work I had put in, and my team before me, left me with absolutely nothing.

I made myself sit still for two minutes simply focusing on breathing, making my head stop sliding around loose on my shoulders, and ignoring the loud ticking of the clock. What could be done in 90 minutes—no, now only 88?

I really had one only option. If it didn't work, I would either lay off someone or file for unemployment.

At 6:05 AM, I started downloading the OpenBSD install floppy image, and then I grabbed a spare desktop machine, selecting it from among many similar machines by virtue of it being on top of the pile. The next few minutes, I alternated between hitting the few required installation commands and dismantling every unused machine unlucky enough to be in reach to find two decent network cards.

By 6:33 AM, I had two Intel EtherExpress cards in my hands and a virgin OpenBSD system. I logged in long enough to shut down the system so I could wrench the case off, slam the cards into place, and boot again. Even early versions of PF included all sorts of nifty filtering abilities, all of which I ignored in favor of the newly released traffic-shaping functions. By 6:37 AM, I was wheeling a cart with a monitor, keyboard, and my new traffic shaper over to the rack.

Then things got hard. I didn't have a spare switch that could handle our Internet bandwidth. The router rack was jammed to overflowing, leaving me no place to put the new shaper. I lost almost half an hour finding a crossover cable, and when I discovered one, it was only two feet long. The router, of course, was mounted in the top of the rack. About 7:10 AM, I discovered that if I put the desktop PC on end, set it on an empty shipping box, and put the box on the cart, the cable *just* reached the router. I stacked everything so it would reach, and began rewiring the network and reconfiguring subnets.

I vaguely recall my manager coming in about 7:15 AM, asking with taut calmness if he could help. If I remember correctly, as I typed madly at the router console, I said, "Yes. Go away."

At 7:28 AM, we had an OpenBSD traffic shaper between the hosting area and our router. All the client applications were reachable from the Internet. I collapsed in my chair and stared blankly at the wall.

While everything seemed to work, the proof would be in what happened as our offending site started its daily business. I watched with growing tension as that client's network traffic climbed toward the red line that indicated

trouble. The traffic grew to just short of the danger line, and then flatlined. Other clients called, happy that their service was restored to its usual quality. One client complained that his site was still slow, but it turned out that bandwidth problem had masked a problem with his application. The client said that his website now ran even slower than before, to which we offered to provide more bandwidth if they would agree to pay for it.

Shortly afterward, I had two new routers and new DS3s. The racks were again clean. The decrepit desktop machine was replaced by two OpenBSD boxes in a live-failover configuration, protecting our big-name commercial firewall as well as shaping traffic. And I now stock crossover cables in a variety of lengths.

If I had started with OpenBSD, I would have had a much better night.

# INDEX

## Symbols



## A

## B

## C

## D

## E

## F

## G



## H

## I

## J



## K

## L

## M

## N

## O



## P

## Q



## R

## S

## T

## U

## V



## W

## X



## Y

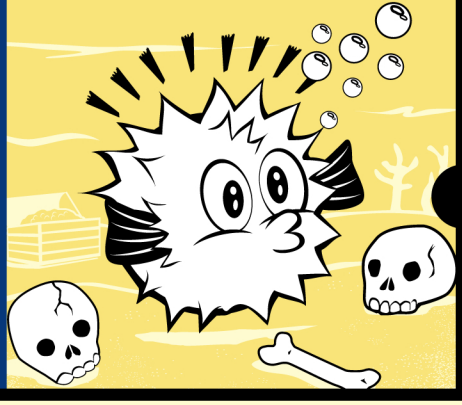


## Z

# UPDATES

Visit *http://nostarch.com/openbsd2e/* for updates, errata, and other information.

# THE DEFINITIVE GUIDE TO OPENBSD



**Foreword by Henning Brauer, OpenBSD PF Developer**

OpenBSD, the elegant, highly secure Unix-like operating system, is widely used as the basis for critical DNS servers, routers, firewalls, and more. This long-awaited second edition of *Absolute OpenBSD* maintains author Michael W. Lucas's trademark straightforward and practical approach that readers have enjoyed for years. You'll learn the intricacies of the platform, the technical details behind certain design decisions, and best practices, with bits of humor sprinkled throughout. This edition has been completely updated for OpenBSD 5.3, including new coverage of OpenBSD's boot system, security features like W^X and ProPolice, and advanced networking techniques.

You'll also learn how to:

- Manage network traffic with VLANs, trunks, IPv6, and the PF packet filter
- Make software management quick and effective using the ports and packages system
- Give users only the access they need with groups, sudo, and chroots
- Configure OpenBSD's secure implementations of SNMP, DHCP, NTP, hardware sensors, and more
- Customize the installation and upgrade processes for your network and hardware, or build a custom OpenBSD release

Whether you're a new user looking for a complete introduction to OpenBSD or an experienced sysadmin looking for a refresher, *Absolute OpenBSD, 2nd Edition* will give you everything you need to master the world's most secure operating system.

### ABOUT THE AUTHOR

Michael W. Lucas is a network/security engineer who keeps getting stuck with network problems nobody else wants to touch. He is the author of the critically acclaimed *Absolute FreeBSD*, *Network Flow Analysis*, *Cisco Routers for the Desperate*, and *PGP & GPG*, all from No Starch Press. Find his website and blog at *http://www.michaelwlucas.com/*, or follow @mwlauthor on Twitter.


no starch press

*THE FINEST IN GEEK ENTERTAINMENT™*

www.nostarch.com

RepKover "Bound To Lay Flat"

*"I LIE FLAT."*

*This book uses RepKover—a durable binding that won't snap shut.*

ISBN: 978-1-59327-476-4

9 781593 274764 55995

6 89145 74769 0

**$59.95** *($62.95 CDN)*

SHELVE IN: OPERATING SYSTEMS/UNIX