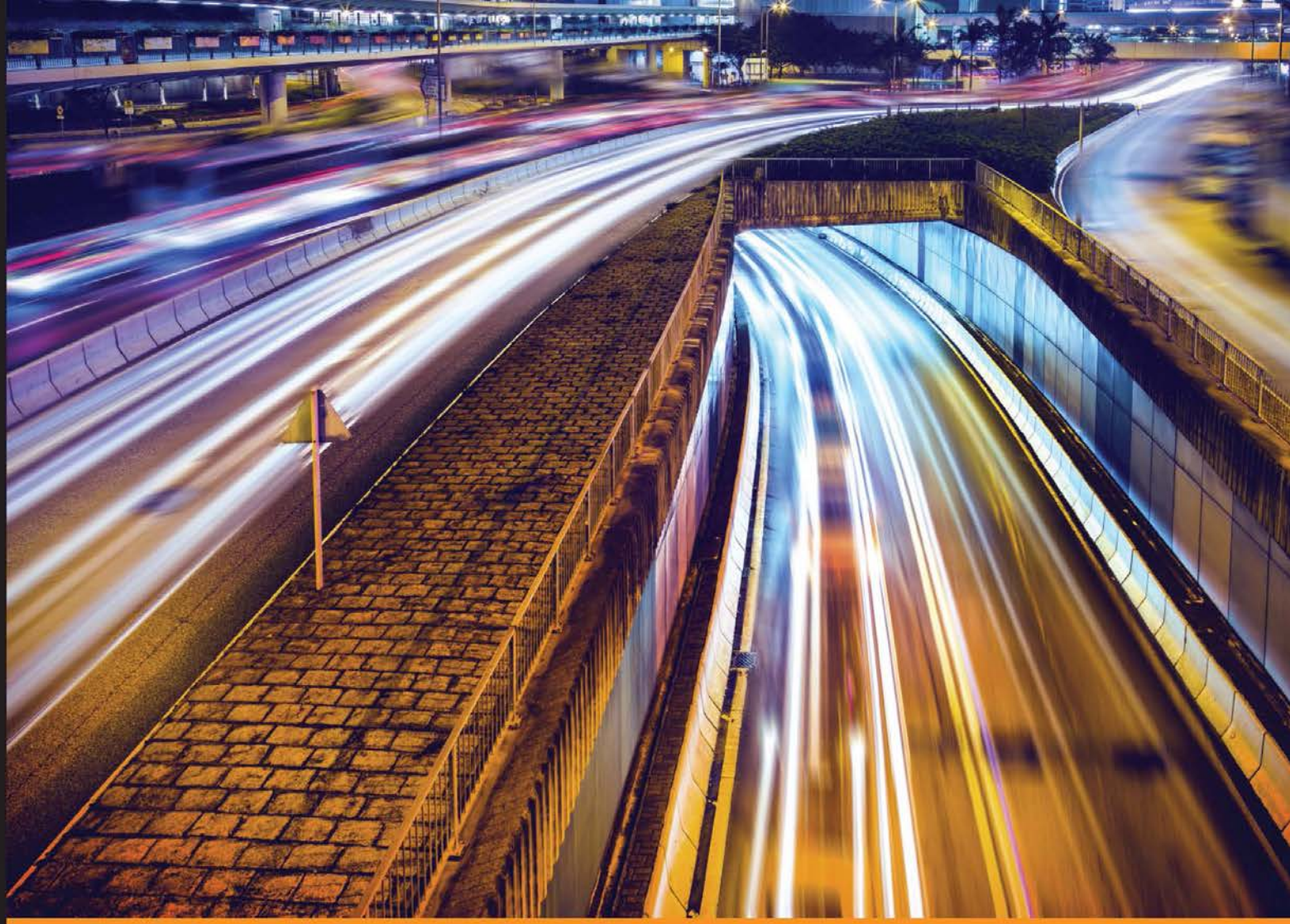


Community Experience Distilled

Mastering pfSense

Master the art of managing, securing, and monitoring your network using the powerful pfSense 2.3

David Zientara

[PACKT] PUBLISHING open source* community experience distilled

Mastering pfSense

Master the art of managing, securing, and monitoring your network using the powerful pfSense 2.3

David Zientara

[PACKT] PUBLISHING open source community experience distilled

BIRMINGHAM - MUMBAI

Mastering pfSense

First published: August 2016

Production reference: 1240816

Published by Packt Publishing Ltd.
Livery Place
35 Livery Street
Birmingham B3 2PB, UK.

ISBN 978-1-78646-343-2

www.packtpub.com

Credits

Author
David Zientara

Reviewer
Brian Scholer

Commissioning Editor
Pratik Shah

Acquisition Editor
Prachi Bisht

Content Development Editor
Abhishek Jadhav

Technical Editor
Vishal K. Mewada

Copy Editor
Madhusudan Uchil

Project Coordinator
Judie Jose

Proofreader
Safis Editing

Indexer
Tejal Daruwale Soni

Graphics
Kirk D'Penha

Production Coordinator
Arvindkumar Gupta

Cover Work
Arvindkumar Gupta

About the Author

David Zientara is a software engineer and IT professional living in northern New Jersey. He has 20 years of experience in IT and has been an enthusiastic supporter of the free and open source software (FOSS) community throughout his career, beginning with his first foray into the open source world with Slackware Linux in 1995.

In the mid-1990s, David became lead software engineer for Oxberry LLC, a digital imaging company headquartered in New Jersey. In this capacity, he played a major role in developing a new software package for the company's film scanners for Windows while also helping maintain Oxberry's legacy software, which had been developed for the SGI IRIX platform. He continued in this role for many years and continues to play a part in software development for Oxberry's corporate successor.

In the mid-2000s, David took an interest in computer networking, an interest that led him to learn about m0n0wall and, eventually, pfSense, a fork of the m0n0wall project. His interest in pfSense prompted him to create a pfSense website, `http://pfsensesetup.com/`, in June 2013.

I would like to thank my parents, who passed along their passion for learning as well as their work ethic. I would also like to thank my editor for having the patience to work with a first-time author, and whose diligence was instrumental in guiding this project. Finally, I would like to thank my many professional associates who have provided assistance over the years.

About the Reviewer

Brian Scholer is a New York City based Systems Engineer with over 14 years of experience across server, cloud, and infrastructure administration, automation, virtualization, software development, web operations, networking, and more. He blogs at `https://www.briantist.com/`.

Table of Contents

Preface

Interest in pfSense, the FreeBSD-based open source router and firewall software, seems to increase with each release, and it is not difficult to understand why. Building on the successes of PF (the stateful firewall that pfSense utilizes) and m0n0wall (the firewall/router project that pfSense began as a fork of), pfSense has undergone over a decade of development under the auspices of a talented group of volunteers. During this period, many improvements to its functionality and ease of use have been made. Equally important is the proliferation of third-party software that further extends pfSense's functionality. These enhancements have transformed pfSense into a powerful tool with many features that could only be found in enterprise-level networking equipment until not too long ago.

pfSense derives its name from the fact that it makes FreeBSD's firewall, PF, make sense to non-technical users. This concept lives on in pfSense 2.3, which was released in April 2016. The web GUI has been redesigned, with old themes replaced by new, CSS-based themes. Pages resize when the browser window resizes, and firewall rules can be reordered by dragging and dropping them, making configuration even easier. Upgrading to newer versions of pfSense is also easy, ensuring that the user can take advantage of the latest features without spending a disproportionate amount of time updating the system.

In this book, we will explore the advantages of using pfSense and learn how to utilize its many features. We will briefly cover installation and configuration, but the main focus will be on some of the more advanced functionality of pfSense, such as VLANs, VPNs, traffic shaping, redundancy, and high availability. This book also includes a brief survey of available third-party packages that can be immensely useful if you have specific requirements, such as implementing dynamic routing or spam blocking. We will conclude by acknowledging that at some point, something is likely to go wrong, and we will therefore cover troubleshooting. By the end of the book, you should have a thorough understanding of the features of pfSense and how to implement these features in your networks.

The arrangement of topics in this book is designed to get progressively more difficult. Therefore, if you read the book from cover to cover, the material should become more challenging. If you find some topics more interesting than others, however, you should be able to jump around without too much difficulty. Moreover, I find that a hands-on approach to learning is often beneficial, and you will likely gain a greater understanding of the material—as well as an understanding of some of the practical issues of networking—if you try to implement some of the features described in the book.

What this book covers

Chapter 1, *pfSense Essentials*, introduces pfSense, the advantages of utilizing it, some hardware considerations and installation/configuration tips and provides solutions for some common problems that arise during installations and upgrades. This chapter provides information to help you get your pfSense system up and running.

Chapter 2, *Advanced pfSense Configuration*, covers configuration of the services most commonly used with pfSense, such as DHCP, captive portal, DNS, Dynamic DNS, and NTP. The services described here are used in a number of common deployment scenarios.

Chapter 3, *Working with VLANs*, discusses the advantages of using Virtual LANs (VLANs), and how to implement them in pfSense. Using VLANs requires the deployment of managed switches, so we briefly discuss switch configuration. The chapter concludes with a discussion of VLAN troubleshooting.

Chapter 4, *pfSense as a Firewall*, covers the creation of firewall rules, including both interface-specific rules and floating rules. Related topics such as Network Address Translation (NAT), aliases, and schedules are also covered.

Chapter 5, *Traffic Shaping*, discusses how to implement traffic shaping in pfSense. We will cover the traffic shaper wizard, but we will also discuss how to manually set up traffic-shaping rules.

Chapter 6, *Virtual Private Networks*, explains the advantages of virtual private networks (VPNs), covers some basic concepts, and shows you how to implement VPN tunnels using all the three protocols supported by pfSense (IPsec, L2TP, and OpenVPN). We will cover both server and client configuration.

Chapter 7, *Redundancy and High Availability*, discusses several ways of using pfSense to eliminate single points of failure within our network. The chapter covers gateway groups, load balancing, and Common Address Redundancy Protocol (CARP, which allows us to set up redundant firewalls).

Chapter 8, *Routing and Bridging*, covers two topics that are likely to arise as your networks become larger and more complex. Both static and dynamic routing are discussed, as are bridging interfaces and the issues associated with configuring bridges in pfSense.

Chapter 9, *Extending pfSense with Packages*, provides an admittedly brief overview of how to install packages and which packages are available. The list of available packages has been trimmed considerably in pfSense 2.3, but the remaining packages, such as Squid, pfBlocker, and Nmap, provide considerable functionality, as this chapter demonstrates.

Chapter 10, *Troubleshooting pfSense*, begins by providing a troubleshooting framework for resolving network problems and covers some of the more common networking problems. We then discuss some of the diagnostic tools pfSense provides that can help us in troubleshooting.

What you need for this book

This book is targeted at intermediate users; therefore, prior mastery of basic networking concepts is a prerequisite. Prior experience with pfSense is a plus, although not strictly necessary. If you need a beginner-level book to help familiarize yourself with pfSense, you might consider *pfSense 2 Cookbook* by Matt Williamson, which provides many useful configuration examples.

If you have never used pfSense before or do not feel comfortable deploying it on your network without testing it first, you might want to run pfSense in a virtual machine. Many of the examples provided in this book were tested in such a manner. I used Oracle VirtualBox, but feel free to use whichever virtualization software you prefer. Virtualization can be resource intensive; I recommend at least a quad-core processor with 8 GB of RAM.

The pfSense project website (`http://pfsense.org`) lists the following minimum requirements for pfSense:

- CPU: 500 MHz
- RAM: 256 MB
- Storage (hard drive or compact flash card): 1 GB

Running pfSense does not require much in terms of resources; virtually any computer manufactured since the early 2000s meets these requirements. Therefore, an old computer is a good candidate for being repurposed as a pfSense system. You may want to run pfSense on a thin client or embedded system as those tend to consume less power, and there are many options if you choose to do so.

Who this book is for

This book's target audience is intermediate-level pfSense users who want more knowledge on how to take advantage of the advanced functionality of pfSense. The book is geared towards someone who is familiar with computer networking (and who is possibly an IT professional) and who has some experience with setting up networks. You should have some familiarity with pfSense, and prior experience installing and configuring pfSense is a plus.

Conventions

In this book, you will find a number of text styles that distinguish between different kinds of information. Here are some examples of these styles and an explanation of their meaning.

This book uses a number of different text styles for specific purposes. This section describes the meaning of each text style.

pfSense menu items, page sections, subsections, and options are denoted with the following font:

DNS Resolver

When describing how to navigate to a specific configuration page, we use the same font, but also specify the menu and menu item separated by a pipe, for example:

Services | **DHCP Server**

This indicates that we can navigate to the **DHCP Server** configuration page by navigating to the **Services** menu and clicking on **DHCP Server**, which is an item on the **Services** menu.

Shell commands also use a different font:

```
ls -al
ps -eaf
ssh-keygen -t rsa
```

Hyperlinks are also distinguished with a different font:

`https://tools.ietf.org/html/bcp38`

New terms and **important words** are shown in bold. Words that you see on the screen, for example, in menus or dialog boxes, appear in the text like this: "Clicking the **Next** button moves you to the next screen."

New terms and important words are printed in **bold**. Warnings and important notes are placed in a separate box, like this:

Warnings or important notes appear in a box like this.

Tips and tricks appear like this.

Reader feedback

Feedback from our readers is always welcome. Let us know what you think about this book—what you liked or disliked. Reader feedback is important for us as it helps us develop titles that you will really get the most out of.

To send us general feedback, simply e-mail `feedback@packtpub.com`, and mention the book's title in the subject of your message.

If there is a topic that you have expertise in and you are interested in either writing or contributing to a book, see our author guide at `www.packtpub.com/authors`.

Customer support

Now that you are the proud owner of a Packt book, we have a number of things to help you to get the most from your purchase.

Downloading the color images of this book

We also provide you with a PDF file that has color images of the screenshots/diagrams used in this book. The color images will help you better understand the changes in the output. You can download this file from `http://www.packtpub.com/sites/default/files/downloads/MasteringpfSense_ColorImages.pdf`.

Errata

Although we have taken every care to ensure the accuracy of our content, mistakes do happen. If you find a mistake in one of our books—maybe a mistake in the text or the code—we would be grateful if you could report this to us. By doing so, you can save other readers from frustration and help us improve subsequent versions of this book. If you find any errata, please report them by visiting `http://www.packtpub.com/submit-errata`, selecting your book, clicking on the **Errata Submission Form** link, and entering the details of your errata. Once your errata are verified, your submission will be accepted and the errata will be uploaded to our website or added to any list of existing errata under the Errata section of that title.

To view the previously submitted errata, go to `https://www.packtpub.com/books/content/support` and enter the name of the book in the search field. The required information will appear under the **Errata** section.

Piracy

Piracy of copyrighted material on the Internet is an ongoing problem across all media. At Packt, we take the protection of our copyright and licenses very seriously. If you come across any illegal copies of our works in any form on the Internet, please provide us with the location address or website name immediately so that we can pursue a remedy.

Please contact us at `copyright@packtpub.com` with a link to the suspected pirated material.

We appreciate your help in protecting our authors and our ability to bring you valuable content.

Questions

If you have a problem with any aspect of this book, you can contact us at `questions@packtpub.com`, and we will do our best to address the problem.

1
pfSense Essentials

While high-speed Internet connectivity is becoming more and more common, many in the online world—especially those with residential connections or **small office/home office** (**SOHO**) setups—lack the hardware to fully take advantage of those speeds. Fiber optic technology brings with it the promise of a gigabit speed or greater, and the technology surrounding traditional copper networks is also yielding improvements. Yet many people are using consumer-grade routers that offer, at best, mediocre performance.

pfSense, an open source router/firewall solution is a far better alternative that is available to you. You have likely already downloaded, installed, and configured pfSense, possibly in a residential or SOHO environment. As an intermediate-level pfSense user, you do not need to be sold on the benefits of pfSense. Nevertheless, you may be looking to deploy pfSense in a different environment (for example, a corporate network), or you may just be looking to enhance your knowledge of pfSense. In either case, mastering the topics in this book will help you achieve these goals.

This chapter is designed to review the process of getting your pfSense system up and running. It will guide you through the process of choosing the right hardware for your deployment, but it will not provide a detailed treatment of installation and initial configuration. The emphasis will be on troubleshooting, as well as some of the newer configuration options. Finally, the chapter will provide a brief treatment of how to upgrade, back up, and restore pfSense.

This chapter will cover the following topics:

- A brief overview of the pfSense project
- pfSense deployment scenarios
- Minimum specifications and hardware sizing guidelines

- An introduction to **Virtual Local Area Networks** (**VLANs**) and **Domain Name System** (**DNS**)
- The best practices for installation and configuration
- Basic configuration from both the console and the pfSense web GUI
- Upgrading, backing up, and restoring pfSense

pfSense project overview

The origins of pfSense can be traced to the OpenBSD packet filter known as PF, which was incorporated into FreeBSD in 2001. As PF is limited to a command-line interface, several projects have been launched in order to provide a graphical interface for PF. m0n0wall, which was released in 2003, was the earliest attempt at such a project. pfSense began as a fork of the m0n0wall project.

Version 1.0 of pfSense was released on October 4, 2006. Version 2.0 was released on September 17, 2011. Version 2.1 was released on September 15, 2013, and Version 2.2 was released on January 23, 2015. At the time of writing, version 2.2.6 (released on December 21, 2015) is the latest version. Version 2.3 is expected to be released soon, and will be a watershed release in many respects. The web GUI has had a major facelift, and support for some legacy technologies is being phased out. Support for **Point-to-Point Tunnelling Protocol** (**PPTP**) will be discontinued, as will support for **Wireless Encryption Protocol** (**WEP**). The current version of pfSense incorporates such functions as traffic shaping, the ability to act as a **Virtual Private Network** (**VPN**) client/server, IPv6 support, and through packages, intrusion detection and prevention, the ability to act as a proxy server, spam and virus blocking, and much more.

Possible deployment scenarios

Once you have decided to add a pfSense system to your network, you need to consider how it is going to be deployed on your network. pfSense is suitable for a variety of networks, from small to large ones, and can be employed in a variety of deployment scenarios. In this section, we will cover the following possible uses for pfSense:

- Perimeter firewall
- Router
- Switch
- Wireless router/wireless access point

The most common way to add pfSense to your network is to use it as a perimeter firewall. In this scenario, your Internet connection is connected to one port on the pfSense system, and your local network is connected to another port on the system. The port connected to the Internet is known as the **WAN** (**wide area network**) interface, and the port connected to the local network is known as the **LAN** (**local area network**) interface.

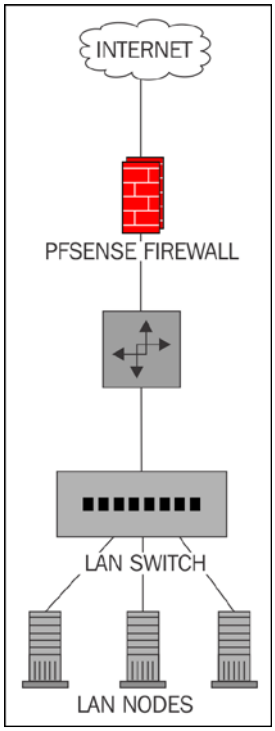


Diagram showing a deployment in which pfSense is the perimeter firewall.

If pfSense is your perimeter firewall, you may choose to set it up as a dedicated firewall, or you might want to have it perform the double duty of a firewall and a router. You may also choose to have more than two interfaces in your pfSense system (known as optional interfaces). In order to act as a perimeter firewall, however, a pfSense system requires at least two interfaces: a WAN interface (to connect to outside networks), and a LAN interface (to connect to the local network).

In more complex network setups, your pfSense system may have to exchange routing information with other routers on the network. There are two types of protocols for exchanging such information: distance vector protocols obtain their routing information by exchanging information with neighboring routers; routers use link-state protocols to build a map of the network in order to calculate the shortest path to another router, with each router calculating distances independently. pfSense is capable of running both types of protocols. Packages are available for distance vector protocols such as **RIP** and **RIPv2**, and link-state protocols such as **Border Gateway Protocol** (**BGP**).

Another common deployment scenario is to set up pfSense as a router. In a home or SOHO environment, firewall and router functions are often performed by the same device. In mid-sized to large networks, however, the router is a device separate from that of the perimeter firewall.

In larger networks, which have several network segments, pfSense can be used to connect these segments. In corporate-type environments, these are often used in conjunction, which allows a single **network interface card** (**NIC**) to operate in multiple broadcast domains via 802.1q tagging. VLANs are often used with the ever-popular *router on a stick* configuration, in which the router has a single physical connection to a switch, with the single Ethernet interface divided into multiple VLANs, and the router forwarding packets between the VLANs. One of the advantages of this setup is that it only requires a single port, and, as a result, it allows us to use pfSense with systems on when adding another NIC would be cumbersome or even impossible: for example, a laptop or certain thin clients. We will cover VLANs in greater depth in *Chapter 3*, *Working with VLANs*.

In most cases, where pfSense is deployed as a router on mid-sized and large networks, it would be used to connect different LAN segments; however, it could also be used as a WAN router. In this case, pfSense's function would be to provide a private WAN connection to the end user.

Another possible deployment scenario is to use pfSense as a switch. If you have multiple interfaces on your pfSense system and bridge them together, pfSense can function as a switch. This is a far less common scenario, however, for several reasons:

- Using pfSense as a switch is generally not cost-effective. You can purchase a five-port Ethernet switch for less than what it would cost to purchase the hardware for a pfSense system. Buying a commercially available switch will also save you money in the long run, as they likely would consume far less power than whatever computer you would be using to run pfSense.

- Commercially available switches will likely outperform pfSense, as pfSense will process all packets that pass between ports, while a typical Ethernet switch will handle it locally with dedicated hardware made specifically for passing data between ports quickly. While you can disable filtering entirely in pfSense if you know what you're doing, you will still be limited by the speed of the bus on which your network cards reside, whether it is PCI, PCI-X, or **PCI Express** (**PCI-e**).
- There is also the administrative overhead of using pfSense as a switch. Simple switches are designed to be plug-and-play, and setting up these switches is as easy as plugging in your Ethernet cables and the power cord. Managed switches typically enable you to configure settings at the console and/or through a web interface, but in many cases, configuration is only necessary if you want to modify the operation of the switch. If you use pfSense as a switch, however, some configuration will be required.

If none of this intimidates you, then feel free to use pfSense as a switch. While you're not likely to achieve the performance level or cost savings of using a commercially available switch, you will likely learn a great deal about pfSense and networking in the process. Moreover, advances in hardware could make using pfSense as a switch viable at some point in the future. Advances in low-power consumption computers are one factor that could make this possible.

Yet another possibility is using pfSense as a wireless router/access point. A sizable proportion of modern networks incorporate some type of wireless connectivity. Connecting to a network's wireless is not only easier, but in some cases, running an Ethernet cable is not a realistic option. With pfSense, you can add wireless networking capabilities to your system by adding a wireless network card, provided that the network card is supported by FreeBSD.

Generally, however, using pfSense as a wireless router or access point is not the best option. Support for wireless network cards in FreeBSD leaves something to be desired. Support for the IEEE's 802.11b and g standards is OK, but support for 802.11n and 802.11ac is not very good.

A more likely solution is to buy a wireless router (even if it is one of the aforementioned consumer-grade units), set it up to act solely as an access point, connect it to the LAN port of your pfSense system, and let pfSense act as a **Dynamic Host Configuration Protocol** (**DHCP**) server. A typical router will work fine as a dedicated wireless access point, and they are more likely to support the latest wireless networking standards than pfSense. Another possibility is to buy a dedicated wireless access point. These are generally inexpensive and some have such features as multiple SSIDs, which allow you to set up multiple wireless networks (for example, you could have a separate guest network which is completely isolated from other local networks). Using pfSense as a router, in combination with a commercial wireless access point, is likely the least troublesome option.

Hardware requirements and sizing guidelines

Once you have decided where to deploy pfSense on your network, you should have a clearer idea of what your hardware requirements are. As a minimum, you will need a CPU, motherboard, memory (RAM), some form of disk storage, and at least two network interfaces (unless you are opting for a router on a stick setup, in which case you only need one network interface). You may also need one or more optional interfaces.

Minimum specifications

The starting point for our discussion on hardware requirements is the pfSense minimum specifications. As of January 2016, the minimum hardware requirements are as follows (these specifications are from the official pfSense site, `https://www.pfsense.org/`):

- CPU – 500 MHz (1 GHz recommended)
- RAM – 256 MB (1 GB recommended)

There are two architectures currently supported by pfSense: i386 (32-bit) and amd64 (64-bit). There are three separate images provided for these architectures: CD, CD on a USB memstick, and embedded. There is also an image for the Netgate RCC-VE 2440 system.

A pfSense installation requires at least 1 GB of disk space. If you are installing to an embedded device, you can access the console either by a serial or VGA port. A step-by-step installation guide for the pfSense Live CD can be found on the official pfSense website at: `https://doc.pfsense.org/index.php/PfSense_IO_installation_step_by_step`.

Version 2.3 eliminated the Live CD, which allowed you to try out pfSense without installing it onto other media. If you really want to use the Live CD, however, you could use a pre-2.3 image (version 2.2.6 or earlier). You can always upgrade to the latest version of pfSense after installation.

Installation onto either a **hard disk drive** (**HDD**) or an SSD is the most common option for a full install of pfSense, whereas embedded installs typically use CF, SD, or USB media. A full install of the current version of pfSense will fit onto a 1 GB drive, but will leave little room for installation of packages or for log files. Any activity that requires caching, such as running a proxy server, will also require additional disk space.

The last installation option in the table is installation onto an **embedded system**. For the embedded version, pfSense uses NanoBSD, a tool for installing FreeBSD onto embedded systems. Such an install is ideal for a dedicated appliance (for example, a VPN server), and is geared toward fewer file writes. However, embedded installs cannot run some of the more interesting packages.

Hardware sizing guidelines

The minimum hardware requirements are general guidelines, and you may want to exceed these minimums based on different factors. It may be useful to consider these factors when determining what CPU, memory, and storage device to use:

- For the CPU, requirements increase for faster Internet connections. Guidelines for the CPU and network cards can be found at the official pfSense site at `http://pfsense.org/hardware/#requirements`. The following general guidelines apply: the minimum hardware specifications (Intel/AMD CPU of 500 MHz or greater) are valid up to 20 Mbps. CPU requirements begin to increase at speeds greater than 20 Mbps.
- Connections of 100 Mbps or faster will require PCI-E network adapters to keep up with the increased network throughput.

If you intend to use pfSense to bridge interfaces—for example, if you want to bridge a wireless and wired network, or if you want to use pfSense as a switch—then the PCI bus speed should be considered. The PCI bus can easily become a bottleneck. Therefore, in such scenarios, using PCI-e hardware is the better option, as it offers up to 31.51 GB/s (for PCI-e v. 4.0 on a 16-lane slot) versus 533 MB/s for the fastest conventional PCI buses.

If you plan on using pfSense as a VPN server, then you should take into account the effect VPN usage will have on the CPU. Each VPN connection requires the CPU to encrypt traffic, and the more connections there are, the more the CPU will be taxed. Generally, the most cost-effective solution is to use a more powerful CPU. But there are ways to reduce the CPU load from VPN traffic. Soekris has the vpn14x1 product range; these cards offload the CPU of the computing intensive tasks of encryption and compression. AES-NI acceleration of IPSec also significantly reduces the CPU requirements.

If you have hundreds of simultaneous captive portal users, you will require slightly more CPU power than you would otherwise. Captive portal usage does not put as much of a load on the CPU as VPN usage, but if you anticipate having a lot of captive portal users, you will want to take this into consideration.

If you're not a power user, 256 MB of RAM might be enough for your pfSense system. This, however, would leave little room for the state table (where, as mentioned earlier, active connections are tracked). Each state requires about 1 KB of memory, which is less memory than some consumer-grade routers require, but you still want to be mindful of RAM if you anticipate having a lot of simultaneous connections. The other components of pfSense require 32 to 48 MB of RAM, and possibly more, depending on which features you are using, so you have to subtract that from the available memory in calculating the maximum state table size.

RAM	**Maximum Connections (States)**
256 MB	~22,000 connections
512 MB	~46,000 connections
1 GB	~93,000 connections
2 GB	~190,000 connections

Installing packages can also increase your RAM requirements; `Snort` and `ntop` are two such examples. You should also probably not install packages if you have limited disk space. Proxy servers in particular use up a fair amount of disk space, which is something you should probably consider if you plan on installing a proxy server such as Squid.

The amount of disk space, as well as the form of storage you utilize, will likely be dictated by what packages you install, and what forms of logging you will have enabled. Some packages are more taxing on storage than others. Some packages require more disk space than others. Proxies such as Squid store web pages; anti-spam programs such as pfBlocker download lists of blocked IP addresses, and therefore require additional disk space. Proxies also tend to perform a great deal of read and write operations; therefore, if you are going to install a proxy, disk I/O performance is something you should likely take into consideration.

You may be tempted to opt for the cheapest NICs. However, inexpensive NICs often have complex drivers that offload most of the processing to the CPU. They can saturate your CPU with interrupt handling, thus causing missed packets. Cheaper network cards typically have smaller buffers (often no more than 300 KB), and when the buffers become full, packets are dropped. In addition, many of them do not support Ethernet frames that are larger than the **maximum transmission unit** (**MTU**) of 1500 bytes. NICs that do not support larger frames cannot send or receive jumbo frames (frames with an MTU larger than 1500 bytes), and therefore they cannot take advantage of the performance improvement that using jumbo frames would bring. In addition, such NICs will often have problems with VLAN traffic, since a VLAN tag increases the size of the Ethernet header beyond the traditional size limit.

The pfSense project recommends NICs based on Intel chipsets, and there are several reasons why such NICs are considered reliable. They tend to have adequately sized buffers, and do not have problems processing larger frames. Moreover, the drivers tend to be well-written and work well with Unix-based operating systems.

For a typical pfSense setup, you will need two network interfaces: one for the WAN and one for the LAN. Each additional subnet (for example, for a guest network) will require an additional interface, as will each additional WAN interface. It should be noted that you don't need an additional card for each interface added; you can buy a multiport network card (most of such cards have either two or four ports). You don't need to buy new NICs for your pfSense system; in fact, it is often economical to buy used NICs, and except in rare cases, the performance level will be the same.

If you want to incorporate wireless connectivity into your network, you may consider adding a wireless card to your pfSense system. As mentioned earlier, however, the likely better option is to use pfSense in conjunction with a separate wireless access point. If you do decide to add a wireless card to your system and configure it for use as an access point, you will want to check the FreeBSD hardware compatibility list before making a purchase.

Using a laptop

You might be wondering if using an old laptop as a pfSense router is a good idea. In many respects, laptops are good candidates for being repurposed into routers. They are small, energy efficient, and when the AC power shuts off, they run on battery power, so they have a built-in **uninterruptable power supply** (**UPS**). Moreover, many old laptops can be purchased relatively cheaply at thrift shops and online.

There is, however, one critical limitation to using a laptop as a router: in almost all cases, they only have one Ethernet port. Moreover, there is often no realistic way to add another NIC: as there are no expansion slots that will take another NIC (some, however, do have PCMCIA slots that will take a second NIC). There are gigabit USB-to-Ethernet adapters (for USB 3.0), but this is not much of a solution. Such adapters do not have the reliability of traditional NICs. Most laptops do not have Intel NICs either; high-end business laptops are usually the exception to this rule.

There is a way to use a laptop with a single Ethernet port as a pfSense router, and that is to configure pfSense using VLANs. As mentioned earlier, VLANs, or virtual LANs, allow us to use a single NIC to serve multiple subnets. Thus, we can set up two VLANs on our single port: virtual LAN #1, which we will use for the WAN interface, and virtual LAN #2, which we will use for the LAN interface. The one disadvantage of this setup is that you must use a managed switch to make this work. Managed switches are switches that can usually be configured and managed as groups, they often have both a command-line and web interface for management, and they often have a wide range of capabilities, such as VLANs. Since unmanaged switches forward traffic to all other ports, they are unsuitable for this setup. You can, however, connect an unmanaged switch to the managed switch to add ports. Keep in mind that managed switches are expensive (more expensive than dual and quad port network cards), and if there are multiple VLANs on a single link, this link can easily become overloaded. In scenarios where you can add a network card, this is usually the better option. If you have an existing laptop, however, a managed switch with VLANs is a workable solution.

Introduction to VLANs and DNS

Two of the areas in which pfSense excels is in incorporating functionality to implement VLANs and DNS servers. First, let's consider why we would want to implement these.

Introduction to VLANs

The standard way to partition your network is to use a router to pass traffic between networks, and configure a separate switch (or switches) for each network. In this scenario, there is a one-to-one relationship between the number of network interfaces and the number of physical ports.

This works well in many network deployments, especially in small networks. As the network gets larger, however, there are issues with this type of configuration. As the number of users on the network increases, we are faced with a choice of either having more users on each subnet, or increasing the number of subnets (and therefore the number of network interfaces on the router). Both solutions also create new problems:

- Each subnet makes up a separate broadcast domain. Increasing the number of users on a subnet increases the amount of broadcast traffic, which can bog down our network.
- Each user on a subnet can use a packet sniffer to sniff network traffic, which creates a security problem.
- Segmenting the network by adding subnets tends to be costly, as each new subnet requires a separate switch.

VLANs offer us a way out of this dilemma with relatively little downside. VLANs allow us to divide traffic on a single network interface (for example, LAN) into several separate networks, by adding a special tag to frames entering the network. This tag, known as an `802.1q` tag, identifies which VLAN to which the device belongs. Dividing network traffic in such a way offers several advantages:

- As each VLAN constitutes a separate broadcast domain, broadcast domains are now smaller, and thus there is less network traffic.
- Users on one VLAN cannot sniff traffic from another VLAN, even if they are on the same physical interface, thus improving security.
- Using VLANs requires us to have a managed switch on the interface on which VLANs exist. This is somewhat more expensive than an unmanaged switch, but the cost differential between a managed and unmanaged switch is less than it might be if we had to buy additional switches for new subnets.

As a result, VLANs are often the most efficient way of making our networks more scalable. Even if your network is small, it might be advantageous to at least consider implementing a VLAN, as you will likely want to make future growth as seamless as possible.

Introduction to DNS

The DNS provides a means of converting an easy-to-remember domain name with a numerical (IP) address. It thus provides us with a *phone book for the Internet* as well as providing a structure that is both hierarchical (there is the root node, which covers all domain names, top-level domains like `.com` and `.net`, domain names and subdomain names) and decentralized (the Internet is divided into different zones, and a name server is authoritative for a specific zone).

In a home or SOHO environment, we might not need to implement our own DNS server. In these scenarios, we could use our ISP's DNS servers to resolve Internet hostnames. For local hostnames, we could rely on NetBIOS under Windows, the **Berkeley Internet Name Domain service** (**BIND**) under Linux (using a configuration that does not require us to run name servers), or OS X under Mac OS X. Another option for mapping hostnames to IP addresses on the local network would be to use `HOSTS.TXT`. This is a text file, which contains a list of hostnames and corresponding IP addresses. But there are certain factors that may prompt us to set up our own DNS server for our networks:

- We may have chosen to utilize `HOSTS.TXT` for name resolution, but maintaining the `HOSTS.TXT` file on each of the hosts on our network may prove to be too difficult. If we have roaming clients, it may even be impossible.
- If your network is hosting resources that are available externally (for example, an FTP server or a website), and you are constantly making changes to the IP addresses of these resources, you will likely find it much easier to update your own data rather than submit forms to third parties and wait for them to implement the changes.
- Although your DNS server will only be authoritative for your domains, it can cache DNS data from the rest of the Internet. On your local network, this cached data can be retrieved much faster than DNS data from a remote DNS server. Thus, maintaining your own DNS server should result in faster name resolution.
- If you anticipate ever having to implement a public DNS server, a private DNS server can be a good learning experience, and if you make mistakes in implementing a private DNS server, the consequences are not as far-reaching as they would be with a public one.

Implementing a DNS server with pfSense is relatively easy. By using the DNS resolver, we can have pfSense answer DNS queries from local clients, and we can also have pfSense utilize any currently available DNS servers. We can also use third-party packages such as `dns-server` (which is a pfSense version of TinyDNS) to add DNS server functionality. We will discuss this in *Chapter 2*, *Advanced pfSense Configuration*.

The best practices for installation and configuration

Once you have chosen your hardware and which version you are going to install, you can download pfSense. Browse to the **Downloads** section of `https://www.pfsense.org/` and select the appropriate computer architecture (**32-bit**, **64-bit**, or **Netgate ADI**), the appropriate platform (**Live CD**, **memstick**, or **embedded**), and you should be presented with a list of mirrors. Choose the closest one for the best performance.

You will also want to download the MD5 checksum file in order to verify the integrity of the downloaded image. Windows has several utilities for displaying MD5 hashes for a file.

Under BSD and Linux, generating the MD5 hash is as easy as typing the following command:

```
md5 pfSense-LiveCD-2.2.6-RELEASE-amd64.iso
```

This command would generate the MD5 checksum for the 64-bit Live CD version for pfSense 2.2.6. Compare the resulting hash with the contents of the `.md5` file downloaded from the pfSense website.

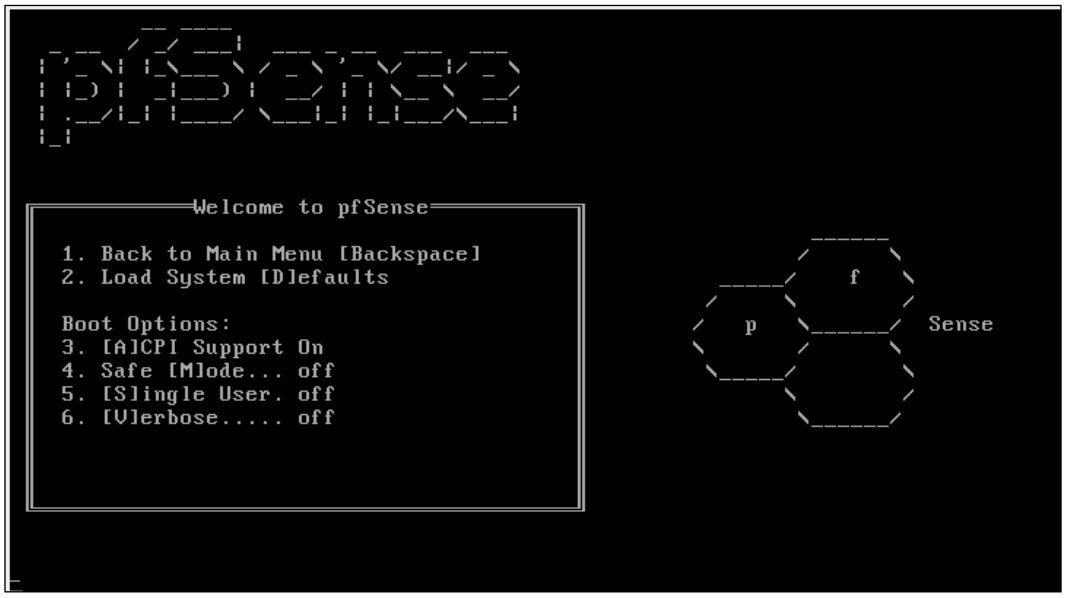
It is not within the scope of this book to cover pfSense installation in a detailed manner. If you are doing a full install from the Live CD or memory stick, then you just need to write the ISO to the target media, boot from either the CD or memory stick, perform some basic configuration, and then invoke the installer. The embedded install is done from a **compact flash** (**CF**) card and console data can be sent to either a serial port or the VGA port, depending on which embedded configuration you chose. If you use the serial port version, you will need to connect the embedded system to another computer with a null modem cable.

Troubleshooting installation

In most cases, you should be able to invoke the pfSense installer and begin installing pfSense onto the system. In some cases, however, pfSense may not boot from the target media, or the system may hang during the boot process. If pfSense is not booting at all, you may want to check to make sure the system is set up to boot from the target media. This can be done by changing the boot sequence in the **BIOS** settings (which can be accessed during system boot, usually by hitting the *Delete* key).

Most computers also have a means of choosing the boot device on a one-time basis during the boot sequence. Check your motherboard's manual on how to do this.

If the system is already set up to boot from the target media, then you may want to verify the integrity of the pfSense image again, or repeat the process of writing the images to the target media.



The initial pfSense boot menu when booting from a CD or USB flash drive.

If the system hangs during the boot process, there are several options you can try. The first menu that appears, as pfSense boots, has several options. The last two options are **Kernel** and **Configure Boot Options**. **Kernel** allows you to select which kernel to boot from among the available kernels. If you have a reason to suspect that the FreeBSD kernel being used is not compatible with your hardware, you might want to switch to the older version. **Configure Boot Options** launches a menu (shown in the preceding screenshot) with several useful options. A description of these options can be found at: `http://www.freebsd.org/doc/handbook/book.html`. Toggling **[A]CPI Support** to **off** can help in some cases, as ACPI's hardware discovery and configuration capabilities may cause the pfSense boot process to hang. If turning this off doesn't work, you could try booting in **Safe [M]ode**, and if all else fails, you can toggle **[V]erbose** mode to **On**, which will give you detailed messages while booting.

The two options after boot are **[R]ecovery**, and **[I]nstaller**. The **[R]ecovery** mode provides a shell prompt and helps recover from a crash by retrieving `config.xml` from a crashed hard drive. **[I]nstaller** allows you to install pfSense onto a hard drive or other media, and gets invoked by default after the timeout period.

The installer provides you with the option to either do a **quick install** or a **custom install**. In most cases, the **quick install** option can be used. Invoking the **custom install** option is only recommended if you want to install pfSense on a drive other than the first drive on the target system, or if you want to install multiple operating systems on the system. It is not likely that either of these situations will apply, unless you are installing pfSense for evaluation purposes (and in such cases, you would probably have an easier time running pfSense on a virtual machine).

If you were unable to install pfSense on to the target media, you may have to troubleshoot your system and/or installation media. If you are attempting to install from the CD, your optical drive may be malfunctioning, or the CD may be faulty. You may want to start with a known good bootable disc and see if the system will boot off of it. If it can, then your pfSense disc may be at fault; burning the disc again may solve the problem. If, however, your system cannot boot off the known good disc, then the optical drive itself, or the cables connecting the optical drive to the motherboard, may be at fault.

In some cases, however, none of the aforementioned possibilities hold true, and it is possible that the FreeBSD boot loader will not work on the target system. If so, then you could opt to install pfSense on a different system. Another possibility is to install pfSense onto a hard drive on a separate system, then transfer the hard drive into the target system. In order to do this, go through the installation process on another system as you would normally until you get to the **Assign Interfaces** prompt. When the installer asks if you want to assign VLANS, type `n`. Type `exit` at the **Assign Interfaces** prompt to skip the interface assignment. Proceed through the rest of the installation; then power down the system and transfer the hard drive to the target system. Assuming that the pfSense hard drive is in the boot sequence, the system should boot pfSense and detect the system's hardware correctly. Then you should be able to assign network interfaces. The rest of the configuration can then proceed as usual.

If you have not encountered any of these problems, the software should be installed on the target system, and you should get a dialog box telling you to remove the CD from the optical drive tray and press *Enter*. The system will now reboot, and you will be booting into your new pfSense install for the first time.

pfSense configuration

Configuration takes place in two phases. Some configuration must be done at the console, including interface configuration and interface IP address assignment. Some configuration steps, such as VLAN and DHCP setup, can be done both at the console and within the web GUI.

Configuration from the console

On boot, you should eventually see a menu identical to the one seen on the CD version, with the boot multi or single user options and other options. After a timeout period, the boot process will continue and you will get an **options** menu. You should select **1** from the menu to begin interface assignment. This is where the network cards installed in the system are given their roles as WAN, LAN, and optional interfaces (OPT1, OPT2, and so on).

If you select this option, you will be presented with a list of network interfaces. This list provides four pieces of information:

- pfSense's device name for the interface (`fxp0`, `em1`, and so on)
- The MAC address of the interface

- The link state of the interface (*up* if a link is detected; *down* otherwise)
- The manufacturer and model of the interface (Intel PRO 1000, for example)

As you are probably aware, generally speaking, no two network cards have the same MAC address, so each of the interfaces in your system should have a unique MAC address. To begin the configuration, press *1* and *Enter* for the **Assign Interfaces** option. After that, a prompt will show up for VLAN configuration. We will cover VLAN configuration in *Chapter 4*, *pfSense as a Firewall*, and we will cover both configuration from the command line and web GUI VLAN configuration. If you wish to set up VLANs, see *Chapter 4*, *pfSense as a Firewall*. Otherwise, type `n` and press *Enter*. Keep in mind that you can always configure VLANs later on.

The interfaces must be configured, and you will be prompted for the WAN interface first. If you only configure one interface, it will be assigned to the WAN, and you will subsequently be able to login to pfSense through this port. This is not what you would normally want, as the WAN port is typically accessible from the other side of the firewall. Once at least one other interface is configured, you will no longer be able to login to pfSense from the WAN port.

Unless you are using VLANs, you will have to set up at least two network interfaces.

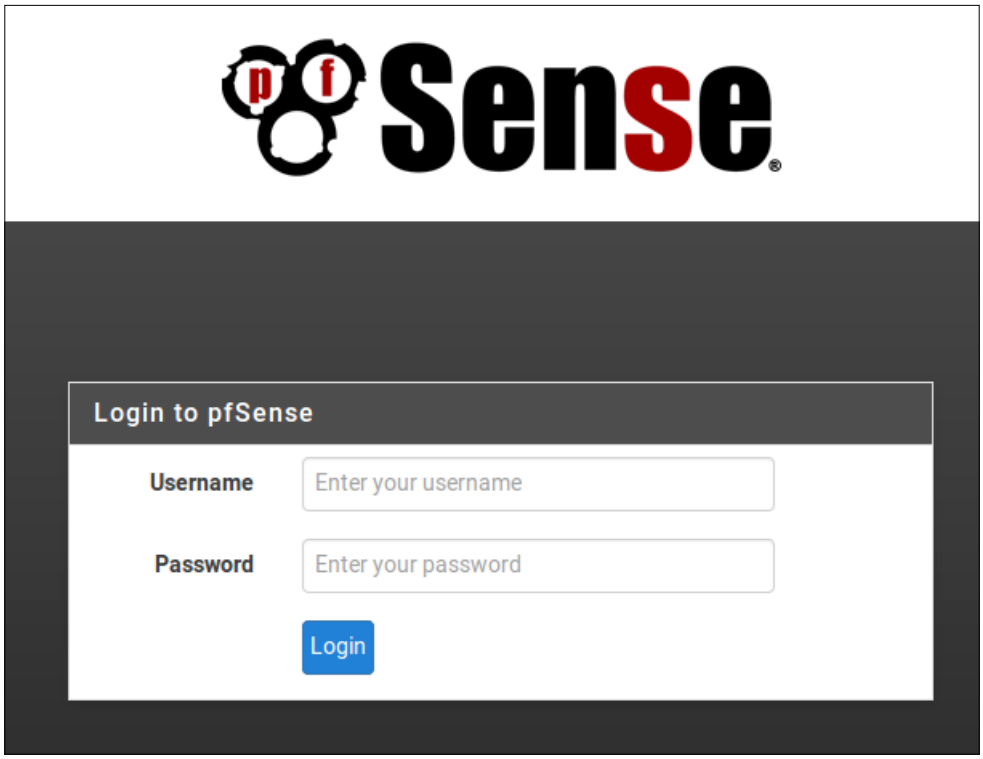
In pfSense, network interfaces are assigned rather cryptic device names (for example, `fxp0`, `em1`, and so on) and it is not always easy to know which ports correspond to particular device names. One way of solving this problem is to use the **automatic interface assignment** feature. To do this, unplug all network cables from the system and then type `a` and press *Enter* to begin auto-detection. The WAN interface is the first interface to be detected, so plug a cable into the port you intend to be the WAN interface. The process is repeated with each successive interface. The LAN interface is configured next, then each of the optional interfaces (OPT1, OPT2). If auto-detection does not work, or you do not want to use it, you can always choose manual configuration. You can always reassign network interfaces later on, so even if you make a mistake on this step, the mistake can be easily fixed. Once you have finished configuration, type `y` at the **Do you want to proceed?** prompt, or type `n` and press *Enter* to re-assign the interfaces.

Option two on the menu is **Set interface(s) IP address**, and you will likely want to complete this step as well. When you invoke this option, you will be prompted to specify which interface's IP address is to be set. If you select **WAN interface**, you will be asked if you want to configure the IP address via DHCP. In most scenarios, this is probably the option you want to choose, especially if pfSense is acting as a firewall. In that case, the WAN interface will receive an IP address from your ISP's DHCP server. For all other interfaces (or if you choose not to use DHCP on the WAN interface), you will be prompted to enter the interface's IPv4 address. The next prompt will ask you for the **subnet bit count**. In most cases, you'll want to enter `8` if you are using a Class A private address, `16` for Class B, and `24` for Class C, but if you are using classless subnetting (for example, to divide a Class C network into two separate networks), then you will want to set the bit count accordingly. You will also be prompted for the IPv4 gateway address (any interface with a gateway set is a WAN, and pfSense supports multiple WANs); if you are not configuring the WAN interface(s), you can just hit *Enter* here. Next, you will be prompted to provide the address, subnet bit count, and gateway address for IPv6; if you want your network to fully utilize IPv6 addresses, you should enter them here. The advantages of IPv6 over IPv4 will be discussed more fully in *Chapter 2*, *Advanced pfSense Configuration*.

We have now configured as much as we need to from the console (actually, we have done more than we have to, since we really only have to configure the WAN interface from the console). The remainder of the configuration can be done from the pfSense web GUI.

Configuration from the web GUI

The pfSense web GUI can only be accessed from another PC. If the WAN was the only interface assigned during the initial setup, then you will be able to access pfSense through the WAN IP address. Once one of the local interfaces is configured (typically the LAN interface), pfSense can no longer be accessed through the WAN interface. You will, however, be able to access pfSense from the local side of the firewall (typically through the LAN interface). In either case, you can access the web GUI by connecting another computer to the pfSense system, either directly (with a crossover cable) or indirectly (through a switch), and then typing either the WAN or LAN IP address into the connected computer's web browser. The login screen should look similar to the following screenshot:



The pfSense 2.3 web GUI login screen.

When you initially log in to pfSense, the default username/password combination will be **admin/pfsense**, respectively. On your first login, **Setup Wizard** will begin automatically. Click on the **Next** button to begin configuration.

The first screen provides a link for information about a pfSense Gold subscription. You can click on the link to sign up, or click on the **Next** button.

On the next screen, you will be prompted to enter the hostname of the router as well as the domain. Hostnames can contain letters, numbers, and hyphens, but must begin with a letter. If you have a domain, you can enter it in the appropriate field.

In the **Primary DNS Server** and **Secondary DNS Server** fields, you can enter your DNS servers. If you are using DHCP for your WAN, you can probably leave these fields blank, as they will usually be assigned automatically by your ISP. If you have alternate DNS servers you wish to use, you can enter them here.

I have entered `8.8.8.8` and `8.8.4.4` as the primary and secondary DNS servers (these are two DNS servers run by Google that conveniently have easy to remember IP addresses). You can keep the **Override DNS** checkbox checked unless you have reason to use DNS servers other than the ones assigned by your ISP. Click on **Next** when finished.

The next screen will prompt you for the **Network Time Protocol** (**NTP**) server as well as the local time zone. The NTP server configuration will be covered in greater detail in the next chapter; you can keep the default value for the server hostname for now. For the **Timezone** field, you should select the zone which matches your location and click on **Next**.

The next screen of the wizard is the **WAN configuration** page. You will be prompted to select the WAN type. You can select either **DHCP** (the default type) or **Static**. If your pfSense system is behind another firewall and it is not going to receive an IP address from an upstream DHCP server, then you probably should choose **Static**. If pfSense is going to be a perimeter firewall, however, then **DHCP** is likely the correct setting, since your ISP will probably dynamically assign an IP address (this is not always the case, as you may have an IP address statically assigned to you by your ISP, but it is the more likely scenario).

If you are not sure which WAN type to use, you will need to obtain this information from your ISP (the other choices are **PPPoE**, **PPTP**, and **Static**. PPPoE stands for Point-to-Point over Ethernet and PPTP stands for Point-to-Point Tunneling Protocol).

The **MAC address** field allows you to enter a MAC address that is different from the actual MAC address of the WAN interface. This can be useful if your ISP will not recognize an interface with a different MAC address than the device that was previously connected, or if you want to acquire a different IP address (changing the MAC address will cause the upstream DHCP server to assign a different address). If you use this option, make sure the portion of the address reserved for the **Organizationally Unique Identifier** (**OUI**) is a valid OUI – in other words, an OUI assigned to a network card manufacturer. (The OUI portion of the address is the first three bytes of a MAC-48 address and the first five bytes of an EUI-48 address).

The next few fields can usually be left blank. **Maximum Transmission Unit (MTU)** allows you to change the MTU size if necessary. **DHCP hostname** allows you to send a hostname to your ISP when making a DHCP request, which is useful if your ISP requires this.

Besides **DHCP** and **Static**, you can select **PPTP** or **PPPoE** as your **WAN type**. If you choose **PPPoE**, then there will be a field for a **PPPoE Username**, **PPPoE Password**, and **PPPoE Server Name**. The **PPPoE dial-on-demand** checkbox allows you to connect to your ISP only when a user requests data that requires an Internet connection. **PPPoE Idle timeout** specifies how long the connection will be kept open after transmitting data when this option is invoked.

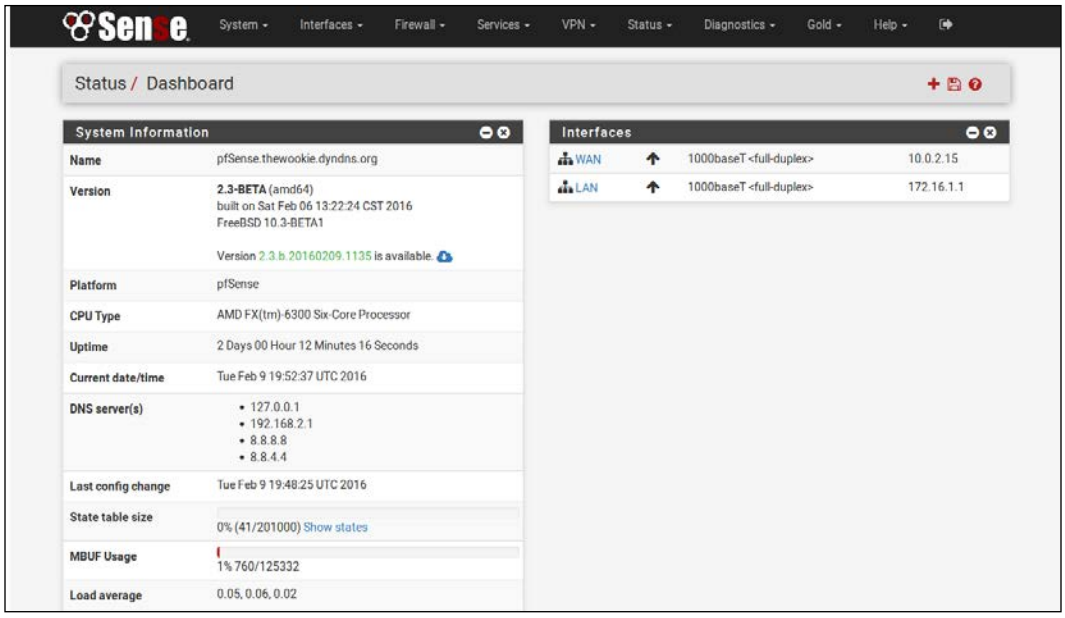
The **Block RFC1918 Private Networks** checkbox, if checked, will block registered private networks (as defined by RFC 1918) from connecting to the WAN interface. The **Block Bogon Networks** option blocks traffic from reserved and/or unassigned IP addresses. For the WAN interface, you should check both options unless you have special reasons for not invoking these options. Click the **Next** button when you are done.

The next screen provides fields in which you can change **LAN IP address** and **subnet mask**, but only if you configured the LAN interface previously.

You can keep the default, or change it to another value within the private address blocks. You may want to choose an address range other than the very common `192.168.1.x` in order to avoid a conflict. Be aware that if you change the **LAN IP address** value, you will also need to adjust your PC's IP address, or release and renew its DHCP lease when finished with the network interface. You will also have to change the pfSense IP address in your browser to reflect the change.

The final screen of the **pfSense Setup Wizard** allows you to change the admin password, which you should probably do. Enter the password, enter it again for confirmation in the next edit box, and click on **Next**. On the following screen, there will be a **Reload** button; click on **Reload**. This will reload pfSense with the new changes.

Once you have completed the wizard, you should have network connectivity. Although there are other means of making changes to pfSense's configuration, if you want to repeat the wizard, you can do so by navigating to **System | Setup Wizard**. Completion of the wizard will take you to the pfSense dashboard.



The pfSense dashboard, redesigned for version 2.3.

Configuring additional interfaces

By now, both the **WAN** and **LAN** interface configuration should be complete. Although additional interface configuration can be done at the console, it can also be done in the web GUI. To add optional interfaces, navigate to **Interfaces | assign the Interface assignments** tab will show a list of assigned interfaces, and at the bottom of the table, there will be an **Available network ports: entry** option. There will be a corresponding drop-down box with a list of unassigned network ports. These will have device names such as **fxp0**, **em1**, and so on. To assign an unused port, select the port you want to assign from the drop-down box, and click on the **+** button to the right.

The page will reload, and the new interface will be the last entry in the table. The name of the interface will be **OPTx**, where **x** equals the number of optional interfaces. By clicking on **interface name**, you can configure the interface. Nearly all the settings here are similar to the settings that were available on the **WAN** and **LAN** configuration pages in the **pfSense Setup Wizard**. Some of the options under the **General Configuration** section, that are not available in the setup wizard, are **MSS** (Maximum Segment Size), and **Speed and duplex**. Normally, MSS should remain unchanged, although you can change this setting if your Internet connection requires it. If you click on the **Advanced** button under **Speed and duplex**, a drop-down box will appear in which you can explicitly set the speed and duplex for the interface. Since virtually all modern network hardware has the capability of automatically selecting the correct speed and duplex, you will probably want to leave this unchanged.

If you have selected **DHCP** as the configuration type, then there are several options in addition to the ones available in the setup wizard. **Alias IPv4 address** allows you to enter a fixed IP address for the DHCP client. The **Reject Leases from** field allows you to specify the IP address or subnet of an upstream DHCP server to be ignored.

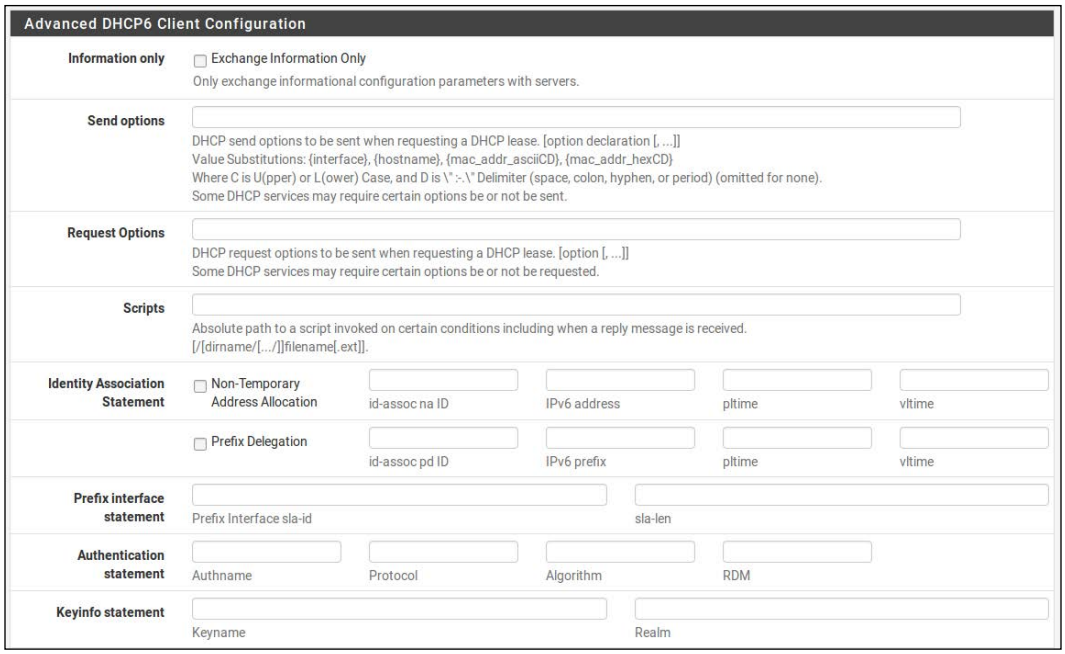
Clicking on the **Advanced** checkbox in the DHCP client configuration causes several additional options to appear in this section of the page. The first is **Protocol Timing**, which allows you to control DHCP protocol timings when requesting a lease. You can also choose several presets (**FreeBSD**, **pfSense**, **Clear**, or **Saved Cfg**) using the radio buttons on the right.

The next option in this section is **Lease Requirements and Requests**. Here you can specify **send**, **request**, and **require** options when requesting a DHCP lease. These options are useful if your ISP requires these options. The last section is **Option Modifiers**, where you can add **DHCP option modifiers,** which are applied to an obtained DHCP lease.

There is a second checkbox at the top of this section called **Config File Override**. Checking this box allows you to enter a DHCP client configuration file. If you use this option, you must specify the full absolute path of the file.

Starting with pfSense version 2.2.5, there is support for IPv6 with DHCP (DHCP6). If you are running 2.2.5 or above, there will be a section on the page called **DHCP6 client configuration**. The first setting is **Use IPv4 connectivity as parent interface**. This allows you to request an IPv6 address over IPv4. The second is **Request only an IPv6 prefix**. This is useful if your ISP supports **Stateless Address Auto Configuration** (**SLAAC**). In this case, instead of the usual procedure in which the DHCP server assigns an IP address to the client, the DHCP server only sends a prefix, and the host may generate its own IP address and test the uniqueness of a generated address in the intended addressing scope.

By default, the IPv6 prefix is 64 bits, but you can change that by altering the **DHCPv6 Prefix Delegation** size in the corresponding drop-down box. The last setting is the **Send IPv6 prefix** hint, which allows you to request the specified prefix size from your ISP.



The advanced DHCP6 client configuration section of the interface configuration page. This section appears if DHCP6 is selected as the IPv6 configuration type

Checking the **Advanced** checkbox in the heading of this section displays the **advanced DHCP 6** options. If you check the **Information Only** checkbox on the left, pfSense will send requests for stateless DHCPv6 information. You can specify **send** and **request** options, just as you can for IPv4. There is also a **Script** field where you can enter the absolute path to a script that will be invoked on certain conditions.

The next options are for the **Identity Association Statement** checkboxes. The **Non-Temporary Address Allocation** checkbox results in normal, that is, not temporary, IPv6 addresses to be allocated for the interface. The **Prefix Delegation** checkbox causes a set of IPv6 prefixes to be allocated from the DHCP server.

The next set of options, **Authentication Statement**, allow you to specify authentication parameters to the DHCP server. The **Authname** parameter allows you to specify a string, which in turn specifies a set of parameters. The remaining parameters are of limited usefulness in configuring a DHCP6 client, because each has only one allowed value, and leaving them blank will result in only the allowed value being used. If you are curious as to what these values are, here they are:

Parameter	Allowed value	Description
Protocol	Delayed	The DHCPv6 delayed authentication protocol
Algorithm	hmac-md5, HMAC-MD5, hmacmd5, or HMACMD5	The HMAC-MD5 authentication algorithm
rdm	Monocounter	The replay protection method; only monocounter is available

Finally, **Key info Statement** allows you to enter a secret key. The required fields are **key id**, which identifies the key, and **secret**, which provides the shared secret. **key name** and **realm** are arbitrary strings and may be omitted. **expire** may be used to specify an expiration time for the key, but if it is omitted, the key will never expire.

The last section on the page is identical to the interface configuration page in the **Setup Wizard**, and contains the **Block Private Networks** and **Block Bogon Networks** checkboxes. Normally, these are checked for WAN interfaces, but not for other interfaces.

General setup options

You can find several configuration options under **System** | **General Setup**. Most of these are identical to settings that can be configured in the **Setup Wizard** (**Hostname**, **Domain**, **DNS servers**, **Timezone**, and **NTP server**). There are two additional settings available. The **Language** drop-down box allows you to select the web configurator language. Under the **Web Configurator** section, there is a **Theme** drop-down box that allows you to select the theme. The default theme of pfSense is perfectly adequate, but you can select another one here.

pfSense 2.3 also adds new options to control the look and feel of the web interface; these settings are also found in the **Web Configurator** section of the **General Settings** page. The **Top Navigation** drop-down box allows you to choose whether the top navigation scrolls with the page, or remains anchored at the top as you scroll. The **Dashboard Columns** option allows you to select the number of columns on the dashboard page (the default is **2**).

The next set of options is **Associated Panels Show/Hide**. These options control the appearance of certain panels on the **Dashboard** and **System Logs** page. The options are:

- **Available Widgets**: Checking this box causes the **Available Widgets** panel to appear on the **Dashboard**. Prior to version 2.3, the **Available Widgets** panel was always visible on the **Dashboard**.
- **Log Filter**: Checking this box causes the **Advanced Log Filter** panel to appear on the **System Logs** page. **Advanced Log Filter** allows you to filter the system logs by time, process, PID, and message.
- **Manage Log**: Checking this box causes the **Manage General Log** panel to appear on the **System Logs** page. The **Manage General Log** panel allows you to control the display of the logs, how big the log file may be, and the formatting of the log file, among other things.

The last option on this page, **Left Column Labels**, allows you to select/toggle the first item in a group by clicking on the left column if checked. Click on **Save** at the bottom of the page to save any changes.

Advanced setup options

Under **System | Advanced**, there are a number of options that you will probably want to configure before completing the initial setup. There are six separate tabs here, all with multiple options, and we won't cover all of them here, but we will cover the more common ones.

The first setting allows you to choose between **HTTP** and **HTTPS** for the web configurator. If you plan on making the pfSense web GUI accessible from the WAN side, you will definitely want to choose **HTTPS** in order to encrypt access to the web GUI. Even if the web GUI will only be accessible over local networks, you probably will want to choose **HTTPS**. Modern web browsers will complain about the SSL certificate the first time you access the web GUI, but most of them will allow you to create an exception. The next setting, **SSL certificate**, allows you to choose a certificate from a drop-down list of available certificates. You can choose **web Configurator default**, or you can add another certificate (by navigating to **System | Cert Manager** and adding one), and use it instead.

The next important setting, also in the **Web Configurator** section, is the **Disable web Configurator** anti-lockout rule. If left unchecked, access to the web GUI is always allowed on the LAN (or WAN if the LAN interface has not been assigned), regardless of any user-defined firewall rules. If you check this option and you don't have a user-defined rule to allow access to pfSense, you will lock yourself out of the web GUI. If you are locked out of the web GUI because of firewall rules, there are several options. The easiest option is probably to restore a previous configuration from the console. You can also reset pfSense to **factory defaults**, but if you don't mind typing in shell commands, there are less drastic options. One is to add an **allow all** rule on the WAN interface by typing the following command at the console shell prompt (type `8` at the console menu to invoke the shell):

```
pfSsh.php playback enableallowallwan
```

Once you issue this command, you will be able to access the web GUI through the WAN interface. To do so, either connect the WAN port to a network running DHCP (if the WAN uses DHCP), or connect the WAN port to another computer with an IP on the same network (if the WAN has a static IP). Be sure to delete the WAN **allow all** rule before deploying the system.

Another possibility is to temporarily disable the firewall rules with the following shell command:

```
pfctl –d
```

Once you have regained access, you can re-enable the firewall rules with this command:

```
pfctl -e
```

In any case, you want to make sure your firewall rules are configured correctly before invoking the anti-lockout option.

You can reset pfSense to factory defaults by selecting **4** from the console menu. If you need to go back to a previous configuration, you can do that by selecting **15** from the console menu; this option will allow you to select from automatically-saved restore points.

The next section is **Secure Shell**; checking the **Enable Secure Shell** checkbox makes the console accessible via a **Secure Shell** (**SSH**) connection. This makes life easier for admins, but it also creates a security concern. Therefore, it is a good idea to change the default SSH port (the default is 22), which you can do in this section. You can add another layer of security by checking the **Disable password login** for the **Secure Shell** checkbox. If you invoke this option, you must create authorized SSH keys for each user that requires SSH access.

The process for generating SSH keys is different depending on your OS. Under Linux, it is fairly simple. First, enter the following at the command prompt:

```
ssh-keygen -t rsa
```

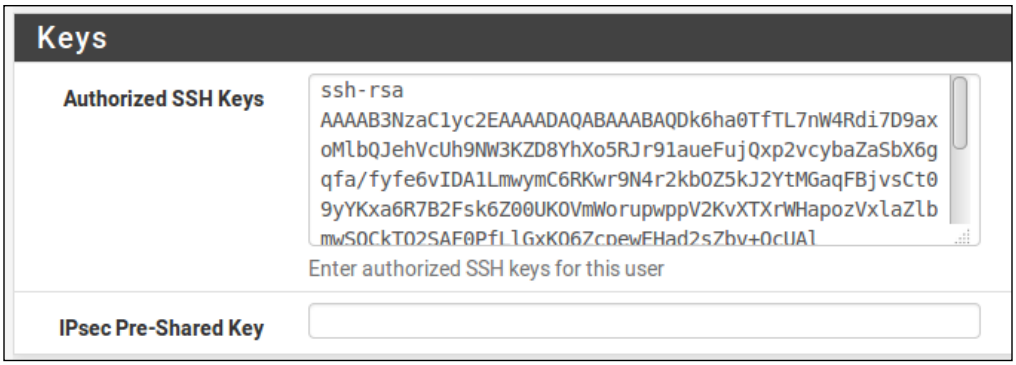
You will receive the following prompt:

```
Enter file in which to save the key (/home/user/.ssh/id-rsa):
```

The directory in parenthesis will be a subdirectory of your home directory. You can change the directory or press *Enter*. The next prompt asks you for a passphrase:

```
Enter passphrase (empty for no passphrase):
```

You can enter a passphrase here or just press *Enter*. You will be prompted to enter the passphrase again, and then the public/private key pair will be generated. The public key will now be saved in a file called `id-rsa.pub`.



Entering SSH keys for a user in the user manager.

The next step is adding the newly generated public key to the admin account in pfSense. Open the file in the text editor of your choice and in the web GUI, select the public key and copy it to the clipboard. Then navigate to **System | User Manager** and click on the **Edit** user icon for the appropriate user. Scroll down to the **Keys** section and paste the key into the **Authorized SSH keys** box. Then click on **Save** at the bottom of the page.

You should now be able add SSH into the admin account without entering the password. Type the following at the command line:

```
ssh pfsense_address -ladmin
```

Here, `pfsense_address` is the IP address of the pfSense system. If you specified a passphrase earlier, you will be prompted to enter it in order to unlock the private key. You will not be prompted for the passphrase on subsequent logins. Once you unlock the private key, you should be logged into the console.

The last section of the page, **Console options**, gives you one more layer of security by allowing you to require a password for console login. Check this checkbox if you want to enable this option, although this could result in being locked out if you forget the password. If this happens, you may still be able to restore access by booting from the live CD and doing a pre-flight install, described in a subsequent section.

The next tab, **Firewall/NAT**, contains a number of important settings relating to pfSense's firewall functionality. **Firewall Optimization Options** allows you to select the optimization algorithm for the state table. The **Normal** option is designed for average case scenario network usage. **High latency**, as the name implies, is for connections in which it is expected that there will be a significant delay between a request and response (a satellite connection is a good example). **Aggressive** and **Conservative** are inverses of each other. **Aggressive** is more aggressive than **Normal** in dropping idle connections, while **Conservative** will leave idle connections open longer than **Normal** would. Obviously, the trade-off here is that if we expire idle connections too soon, legitimate connections may be dropped, while keeping them open too long will be costly from a resource (CPU and memory) standpoint.

In the **Firewall Advanced** section, there is a **Disable all packet filtering** checkbox. Enabling this option disables all firewall functionality, including NAT. This should be used with caution, but may be useful in troubleshooting.

The **Firewall maximum** settings and **Firewall maximum table entries** options allow you to specify the maximum number of connections and maximum number of table entries respectively to hold in the system state table. If you leave these entries blank, pfSense will assign reasonable defaults based on the amount of memory your system has. Since increasing the maximum number of connections and/or state table entries will leave less memory for everything else, you will want to invoke these options with caution.

The **static route filtering** checkbox, if checked, will result in firewall rules not taking effect for traffic that enters and leaves through the same interface. This can be useful if you have a static route in which traffic enters pfSense through an interface, but the source of the traffic is not the same as the interface on which it enters. This option does not apply to traffic whose source and destination is the same interface – such traffic is intra-network traffic, and firewall rules would not apply to it whether or not this option was invoked.

The next section of the page, **Bogon Networks**, allows you to select the update frequency of the list of addresses reserved, or not yet assigned, by IANA. If someone is trying to access your network from a newly-assigned IP address, but the Bogon networks list has not yet been updated, they may find themselves blocked. If this is happening on a frequent basis, you may want to change the update frequency.

The next tab, **Networking**, contains a number of IPv6 options. The **Allow IPv6** checkbox must be checked in order for IPv6 traffic to pass (it is checked by default). The next option, **IPv6 over IPv4 Tunneling**, allows you to enable the transitional IPv6 over IPv4. There is also an option called **Prefer IPv4 even when IPv6 is available**, which will cause IPv4 to be used in cases where a hostname resolves both IPv4 and IPv6 addresses.

The next tab is called **Miscellaneous**. The **Proxy Port** section allows you to specify a URL for a remote proxy server, as well as the proxy port and a username and password. The following section, **Load Balancing**, has two settings. The first setting, **Use sticky connections**, causes successive connections from the same source to be connected to the same server, instead of directing them to the next web server in the pool, which would be the normal behavior. The timeout period for sticky connections may be adjusted in the adjacent **Edit** box. The default is **0**, so the sticky connection expires as soon as the last connection from the source expires. The second setting, **Enable default gateway switching**, switches from the default gateway to another available one when the default gateway goes down. This is not necessary in most cases, since it is easier to incorporate redundancy into gateways with gateway groups.

The **Scheduling** section has only one option, but it has significance if you use rule scheduling. Checking the **Do not kill connections when schedule expires** checkbox will cause connections permitted by the rule to survive even after the time period specified by the schedule expires. Otherwise, pfSense will kill all existing connections when a schedule expires.

Upgrading, backing up, and restoring pfSense

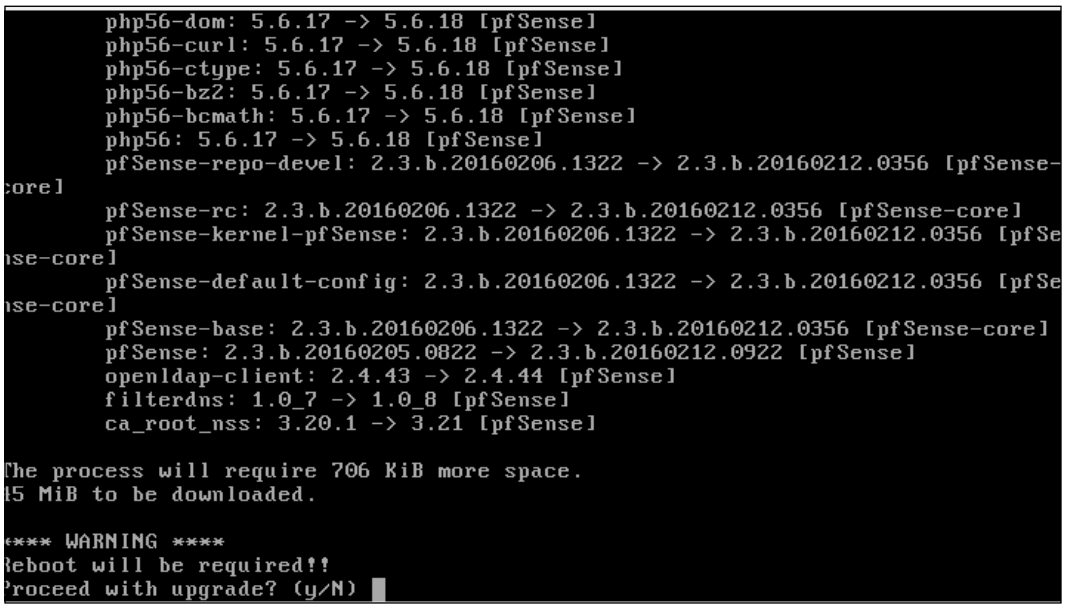
You can usually upgrade pfSense from one version to another, although the means of upgrading may differ depending on what platform you are using. So long as the firmware is moving from an older version to a newer version, pfSense will work unless otherwise noted.

Before you make any changes, you should make an up-to-date backup. In the web GUI, you can back up the configuration by navigating to **Diagnostics | Backup/ Restore**. In the **Backup Configuration** section of the page, set **Backup Area** to **ALL**. Then click on **Download Configuration** and save the file.

Before you upgrade pfSense, it is a good idea to have a plan on how to recover in case the upgrade goes wrong. There is always a chance that an upgrade will leave pfSense in an unusable state. In these cases, it is always helpful to have a backup system available. Also, with advance planning, the firewall can be quickly returned to the previous release.

There are three methods for upgrading pfSense. The first is to download the upgrade binaries from the official pfSense site. The same options are available as are available for a full install. Just download the appropriate image, write the image to the target media, and boot the system to be upgraded from the target media. For embedded systems, releases prior to 1.2.3 are not upgradable (in such cases, a full install would be the only way to upgrade), but newer NanoBSD-based embedded images do support upgrades.

The second method is to upgrade from the console. From the console menu, select **13** (the **Upgrade from Console** option). pfSense will check the repositories to see if there is an update, and if there is, how much more disk space is required, and also inform you that upgrading will require a reboot. It will also prompt you to confirm that the upgrade should proceed. Type `y` and *Enter*, and the upgrade will proceed. pfSense will also automatically reboot 10 seconds after downloading and installing the upgrade. Rebooting may take slightly longer than it would normally, since pfSense must extract the new binaries from a tarball during the boot sequence.

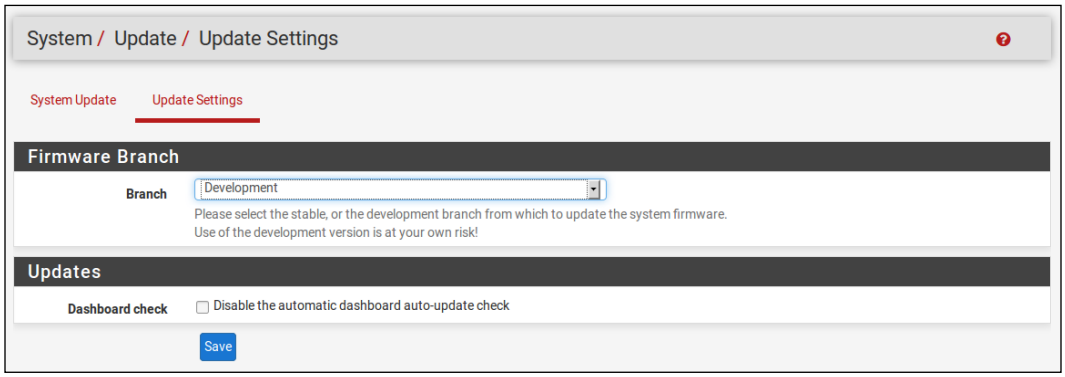


Upgrading pfSense from the console.

The third method is the easiest way to upgrade your system: from the web GUI. Navigate to **Status | Dashboard** (this should also be the screen you see when initially logging into the web GUI). The **System Information** widget should have a section called **Version**, and this section should provide:

- The current version of pfSense
- Whether an update is available

If an update is available, there will be a link to the **firmware auto update** page; click on this link. Alternatively, you can access this page by navigating to **System | Update** and clicking on the **System Update** tab (note that on versions prior to 2.3, this menu option was called **Firmware** instead of **Update**. If there is an update available, this page will let you know.



Choosing a firmware branch from the Update Settings tab of the Update option.

The **Update Settings** tab contains options that may be helpful in some situations. The **Firmware Branch** section has a drop-down box, allowing you to select either the **Stable** branch or **Development** branch. The **Dashboard check** checkbox allows you to disable the dashboard auto-update check.

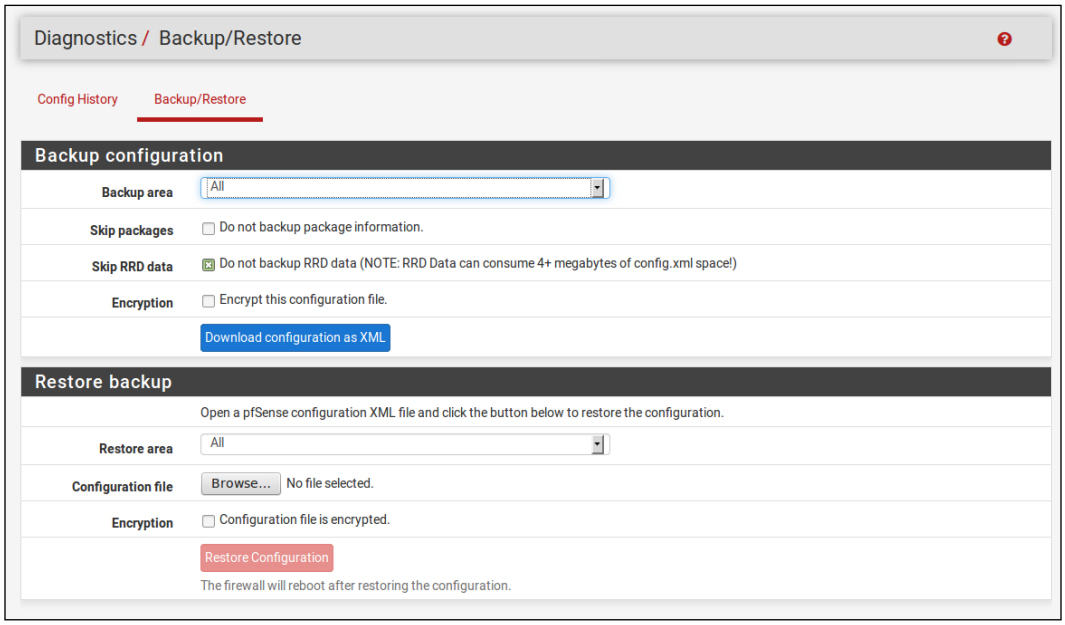
Once you are satisfied with these settings, you can click on the **Confirm** button on the **System Update** tab. The updating process will then begin, starting with the backup (if you chose that option). Upgrading can take as little as 15 minutes, especially if you are upgrading from one minor version to another. If you are upgrading in a production environment, you will want to schedule your upgrade for a suitable time (either during the weekend or after normal working hours). The web GUI will keep you informed of the status of the update process and when it is complete.

Another means of updating pfSense in the web GUI is to use the **manual update** feature. To do so, navigate to **System | Update** and click on the **Manual Update** tab. Click on the **Enable firmware upload** button. When you do this, a new section should appear on the page. The **Choose file** button launches a file dialog box where you can specify the firmware image file. Once you select the file, click on **Open** to close the file dialog box. There is a **Perform full backup prior to upgrade** checkbox you can check if you want to back up the system, and also an **Upgrade firmware** button that will start the upgrade process.

If the update is successful, the **System Information** widget on the **Dashboard** should indicate that you are on the current version of pfSense (or the version to which you upgraded, if you invoked the manual update). If something went wrong and pfSense is not functioning properly, and you made a backup prior to updating, you can restore the old version. Available methods of backing up and restoring pfSense are outlined in the next section.

Backing up and restoring pfSense

The following screenshot shows the options related to backing up and restoring pfSense:



Backup and restore options in pfSense 2.3.

You can back up and restore the `config.xml` file from the web GUI by navigating to **Diagnostics | Backup/Restore**. The first section, **Backup configuration**, allows you to back up some or all of the configuration data. There is a drop-down box which allows you to select which areas to backup. There are checkbox options such as **do not backup package information**, and **Encrypt this configuration file**. The final checkbox, selected by default, allows you to disable the backup of **round robin database** (**RRD**) data, real-time traffic data which you likely will not want to save. The **Download Configuration as XML** button allows you to save `config.xml` to a local drive.

Restoring the configuration is just as easy. In the **Restore configuration** section of the page, select the area to restore from the drop-down box and browse to the file by clicking on the **Choose File** button. Specify whether `config.xml` is encrypted with the corresponding checkbox, and then click the **Restore configuration** button.

Restoring a configuration with Pre-Flight Install

You may find it is necessary to restore an old pfSense configuration. Moreover, it is possible that restoring an old configuration from the console or web GUI as described previously in this chapter is not possible. In these cases, there is one more possible way of restoring an old configuration, and that is with a **Pre-Flight Install** (**PFI**). A PFI essentially involves the following:

1. Copying a backup `config.xml` file into a directory called `conf` on a DOS/FAT formatted USB drive.
2. Plugging the USB drive into the system whose configuration is to be restored, and then booting off the Live CD.
3. Installing pfSense from the CD onto the target system.
4. Rebooting the system, and allowing pfSense to boot (off the target media, not the CD). The configuration should now be restored.

Another option that is useful if you want to retain your configuration while reinstalling pfSense is to choose the menu option **Rescue config.xml** during the installation process. This allows you to select and load a configuration file from any storage media attached to the system.

Summary

The goal of this chapter was to provide an overview of how to get pfSense up and running. Completion of this chapter should give you an idea of where to deploy your pfSense system as well as what hardware to utilize. You should also know how to troubleshoot the most common installation problems, and how to do basic system configuration and interface setup for both IPv4 and IPv6 networks. You should know how to configure pfSense for remote access. Finally, you should know how to upgrade, backup, and restore pfSense.

In the next chapter, we will look at some of the more advanced configuration options. We will cover DHCP and DHCPv6 in depth. We will also consider DNS and Dynamic DNS, as well as other capabilities you are likely to consider utilizing: **Captive Portal**, **Network Time Protocol** (**NTP**), and **Simple Network Management Protocol** (**SNMP**).

The subject matter covered in the remaining chapters is not always easy, but if you have made it this far, you are more than likely to have the aptitude to absorb it. It is my hope that your journey to mastering pfSense will not only be educational, but fun as well.

2
Advanced pfSense Configuration

The information provided in the first chapter should have enabled you to deploy your pfSense router/firewall on your network. In this chapter, we will go beyond this basic functionality and explore some of the features pfSense has that many consumer grade routers do not have, yet you are likely to want to implement. In particular, we will focus on the following topics:

- **Dynamic Host Configuration Protocol** (**DHCP**)
- **Domain Name System** (**DNS**)
- **Dynamic DNS** (**DDNS**)
- Captive portal
- **Network Time Protocol** (**NTP**)
- **Simple Network Management Protocol** (**SNMP**)

DHCP

You have probably configured a router to act as a DHCP server at some point. Configuring pfSense to act as a DHCP server is just as easy, and it has a number of features many routers do not have. DHCP configuration can be done either at the console, or within the web GUI, and both possibilities will be covered here.

DHCP configuration at the console

DHCP configuration at the console can be done with the following steps:

1. At the console, select **Set interface(s) IP address** on the menu.
2. Select the interface on which you want to run the pfSense DHCP server (this is usually LAN, but it could be any interface other than the WAN interface). You will be prompted for the interface's IPv4 IP address.
3. Type in the address (or leave the line blank for none) and press *Enter*.
4. The next prompt is for the subnet bit count. Type in the correct bit count and press *Enter*.
5. Next, you will be prompted for the upstream gateway address. You *do not* need to provide this information, so just press *Enter*. IPv4 address configuration is now complete.

```
>

Do you want to enable the DHCP server on LAN? (y/n) y
Enter the start address of the IPv4 client address range: 172.16.1.100
Enter the end address of the IPv4 client address range: 172.16.1.200

Do you want to enable the DHCP6 server on LAN? (y/n) y
Enter the start address of the IPv6 client address range: 1234:5678:9a::10
Enter the end address of the IPv6 client address range: 1234:5678:9a::100

Please wait while the changes are saved to LAN...
 Reloading filter...
 Reloading routing configuration...
 DHCPD...

The IPv4 LAN address has been set to 172.16.1.1/16


The IPv6 LAN address has been set to 1234:5678:9a::1/48
You can now access the webConfigurator by opening the following URL in your web
browser:
                http://172.16.1.1/
                http://[1234:5678:9a::1]/

Press <ENTER> to continue.
```

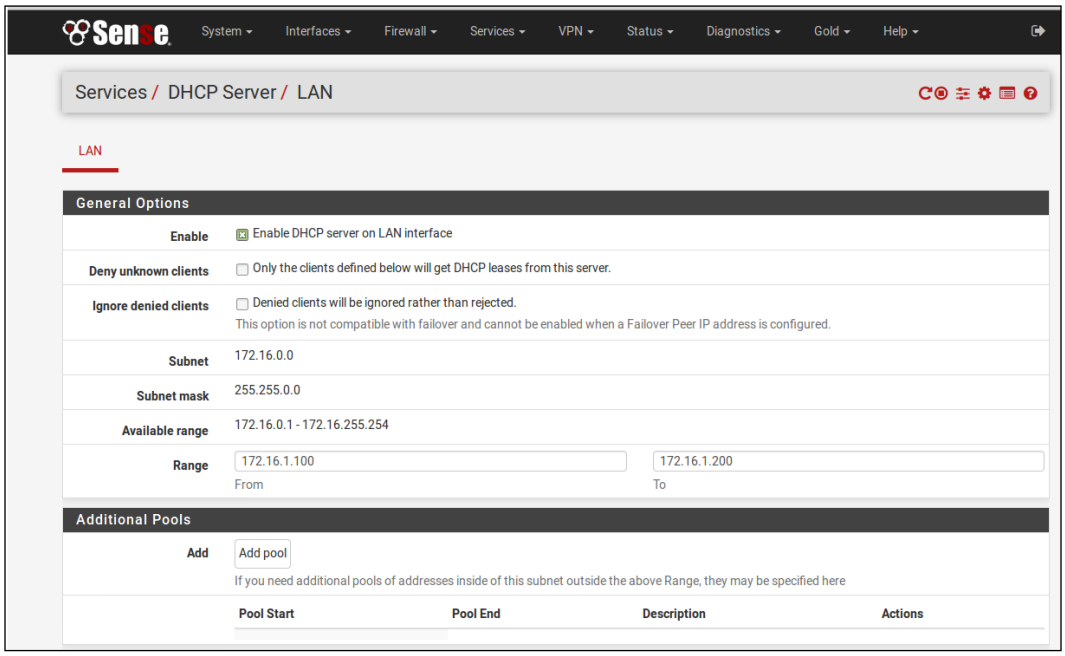
DHCP configuration from the console, with both the DHCP and DHCP6 server enabled.

6. The next prompt will be for the IPv6 address. If you have a small network, IPv6 configuration is not necessary, although there are some advantages to IPv6 configuration, such as the ability to assign addresses automatically, enhanced security, and even better mobility features. Enter an IPv6 address if you want to use IPv6 on the interface.
7. After you enter the IPv6 address, you will be prompted to enter the subnet bit count, so enter the bit count and press *Enter*. Since you don't need to specify an upstream gateway, you can press *Enter* there as well.
8. The next two prompts will ask you whether to start the DHCP server on IPv4 and IPv6, respectively. If you specify `y` for either one, you will be prompted to enter the address range for DHCP. Here you can specify any valid address range for your subnet. Keep in mind that you don't have to start the DHCP server for IPv6 unless you want clients to have their IPv6 addresses assigned to them. Instead, you can utilize client address configuration, as described earlier.

Now that you have enabled DHCP at the console and assigned addresses ranges, you should be able to connect to your network via DHCP. Configuring networking on the client for DHCP will be different for each platform, but virtually all modern OSes allow you to select either static IP assignment or DHCP (if it's not explicitly called DHCP, it will likely be called **automatic IP assignment** or something like that). You may have to reset your network connection, but once you do, the DHCP server should assign you an IP address.

DHCP configuration in the web GUI

You can also set up your DHCP server in the web GUI, which includes many more options than the console does. Navigate to **Services | DHCP Server**. There will be a separate tab for each non-WAN interface. Click on the tab for the interface you want to configure. The following screenshot shows the configuration page for the LAN interface:



The DHCP configuration page (for IPv4) in pfSense.

In the **General Options** section, there is an **Enable** checkbox, which, as you probably guessed, enables the DHCP server on the interface. There are also **Range** edit boxes where you can define the range of assigned addresses. If this is all you wanted to do, you can click on the **Save** button at the bottom of the page and the DHCP server will now be up and running.

There are other options available. The **Additional Pools** section allows you to specify additional pools of addresses outside of the range specified in **General Options**. You add address pools by clicking on the **Add pool** button and entering the new range. Once a new pool has been added, it will appear under the **Additional Pools** section, and you will be able to edit or delete the pool from the **DHCP Server** page.

You may want to set up your system so that only devices with certain MAC addresses receive DHCP leases. If so, check the **Deny unknown clients** checkbox. You will then have to scroll down to the **Other Options** section and click on the **Advanced** button next to the **MAC Address Control** section. In the **MAC Allow** edit box, specify the MAC addresses of the devices (as comma-separated values with no spaces) to which you want to allow access. If you want to deny access to certain devices, you can specify their MAC addresses in the **MAC Deny** edit box.

Be aware that MAC address control only provides a minimal level of security. A user who relies on auto-configuration to connect to the Internet will be locked out, but a determined hacker can easily resort to MAC address spoofing which, as you probably know, is one of pfSense's capabilities. Therefore, it's not a good idea to rely on MAC address control as a security measure.

There may be devices on your network which need to have the same IP address at all times. For these devices, you can rely on static mappings. If you scroll down to the bottom of the page, you will find a section labeled **DHCP Static Mappings for this Interface**. Below this heading and to the right, there will be an **Add** button which will launch a page on which you can add a mapping.

The first setting on this page is **MAC controls**. Here, you must enter the MAC address of the device which is to receive a static mapping. To the right of the **MAC controls** edit box, there is a **Copy My MAC** button that will copy the MAC address of the device currently being used to connect to pfSense; this is provided for your convenience.

The MAC address is the only field you must enter. If this is all you enter, this MAC address will be added to the list of allowed MAC addresses for the DHCP server. To obtain a static mapping for this device, you need to enter an IP address in the **IP Address** field.

There is also a **Hostname** field, in which you can specify the hostname, minus the domain. This field is optional, but, if specified, will be forwarded to the DNS server to help identify the client. Another optional field is **Description**, which just allows you to enter a text description of the static mapping. The **Client Identifier** field allows you to enter a client identifier string which will then be sent to the DHCP server. If the client identifier is specified, this identifier, along with the assigned network address, will be used by the DHCP server to identify the client, per RFC 2131. The **Client Identifier** field allows you to enter a client identifier string which, when specified, is used along with the assigned network address by the DHCP server to identify the client, per RFCs 2131 and 6842.

In the **Servers** section, you can specify both WINS servers and DNS servers. WINS servers provide Windows with a means of mapping NetBIOS names to network addresses. If you don't have a WINS server on your network, you can leave this blank. The **DNS Servers** fields need not be filled in most cases. If these fields are left blank and the DNS forwarder is enabled, pfSense will automatically assign itself as the DNS server for client PCs. If the DNS forwarder is disabled and these fields are left blank, the default DNS servers specified in **System | General Setup** will be used. There are, however, circumstances in which you may want to override either the default DNS servers or the DNS forwarder:

- When you need to specify custom DNS servers (for example, an Active Directory configuration in which Active Directory has its own DNS servers)
- If you are using **Common Address Redundancy Protocol** (**CARP**) in conjunction with the DNS forwarder, you should specify the CARP IP here

The **Other Options** section is reserved for less frequently used options. The **Gateway** field can be left blank if pfSense is the gateway for this interface. Otherwise, you can specify a different gateway IP here. When using CARP, you should enter the CARP IP address here. **Default Lease Time** and **Maximum Lease Time** control the DHCP lease time. The former is for clients that do not ask for a specific lease time, and the latter is for clients that ask for a specific lease time. If **Default Lease Time** is left blank, it will be 7,200 seconds; if **Maximum Lease Time** is left blank, it will be 86,400 seconds.

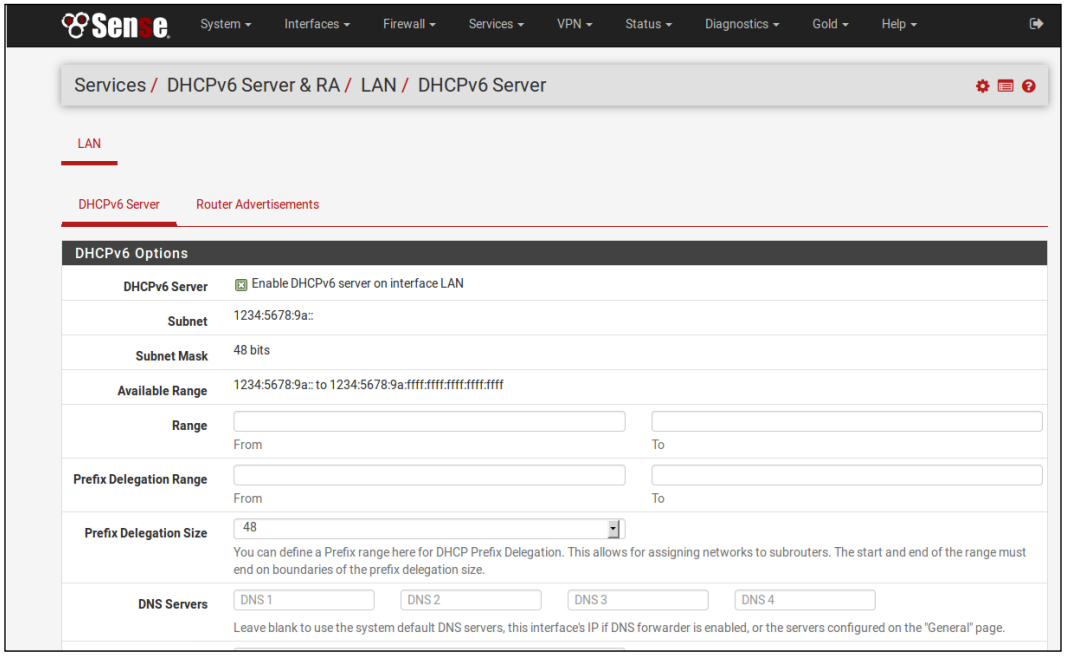
There is a **Failover Peer IP** field in which you can specify the failover peer IP address if this system is part of a failover group, such as a CARP cluster. The IP address specified should be the real IP address of the failover system, not the shared CARP address.

The **Enable Static ARP entries** checkbox works in a similar way to **Deny unknown clients** in that it will prevent any clients not specified on the **MAC allow** list from obtaining DHCP leases, but it will go even further than that. If this option is enabled, unknown clients will not even be allowed to communicate with pfSense. This prevents someone from circumventing DHCP restrictions by entering a static IP address.

If you want to register the client with a DDNS server, you can enter this information by scrolling down to **Dynamic DNS** and clicking on the **Advanced** button. The **Enable registration of DHCP client names in DNS** checkbox enables DNS registration. If you want to enable DDNS registration, you must fill in the **DDNS Domain** field. There are also fields for the primary domain name server IP address, as well as the DDNS key name and key secret.

DHCPv6 configuration in the web GUI

As with DHCP configuration on IPv4 networks, DHCP configuration on an IPv6 network (DHCPv6) has many options. This section will focus on options that are only available with DHCPv6 rather than options that are present in both DHCP and DHCPv6. To configure DHCPv6, navigate to **Services** | **DHCPv6/RA**.

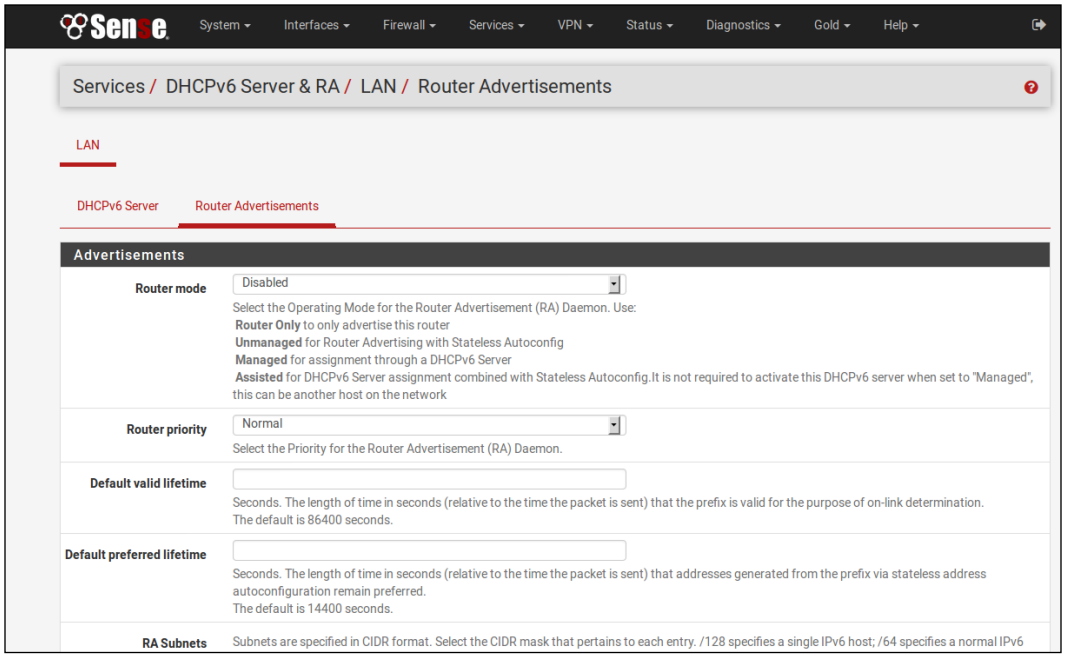


The DHCPv6 Server configuration page.

Under **DHCPv6 Options**, there are several useful settings. The purpose of the **Prefix Delegation Range** option, as the name implies, is to delegate to clients the ability to act as DHCPv6 servers. This is done by assigning portions of the subnet to them. To illustrate this, consider one of the common IPv6 prefix examples: `fd12:3456:789a::` with a subnet mask of `48`. The remaining bits are available for delegation, so we have an available range of `fd12:3456:789a::` to `1234:5678:9a:ffff:ffff:ffff:ffff:ffff`. We can delegate any subset of this range. The **Prefix Delegation Size** indicates the CIDR of the client's subnets. It must be on the boundaries of the range indicated in the **Prefix Delegation Size**.

In our previous example, we had a ULA with a prefix of `fd12:3456:789a::/48`. If we wanted our clients to receive portions of the subnet, then we could set a **Prefix Delegation Range** of `fd12:3456:789a:0000::` to `fd12:3456:789a:ff00::` with a **Prefix Delegation Size** of `56`. This would provide a maximum of 256 blocks of addresses to be delegated.

There is another tab on this page for **Router Advertisements** (**RA**). This enables an IPv6-capable router to advertise its presence to other routers, and keep other nodes informed of any changes in the network.



The Router Advertisements tab in pfSense.

On IPv4 networks, the DHCP server makes information about the gateway available. On IPv6 networks, this functionality is performed via RAs. You can set the **Router Advertisement** mode in the **Operating Mode** drop-down box. Selecting **Router Mode** results in the clients having to set their IPv6 addresses statically; they will not be assigned an address by the DHCPv6 server. A setting of **Unmanaged** results in the clients getting addresses through **Stateless Address Auto Configuration** (**SLAAC**). If the setting is **Managed**, client addresses will be assigned only by DHCPv6. Finally, **Assisted** is a hybrid mode, assigning client addresses by either DHCPv6, SLAAC, or both.

Most modern operating systems support both SLAAC and DHCPv6, so you should be able to choose either **Unmanaged** or **Managed** in most cases. If you are not sure which modes are supported on your systems, you can choose **Assisted** mode.

The **Default valid lifetime** field defines the length of time in seconds that the prefix is valid for the purpose of on-link determination. The **Default preferred lifetime** field defines the length of time in seconds that the addresses generated from the prefix via SLAAC remain preferred. The defaults are `86400` seconds and `14400` seconds, respectively.

The **RA Subnets** field allows you to specify subnets on which RA will take place. If no subnet is specified, the RA daemon will advertise on the subnet to which the router's interface is assigned. You must specify both the subnet and the CIDR mask. This option allows you to perform RA only on selected subnets.

The **DNS Servers** section allows you to specify different DNS servers than the default ones (the interface IP if **DNS Forwarder** or **Resolver** is enabled, or the servers configured on the **General** page if neither of these is enabled). In the **Domain search list**, you can specify an optional list, and there is also a **Use same settings as DHCPv6 server** if you just want the RA daemon to use the same DNS servers specified on the **DHCPv6** tab.

DHCP relay and DHCPv6 relay

Especially in larger networks, it is possible that you don't want to run the DHCP server on your system, but instead want to pass on DHCP requests to another server. In this case, you can use the pfSense DHCP relay, which can be found by navigating to **Services | DHCP Relay**. In order to use **DHCP Relay**, the DHCP server must be disabled on all interfaces. Note, however, that the DHCPv6 server may still be enabled. The converse is also true: in order to use **DHCPv6 Relay**, you must disable the DHCPv6 server on all interfaces, but you do not have to disable the DHCP server. Also note that if you later enable the DHCP server, the DHCP relay will be automatically disabled, and if you enable the DHCPv6 server, the DHCPv6 relay will be disabled.

To enable the DHCP relay, check the **Enable** checkbox. There is also an **Interface(s)** listbox where you can select the interfaces on which the DHCP relay will be enabled. If you want the DHCP relay to append the circuit ID (the pfSense interface number) and the agent ID, you should check the **Append circuit ID and agent ID to requests** box. The **Destination server** edit box allows you to specify the IP address of the DHCP server. You can specify more than one IP address; you can use the **Add** and **Delete** buttons to add/delete entries.

The DHCPv6 relay can be enabled by navigating to **Services | DHCPv6 Relay**. The settings for the DHCPv6 relay are identical to the settings for the DHCP relay.

DHCP and DHCPv6 leases

If you want to see what DHCP leases have been issued, navigate to **Status | DHCP Leases**. This page offers several pieces of information about active and inactive leases:

- The IP address of the lease.
- The MAC address of the client that has received the lease.
- The hostname of the client.
- A description of the client, if one is available.
- The start and end time of the lease.
- Whether the client is online, and the type of lease: static, active, inactive. Static is for statically mapped DHCP leases; active and inactive is for dynamically allocated leases. Active denotes those clients that are using their leases, while inactive is for inactive clients whose DHCP leases have not yet expired.

There are also two actions that can be performed on each lease in the table. The first plus (**+**) button on the right side of each entry is for **Add static mapping**. This allows you to easily create a static mapping for this client. What it does is take you to the **Edit static mapping** page with the MAC address field pre-filled with the MAC address of the client.

The second plus button is for **Add WOL mapping**. WOL stands for Wake on LAN, which, when invoked, sends a *magic* packet to the client that can be used to power on the client machine, assuming that the system's BIOS supports WOL. Clicking on this button takes you to the **Wake on LAN** page with the MAC address filled out with the client's MAC address. To wake the client, you must click on the appropriate MAC address in the **Wake-on-LAN-Devices** table on the **Wake on LAN** page.

If the lease type is static, there will also be an option on the right of the column to **Edit static mapping**. There will also be an option (denoted by an icon that looks like a power button) to **Send WOL packet to this client**.

The second section of the page, **Leases in Use**, is a table which shows all the different lease pools that have been defined, as well as the number of leases from each pool in use. The button at the bottom of the page allows us to toggle between showing all configured leases, or showing just the active and static leases.

To find out what DHCPv6 leases have been issued, navigate to **Status** | **DHCPv6 Leases**. All of the information about DHCP leases that the **DHCP Leases** page contains is contained on the **DHCPv6 Leases** page with respect to DHCPv6 leases. The **Leases** table also has two additional fields. **IAID** is each lease's Identity Association ID. An **Identity Association** (**IA**) is a collection of addresses assigned to a client, and each IA has its own ID – the IAID. **DUID** is the DHCP Unique Identifier, which is a globally unique identifier each DHCPv6 client and server has for identification purposes.

There is a second table on this page called **Delegated Prefixes**. The purpose of this table is to list all prefixes that have been assigned to clients, so they can act as routers. Once again, the IAID and DUID are present in the table, as well the **Start** and **End** time of the delegation, and the **State** of the delegation. Note that a client must request a delegation from pfSense before it appears in this table.

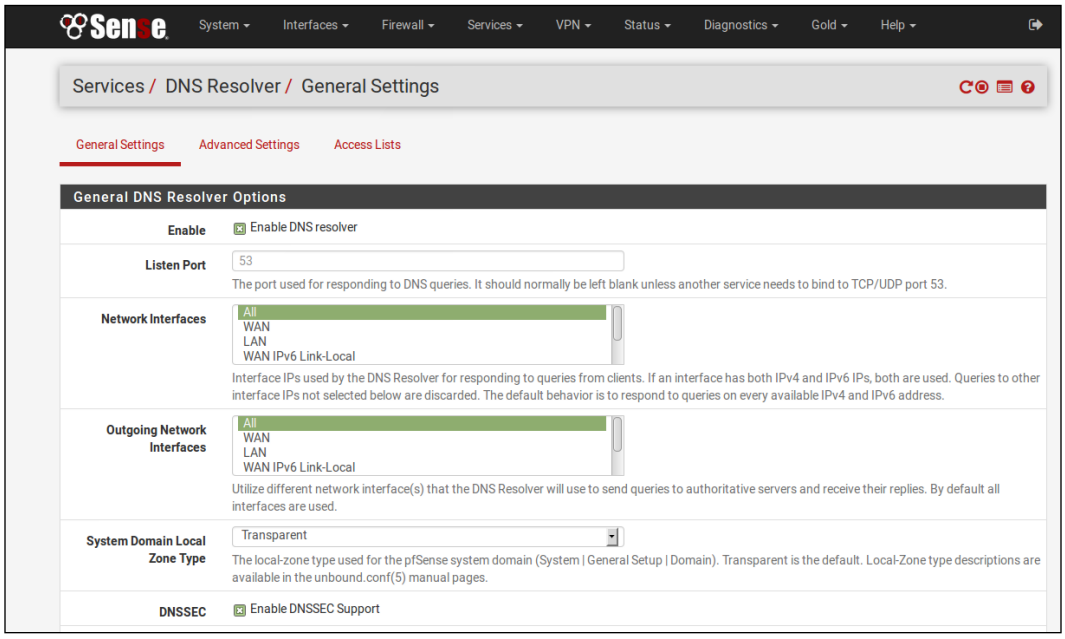
DNS

In a small network, you may never have the occasion to set up your own DNS server. However, there are compelling reasons to do so (for example, reducing administrative overhead and improving the speed of DNS queries), especially as our networks get larger. Fortunately, pfSense makes the process of implementing a private DNS server fairly easy.

It should be noted that pfSense has two separate services for DNS. Prior to version 2.2, DNS services were configurable via **Services** | **DNS Forwarder**, which invokes the **dnsmasq** daemon. For version 2.2 and later, **Unbound** is the default DNS resolver, and it is configurable by navigating to **Services** | **DNS Resolver**. New installs of version 2.2 or greater have **DNS Resolver** enabled by default, while upgrades from earlier versions will have **DNS Forwarder** enabled by default. You can still use **DNS Forwarder** on newer versions, but if you do, you will have to disable **DNS Resolver** or change the port settings for it. By default, both **DNS Forwarder** and **DNS Resolver** are configured to bind to port 53, and both services cannot bind to the same port.

DNS Resolver

Since **DNS Resolver** is the default resolver in the current version of pfSense, we will begin by looking at the options available for it. The first tab is labeled **General Settings**, and the first section on the page is **General DNS Resolver Options**. The first option is **Enable**, which enables **Unbound**, and is checked by default. The next option is **Listen Port**, which allows you to set the port used for responding to DNS queries. The default port is port 53 (DNS traditionally uses port 53 and the User Datagram Protocol, or UDP, although DNS also uses TCP for responses larger than a datagram, including DNSSEC and some IPv6 lookups, so take this into account when creating firewall rules for DNS).



The DNS Resolver configuration page. The DNS Resolver is the default DNS server in the current version of pfSense.

The **Network Interfaces** listbox allows you to select which interface IPs are used by **Unbound** to respond to queries from clients. Queries to interfaces not selected are discarded. If **Unbound** is enabled, however, you must select either **All** or **localhost** for this option. The **Outgoing Network Interfaces** listbox allows you to choose which network interfaces the **DNS Resolver** may use to send queries to authoritative servers and receive their replies.

When there is no domain match from local data, **System Domain Local Zone Type** determines how the **DNS Resolver** handles the query. There are several options available in this drop-down box:

- **Deny**: The **DNS Resolver** will only answer the query if there is a match in the local data. If there is no such match, then the query will be dropped silently.
- **Refuse**: This option is similar to **Deny**, except that when there is no match from the local data, the rcode **REFUSED** will be returned, so the client knows the query was refused.
- **Static**: The **DNS Resolver** looks for a match in the local data. If there is no match, it returns **nodata** or **nxdomain**, but it will also return the **Start of Authority** (**SOA**) for the root domain, provided that such information exists in the local data.
- **Transparent**: The **DNS Resolver** will answer the query from local data if there is match. If there is no match in local data, the query will be passed on to upstream DNS servers. If there is a match in the local data, but the type of data for which the query is being made does not exist in the local data, then the **DNS Resolver** will return a **noerror/nodata** message.
- **Type Transparent**: This option is similar to **Transparent**, but in cases in which there is a match in the local data but the type of data being asked for does not exist, the **DNS Resolver** will pass the query on to upstream DNS servers.
- **Redirect**: The **DNS Resolver** will attempt to answer the query from local data. If there is no local data other than the zone name, the query will be redirected.
- **Inform**: Identical to **Transparent**, except that the client IP address and port number will also be logged.
- **Inform/Deny**: Identical to **Deny**, except that the query will be logged.
- **No Default**: Default contents for AS112 zones will not be returned by queries.

The next option, enabled by default, is **Enable DNSSEC Support**. **DNSSEC** is a means of protecting DNS data from attacks which use forged or manipulated DNS data, such as DNS cache poisoning.

The **Enable Forwarding Mode** checkbox allows you to control whether **Unbound** will query root servers directly (if this option is unchecked) or if queries will be forwarded to the upstream DNS servers. You should only enable this option if the upstream DNS servers are trusted. If you have enabled DNSSEC support, and you consider this to be important, you should also make sure the upstream DNS servers provide DNSSEC support. Forwarding mode is necessary if you are using a **Multi-WAN** configuration which does not have default gateway switching.

Register DHCP leases in the DNS Resolver allows you to register DHCP static mappings. This in turn enables the resolving of hostnames that have been assigned IP addresses by the DHCP server. **Register DHCP static mappings in the DNS Resolver** is similar to **Register DHCP leases in the DNS Resolver**, except the former allows you to register DHCP static mappings instead of DHCP leases. The **Custom Options** button reveals a textbox when you click on it. You can enter any additional parameters here.

The next two sections are **Host Overrides** and **Domain Overrides**. **Host Overrides** allows you to configure a specific hostname to resolve differently than it otherwise would with the DNS servers being used by the DNS forwarder. This can be used for split DNS configurations; it also provides one possible way of blocking access to certain sites (although the user could always defeat this measure by simply entering the correct IP address of the target domain).

Domain Overrides is similar, except that it allows you to specify a different DNS server to use when resolving a specific domain. This can be useful in certain scenarios; for example, if you have a Windows Active Directory configuration and DNS queries for Active Directory, servers must be directed to Active Directory's DNS server.

The next tab is **Advanced Settings**. We will not cover all the settings that are configurable in this section, but here are some of the more interesting settings:

- **Prefetch DNS Key Support**: Enabling this option causes DNSKEYs to be fetched earlier in the validation process, thus lowering the latency of requests (but increasing CPU usage).
- **Message Cache Size**: This controls the size of the message cache, which stores DNS response codes and validation statuses. The default size is 4 MB.

- **Experimental Bit 0x20 Support**: The small bit size (16 bits) of a DNS transaction ID makes it a frequent target for forgery, which creates a security risk. One of the ways of improving the security of DNS transactions is to randomize the 0x20 bit in an ASCII letter of a question name. For example, the names `www.mydomain.com` and `WWW.MYDOMAIN.COM` will be treated the same by a requester, but could be treated as unequal by a responder. It can thus serve as a sort of covert encryption channel and make DNS transactions more secure.

The final tab is **Access Lists**, which enables you to allow or deny access to your network's DNS servers for specified blocks of network addresses (known as netblocks). This can be useful if you need to grant access to them for remote users (such as users connecting through a VPN), or to deny access to certain local netblocks. You can add an access list entry by clicking on the green **+Add** button below and to the right of the access list table.

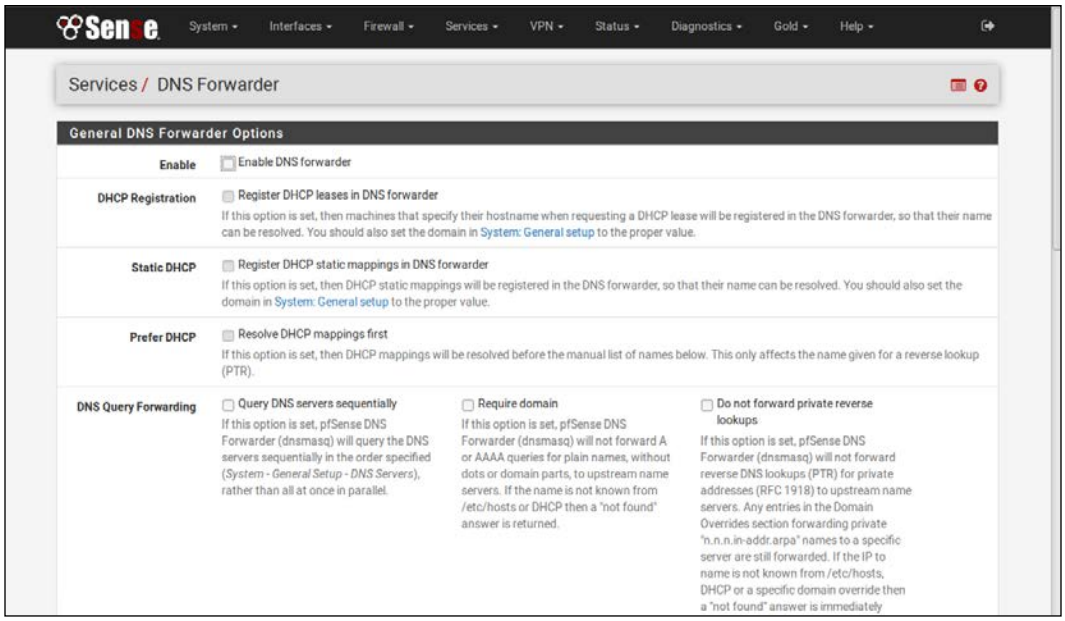
The first option is the **Access List name**, in which you can specify a name for the access list. The next option is the **Action** drop-down box, in which you can specify what to do with DNS queries that originate on the netblock defined by this access list entry. The options are as follows:

- **Deny**: Stops queries from the defined netblock. Queries are dropped silently.
- **Refuse**: Stops queries from the defined netblock. Instead of dropping the query silently, it sends back a DNS rcode **REFUSED**.
- **Allow**: Allows queries from hosts within the defined netblock.
- **Allow Snoop**: Similar to **Allow**, but allows both recursive and nonrecursive access from hosts within the defined netblock. This should only be configured for the administrator for such uses as troubleshooting.

The **Description** field allows you to enter a (non-parsed) description. Finally, the **Networks** field is where you enter the netblock (subnet) on which the access list takes effect. You must also select the CIDR of the subnet in the adjacent drop-down box. To the right, you can enter a description of this netblock. You can add the newly defined access list by pressing the green **Add Network** button at the bottom of the page.

DNS Forwarder

Although the **DNS Resolver** is the default DNS service in pfSense 2.2 and later, you can use **DNS Forwarder** instead. To do so, navigate to **Services | DNS Forwarder** and click on the **Enable DNS forwarder** checkbox (make sure to disable DNS Resolver first). Many of the settings for DNS Forwarder are identical to the DNS Resolver settings. In this section, we will focus on the settings which are unique to DNS Forwarder:



The DNS Forwarder configuration page.

As with the DNS Resolver, you can register DHCP leases and static mappings, but there is also an option called **Resolve DHCP mappings first**. Invoking this option causes the DHCP mappings to be resolved before the names provided in the **Host Overrides** and **Domain Overrides** tables.

The **DNS Query Forwarding** section has several unique options. The **Query DNS servers sequentially** checkbox, as the name implies, causes the DNS servers specified on the **General Setup** page to be queried sequentially instead of being queried at the same time. The **Require domain** checkbox will drop DNS queries from upstream servers if they do not contain a domain (in other words, queries for plain names). The **Do not forward private reverse lookups** option, if enabled, results in the DNS Forwarder not forwarding reverse lookups for RFC 1918 private addresses (`10.0.0.0` addresses, `172.16.0.0` to `172.31.0.0` addresses, and `192.168.0.0` addresses).

The **Strict interface binding** checkbox causes the DNS Forwarder to only bind to the IP addresses of interfaces selected in the **Interfaces** listbox. If this option is not enabled, DNS Forwarder will bind to all interfaces. Some of the settings available in the DNS Resolver are also available in the DNS Forwarder, such as the ability to set the port for resolving DNS queries, and the ability to bind only to selected interfaces. One significant limitation of the DNS Forwarder is that **Strict Interface Binding** does not work with IPv6 addresses. As with the DNS Resolver, the DNS Forwarder allows you to add **Host Overrides** and **Domain Overrides**, and there is a field for **Custom Options** as well.

DDNS

Although DNS changes propagate through networks relatively quickly, the distributed nature of DNS and the fact that it is not fully automated means that it may take several hours to distribute a DNS change. While this is adequate for a service that only changes its IP address infrequently, it can be a problem if your IP address changes more often. For example, if you are running a server on an ISP that assigns IP addresses via DHCP, your public IP address will likely change more frequently. This is where DDNS, which provides a means of rapidly updating DNS information, comes in handy.

DDNS actually refers to two separate services. The first involves using a client to "push" the DNS change out to a remote DNS server. The second involves updating traditional DNS records without manually editing them (this mechanism is specified by the IETF's RFC 2136). pfSense provides the ability to configure clients for use with both services, and we will cover both of them.

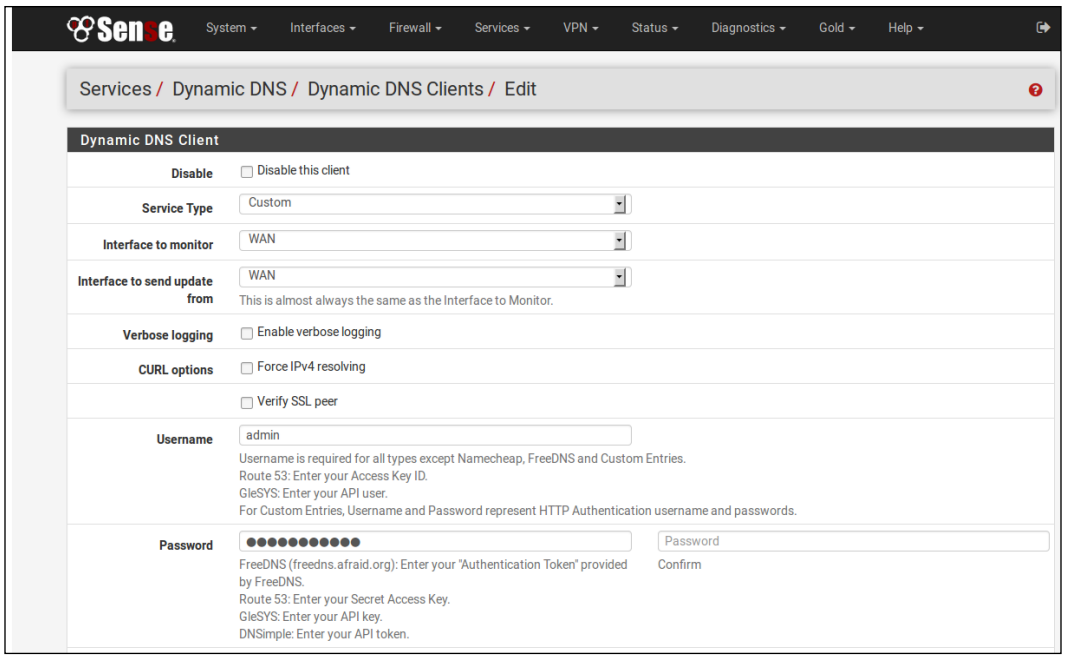
DDNS updating

DDNS updating without RFC 2136 can be configured by navigating to **Services** | **Dynamic DNS** and clicking on the **Dynamic DNS** tab (the first tab). This tab will show you a table with all the DDNS clients that have been added.

To utilize DDNS, you must first find someone that provides DDNS services. Your ISP may provide DDNS services; if not, there are several organizations that provide DDNS services for a variety of costs (some provide them for free). Cost, ease of use, and the existence of additional security features (such as invisible domains) are all factors you might consider when choosing a service.

Once you have chosen a DDNS service, you can begin the configuration process from your DDNS service's website. First, you will need to create at least one (sub)domain. Once you have created a domain, you need to find out the username and password (if any) that are required for the service, as well as the update URL. You should be able to find this information on the service's website.

Once you have this information, you can go back to the **Dynamic DNS** page in the pfSense web GUI, make sure you have selected the **Dynamic DNS** tab, and click on the green **+Add** button to add a DNS client. This will launch the client configuration page, as follows:



Configuring a (non-RFC 2136) DDNS client in pfSense.

The first option is the **Disable this client** checkbox. This allows you to enter the client information without activating DDNS. The **Service Type** drop-down box allows you to select your service from a number of options; many DDNS service providers are listed here (in some cases, there are multiple listings for the same provider). Select your provider here; if there is more than one listing for your provider, check your provider's website for guidance on which option to choose. If your provider is not listed, you can select **Custom**.

Note that if you select **Custom**, several options will appear below the **Service Type** drop-down box that would not appear otherwise. The **Enable verbose logging** checkbox, if checked, provides more detailed logging information. Normally, if both IPv4 and IPv6 addresses are enabled, IPv6 addresses will be preferred, but if you want IPv4 resolution instead, you can check the **Force IPv4 resolving** checkbox. Finally, **Verify SSL peer** will cause `libcurl` to verify peer certificates, thus providing the greatest possible level of security on SSL/TLS connections between pfSense and the DDNS provider.

If you do not select **Custom**, then the next option will be the **Interface to monitor** drop-down box. In virtually all cases, this should be set to **WAN**. In the **Hostname** edit box, you need to enter the fully qualified hostname of the hostname you added on your service provider's website. The **MX** edit box allows you to add an IP address of a mail server. Not all services allow you to set up a separate mail server, but if yours does, this is where you would specify it. The **Enable Wildcard** checkbox, if checked, causes anything typed before your domain name to resolve to your domain name: for example, if your domain name is `mydomain.duckdns.org`, `www.mydomain.duckdns.org` will resolve to `mydomain.duckdns.org`. **Enable verbose logging** provides for a more verbose level of logging, which can be helpful in troubleshooting.

Finally, the **Username** and **Password** fields are where you enter the username/password combination you got from your DDNS provider's website. You may be able to leave these fields empty; in other cases, you may have to enter an API user/key combination or some other key or token. Finally, in the **Description** field you can enter a brief description. Press the **Save** button at the bottom of the page to save the client information. This should return you to the page with the DDNS client table, and the entry you just made should be in the table.

Once you have entered the DNS client information, you still need a means of sending out DNS changes to your DDNS provider. This often comes in the form of updater software that must be run on one of your computers. Once the software is installed, the parameters that you must enter may include such things as:

- The domain which you want to update
- A token or some other kind of identifier
- The refresh interval (5 minutes, 10 minutes, and so on)

The software may also provide a means of forcing an update, so that when your WAN address changes, you don't have to wait for the automatic update. Your DDNS provider will have more detailed information on how to install and configure your updater software.

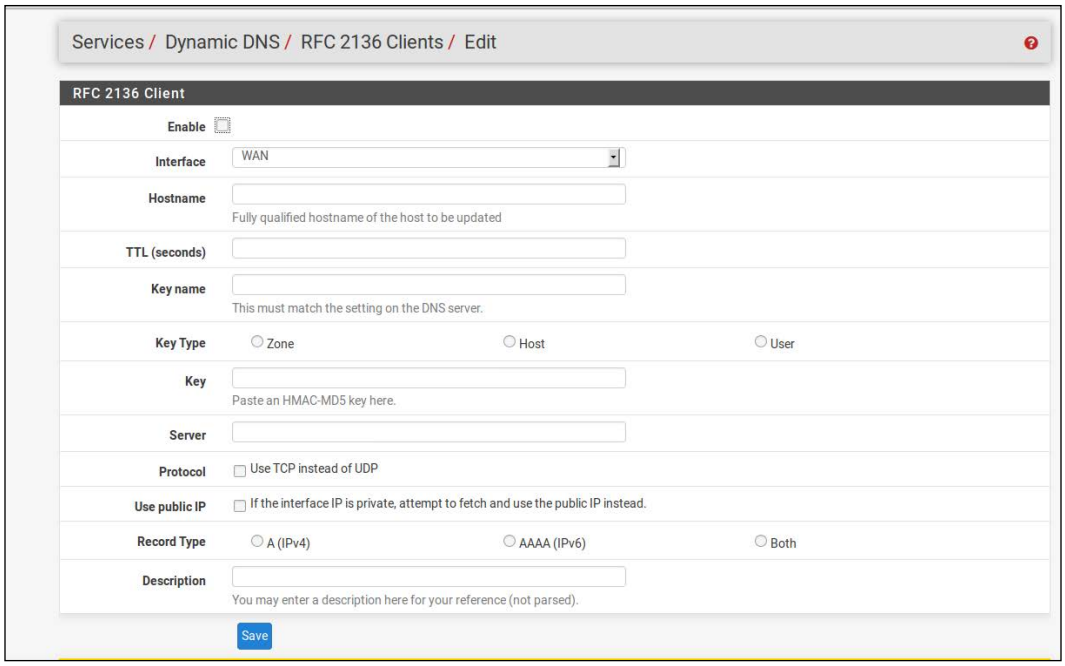
RFC 2136 updating

The other form of DDNS supported by pfSense is RFC 2136 updating. This form of DDNS is more like traditional DNS, and is the standardized method of dynamically updating DNS records. It offers the following advantages over the DDNS method described in the previous section:

- **More secure**: RFC 2136 uses **TSIG** (**Transaction Signature**), which uses shared secret keys and one-way hashing in order to provide a cryptographically secure means of authenticating DNS updates.
- **Good for enterprises**: RFC 2136 is supported by many enterprise-level applications, including such directory services as LDAP and Windows' Active Directory. It is also supported by BIND servers and Windows Server DNS servers.
- **Standardized**: Whereas the DDNS services described in the last section often must be configured in different ways depending on which provider you use, all systems that utilize RFC 2136 are following the same standard; thus, configuration is somewhat easier.

There are also some disadvantages to using RFC 2136. Wildcarding is not supported by this standard. Also, there does not seem to be a means of forcing updates, so it may take somewhat longer for updates to take effect.

You can get started with RFC 2136 configuration by navigating to **Services** | **Dynamic DNS** and clicking on the **RFC 2136** tab. You will see an RFC 2136 client table which is similar to the table on the **Dynamic DNS** tab. Click on the green **+Add** button below and to the right of the table to add a client.



Adding an RFC 2136 client.

While the DDNS client configuration page had a **Disable** checkbox, the RFC client configuration page starts off with an **Enable** checkbox that you must check for this client to be enabled. The next option is the **Interface** drop-down box. The selected interface should almost always be **WAN**. Next is **Hostname**, in which you must enter the fully qualified domain name of the host to be updated. Below that is **TTL**, or Time to Live, which controls how long the DNS record to be updated should be cached by caching nameservers. You will likely want to make this a relatively small number (smaller than the traditional 86,400 seconds), as this parameter controls how long a DNS server could be showing the old value after an update.

The next value is **Key Name**, which is whatever name you gave the key when you created it on your DNS server. Usually it is identical to the fully qualified domain name. The **Key Type** value must match the type of the key specified in **Key Name**; usually you can specify **Host** as the option. The **Key** field should be the secret key generated when you created the specified key.

In the **Server** field, you must specify the IP address of the DNS server the client will be updating. The next option is the **Use TCP instead of UDP** checkbox. DNS uses TCP for zone transfers and for queries larger than 512 bytes and UDP for name queries, so in most cases, you should leave this unchecked. If you are updating a zone record, however, you will want to check this box. You should probably check this box, especially if you are using DNSSEC and/or IPv6.

The **Use public IP** checkbox will attempt to use the public IP address to fetch if the DNS server's IP address is private. The **Record Type** option allows you to specify whether the client should update A records (for IPv4), AAAA records (for IPv6), or both. Finally, in **Description** you can enter a brief (non-parsed) description of this entry. Click on the **Save** button to save the entry, and you should be returned to the client table with the new entry in the table.

Troubleshooting DDNS

If you tried to implement dynamic DNS but it is not working, there are several potential causes. If you are using DDNS via a DDNS provider, you should confirm that you set up the domain correctly and also confirm that your provider's service works with pfSense. Once you have done that, you should go through the client configuration step-by-step. Many DDNS providers have instructions for different routers, including pfSense routers, and if such instructions are available, you should follow them. Also, make sure you have installed and configured your provider's updater software correctly. If you have gone through all of these steps and DDNS is still not working, you may want to contact your provider's technical support, if such support is available.

If you are trying to implement RFC 2136 DDNS, the process involves setting up the initial records on the DNS server, generating the keys, and configuring the client under pfSense. You need to make sure both the server and client configuration were done correctly. Some possible sources of problems include:

- The TTL setting is too long, which could result in cached nameservers not updating quickly enough
- Not setting the client up to update IPv6 (AAAA) records in an environment where IPv6 is being used – check the **Record Type** setting
- Trying to update a zone record without checking the **Use TCP instead of UDP** checkbox

Another point that seems fairly obvious but is worth mentioning is that you need to check DDNS functionality from the other side of the firewall. This is especially true if you have services that rely on NAT port forwarding. In most cases, NAT is configured to forward traffic to certain ports only if they come in on one of the WAN interfaces. Since internal traffic does not come in on a WAN interface, NAT will not be invoked, and no port forwarding will take place.

Captive portal

If you are making your Internet connection available for other people to use, you may want to redirect users to a login page to control access. Even if you don't want to require authentication, you may still want to redirect users to a page containing your terms of service. This is common in cases where you are allowing wireless access to your network: for example, you run a business that gives customers free wireless Internet access. In such cases, you can utilize pfSense's captive portal service. Captive portal can be used to redirect wireless users to a login page, and it can also be used for wired users. Earlier versions of pfSense were limited to use of one interface on your firewall, but the current version allows you to enable captive portal on multiple interfaces.

Implementing captive portal

To get started implementing a captive portal on your network, navigate to **Services | Captive Portal**. This page displays a table with all of the defined captive portal zones. There is a green **+Add** button below and to the right of the table; pressing this button allows you to add a zone.

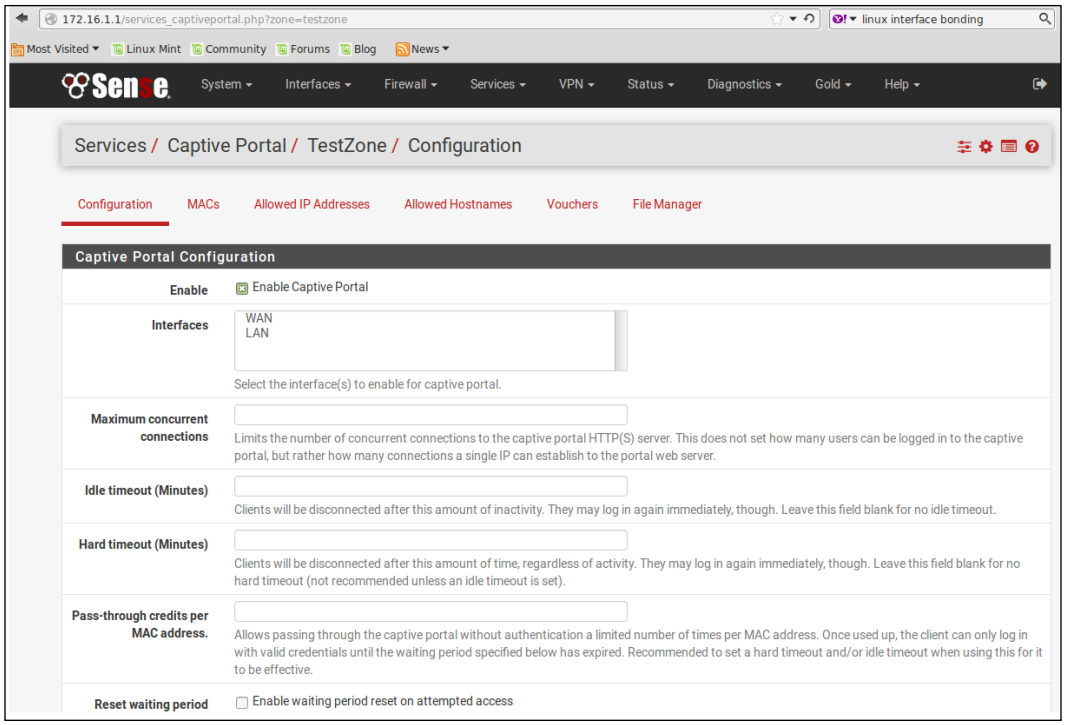
When you add a zone, you are initially directed to the **Add Zone** page. Here you are required to enter **Zone Name**, which can only contain letters, digits, and underscores. You can also enter a brief (non-parsed) description in the **Description** field. Enter this information and press the **Continue** button.

Now we will be directed to the **Configuration** page, where we are presented with a warning which contains the following information:

- Make sure to enable the DHCP server on the captive portal interface
- Make sure the maximum DHCP lease time is longer than the captive portal hard timeout
- Make sure the DNS Forwarder or DNS Resolver is enabled, or DNS lookups will not work for unauthenticated clients

To begin configuration, check the **Enable Captive Portal** checkbox. Once this box is checked, the other options will appear on the page. The first option is the **Interfaces** drop-down box, in which you select the interface on which captive portal will be enabled. In most scenarios where you are setting up a captive portal, you probably want to have a separate interface or interfaces for captive portal users. The next option is **Maximum concurrent connections**. This controls not how many users can be logged into the captive portal, but rather how many concurrent connections are allowed per IP address.

The next two settings are **Idle Timeout (Minutes)** and **Hard Timeout (Minutes)**. **Idle Timeout (Minutes)** controls how long it is before an idle client is disconnected, while **Hard Timeout (Minutes)** controls how long it is before a client is disconnected even if they are active. Both settings are optional and leaving them blank disables them.



The Configuration tab on the captive portal configuration page.

The next setting is the **Pass-through credits per MAC address.** edit box. Entering a number here allows a client to pass through the captive portal this number of times without being directed to the captive portal page. Once this number is exceeded, the user is directed to the captive portal login page again. As the name implies, this is done on a per-MAC address basis.

The **Reset waiting period** checkbox, if checked, will result in the waiting period on login attempts being imposed on clients whose pass-through credits have been exhausted. If not checked, such users will be allowed to login again immediately. The **Logout popup window** checkbox, if checked, will display a pop-up logout page when the users initially pass through the captive portal. This can be used to allow users to explicitly log out, but it also can be used if you want to display a page informing the user that they have successfully passed through the captive portal.

There are three options covering URL redirects. You can specify a URL on another server by entering it in the **Pre-authentication redirect URL** edit box. After accessing this page, the user will be redirected to the login page. Normally, after login, the user will be able to access the URL they tried to access before logging in, but if you set **After authentication Redirection URL**, you can redirect them to a different page. If you want users whose MAC addresses were blocked to be informed so, you can set the **Blocked MAC address redirect URL**.

If you check the **Disable MAC filtering** checkbox, then the captive portal will not check to confirm that a user's MAC address remains the same during their session. This can be helpful in cases where pfSense cannot confirm the user's MAC address (for example, in cases where the user is separated from the pfSense system by several routers). The downside of this option is that when MAC filtering is disabled, RADIUS MAC authentication is not possible.

The **Enable Pass-through MAC automatic additions** option, if checked, will result in a MAC passthrough entry being added for every user who successfully authenticates (or in cases where authentication is not required, every user who successfully passes through the captive portal). Users of the authenticated MAC address will not have to log in again, unless the MAC passthrough entry is removed from the table on the **MAC** tab.

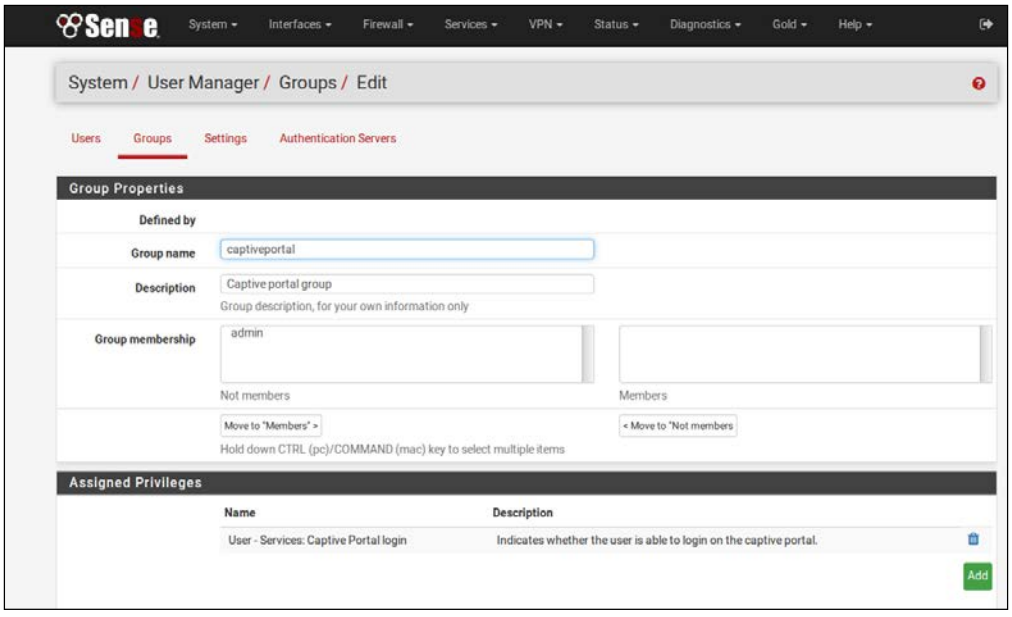
The **Enable Pass-through MAC automatic addition with username** option takes effect only if it is checked and the **Enable Pass-through MAC automatic additions** option is also checked. If both are checked, the username used during authentication will be saved.

The **Enable per-user bandwidth restriction** option, if checked, allows you to restrict each user who logs in to a specified bandwidth. If you enable this option, you need to specify a **Default download** and **Default upload** in the next two edit boxes. RADIUS can override these default settings.

The next section of the page is called **Authentication**. There are three options for authentication: **No Authentication**, **Local User Manager/Vouchers**, and **Radius Authentication**. If you choose **No Authentication**, users on interfaces on which the captive portal service is active will be directed to a captive portal page, but no login will be required.

If you choose **Local User Manager/Vouchers**, then authentication will take place either through the pfSense **User Manager**, or via voucher authentication. If you want to utilize the user manager, navigate to **Services | User Manager**. You will then need to add as many users as you need to for captive portal access. It might also be a good idea to set up a separate group for captive portal users, and you can do that by clicking on the **Groups** tab. Once there, you can click on the **+Add** button on the right side of the page below the table to add a group. There is a single section on this page titled **Group Properties**, and in this section, you need to enter a **Group Name**. You can also enter a description in the **Description** field. In the **Group membership** listboxes, you can add other groups to which you want members of the new group to belong. Once you are done, press the **Save** button.

We still haven't assigned captive portal privileges to the newly created group, so once you are redirected to the table, find the group in the table and, under the **Actions** column, click on the **Edit group** icon (the pencil). Once again, the **Group Properties** section is there, but underneath it is a section called **Assigned Privileges** where, as you probably guessed, you can assign privileges to the group. Clicking on the **Add** button will enable you to add privileges. This will load a page with a listbox with many options; for this group we want to select **User – Services: Captive Portal login**. Select this and click on the **Save** button at the bottom of the page. This will take you back to the previous page, so you need to click on the **Save** button on that page, which will return you to the main **Groups** page. We have created a group with captive portal login privileges.

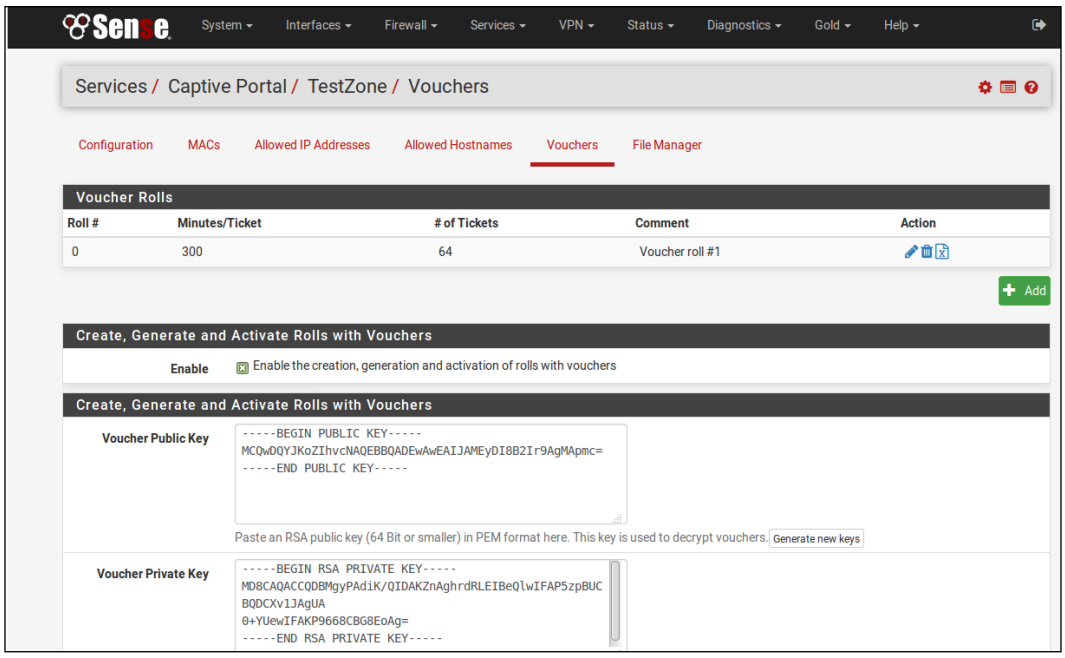


Creating a group with captive portal login privileges.

Now you need to go back to the **Users** tab and add users to the group that you created in the previous step by pressing the **+Add** button, adding information for each user, pressing the **Save** button, and repeating the process for as many users as you need to add. At a minimum, you need to enter a username and password for each user, and make the user a member of the new group. There are also options to create a user certificate, add an SSH key (so the user can connect to pfSense via SSH without entering a username/password combination), and a field for an IPsec pre-shared key.

Now that we have created some captive portal user accounts, we can return to the **Captive Portal** configuration. Note that below the radio buttons where we select the authentication mention, if **Local User Manager/Vouchers** is selected, there is an **Allow only users with "Captive Portal login" privilege set** checkbox. Although this checkbox is selected by default, when we click on the **Local User Manager/Vouchers** radio button, we can uncheck it, thus eliminating the need to create a group with this privilege added to it.

You can also use vouchers for authentication, and this is done by clicking on the **Vouchers** tab under **Captive Portal**. This page has two sections: **Voucher Rolls**, which shows any existing vouchers, and **Create, Generate and Activate Rolls with Vouchers**. The **Enable** checkbox, when checked, begins the process of creating vouchers.



Creating voucher rolls for a captive portal.

The next two fields are for the **Voucher Public Key** and the **Voucher Private Key**, as shown in the preceding screenshot. Here, you should paste an RSA public key and RSA private key (64 bits or smaller). The next field is **Character set**; this defines the characters contained in the generated tickets. You can probably keep the default value. The **# of Roll bits** field reserves a range in each voucher to store the roll number to which it belongs. The **# of Ticket bits** field reserves a range in each voucher to store the ticket number to which it belongs. Finally, the **# of Checksum bits** field reserves a range in each voucher to store a checksum over the roll number and ticket number. The sum of roll, ticket, and checksum bits must be one less bit than the RSA public/private key.

The **Magic number** field defines a magic number to be stored in each voucher, which is only stored if there are bits left over in the roll, ticket, and checksum bits. The **Invalid voucher message** and **Expired voucher message** fields define messages to display when the voucher is invalid and expired, respectively.

The **Voucher Database Synchronization** section of the page allows you to enter the master voucher database ID, sync port, and username/password combination. If this node is the master voucher database node, or if it will be the only node using vouchers, you can leave these fields blank. Press the **Save** button at the bottom of the page when you are done.

When the **Voucher** page reloads, there will be a new section at the top of the page called **Voucher Rolls**. You can generate new voucher rolls by pressing the **+Add** button below the table on the right side. There are fields for the **Roll #** (the number found on top of the generated vouchers), the **Minutes per ticket** (the time in minutes a user is allowed access), and **Count** (the number of vouchers generated). There is also a **Comment** field where you can enter a non-parsed comment. When you have filled out these fields, press the **Save** button.

When you return to the main **Voucher** page, the newly created voucher roll will be listed in the table at the top. Under the **Action** column, you can click on the **Export vouchers** icon (the sheet) to download the voucher roll as a `.csv` file. The file contains a series of vouchers that can be used for captive portal authentication. In order to accept captive portal login via vouchers, your portal login page must include the following field:

```
<input name="auth_voucher" type="text">
```

The third authentication option is **RADIUS Authentication**. RADIUS, or Remote Authentication Dial-In User Service, provides a means of centralized authentication, authorization, and accounting for network users. To use RADIUS to authenticate captive portal users, you must have a RADIUS server. It is beyond the scope of this book to explain how to configure a RADIUS server, but we will cover some of the more important RADIUS options on the **Captive Portal Configuration** page.

pfSense supports several protocols for sending and receiving data from the RADIUS server. **Password Authentication Protocol** (**PAP**), **Challenge Handshake Authentication Protocol** (**CHAP**), MS-CHAPv1, and MS-CHAPv2 are all supported. You can supply a **Primary Authentication Source** and **Secondary Authentication Source**, each of these having a **Primary RADIUS Server** and **Secondary RADIUS Server**. You can supply an IP address, port, and shared secret for each. Entering an IP address for each RADIUS server used is required. If the **RADIUS port** field is left blank, pfSense will use the default RADIUS port. Entering **RADIUS shared secret** is not required, but is recommended.

One of the authentication options under **RADIUS Options** is the **Reauthenticate connected users every minute** checkbox. If this option is enabled, pfSense will send Access-Requests to RADIUS for each user every minute. If an Access-Reject is received for any user on one of these requests, the user is disconnected from the captive portal immediately. There is also an option called **RADIUS MAC Authentication**. Checking this box will cause RADIUS to try to authenticate captive portal users by sending their MAC address as the username and the **MAC authentication secret**, specified in the next edit box, as the password.

The last two sections of the page are **HTTPS Options** and **HTML Page Contents**. **HTTPS Options** initially has a single option: the **Enable HTTPS login** checkbox, which when checked, will cause the captive portal username and password, over an HTTPS connection, to take advantage of the SSL encryption such a connection provides. If this box is checked you must provide the HTTPS server name and the SSL Certificate. The server name should match the **Common Name** (**CN**) in your certificate.

By default, when HTTPS login is enabled, clients can connect to the captive portal via HTTPS. You can prevent this by checking the **Disable HTTPS Forwards** checkbox, in which case attempts to connect to port 443 sites will not be forwarded to the captive portal. Users will then have to attempt a connection to port 80 to get forwarded to the captive portal.

The final section, **HTML Page Contents**, is where you can upload the captive portal pages. A minimal knowledge of HTML or PHP is required to create these pages, and if you don't want to create your own, you should be able to find sample captive portal pages that you can use (some may require some slight modification for your needs). The pages you can upload are the **Portal page contents** (the actual captive portal login page), **Auth error page contents** (the page to display when an authentication error occurs), and **Logout page contents** (the page to display on authentication success when the logout popup is enabled, and which may or may not contain an option to log out of the captive portal). When you have uploaded these pages, you will be done with configuration of this captive portal zone, and you can press the **Save** button at the bottom of the page.

There are several other options on other tabs worth mentioning. The **MACs** tab allows you to control access to the captive portal based on MAC addresses. Clicking the **+Add** button on this page allows you to add a MAC address. Once you do this, you will be at the **Edit MAC Address Rules** page. Here you can specify a **MAC address** (the button to the right of this option allows you to copy your MAC). The **Action** drop-down box allows you to choose what to do with traffic from this MAC address (the options are **Pass** and **Block**). You can also specify **Bandwidth up** and **Bandwidth down** limitations for the MAC address (in Kbit/s), as well as a non-parsed description in the **Description** field.

The **Allowed IP Addresses** tab allows you to control captive portal access by IP address. Clicking on the **+Add** button on this page takes you to the **Edit Captive Portal IP Rule** page. At a minimum, you must enter the IP address and the CIDR of the address. You can also specify the direction of the access. **From** allows access from the client IP through the captive portal. **To** allows access from all the clients behind the portal to the IP. The **Both** option allows traffic in both directions. As with MAC addresses, you can specify **Bandwidth up** and **Bandwidth down** for the specified IP address.

The **Allowed Hostnames** tab allows you to control captive portal access based on hostname. Again, the **+Add** button on this tab allows you to add entries. You need to enter a hostname in the **Hostname** field, and, as with **Allowed IP Addresses**, you can control the direction of the access, as well as **Bandwidth up** and **Bandwidth down**. You may also enter a non-parsed description in the **Description** field.

The **File Manager** tab, as the name implies, allows you to upload files. Any files you upload via this tab with the filename prefix of `captiveportal-` will be made available in the root directory of the captive portal server. This is useful if you have files which you want to reference in your portal page (for example, a company logo). In addition, you can upload PHP files for execution. The total size limit for all files uploaded via this tab is 1 MB. To add a file, click on the **+Add** button, which is below the **Installed Files** table and to the right. This loads a separate page where you can upload the file. Click on the **Browse** button to launch a file dialog box, select a file, click on the **Open** button in the file dialog box, and then click on the **Upload** button.

Troubleshooting captive portal

pfSense's captive portal service has many options, which means that there are many more things that can go wrong with captive portal access. We can divide these issues into two general categories:

- Authentication issues (client cannot authenticate, even with seemingly valid credentials)
- Client can establish a captive portal connection, but some other aspect of the service is not working (for example, DNS is not functioning, websites are blocked, and so on)

We will first consider authentication issues. The authentication options are **Local User Manager/Vouchers** and **RADIUS Authentication**. If you are using the local user manager, you should confirm that you have created the user accounts correctly and, if **Allow only users/groups with "Captive portal login" privilege set** is checked, you should confirm that the users have this privilege. You can, of course, disable this option and see if the users can connect to troubleshoot the issue. If you are using vouchers to authenticate, you should confirm that your captive portal login page has `<input name="auth_voucher" type="text">` for entering the voucher.

One possible issue that might arise is that you are trying to use MAC addresses for authentication, but the captive portal service cannot confirm that the MAC address is correct. This could happen if there is a router between the captive portal client and pfSense, and this issue could occur both in cases where a RADIUS server is being used for authentication, and without a RADIUS server. For troubleshooting, you might try allowing users access by IP address and see if this works. If it does, there's a good chance pfSense is unable to confirm the MAC address.

One other possibility is that the user is trying to access the captive portal page through HTTPS, but your captive portal zone is only configured for HTTP access. In this case, the solution is for the user to try again with HTTP at the beginning of the URL.

One problem that has been reported is that sometimes, when using captive portal on a VLAN, the captive portal page will not load. This apparently happens when the parent interface of the VLAN is also being used as a separate interface on pfSense. To prevent this problem, when a parent interface is partitioned into VLANs (VLAN1, VLAN2, and so on), the parent interface (for example, OPT1) should not be used separately; only the VLANs should be used.

If a RADIUS server is being used for authentication, then the problem could be either a client or server issue. The RADIUS server may be misconfigured, or it may be down entirely. If you have confirmed that the RADIUS server is functioning properly, the problem may be an incorrect configuration of pfSense. The log files can be helpful in further pinpointing the exact problem. Navigate to **Status | System Logs** and click on the **Captive Portal Auth** tab. If pfSense cannot connect to the RADIUS server at all, you should check the IP address/port settings for the RADIUS servers, as well as the shared secret.

The second category of issues is when the user is able to pass through the captive portal, but there are other issues. For example, the user may be having DNS issues. Once again, a good indication that a problem is related to DNS is when you can ping the IP address of a site, but you cannot ping the hostname. DNS is likely not functioning if pinging a valid hostname (for example, `google.com`) returns the following result:

```
ping: unknown host google.com
```

If you are running the command prompt under Windows, the response might look like this:

```
Ping request could not find host google.com. Please check the name and
try again.
```

If it looks like DNS resolution is the problem, you should check to make sure either DNS Forwarder or DNS Resolver is running, but not both. If you have confirmed that one of these is running and you are still having problems, the issue may be a DNS server that is down or is not configured properly.

If the user cannot access certain websites, the problem may be that the firewall or proxy server has blocked access to the site. You should navigate to **Firewall | Rules** and check to see if there are any rules for the captive portal interface that might block access. Proxy servers usually have the capability of blocking websites, so if you are running one, you will want to check the settings for the proxy server. We will cover both firewall rules and proxy servers in greater depth in future chapters.

NTP

NTP is an application layer protocol that controls the synchronization of various devices over the Internet to within a few milliseconds of **Coordinated Universal Time** (**UTC**). NTP is hierarchical, with servers organized into different strata. At stratum 0 are high-precision time devices such as atomic clocks. At Stratum 1 are computers that are synchronized within a few microseconds to their directly connected Stratum 0 devices. At Stratum 2 are computers that are directly connected to Stratum 1 computers, and so on. Synchronization is achieved by adjusting the system time based on an offset. The offset is calculated by taking an average of the differences of the timestamps on request and response packets between the client and the server. The clock frequency is then adjusted to reduce the offset gradually, and the newly adjusted clock provides timestamps for the next request and response packets, creating a feedback loop known as clock discipline.

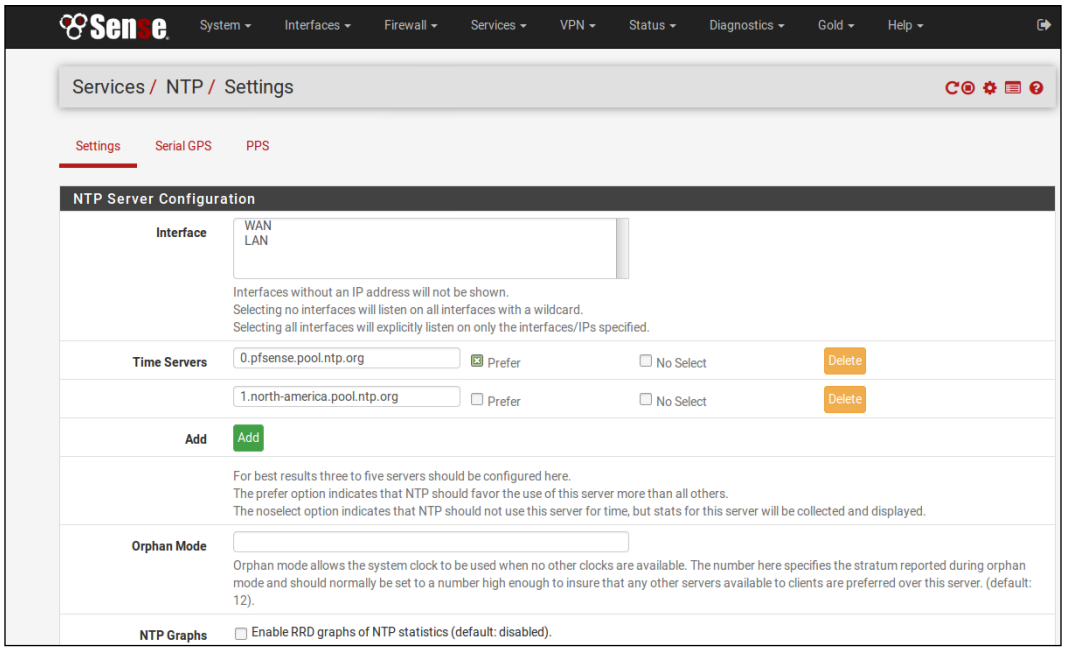
NTP is often overlooked, mainly because it does its job and in pfSense, it requires minimal configuration. You may recall that in the **Setup Wizard**, you were asked to specify a time server, but a default time server was provided. Many users will give no further thought to NTP configuration. You may, however, have reason to deviate from the default settings:

- Your pfSense system may be involved in validating certificates as part of a PKI infrastructure, in which case time synchronization is essential
- You may be running pfSense on an embedded system which does not have a battery to preserve the time and date settings
- Even if you don't fall into either of these categories, maintaining the proper time is still important, since it determines the timestamp on logs

pfSense's NTP service provides for synchronization via a conventional NTP server, as well as from **Global Positioning System** (**GPS**) devices and **Pulse Per Second** (**PPS**) devices. We will cover all of these methods in this section.

NTP configuration

To begin NTP configuration, navigate to **Services** | **NTP**, as shown in the following screenshot. The **NTP** page has three tabs and the first (and default) tab is **Settings**. The first option on this page is the **Interfaces** listbox, in which you can select the interfaces on which the NTP service will listen. The default setting is to listen on all interfaces, but since the NTP server is probably upstream, you can select **WAN** as the only interface on which to listen (or multiple WAN interfaces if you have them).



Configuring basic NTP settings in pfSense.

The next option is **Time Servers**. The time server you specified when you initially configured the system will be listed here, but you can also specify additional servers by clicking on the **Add** button. You need to specify the hostname. You can optionally check either the **Prefer** or **No Select** option. **Prefer** indicates that the NTP services should favor this server over all others. **No Select** indicates that NTP should not use this server for time, but it will collect and display stats from the server. You can check more than one **Prefer** checkbox, but when you save the settings, only the first **Prefer** checkbox on the list that you checked will remain checked.

The **Orphan Mode** option allows pfSense to use the system clock when no other clocks are available. The number entered in this edit box specifies the stratum reported during orphan mode. You might recall that stratum indicates how close the computer is to a high-precision time device; higher numbers indicate that the device is further away from such a device and thus have a lower priority. Whatever number you set here should be high enough to ensure that all other servers are preferred over this server. The default is 12.

The **NTP Graphs** checkbox, if enabled, generates **round-robin database** (**RRD**) graphs of NTP data. You can view these graphs by navigating to **Status | RRD Graphs** and clicking on the **NTP** tab. The next two subsections involve logging options. **Log peer messages**, if enabled, logs messages between the NTP client and server, while **Log system messages** logs other messages generated by the NTP service. **Log reference clock statistics** logs statistics generated by reference clocks, which are generally radiotime code receivers synchronized to standard time (for example, a GPS or PPS device). **Log clock discipline statistics** logs statistics related to the clock synchronization process, while **Log NTP peer statistics** logs statistics related to NTP client/server communication.

The next subsection is **Access Restrictions**, and it contains a number of important options. The first option is **Enable Kiss-o'death packets**. When checked, this enables the client to receive kiss-of-death packets, which are packets sent by the NTP server to tell the client to stop sending packets that violate server access controls. This in turn will cause the client to stop sending data to the server. The next option is **Deny state modifications by ntpq and ntpdc**. The `ntpdc` daemon queries the `ntpd` daemon about its current state and then requests changes to that state. If this option is checked (the default), then ntpdc's change requests will be denied. The next two options are inverses of each other: **Disable ntpq and ntpdc queries** and **Disable all except ntpq and ntpdc queries**. **Deny packets that attempt a peer association**, if checked, will block any peer associations that are not explicitly configured. Finally, **Deny mode 6 control message/trap service**, if enabled, will decline to provide mode 6 control message trap service to hosts. This service is a subsystem of mode 6, which is intended for use for remote event logging.

The final option on this page is **Leap seconds**. **Leap seconds** have been implemented to keep UTC close to mean solar time, and are added to UTC on an average of one per 18 months. This option allows the NTP service to advertise an upcoming leap second addition or subtraction. You must add a leap second configuration routine in order to do this; it can be pasted into an available edit box or uploaded in a file. Configuring this option is only important if your NTP server is a Strata 1 server, in which case it likely has other NTP servers making queries to it. When you are done configuring these options, you can press the **Save** button at the bottom of the page.

If configuring all these options doesn't provide enough accuracy for you, you can always connect either a GPS or a PPS device to the serial port and use it as a reference clock. Also, if the GPS device supports PPS, it may be used as a PPS clock reference. Using a USB GPS is not recommended owing to USB bus timing issues; however, a USB GPS device may work.

You can configure a GPS device, by clicking on the **GPS** tab. The first option is the **GPS Type** drop-down box, which lets you select a predefined configuration. If your GPS type is listed in the box, you should select that type. If it is not listed, you should select **Generic**. Selecting **Default** is not recommended.

The next option is the **NMEA Sentences** listbox. NMEA defines an electrical and data specification for communication between marine electronics; GPS is but one of the types of devices that utilize it. There are different NMEA sentence types, and they are listed in this listbox. If you know what sentence type your device uses, you can select it here; otherwise, you can leave it set to **All**.

The **Fudge Time 1** edit box allows you to specify a GPS PPS signal offset, while **Fudge Time 2** allows you to specify the GPS time offset. The **Stratum** edit box allows you to set the GPS clock stratum. Normally you would probably want to set it to `0` (and that is the default value), but you can change it here if you want ntpd to prefer a different clock.

There are several flags you can set. Prefer this clock, as the name implies, causes the GPS clock to be preferred over all other clocks. If you went through the trouble of setting up a GPS clock, you probably want to use it, but if you don't, you can check the **Do not use this clock, display for reference only** checkbox. The **Enable PPS signal processing** checkbox, if enabled, treats the GPS as a PPS device. By default, PPS processing occurs on the rising edge of the pulse, but checking **Enable falling edge PPS signal processing** will cause processing to occur on the falling edge. The **Enable kernel PPS clock discipline** checkbox, if checked, will result in NTP using the `ppsu` driver, which reduces incidental jitter sometimes associated with PPS clocks. Normally, the GPS will send location data to ntpd, but if you check the **Obscure location in timestamp** checkbox, it won't. Finally, if you need to fine tune the GPS time offset (**Fudge Time 2**), you may want to check the **Log the sub-second fraction of the received timestamp** checkbox.

In the **Clock ID** edit box, you can enter a GPS clock ID. If the **Advanced** button in the **GPS Initialization** subsection is clicked, you will see the GPS initialization commands, and you will also be able to edit them. Finally, **NMEA Checksum** allows you to calculate an NMEA checksum by entering an NMEA command string and pressing the **Calculate** button. The result will appear in the box to the right of the **Calculate** button. When you are done making changes, press the **Save** button at the bottom of the page.

If you have a serial PPS device such as a radio that receives WWV (time) signals, you can configure it by clicking on the **PPS** tab. The first option on this page is the **Fudge Time** edit box, which is used to specify the PPS signal offset. In the **Stratum** edit box, you can enter the PPS clock stratum. As with GPS devices, you probably want to leave it at **0** (the default), but you can change it here.

The first two flags, **Enable falling edge PPS signal processing** and **Enable kernel PPS clock discipline**, are identical to the flags available on the **GPS** tab. The only unique flag on this tab is the **Record a timestamp once for each second** option, which is useful in constructing frequency deviation plots.

The last option is the **Clock ID** edit box, which is identical to the **same** option on the **GPS** tab and simply allows you to change the PPS clock ID. When you are done making changes, click on the **Save** button at the bottom of the page.

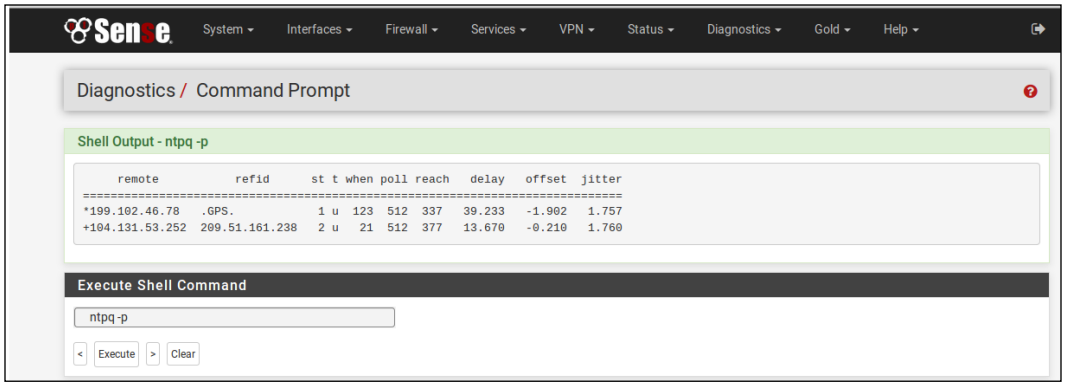
NTP troubleshooting

NTP is a fairly straightforward protocol, and unless you are using some of the more esoteric NTP options, there is little that can go wrong, but if it does break, it can create problems with other services – for example, the aforementioned certificate validation. Therefore, you shouldn't overlook the possibility of an NTP failure.

Checking to make sure the preferred NTP server is up is always a good idea, and you can do that with the `ntpq -p` command. You can do this by typing the following at the console shell (or just navigate to **Diagnostics | Command Prompt** and type this in under **Execute Shell command**):

```
ntpq -p HOSTNAME
```

Where `HOSTNAME` is the hostname of the site whose NTP server we wish to query. If `HOSTNAME` is omitted, the local NTP server is queried. Running this query will result in output something like this:



Checking to see if the preferred NTP server is running at the command prompt.

As you can see, running this command produces a wealth of information about the local NTP server. **remote** is the IP address of the remote NTP server, while **refid** is the IP address of the time source to which remote is synced. **st** is the stratum of the remote NTP server, and **t** is its type (in this case, **u** for **unicast**). **when** is the number of seconds elapsed since the remote NTP server was polled, while **poll** is the polling interval (both these fields are in seconds).

reach is an 8-bit left-shifting register which indicates success or failure within connecting with the NTP server. A **1** indicates success, while **0** indicates failure. The register is presented in octal format. The octal value of **377** is **11111111** in binary, indicating here that the last eight attempts to connect to the NTP server were all successful.

delay is the time delay in milliseconds to connect to the NTP server, while **offset** is the offset between local and remote time. Finally, **jitter** is the observed jitter of time with the remote server.

If you are trying to set up a GPS or PPS device as a reference clock, that can create a host of potential causes. One possibility is to try temporarily disabling these devices (with the **Do not use this clock** option) and see if it solves your NTP problems. If it does, then you know you have to revisit your **GPS** and **PPS** settings. If you are using a GPS device, it is possible that you selected the wrong GPS type or wrong option for NMEA sentences. It is also possible that your GPS device is not supported by your version of pfSense. If so, you may still be able to get it to work by manually entering the GPS initialization commands.

PPS devices are a bit more straightforward, but you may want to try checking the **Enable PPS clock discipline** checkbox and see if it resolves your problem. You may also want to try changing signal processing from the rising edge of the pulse to the falling edge.

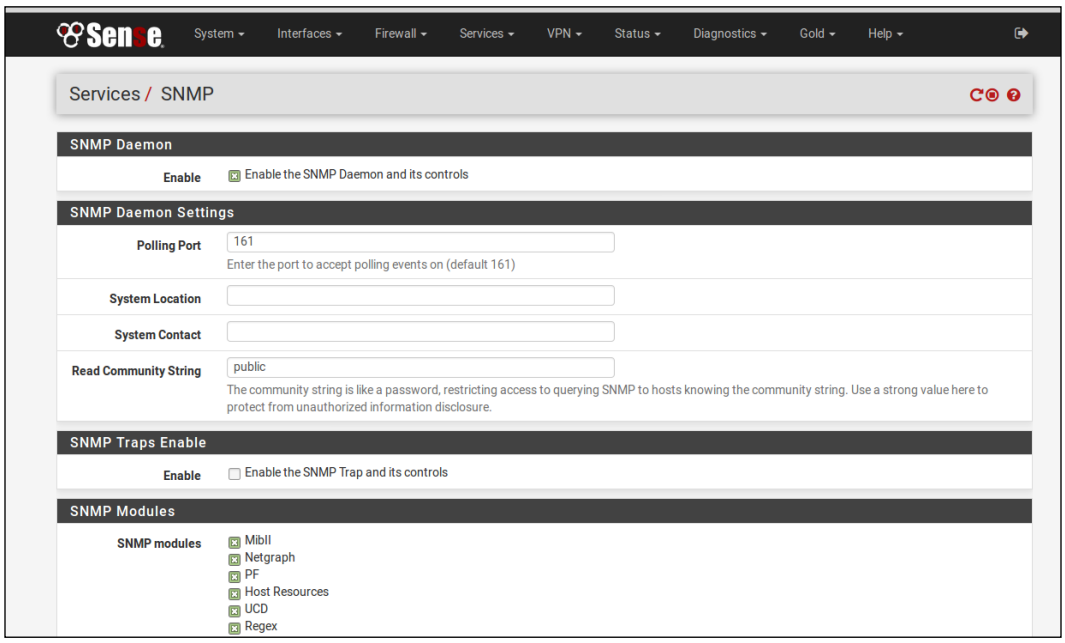
SNMP

SNMP is another application layer protocol supported by pfSense. SNMP collects and organizes information about managed devices, and is often used for monitoring network devices. SNMP-managed networks consist of managed devices, software running on the managed devices (known as agents), and software running on the manager, known as a **network management station** (**NMS**). The management data is organized hierarchically in structures known as **management information bases** (**MIBs**).

Enabling SNMP in pfSense will allow it to act as a network management station, and this in turn will enable you to monitor network traffic and flows, pfSense queues, as well as system information (for example, CPU, memory, and disk usage). It is also capable of running traps on managed devices that are triggered by certain events. SNMP is implemented under pfSense with the `bsnmpd` service. It contains the most basic MIBs available, but it can be extended by loadable modules.

Configuring SNMP

To activate the SNMP daemon, navigate to **Services** | **SNMP** and check the **Enable** checkbox under the **SNMP Daemon** section. You can run SNMP without changing any of the defaults, but you should review the options before continuing.



The SNMP configuration page.

The second section is **SNMP Daemon Settings**, and the first option under it is the **Polling Port** edit box. The default port is `161` (the standard port for SNMP), but you can change it if necessary. You can enter an optional **System Location** and **System Contact** in the next two edit boxes. In the **Read Community String** edit box, you can enter a passphrase that will be required by all hosts querying the SNMP daemon. You should enter a strong passphrase here.

The next section is **SNMP Traps Enable**, under which there is an **Enable** checkbox for enabling traps. Checking this box reveals the **SNMP Trap Settings** section with several trap options. In the **Trap server** edit box, you should enter the hostname or IP address of the trap server. In the **Trap Server Port**, you can enter the port where the traps will be received. The default is `162`, but if your SNMP trap receiver is on a different port, you can change it here. The **SNMP Trap String** field is a string that will be sent along with any generated trap.

Under the **SNMP Modules** section, you can choose which modules to run. The choices are as follows:

- **MIBII**: This provides information provided in the management information base tree (defined by RFC 1213), which covers networking information and networking interfaces. This module will allow you to query network interface information.
- **Netgraph**: This module provides some netgraph-related information. Netgraph is a graph-based kernel networking subsystem that is a part of FreeBSD.
- **PF**: This provides information about pfSense, including the rules, states, interface information, tables, and so on.
- **Host Resources**: A module that provides additional information from the MIB tree (for example, system uptime, the amount of physical memory, and so on).
- **UCD**: A module which implements parts of the UCD-SNMP-MIB toolkit. It allows you to get memory, load average, and CPU usage, among other things.
- **Regex**: A module which produces counters from logs or other text files.

The last section of the page, **Interface Binding**, has only one option: the **Interface Binding** drop-down box, which determines which interfaces on which the SNMP daemon is listening. The default is **All**, but you can select a single interface on which to listen (or **localhost**). Selecting multiple interfaces without using the **All** option is not supported. When you are done making changes, click on the **Save** button at the bottom of the page.

Troubleshooting SNMP

If you are having problems with SNMP, you should first confirm that SNMP is running on pfSense. You can do this by navigating to **Status | Services** and look for **bsnmpd** in the table. If it is not running even though you enabled it, there may be a resource allocation issue.

If not, the most common problem with SNMP is that the agents are unable to communicate with **bsnmpd**. This could happen for a variety of reasons. There may be no connectivity between the agent and **bsnmpd**; it is unlikely, but it is still a possibility that should be considered before moving on to other possible causes. It is possible that access to the SNMP ports is being blocked by pfSense or another network device; check your firewall settings to see if this is the case.

Once you have determined that a node has connectivity with the pfSense node running **bsnmpd**, you should make sure the agent software is running on the node. If the agent software is running, make sure the agent is sending the correct community string; without it **bsnmpd** will reject any attempts to connect to it. Keep in mind that community strings are case-sensitive.

If none of these works you may consider other possibilities, such as the following:

- **Wrong version of SNMP**: The SNMP daemon on pfSense runs version 3; the agent may be using an earlier version
- **Incorrect Object Identifier**: In a custom probe, the **Object Identifier** (**OID**) used by the agent may be wrong
- **Software bug in the agent**: This is not likely if the software is relatively stable, but is still a possibility

In many cases, once the obvious possibilities have been exhausted, the process of troubleshooting an SNMP node is dependent on the platform you are using (Windows, Linux, Mac OS, and so on) and the software you are using. As a result, consulting any troubleshooting resources the software provider has made available is an important step in resolving the problem.

Summary

In this chapter, we covered several useful services that are available with pfSense. DHCP, DDNS, and DNS are three services that you will probably want to implement at some point, even if you are using pfSense in a home or SOHO environment. The remaining services: captive portal, NTP, and SNMP are services you might not be likely to implement unless you are using pfSense in a corporate environment. Nonetheless, it's a good idea to have a working knowledge of these services.

In the upcoming chapters, you will learn how to further unleash the power of pfSense, with an eye towards making our networks more robust and scalable. One of the ways we can make our networks more scalable is by implementing VLANs, and we will examine that in the next chapter.

3
Working with VLANs

802.3 Ethernet networks are based on the media access control method known as **Carrier Sense Multiple Access/Collision Detection** (**CSMA/CD**). According to this protocol, a signal sent out over the collision domain had to reach every part of the network within a specified amount of time. As a result, networks were limited to a few hundred meters in length. The advent of switches solved this problem by turning each switch into a separate collision domain. Having solved the collision problem, network engineers turned to another problem that, if solved, would yield a major improvement in network performance: reducing the amount of broadcast traffic.

It turned out that the solution to the problem was to eliminate the one-to-one relationship between the network and the physical interface that exists in traditional networking, in which users of a particular network are on the same physical interface. VLANs differ from this paradigm in that a single physical interface can have several networks, and a network can span more than one interface. This can be helpful for several reasons. First, it makes it easier to segregate network traffic. Normally, users on the same interface connecting through the same switch would be on the same subnet and therefore could communicate with each other. Yet we might have legitimate reasons for isolating one group of users from another. For example, half the users might be in the sales department and the other half might be in the marketing department. By separating these users into two separate VLANs, we can improve network performance and security.

Secondly, with VLANs, users on the same VLAN connecting through separate interfaces and separate switches is possible, thus making it possible to group together users who are on different interfaces and possibly even in different buildings. In fact, it is possible to set up VLANs so that certain users will automatically join a VLAN regardless of what port to which they connect. This gives us considerable flexibility in moving users around on the network as well as reducing the amount of administrative overhead. Without VLANs, we would have to ensure that a user who belonged to a specific network was connected to a specific switch, which could get challenging as users move around the building and networks get larger.

We will begin this chapter by introducing an example that will be repeated throughout the chapter: *configuring separate developers and engineering networks*. We will first consider how VLANs might make the task easier, and then use it as a concrete example in the configuration sections. This chapter contains the following topics:

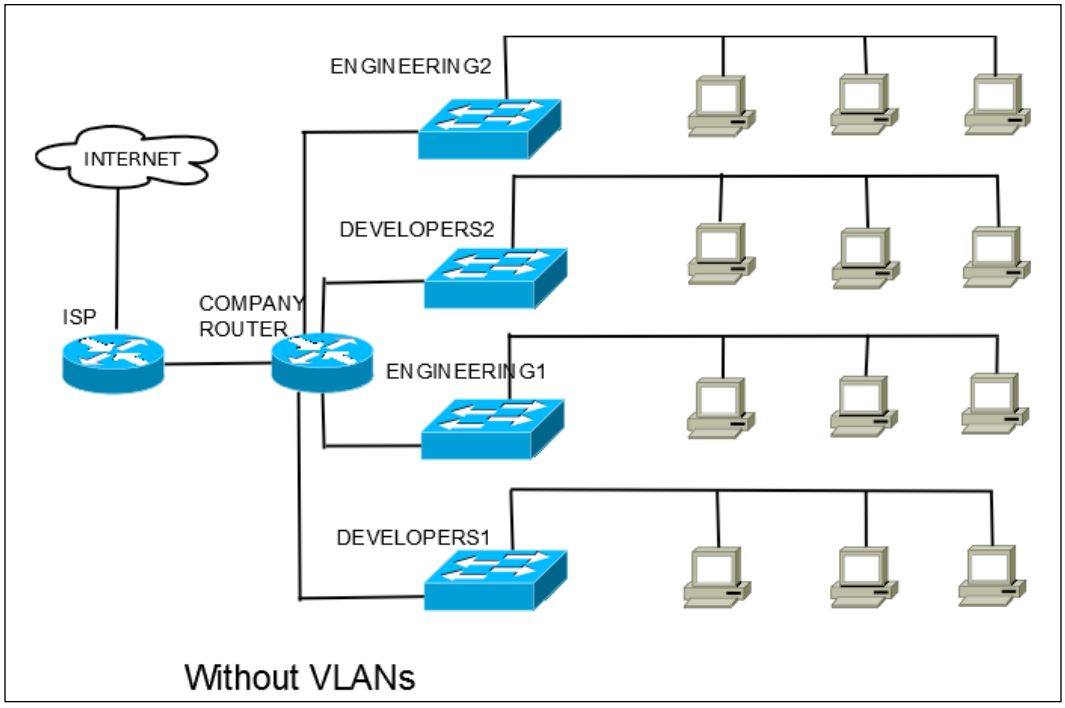
- Basic VLAN concepts
- VLAN configuration at the console
- VLAN configuration in the web GUI
- VLAN configuration at the switch
- Troubleshooting VLANs

Basic VLAN concepts

Before we consider the technical aspects of VLANs, it might be helpful to consider an example network, step back and consider how it might be implemented using a traditional networking model, then consider how the same network might be implemented with VLANs.

An example network

To illustrate the usefulness of VLANs, let's consider the simple case of a midsized company that has a software department and an engineering department. The software department occupies floors one and three, while the engineering department occupies floors two and four, and each floor has its own wiring closet with a switch connected to the company router. Let's also assume that we want to have separate networks for software developers and engineers, so that the developers can communicate with each other via the developers' network, and the engineers can communicate with each other via the engineering network, but the developers shouldn't be able to access the engineering network and engineers shouldn't be able to access the developers' network. The following diagram shows this setup:



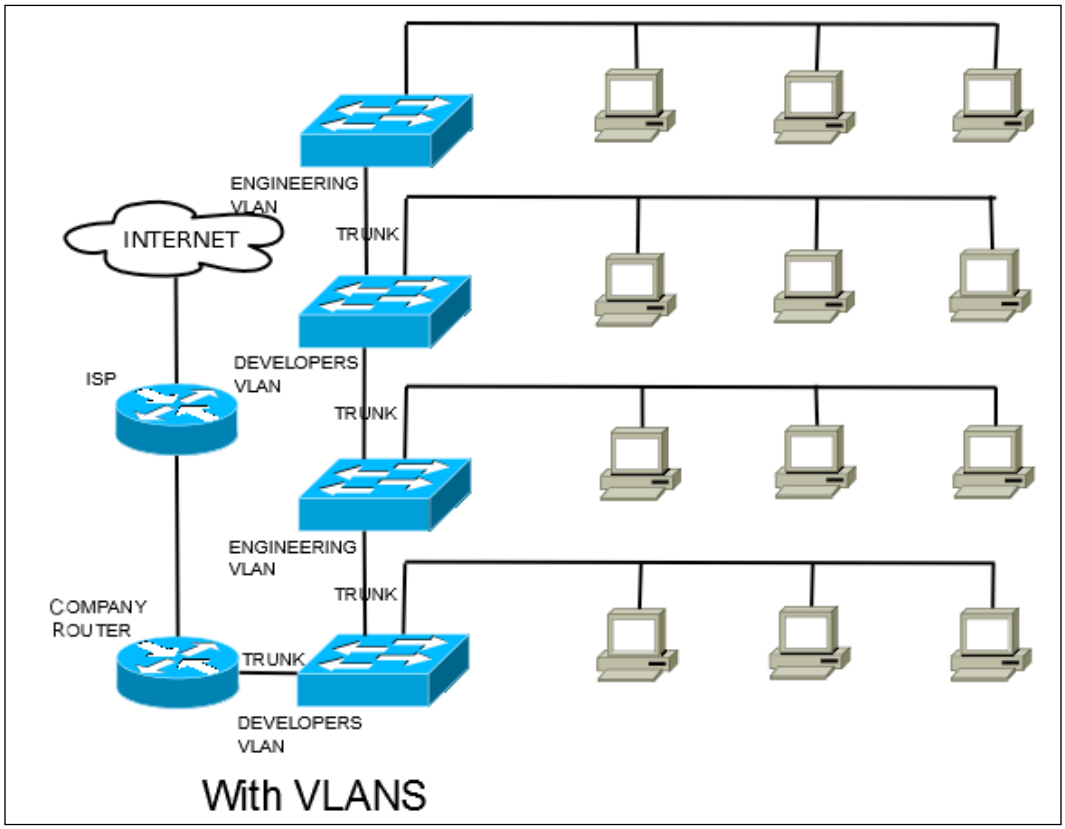
This is what our network could look like without VLANs.

As you can see, accomplishing our goal of having separate networks for developers and engineers in a traditional network is somewhat difficult. The developers are not all on the same interface, and neither are the engineers. One possibility is to continue having a subnet for each floor: we could call the first floor network **DEVELOPERS1**, the second floor network **ENGINEERING1**, the third floor network **DEVELOPERS2**, and the fourth floor network **ENGINEERING2**. Then we set up firewall rules to allow **DEVELOPERS1** to access **DEVELOPERS2** and vice versa, and do the same for **ENGINEERING1** and **ENGINEERING2**. This would be the easiest way of segregating the developers from the engineers with the current setup, but it still falls short of our goal of having one network for developers, and one for engineers. What we have actually done is set up two network groupings with two networks in each of them. Moreover, if our setup gets more complex (for example, in addition to the first four floors, we add developers and engineers to the fifth floor), it is going to be challenging to reconfigure our network.

Another possibility is to connect the first and third floor switches, and connect the second and fourth floor switches. In this scenario, each network has two switches, one of which is directly connected to the company router. The second switch will be connected to the first switch via the uplink port. As a result, the two switches will be on the same network, and we will achieve our goal of having separate networks for the developers and engineering. There are, however, some problems with this configuration:

- We will have to run cabling between the first and second switches for the developers and engineering networks. In a small enough office, this may not be a big problem. For example, assume that in our hypothetical network in the preceding diagram that the company router is on the second floor of the building, in the same wiring closet as the **ENGINEERING1** switch. The engineering network requires no additional cabling, as we can just disconnect **ENGINEERING2** from the router and connect it to **ENGINEERING1** (which will remain connected directly to the router). Thus, all we need to do is run cabling between **DEVELOPERS1** and **DEVELOPERS2**. Nevertheless, it is not difficult to see how this is not a very scalable configuration. If we double or triple the number of floors in our hypothetical, we can see how the time and cost of running additional cabling can add up.
- This solution is not very flexible, either. For example, if the company decides to move some of the developers onto the fourth floor, we will have to either put them on the same switch as the engineers (in which case they won't be on the developers' network), or we will have to add another switch for the developers.

Now let's consider how we would go about setting up different developer and engineering networks using VLANs. Again, each floor will have its own switch, except that the switch will be a managed switch, capable of processing VLAN traffic. There will be trunk lines connecting each switch with the switch on the floor above it (except for the fourth floor switch) and the floor below it (except for the first floor). The switch on the first floor will be connected via the trunk port to the company router. Again, we have a diagram of this configuration, as follows:



Our new and improved configuration.

The cost of setting up this VLAN may initially be higher, because we have to use managed switches, whereas in the non-VLAN scenario, we could have used unmanaged switches, which are typically cheaper than managed switches (although we will likely save some money on cabling). Our network is now much more scalable than before, as adding another floor to the network only requires (in addition to cabling to each node) an additional switch and trunk cabling to the switch on the previous floor. Moreover, on a managed switch, we can configure individual ports, so if management decides to move the software development and engineering departments around, we can just reconfigure ports on the switches. For a relatively small network, the benefits might not be that significant. But as you might have gathered, as our networks get bigger, using VLANs makes the task of configuring and maintaining networks much easier. And as we shall see later in the chapter, technologies such as Cisco's VLAN trunking protocol make administration even easier.

To summarize the most obvious advantages of VLANs, we have:

- The ability to easily segregate network traffic into different broadcast domains, which decreases bandwidth utilization and improves network performance
- Increased security from being able to easily segregate network traffic—even if two nodes are on the same switch, if they are on separate VLANs, they cannot talk to each other unless the router has been configured to grant them access
- The ability to create separate networks at a much lower cost than would be possible than with traditional networks, and with a greatly reduced workload for those tasked with setting up the network

But VLANs also have many other features not available via traditional networking. They include:

- The ability to double tag traffic, referred to as *QinQ*.
- The ability to prevent a host from communicating with any other host on the network (hosts will only be able to communicate with the default gateway). Such a configuration is known as a **private VLAN** (**PVLAN**), and allows the network firewall to gain a more granular level of control over traffic. Otherwise, hosts could not be prevented from communicating with another host on the same subnet, as the traffic never reaches the firewall.

Hardware, configuration, and security considerations

VLANs are a layer 2 (data link layer) construct originally conceived of as a means of improving network bandwidth by allowing for multiple spanning trees on a network. This was accomplished by adding a special header, referred to as a tag, to every Ethernet frame. Each VLAN packet has a tag containing the VLAN ID for the VLAN to which it belongs, which switches and routers can then use to differentiate VLAN traffic. Several proprietary tagging mechanisms arose, but eventually the IEEE developed the 802.1Q standard for VLAN tagging. Although 802.1Q is not the sole encapsulation method for VLANs, it is the method supported by pfSense, and it is the tagging mechanism (sometimes referred to as the encapsulation method) with which we are primarily concerned in this chapter.

802.1ad is the IEEE standard for double tagging (QinQ). 802.1aq incorporates shortest-path bridging into VLANs. 802.3ac increased the maximum Ethernet frame size from 1518 bytes to 1522 bytes, to incorporate the four-byte VLAN tag.

Because each frame has this four-byte 802.1Q tag attached to it, a VLAN Ethernet frame can be up to 1522 bytes. It can actually get even larger than this with QinQ tagging. This exceeds the usual maximum frame size for 1500 **Maximum Transmission Unit** (**MTU**) Ethernet. Not all network cards work well with these larger frames, and some will drop these larger frames, resulting in decreased network performance when VLANs are implemented. Therefore, it is a good idea to make sure your network cards are VLAN-compatible. Even if the chipset supports longer frames, the network cards particular implementation of the chipset may not properly support them.

In addition, any switch on interfaces on which VLANs are implemented must be VLAN-aware. Any managed switch manufactured since 2000 should do, but unmanaged switches will not. As is the case with network cards, you will want to do some research into choosing what switches to deploy on your network.

Each VLAN has a number between 1 and 4094: this is used as an ID. In order to set up a VLAN on your network, you will need one or more managed switches. On a managed switch that has not been configured for VLANs, every port can talk to every other port. These switches tend to either have VLANs completely disabled, or enabled with a default VLAN of which every port is a member. VLAN1 is designated as the default VLAN, and therefore it is recommended that you not use VLAN1. If you do, then there are potential security issues, as someone with physical access to the switches could plug a device into an unused port and have access to all the hosts in VLAN1. Even if a hacker doesn't have direct access to the switches, they will undoubtedly use the fact that VLAN1 is the default VLAN as a factor in formulating their attacks.

What VLAN naming convention should you use? Other than not using VLAN1, you can use whatever convention you choose. One common convention is to start with VLAN2 and increment by one for each additional VLAN. It is also commonplace to use the third octet of the IP address to match the VLAN ID: for example, for VLAN 2 we could have `192.168.2.0`, for VLAN 3, `192.168.3.0`, and so on. The same convention could be used with Class A and Class B private networks; for example, `172.16.2.0` or `10.1.2.0`. Another common convention is to increment by 10 for each VLAN, starting with VLAN10. In this scenario, we would have VLAN10 and subnet `192.168.10.0`; VLAN20 and subnet `192.168.20.0`, and so on.

Each VLAN resides on a physical interface, which is known as the parent interface. When VLANs are created, they are assigned a virtual interface, with names such as VLAN0, VLAN1, and so on, similar to the device names for physical interfaces. The virtual interface names do not correspond to the VLAN IDs. You should not assign the parent interface of a VLAN to an interface, although you can. It should only function as the parent interface for whatever VLANs reside on it. In one case, in which the author negligently assigned the parent interface to a pfSense subnet, the web GUI became inaccessible, and the issue was only resolved when all assigned interfaces were deleted and reconfigured from the console. It has also been known to cause problems with switch configuration and captive portal configurations.

There are also some security issues related to VLANs. VLAN misconfiguration may result in users gaining access to networks to which they should not have access. Because of this possibility, it is considered good practice to keep separate networks of different trust levels. For example, it is generally not a good idea to put the WAN and LAN networks on the same interface, even though it is possible.

Attacks which attempt to gain unauthorized access to VLANs are known as VLAN hopping. One method, known as **switch spoofing**, involves spoofing a trunking switch by using the trunking/tagging protocols. The other method, known as **double tagging**, involves the attacker placing two VLAN tags on a packet. The outermost tag is for VLAN1 (the native VLAN). The inner tag is for the VLAN the attacker wants to access (for example, VLAN2). The attacker sends the packet to a host on VLAN2, which can only be accessed by hosts on VLAN2. The first switch sees the VLAN1 header, removes it, and forwards the packet. The next switch sees the VLAN2 header (visible now that the VLAN1 header was removed) and sends the packet to the host on VLAN2. Thus, the attacker was able to trick the switch into thinking that the packet originated on VLAN2.

The good news is that most of the attack vectors involving VLANs can be mitigated—or even eliminated entirely—through proactive switch configuration. For example, disabling auto-negotiation can eliminate switch spoofing, and not placing hosts on the native VLAN can eliminate double tagging. Nonetheless, you should be aware of possible security issues related to your hardware and network configuration.

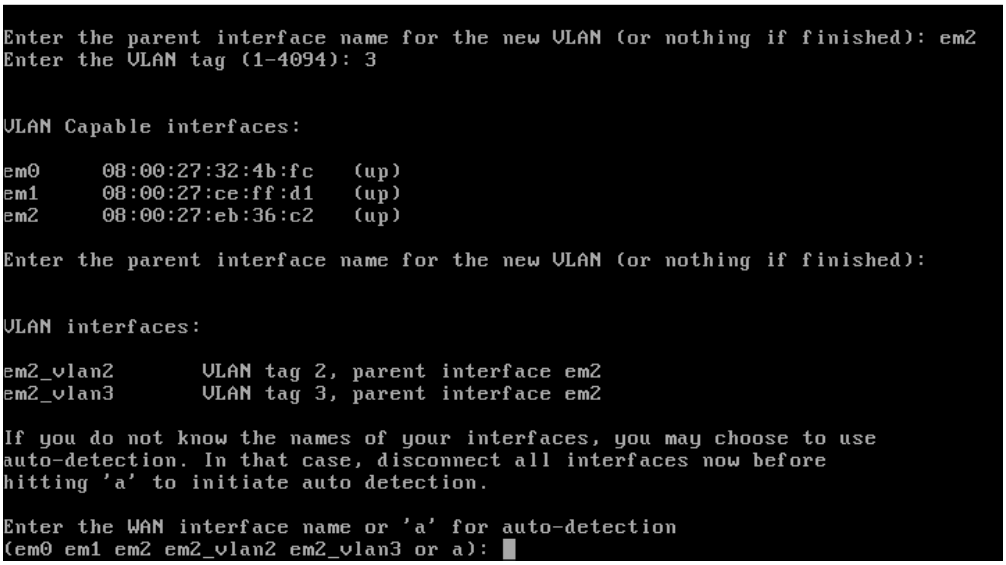
You will want to do some research to see what degree of security testing switches have undergone before making a purchase, and you should ensure that you are running the latest firmware.

VLAN configuration at the console

VLAN configuration can be done at the console; in fact, it can even be done on the initial setup. To begin VLAN configuration from the console, use the **Assign Interfaces** option in the console mention (it should be option 1). pfSense will provide a list of available interfaces in a table which provides the interface device name, the MAC address, link status (up or down), and a description of the interface. For VLAN configuration at the console, perform the following steps:

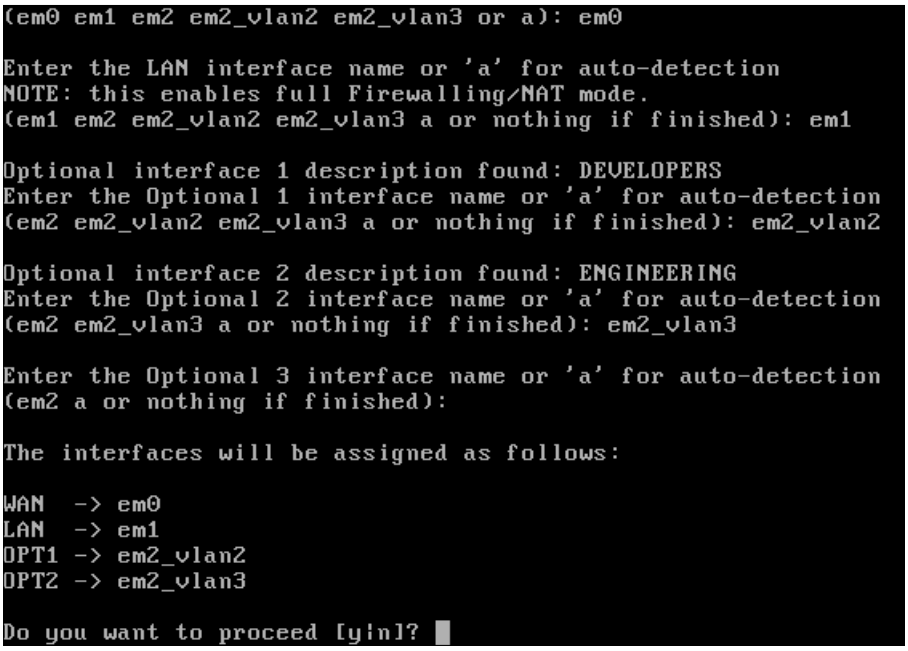
1. When you select the **Assign Interfaces** option, the first prompt will be: **Do you want to set up VLANs now [y|n]?**
2. At this prompt, type `y` and press *Enter* to begin VLAN configuration.
3. A confirmation prompt is presented next: **WARNING: All existing VLANs will be cleared if you proceed! Do you want to proceed [y|n]?**
4. Type `y` and press *Enter* to proceed.
5. Next, pfSense will provide a list of VLAN-capable interfaces and another prompt: **Enter the parent interface name for the new VLAN (or nothing if finished)**.

6. Enter the parent interface name (the device name in the table) and press *Enter*. The next prompt is for the VLAN tag: **Enter the VLAN tag (1-4094)**.
7. Enter a VLAN tag other than 1 and press *Enter*.
8. After you enter the VLAN tag, you will be returned to the **Enter the parent interface** prompt, where you can repeat the process for as many VLANs you wish to set up, and then enter nothing when finished. When you are finished creating VLANs, you will be prompted to assign interfaces, starting with the WAN interface. If you have at least one interface that has not been partitioned into VLANs, you should probably assign one of these interfaces to the WAN. If you do assign a VLAN to the WAN, you will want to make sure the WAN is on a separate switch, for the reasons outlined in the previous section.



Creating VLANs from the console in pfSense.

9. The next prompt will be for the LAN interface, and you can assign a VLAN to the LAN, although you should be aware of any security issues this creates. Enter the LAN interface and press *Enter*.
10. When you are done assigning interfaces, press *Enter* at the prompt and you will be presented with a list of interfaces and their assignments. Your list might look something like this:



VLAN configuration at the console just prior to completion.

11. After the list, you will see a confirmation prompt: **Do you want to proceed [y|n]?**
12. Type `y` and press *Enter*. pfSense will write and reload the configuration. We are now done with the pfSense portion of the initial configuration. We still must configure the switch, and we will cover that after we consider how to set up VLANs in the pfSense web GUI.

VLAN configuration in the web GUI

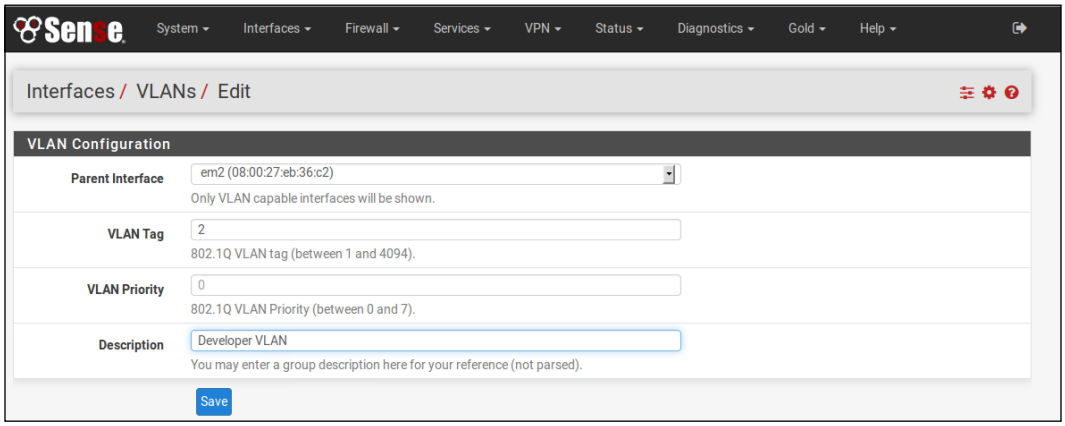
VLAN configuration can also be done within the web GUI, along with any other tasks related to the setup of VLANs (for example, DHCP and rule creation). To get started with VLAN configuration in the web GUI, log into pfSense in the web browser of your choice and navigate to **Interfaces | (assign)**. From the **Interface Assignments** page, click on the **VLANs** tab. From the **VLANs** tab, you will see a table with any previously created VLANs. Click on the **+Add** button to add a new VLAN.

On the **VLAN Configuration** page, the first setting is the **Parent Interface** drop-down box. Select the interface you want to be the parent interface of your VLANs. Next is the **VLAN Tag** edit box. Valid values for this field are 1 to 4094; you shouldn't use 1, but you can use any other values up to and including 4094. Some low-end managed switches may have problems with larger numbers, so you may want to use low numbers (2 to 8) if you have one of these.

The **VLAN Priority** edit box is new to pfSense 2.3. This allows you to utilize the 802.1Q **priority code point** (**PCP**) field. This is a 3-bit field which makes reference to the IEEE 802.1p class of service. 802.1p defines how traffic should be treated based on the value of this field:

PCP value	Priority level	Description
0	1	Traffic gets best effort treatment.
1	0	Traffic is assigned the lowest priority. It is handled in the background.
2	2	Traffic gets excellent effort treatment, which is one step below best effort.
3	3	Suitable priority level for critical applications.
4	4	Suitable for video requiring < 100 milliseconds of latency and jitter.
5	5	Suitable for voice requiring < 10 milliseconds of latency and jitter.
6	6	Suitable for internetwork control.
7	7	Traffic gets highest priority.

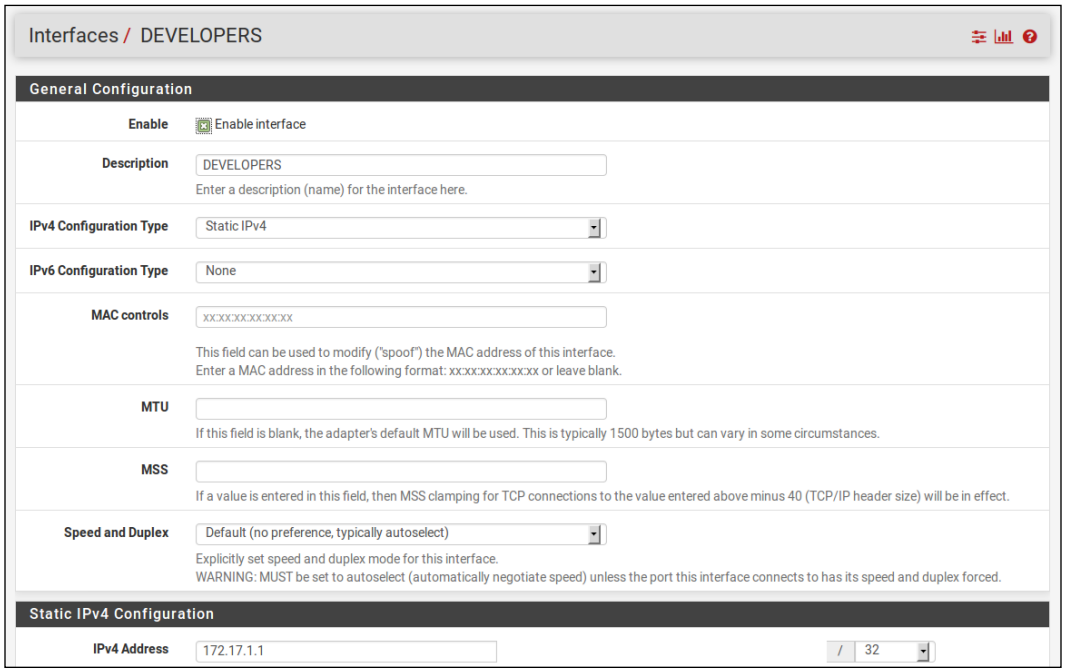
As you can see, if you know what type of traffic is going to be prevalent on the VLANs you are creating, you can set the **VLAN Priority** value accordingly. Otherwise, you can set this value to `0`. The last field, **Description**, allows you to enter a non-parsed description of the VLAN. When you are done making changes, click on the **Save** button at the bottom.



Adding a VLAN in pfSense 2.3.

In the first step, we have only created the VLANs and have not assigned them to interfaces, so in the next step, we must return to the **Interface Assignments** tab. There will be a table on which all interface assignments up to this point will be shown, and you can add VLAN assignments by selecting one of the VLAN interfaces created in the previous step from the drop-down box in the last row (the one labeled **Available network ports:**) and clicking on the **Add** button. Repeat this process for as many VLANs as you created in the previous step.

Once interface assignment is complete, the next step is to configure each of the VLANs. They will be given generic default names (**OPT1**, **OPT2**, and so on); click on the first VLAN in the **Interface** column. This will load the **Interface Configuration** page. In the **General Configuration** section, check the **Enable** checkbox. In the **Description** field, you can rename the interface. In the **IPv4 Configuration Type** drop-down box, you will likely want to choose **Static IPv4**. If your VLAN is going to support IPv6, you will likely want to choose **Static IPv6** in the **IPv6 Configuration Type** drop-down box. Depending on whether you selected IPv4 or IPv6 or both, you will have to enter IPv4 and/or IPv6 addresses in the sections below the **General Configuration** section. Note that you must enter both the IP address of the interface and the CIDR. For **IPv4 Upstream** gateway and **IPv6 Upstream** gateway, you can leave these dropdown boxes set to **None**.

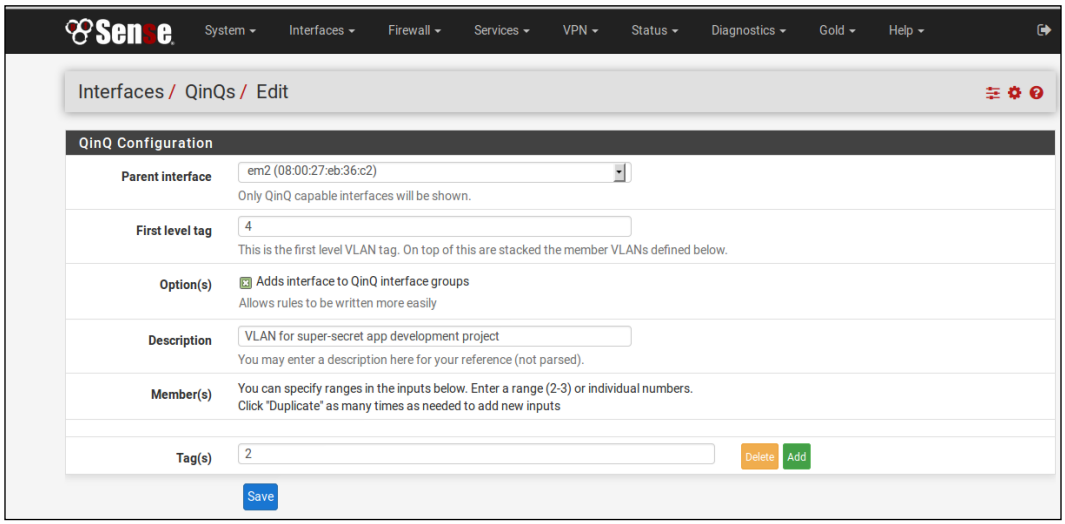


VLAN interface configuration, which is very similar to configuring a physical interface.

The rest of the fields you can likely leave unchanged, but if you are having problems with dropped frames, you may want to enter a larger value in the **MTU** field. When you are done making changes, click on the **Save** button at the bottom of the page. Once you have clicked on the **Save** button, you must click on the **Apply Changes** button at the top of the page for the changes to take effect. Repeat the interface configuration as many times as needed. You can reach the configuration page for each VLAN by accessing it from the drop-down menu at the top of the page, or by navigating to **Interfaces** | **(assign)** once again, and clicking on the appropriate VLAN in the **Interface** column.

This covers the steps that are absolutely necessary for the initial VLAN configuration, but there are some additional features worth mentioning. pfSense supports QinQ tagging; you can configure QinQ by clicking on the **QinQs** tab on the **(assign)** page. This will take you to a table showing all the interfaces that have been configured for QinQ. You can add another QinQ interface by clicking on the **Add** button.

The first option on the QinQ configuration page is the **Parent Interface** drop-down box. As with VLAN configuration, the parent interface should be an interface that is not being used as an interface on pfSense (in other words, an interface that is being used solely as a parent interface for VLANs). The next option is **First level tag**. This is the tag on which all other tags are stacked; it is at the bottom of the nesting of tags. It cannot match any of the VLAN IDs for VLANs on this interface; for example, if VLAN 2 is on this interface, the first level tag cannot be 2.



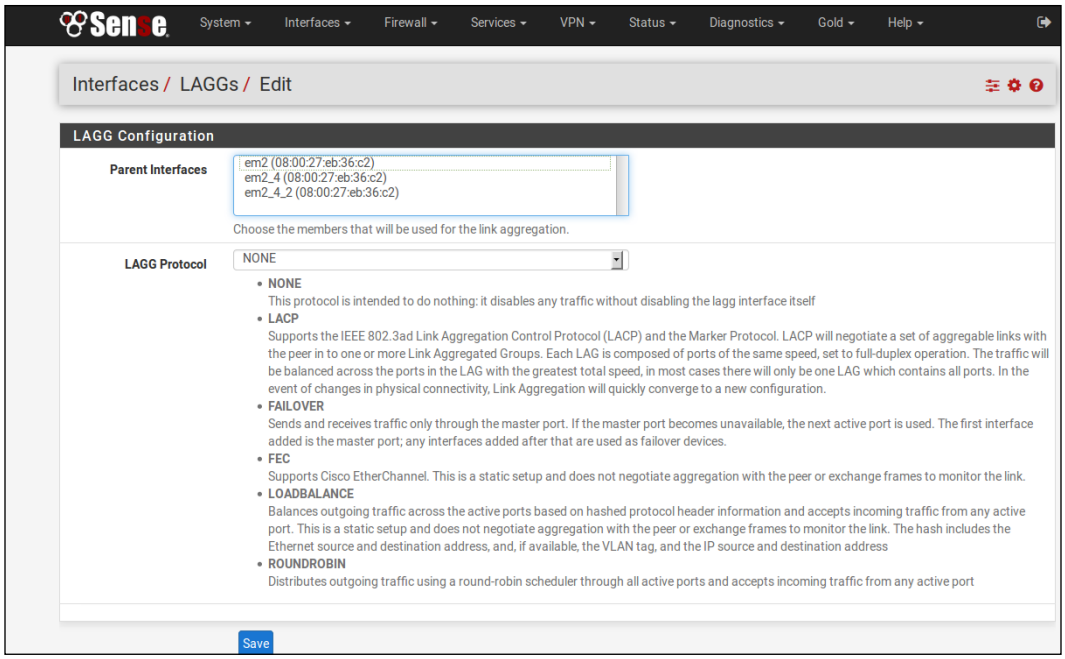
Adding a QinQ interface in pfSense 2.3.

Next is the **Add interface to QinQ interface groups** checkbox. If enabled, an entry will be added on the **Interface Groups** tab for this QinQ interface. This will make rule creation somewhat easier, as once an interface group is created and configured, rules can be created based on that interface group. You can enter a brief, non-parsed description in the next edit box. Finally, in the **Tag(s)** edit box, you can enter a VLAN tag or range of tags, which will also be attached to traffic on this interface. Pressing the **Add** button allows you to add another tag or range of tags, while the **Delete** button deletes that tag. Press the **Save** button at the bottom of the page when you are done making changes.

If you added an interface group for the new QinQ entry, click on the I**nterface Groups** tab. Find the newly created interface group and click on the **Edit** icon that corresponds to the group. This will launch the **Interface Group Configuration** page. Here you can edit the **Group Name** and enter a non-parsed group description. You can also select which interfaces will be members of this group in the **Group Members** listbox. When you are done making changes, click on the **Save** button.

You now have a QinQ VLAN, which you can add via the **Interface Assignments** tab just as you would an ordinary VLAN. The ability to nest tags in this way allows you to have even more VLANs on a single router than you would otherwise. With a single VLAN tag, you are limited to 4093 VLANs (you are allowed to use IDs of 1 to 4094, but VLAN1 is the default VLAN). With one level of nesting, this increases to 4093 * 4093 or 16,752,649 VLANs (you can have multiple levels of nesting, however, you could have even more combinations than that).

Another option we should consider addressing is link aggregation, which can be configured by clicking on the **LAGGs** tab on the **(assign)** page. Link aggregation (usually abbreviated as LAG) allows us to combine multiple ports in parallel, which accomplishes two goals. It increases the amount of throughput (for example, if you have two trunk ports per switch, you will have more throughput than you would with a single port), and it also provides some redundancy in case one or more ports go down. The **LAGGs** option does not refer to an interface; rather, it refers to LAGG, the FreeBSD link aggregation and link failover driver. Typically, trunk ports involve some form of link aggregation; with some switches, trunks have to be configured as pairs of ports:



The LAGG Configuration page.

To add a new LAGG interface, click on the **Add** button on the **LAGGs** tab. This will take you to the **LAGG Configuration** page. In the **Parent Interfaces** listbox, you can choose the interfaces that will be used for this link aggregation. In the **LAGG Protocol** drop-down box, you can select which protocol to use on the interface. The choices are as follows:

Protocol	Description
NONE	Disables traffic, but does not disable the interface.
LACP	The Link Aggregation Control protocol, defined by IEEE 802.3ad. LACP provides a form of load balancing by automatically bundling together links.
FAILOVER	One port is designated as the active port; all other ports are used as failover ports. If the active port goes down, one of the failover ports becomes the new active port.
FEC	This protocol supports Cisco Fast EtherChannel, unlike most of the other options, it is a static setup.
LOADBALANCE	This protocol balances all outgoing traffic on the member ports. This is also a static setup.
ROUNDROBIN	Distributes outgoing traffic in a round robin fashion; in other words, in equal slices and in a circular pattern.

When you are done making changes to the new LAGG interface, click on the **Save** button. The new interface should now be listed in the table on the main **LAGGs** page.

There are some additional steps needed before your VLANs are fully functional. At this point, your VLANs have been created and configured, but they will not be able to access the Internet or other subnets, because the default in pfSense is to block all network traffic. The next chapter will have a detailed treatment of firewall rule creation, and you can reference it if you need more detailed information about firewall rules.

If you just want to create rules to allow your VLANs to access all other networks, however, there is an easy way to do this. Navigate to **Firewall | Rules** and click on the **LAN** tab. There should be two rules that were created automatically when the LAN interface was created: the **Default allow LAN to any** rule and the **Default allow LAN IPv6 to any** rule. Click on the **Copy** icon for whichever rule you want to copy (the **Copy** icon should be under the **Actions** column and is represented by two sheets with one on top of the other). This will take you to the **Edit** page for that rule. Under the **Edit Firewall Rule** section, change the interface in the **Interface** drop-down box to one of the VLANs you created earlier. In the **Source** section, change the source in the drop-down box to match the VLAN in the **Interface** drop-down box (be sure to select a net and not just a single address – for example, if you want to create a rule for VLAN2, you need to select **VLAN2 net** here, and not **VLAN2 address**). Then click on the **Save** button at the bottom of the page, which will take you to the **Rules** page for the VLAN that has just been configured. On this page, click on the **Apply Changes** button, at the top right. Repeat this process for as many VLANs to which you want to grant access.

If you have a standard pfSense configuration, creating these rules should be enough to give the VLANs access to the Internet. If you have enabled **Manual Outbound NAT rule generation**, however, you will have to add NAT rules in order for your VLANs to be able to reach the Internet. You may have enabled this mode in order to add rules needed to connect to an external VPN server or for other reasons. If so, you should navigate to **Firewall | NAT** and click on the **Outbound** tab. You need to create two NAT rules for each VLAN: a rule to enable NAT between the VLAN and the WAN on port 500 with a static port configuration (this is for ISAKMP, or Internet Security Association and Key Management Protocol), and a rule to enable NAT between the VLAN and WAN on all ports with a non-static port configuration. Fortunately, your outbound NAT rule set probably has similar rules for at least one interface (for example, the LAN interface), so you can easily copy these rules by clicking on the **Copy** icon under the **Actions** column for the entry you want to copy, and then just changing the IP address listed in **Source** to correspond to the VLAN for which you want to create a NAT rule. You probably want to modify the **Description** as well. Click on the **Save** button when you are done.

There is an even easier way, however, to generate these rules. From the **Outbound** tab, click on the **Automatic outbound NAT rule generation** radio button. Then click on the **Save** button, and when the page reloads, click on the **Apply Changes** button at the top right. If you scroll down to the **Automatic Rules:** section of the page, you should see the VLAN subnets listed under the **Source** column for each rule. Now, click back on the **Manual Outbound NAT rule generation** radio button at the top and click on the **Save** button and then click on the **Apply Changes** button again when the page reloads. The NAT rule listing on the page will now include rules for the VLANs. Furthermore, any rules, which were manually created earlier, will also be there. If you want your VLANs to be able to access the Internet through your VPN server, you will still have to add NAT rules for the VPN, but you can do that easily by following the rule-copying procedure described previously.

Finally, you will have to configure any services you want to run on the VLANs. If you are using DHCP on your other interfaces, you will probably want to enable the DHCP server on the VLAN interfaces. Since we provided a detailed description of how to configure the DHCP server in the previous chapter, we will not repeat it here, but at a minimum, you will want to do the following:

1. Enable the DHCP server on the interface.
2. Specify the IP address range for this interface.
3. Add any static DHCP mappings that are needed.

If you need to enable any other services on the VLAN interfaces, such as **Captive Portal** or **DHCP Relay**, you will want to do that as well.

VLAN configuration at the switch

Before your VLAN configuration is complete, you must configure each of the switches which will be connected to the VLAN interfaces. The process will be different depending on which switch you are using; in this section, we will first discuss switch configuration in general, and then walk through a concrete example of VLAN switch configuration.

There will be differences in switch configuration depending on who the manufacturer is and what type of switch it is; however, all switch configurations include at least the following steps:

1. Trunk ports (the ports that connect the switch with the router and other switches) must be configured.
2. The VLANs must be created.
3. Ports must be assigned to the VLANs.

Some switches also require you to configure a **Port VLAN ID** (**PVID**), which sets a default VLAN ID for each port.

Switches differ in the type of interfaces provided. Some provide only a command-line interface; some provide a web-based interface; some provide both. Still others provide their own utilities for configuration. In cases where you have to use a vendor-provided utility to configure the switch, be aware that these utilities often do not have the ability to detect switches not on the current subnet, so you won't be able to configure the switch from another network.

Most switches support 802.1Q VLANs, but some also support port-based VLANs. With port-based VLANs, each port is statically assigned to a VLAN; any traffic that enters or exits the port does not have a VLAN tag. With 802.1Q VLANs, traffic entering a port assigned to a specific VLAN is tagged with an 802.1Q header. This allows for VLANs spanning multiple switches. Traffic between two nodes on the same VLAN and different switches can be sent out over a trunk port, which provides connectivity to other VLAN-capable switches. The switch on which the destination node resides will then recognize the destination port as a local switch port (by looking up the destination MAC address), and will send the traffic to the destination.

Since 802.1Q VLANs are supported by pfSense, we will use 802.1Q VLANs in the example. Assume that we have created two VLANs in pfSense: a `DEVELOPERS VLAN` (VLAD ID = 2) and an `ENGINEERING VLAN` (VLAN ID = 3). Our example demonstrates VLAN switch configuration with a Cisco switch. If you are deploying networks in a corporate environment, you are likely to encounter Cisco switches at some point, and they have even found their way into some SOHO networks.

VLAN configuration example one – TL-SG108E

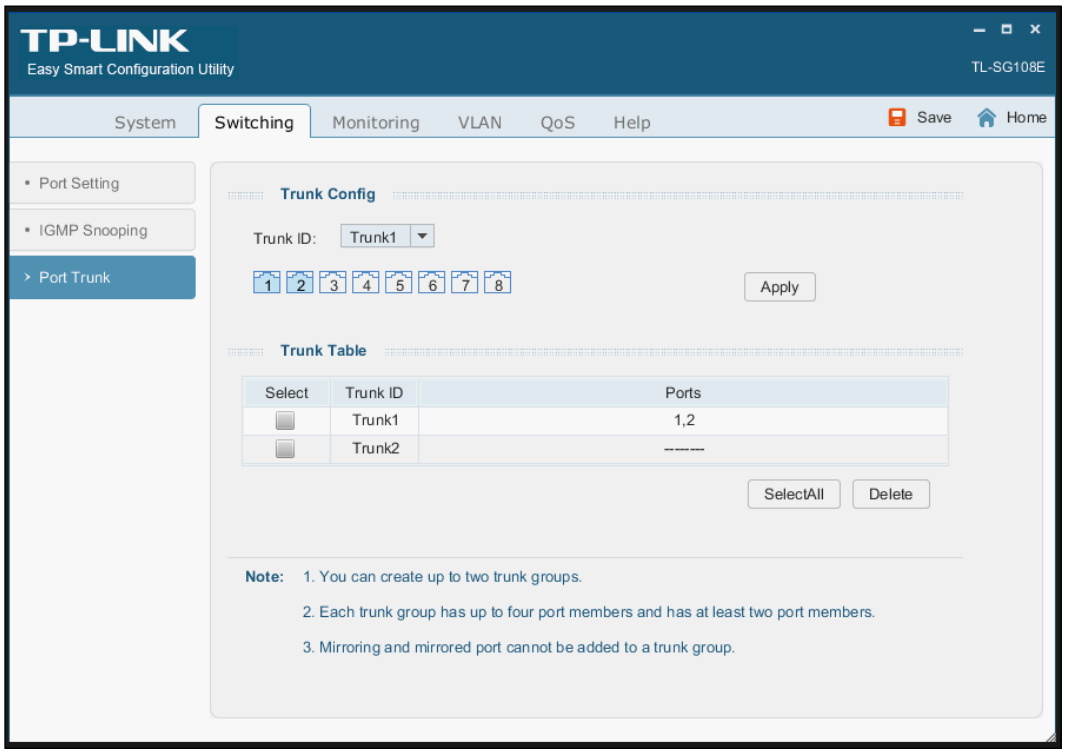
The TL-SG108E comes with a resource CD, which contains a utility (the Easy Smart Configuration Utility) that you will need to install in order to configure the switch (there is no web-based interface available for this switch). Unfortunately, the utility only runs under Windows (it does not seem to work with Linux even with the WINE emulator), so a Windows computer running XP Service Pack 3, or later, is required. For the rest of the configuration, you will need to have this computer connected to the switch via an Ethernet cable.

Note that switch configuration differs from pfSense configuration (and for that matter, configuration of any router) in one significant way: whereas you can configure pfSense from anywhere on the network, to configure a switch, you must be on the same subnet as the switch.

When you run the TP-LINK Easy Smart Configuration Utility for the first time, the utility will display a table called **Discovered Switches**, which will show any switches the utility was able to find. This will include any switches to which the computer is connected, as well as any switches which were uplinked to those switches. If you click on the entry for the switch you want to configure, you will be prompted for the login credentials of the switch. We enter the admin username and password and click on the **Login** button.

Once you are logged in to the switch, the configuration screen will have several tabs. We click on the **Switching** tab, which initially displays a table showing the status of each of the switch's eight ports. We first need to configure a trunk for the switch, so we click on **Port Trunk** on the left sidebar menu.

[Note that link aggregation is employed, with trunks assigned in pairs.]



The Trunk Config page.

On the **Port Trunk** page, we can configure up to two trunks, each having a minimum of two ports and a maximum of four ports. Mirroring and mirrored ports cannot be added to a trunk group. We only need one trunk, so we select **Trunk1** in the **Trunk ID** drop-down box. Then we click on **ports 1** and **2** in the graphic below the drop-down box (you can select whichever ports you want for the trunk, as long as they don't conflict with any other port assignments) and then click on the **Apply** button. A confirmation dialog will appear, and we click on the **Yes** button in this dialog box. Trunk configuration is now complete.

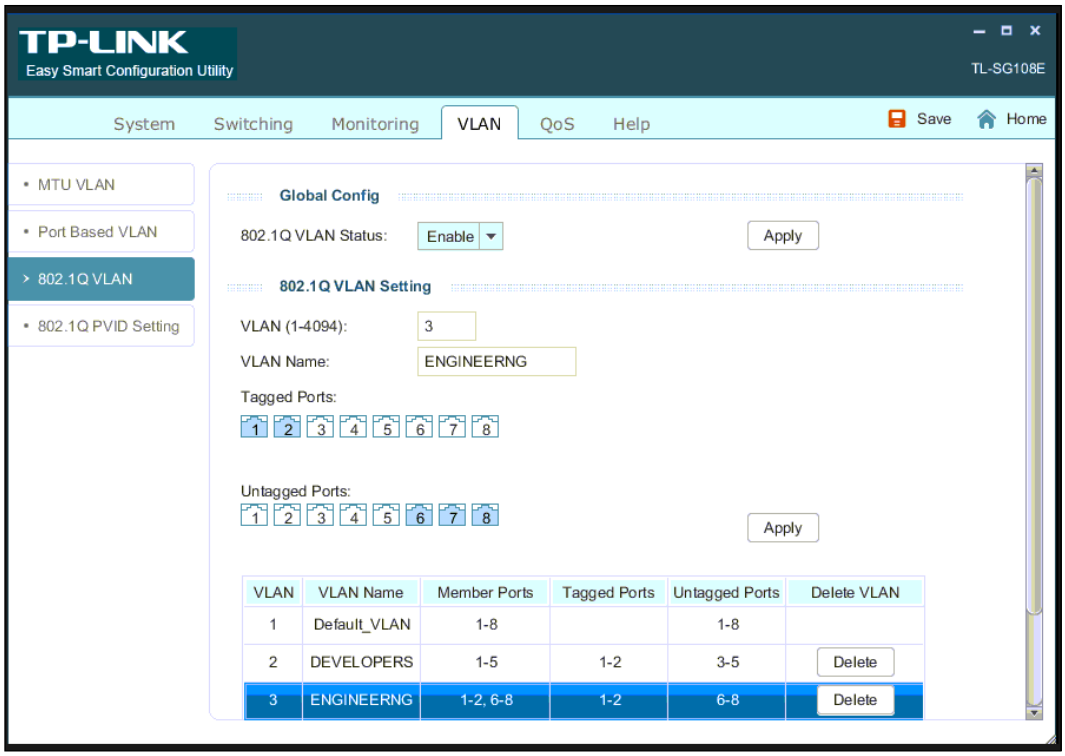
Now we can begin VLAN configuration, while being mindful of the fact that two of the eight ports have already been allocated for the trunk. We click on the **VLAN** tab at the top of the page. The three VLAN options offered on the sidebar menu are: **MTU VLAN**, **Port Based VLAN**, and **802.1Q VLAN**.

MTU VLAN is an option that allows us to have a single uplink port instead of having trunk ports, giving us an additional access port to which we can connect nodes. It is suitable if you want each port to be on its own VLAN. Since this is not what we want, we will not use this mode.

Port Based VLAN is a VLAN configuration option in which Ethernet frames entering and leaving the port are not tagged. The VLAN to which a port is assigned in the switch configuration is what determines which VLAN to which the traffic should be sent. Since this is not the mode supported by pfSense, we will not use it.

802.1Q, however, is the official IEEE standard for tagging VLAN traffic and is supported by pfSense. Therefore, we will utilize this method and we click on the **802.1Q VLAN** option on the sidebar menu.

Note that we have assigned three ports to each of the two VLANs.



The 802.1Q VLAN configuration page.

The **802.1Q configuration** page has two sections: **Global Config**, where the only option is to enable or disable 802.1Q VLANs, and the **802.1Q VLAN Setting** section, where we can enter information about our VLANs. Since we want to enable 802.1Q VLANs, we select **Enable** from the drop-down box and click on the **Apply** button, once again pressing the **Yes** button in the confirmation dialog box.

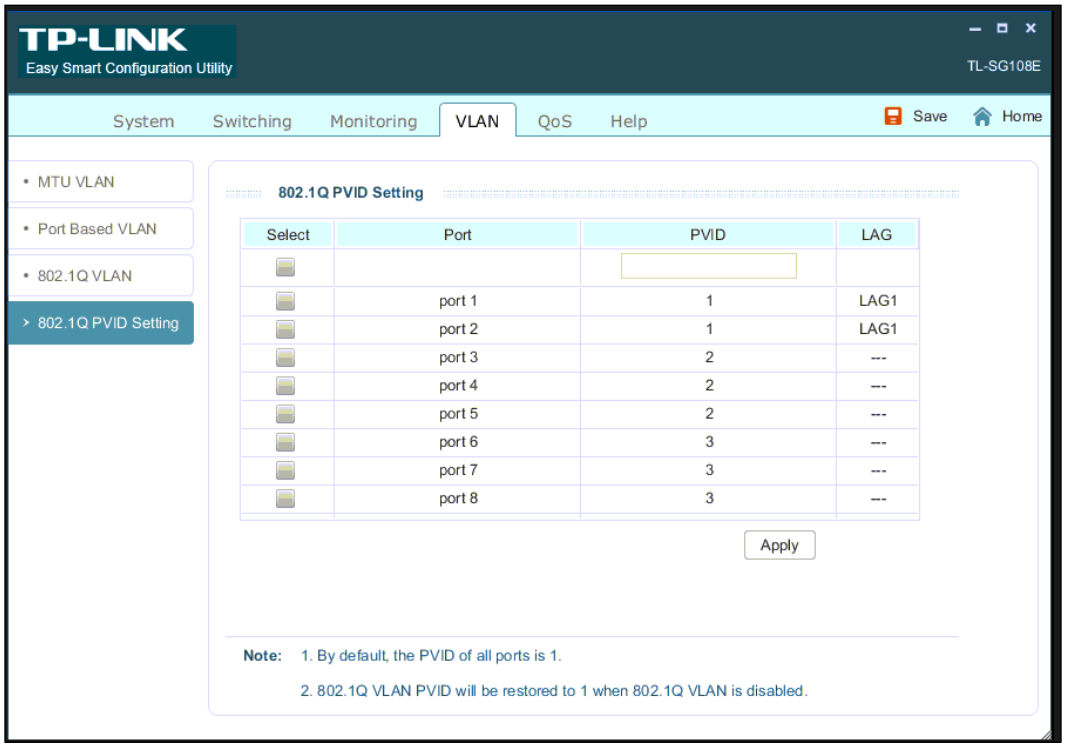
In the **802.1Q VLAN Setting** section, we enter several parameters. They are:

- **VLAN (1-4094)**: This should match the VLAN ID(s) of the VLANs you created during the pfSense portion of the configuration.
- **VLAN Name**: These can be any arbitrary names, but administration will be easier if the names match the names assigned to the VLANs in pfSense.
- **Tagged Ports**: These ports are the ports on which outbound traffic will have 802.1Q tags attached. Therefore, they should match the trunk ports assigned during the previous step. We select **1** and **2** as the tagged ports.

- **Untagged Ports**: These are the ports on which outbound traffic will have any 802.1Q tags removed. They should match the inbound ports for the VLANs. We are going to allocate three ports for each of our two VLANs, so we set ports **3** to **5** as the untagged ports for VLAN 2 (the `DEVELOPERS VLAN`), and we set ports **6** to **8** as the untagged ports for VLAN 3 (the `ENGINEERING VLAN`).

We enter **VLAN ID**, **VLAN Name**, **Tagged Ports**, and **Untagged Ports** for each of the VLANs, pressing the **Apply** button after the information for each VLAN is entered and clicking on **Yes** in the confirmation dialog box.

The next step is to click on **802.1Q PVID Setting** on the left sidebar, which sets the PVID, or Port VLAN ID, of the port. This ensures that when the switch receives a packet without a VLAN tag, it adds a VLAN tag for the VLAN matching the PVID before sending the packet to the trunk ports. On the TL-SG108E, setting the PVID is necessary for 802.1Q tagging to work, and setting the PVID also determines the broadcast domain for a port – broadcast packets received by a port will be sent to all ports with a matching PVID.



The PVID Setting page.

Since ports 3 to 5 are being used by VLAN 2 (DEVELOPERS) and ports 6 to 8 are being used by VLAN 3 (ENGINEERING), we want to set ports 3 to 5 to 2 and ports 6 to 8 to 3. To do this, we check on the checkboxes for the ports we want to set, enter the PVID in the edit box at the top of the **PVID** column in the table, and click on the **Apply** button, once again clicking on **Yes** in the confirmation dialog box. Now that switch configuration is complete, we click on the **Save** button in the upper right of the page and click on **Yes** in the confirmation dialog.

At this point, both pfSense and the switch are configured, and the VLANs should be functioning. We now have two VLANs, DEVELOPERS and ENGINEERING, with the following attributes:

- Both VLANs have access to the Internet
- Both VLANs can access all other subnets, including each other
- DHCP is enabled on both interfaces

This may not match your VLAN requirements, but you can make adjustments if necessary. In particular, you can alter the firewall rules to block access to other subnets if necessary.

VLAN configuration example two – Cisco switches

Configuring VLANs on most Cisco switches is a fairly simple process. Cisco provides a command-line interface, which only requires a few commands. Moreover, Cisco provides three different ways of configuring a VLAN:

- Static VLAN creation
- VLAN creation with Dynamic trunking protocol
- VLAN creation with VLAN trunking protocol

Static VLAN creation

A static VLAN is created when the administrator manually assigns switch ports to belong to a VLAN. Initially, the default is for all ports to be assigned to VLAN1.

Static VLANs can be created in VLAN configuration mode. Creating our two VLANs involves only a few commands:

1. First, we move from privileged EXEC mode to configuration mode:

```
Switch# configure terminal
```

2. Next, we create the first VLAN (VLAN 2, the DEVELOPERS VLAN):

```
Switch (config)# vlan 2
```

3. Now we can assign it a name:

```
Switch (config-vlan)# name DEVELOPERS
```

4. Next, we want to apply the changes, increase the revision number, and return to the global configuration mode:

```
Switch (config-vlan)# exit
```

5. We follow the same steps for the ENGINEERING VLAN, except for entering configuration mode, since we are already in that mode:

```
Switch (config)# vlan 3
Switch (config-vlan)# name ENGINEERING
Switch (config-vlan)# exit
```

6. Next, we need to assign ports to the VLANs. We can set up non-trunking access ports with a few commands. First, we move to interface configuration mode:

```
Switch (config)# interface range fastethernet 1/3-5
```

   In this command, `interface` indicates that we are entering interface configuration mode. `range` indicates that we are configuring a range of ports, not a single port. `fastethernet` is the interface type. Other possible values include `ethernet`, `fddi` (for fiber connections), `token` or `tokenring` (for Token Ring networks), `atm`. `1` is the slot (Cisco switches have slots, which refer to either ports on the switch itself or expansion slots/modules), and `3-5` indicates that we are configuring ports 3 to 5.

7. Next, we configure ports 3 to 5 as access ports:

```
Switch (config-if-range)# switchport mode access
```

8. Finally, we assign ports 3-5 to VLAN 2 and return to the global configuration mode:

```
Switch (config-if-range)# switchport access vlan 2
Switch (config-if-range)# exit
```

9. Next, we will enter interface configuration mode for ports 6 to 8 and set up these ports as access ports for VLAN 3:

```
Switch (config)# interfacerange fastethernet 1/6-8
Switch (config-if-range)# switchport mode access
```

```
Switch (config-if-range)# switchport access vlan 3
Switch (config-if-range)# exit
```

10. Note that for both VLANs, we used the `range` command to select a range of ports. If you just want to configure a single port, the syntax is:

    ```
    Switch (config)# interface fastethernet 0/1
    ```

    This command would allow you to configure slot `0`, port `1`.

11. Next, we need to configure at least one port as a trunk port. First we indicate the interface type, slot and port:

    ```
    Switch (config)# interface fastethernet 1/1
    ```

12. Then we set the mode to `trunk`:

    ```
    Switch (config-if)# switchport access mode trunk
    ```

    This sets slot `1`, port `1` as a trunk port.

13. By default, the native VLAN for this trunk port is the default VLAN (VLAN 1). We can change this with the following command:

    ```
    Switch (config-if)# switchport trunk native vlan 2
    ```

    This changes the native VLAN to VLAN 2. By default, a trunk port will carry traffic for any VLAN, but if we want, we can restrict the allowed VLANs for this trunk port:

    ```
    Switch (config-if)# switchport trunk allow vlan 2-3
    ```

    This will restrict the `trunk` port to allow only VLANs 2 and 3, our `DEVELOPERS` and `ENGINEERING` VLANs. Other possible values for this command are `all` (to allow all VLANs), `none` (for no VLANs), a list of allowed VLANs, `remove` to remove a VLAN, or `add` to add a VLAN. For example, we could type:

    ```
    Switch (config-if)# switchport trunk remove vlan 2
    ```

    This would remove access for VLAN 2 without affecting VLAN 3. We could add VLAN 2 back again as well:

    ```
    Switch (config-if)# switchport trunk add vlan 2
    ```

14. To verify this configuration, we exit configuration mode and use the `show` command. For example, to verify the `DEVELOPERS` VLAN, we type:

```
Switch (config-if)# exit
Switch (config)# exit
Switch# show vlan name DEVELOPERS
```

    This command will display configuration information for VLAN 2. The following command also works equally well:

```
Switch# show vlan id 2
```

Dynamic Trunking Protocol

Another approach is to use **Dynamic Trunking Protocol** (**DTP**). This protocol allows you to auto-configure both the trunking and the type of trunking encapsulation on a Cisco switch. First, enter switch configuration and interface configuration mode:

```
Switch# configure terminal
Switch (config)# interface fastethernet 0/1
```

Slot `0` port `1` can be statically converted into a trunk port with the following command:

```
Switch (config-if)# switchport mode trunk
```

Dynamic trunk configuration can be done in two different ways. If the neighboring interface is set to `trunk`, `desirable`, or `auto`, then the port will become a trunk if we issue this command:

```
Switchport mode dynamic desirable
```

If the neighboring interface is set to trunk or auto, the port will become a trunk with the following command:

```
Switch (config-if)# switchport mode dynamic auto
```

Keep in mind, however, that enabling DTP can make your network vulnerable to VLAN hopping attacks. At the very least, you will want to make sure that only trunk ports are configured to use DTP.

VLAN Trunking Protocol

VLAN Trunking Protocol (**VTP**), like DTP, is a proprietary protocol for Cisco switches. The purpose of VTP is to make VLAN configuration easier by synchronizing VLAN configuration information throughout a VLAN domain. This is done by designating one switch as the VTP server, and letting it handle the addition, deletion, and renaming of VLANs throughout the domain.

The three available modes in a VTP domain are as follows:

- **Server**: This is the default mode. When changes are made on a VTP server, the changes propagate to all other switches on the domain. The VTP server is also responsible for creating VTP advertisements, which make this propagation possible.
- **Transparent**: If a switch is in transparent mode, changes made to the configuration will affect only that one switch. Transparent switches cannot create VTP advertisements, but they can forward VTP advertisements.
- **Client**: Switches in client mode cannot make any changes to the configuration, but they can send VLAN information in their databases to other switches. They can also forward VTP advertisements to other switches.

Obviously, the larger your network gets, the greater the potential is for VTP to make your life easier, since instead of configuring dozens or even hundreds of switches, you will only have to configure a single switch. In addition, VTP has a feature called **VTP Pruning**, which forwards broadcast and unknown unicast messages to switches only if the switch has ports for the VLAN on which the broadcast/unicast messages are being sent. This makes for more efficient use of trunk bandwidth.

Configuring VTP requires only a few additional commands. Since we are making changes for the entire switch and not just a port or range of ports, we can use global configuration mode:

1. First, enter global configuration mode:

   ```
   Switch# configure terminal
   ```

2. Next, set the switch as a VTP server, with the following command:

   ```
   Switch (config)# vtp mode server
   ```

3. You can also put the switch in `client` mode or `transparent` mode:

   ```
   Switch (config)# vtp mode client
   Switch (config)# vtp mode transparent
   ```

4. To set the domain name, use this command:

   ```
   Switch (config)# vtp domain <domain_name>
   ```

   Here, `<domain_name>` is the domain name to which you want to set the domain.

5. You can set a password with the following command:

   ```
   Switch (config)# vtp password <password>
   ```

6. To set the VTP domain to VTP version two, type the following (the current version is version three):

```
Switch (config)# vtp v2-mode
```

7. Finally, to enable pruning, use this command:

```
Switch (config)# vtp pruning
```

The remainder of the configuration is identical to the steps outlined earlier. You must configure both the access ports and trunk ports, create the VLANs, and assign ports to them. By using VTP, however, configuration will be much easier, and it will be easier to make changes when necessary.

Troubleshooting VLANs

VLAN troubleshooting is somewhat different than troubleshooting other network problems in that if you have an enterprise-level switch, the manufacturer will have troubleshooting guidelines tailored to the switch. You still need to verify that the pfSense component of your configuration is correct, however, and there are some troubleshooting elements that are common to all brands of switches. We will begin by considering general configuration issues.

General troubleshooting tips

It is good practice to work our way down on the OSI network model, which means starting at the Physical Layer. You should check your cabling, and if necessary, you should replace suspect cabling with known good cabling. Having a working time-domain reflectometer, which can be used to locate discontinuities in a network cable, can be helpful in checking cabling.

The next step is to make sure that the ports are functioning. Even if they are physically functional, the layer 2 protocol (Data Link Layer) may not be running on the ports you are using. On a Cisco switch, you can use the `no shutdown` command to restart a disabled port. You might also have a speed mismatch between the switch and the router; for example, the switch may be 1 Gbps, while the router might be 100 Mbps. For this reason, it is generally a good idea to have auto-negotiation set on both sides.

Verifying switch configuration

Once you have confirmed that you have physical connectivity, that the ports are enabled, and the port configuration is correct, you should confirm the following:

- Trunk ports are configured correctly and there is at least one connection between the trunk ports and the router. If you have a Cisco switch and are using DTP, you may want to switch to static port configuration until you confirm that the trunk ports are working correctly.
- Access ports are configured correctly and the nodes are connected to ports that are assigned to the VLANs to which they should belong.
- VLANs have been set up correctly and have been assigned VLAN IDs that correspond to the VLAN IDs assigned in pfSense.
- The correct encapsulation format is being used (for VLANs in pfSense, it should be 802.1Q encapsulation).

There are aspects of switch configuration that are peculiar to different brands and models of switches, so you will want to consult any documentation the switch manufacturer has provided. Doing a web search to see if there are any issues specific to your switch may be helpful. Cisco switches have copious amounts of documentation, and administration of these switches is a topic too involved to be fully addressed here. If you want to pursue it, though, there are books, tutorials, and even professional certifications you can obtain to demonstrate your proficiency in Cisco switch configuration.

Trunk port configuration is relatively easy. You need at least one trunk port per switch (some switches assign trunk ports in pairs), and these ports will be available for connections to the router and to other switches. With some switches, the trunk port configuration can be done after the VLAN is configured; in other cases, setting up the trunk ports is a prerequisite to setting up a VLAN. You should confirm that the VLAN is active on the trunk, and that packets from the VLAN are allowed on the trunk.

Configuring access ports should be simple as well. You need to assign the correct VLANs to the ports. In addition, you need to have the correct settings for VLAN tagging. Keep in mind that packets entering the access ports should be untagged – inbound packets should be ordinary Ethernet frames, unless they are double-tagged – whereas ports leaving the trunk ports should be tagged, so the router and switch know to which VLAN the packet belongs.

Another configuration element to consider is the PVID, or Port VLAN ID, which is the default VLAN ID for a port. Some managed switches require the PVID to be set in order for VLANs to work at all. If you cannot get your VLAN to work, and you have verified physical connectivity, you may try configuring the PVID for the ports you are using. The PVID settings for the access ports should mirror the access port VLAN assignments you made when you initially configured the VLAN on the switch.

Verifying pfSense configuration

Once you have confirmed that the switch is configured properly, you should log in to pfSense and confirm that pfSense's VLAN configuration is correct. First, go to **Interfaces | (assign)**, click on the **VLANs** tab, and confirm that the VLAN IDs for the created VLANs correspond to the VLAN IDs configured on the switch or switches. Then click on the **Interface Assignments** tab and confirm that the VLAN IDs are assigned to the correct interfaces.

If you are using DHCP or DHCPv6, you should confirm that the DHCP/DHCPv6 server is running on the VLAN interfaces and that they are configured correctly. If you have any doubts, you could try a static IP configuration on one of your nodes and see if you are able to access the VLAN (just remember to choose an IP address outside of the range of addresses assigned by the DHCP server). If you are using DHCPv6 and you have any doubts as to the IPv6 compatibility of either your switch or operating system, you might want to try DHCP first.

You may have a situation in which nodes can connect to the VLAN, but have no Internet connectivity and may not be able to access other subnets at all. Keep in mind that VLANs, like traditional networks, need to be configured so that they have access to other networks. Other than the LAN, for which pfSense creates a default *allow LAN to any rule*, the default for any newly created network is to have all access to other networks blocked. Therefore, you must go to **Firewall | Rules** and create a rule to allow the VLAN to access the WAN interface. As mentioned earlier, an easy way of doing this is to use the rule **Copy** option and change a rule for another interface by changing the **Interface** and **Source** fields to match the VLAN for which you want to create the rule.

The default setting for NAT in pfSense is for automatic outbound rule generation. If you are in this mode of NAT rule configuration, the NAT outbound rules are created automatically and you don't have to configure any NAT rules. If you are using manual outbound rule generation, however, you will have to create rules for each of the VLANs you have created. You may be using manual outbound rule generation if you had to create outbound NAT rules in order to connect to a VPN server, so if you subscribe to a VPN service, you should check to make sure there are outbound NAT rules for your VLANs. You can do this by navigating to **Firewall | NAT**, clicking on the **Outbound** tab, and reviewing the rules there. One of the ways to avoid having to manually create rules is to utilize hybrid rule generation mode, in which pfSense still automatically generate rules, but you can also have manually created rules. To do this, select the **Hybrid Outbound NAT rule generation** radio button on the **NAT Outbound** tab and press the **Save** button below the radio buttons.

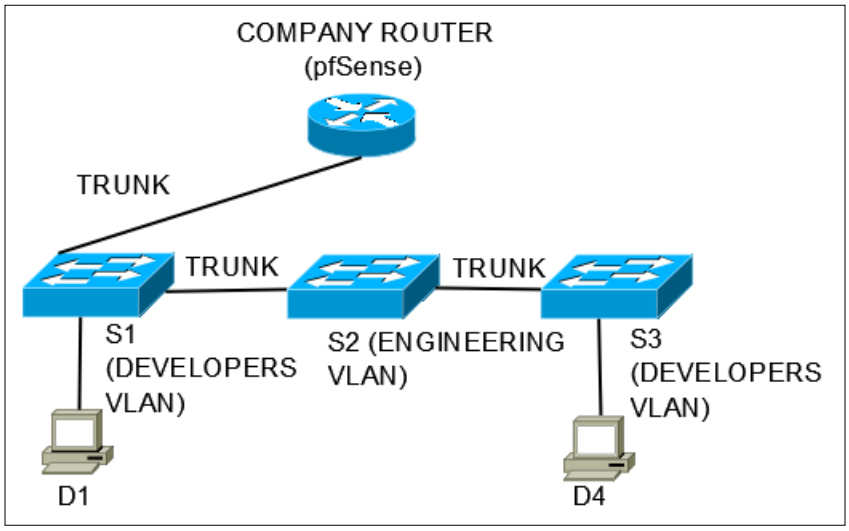
Here is a VLAN troubleshooting table that covers some of the common VLAN communication issues:

Problem	**Possible cause**	**Solution**
Node not able to communicate with other nodes on the same VLAN and the same switch	Possible cable fault or switch hardware failure; possible switch configuration error or misconfiguration on one or more nodes	Confirm cabling (possibly replacing cabling with known good cabling); confirm that the switch is functioning and configured properly
Nodes able to communicate with nodes on the same VLAN and switch, but not with nodes on the same VLAN/different switches	Possible cable fault; possible trunk port misconfiguration	Confirm cabling; check trunk port configuration on switches connected to affected nodes
Nodes able to communicate with nodes on the same VLAN, but cannot access the Internet or other local networks	Rules to allow VLAN traffic not created or were created improperly	Confirm that pass-through rules have been created for the VLAN; confirm that outbound NAT rules have been created
Node is on the wrong VLAN	Node is connected to the wrong port or port is misconfigured	Confirm that the node is connected to the correct port and that the port has been configured correctly

Troubleshooting example

It might be helpful to provide a concrete example of a VLAN connectivity problem, so we will return to the developers and engineering VLAN scenario developed throughout the chapter, and present a pair of hypothetical problems.

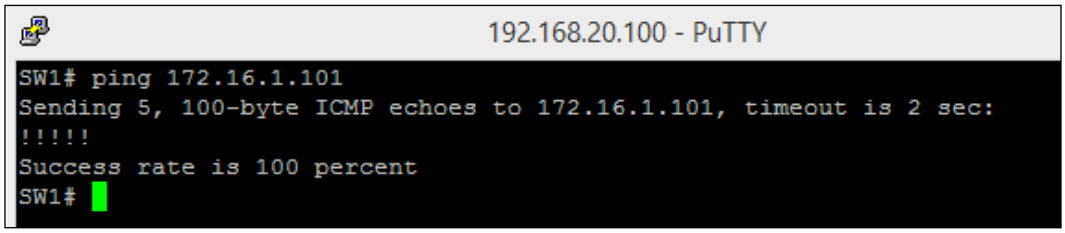
Let's assume that node **D1** on the developers' VLAN cannot access node **D4**, also on the developers' VLAN. **D1** is on the first floor, while **D4** is on the third floor. In this scenario, the developers' VLAN is on the `172.16.0.0` subnet, and **D1** IP address is `172.16.1.101`, while **D4** IP address is `172.16.1.104`. Switch **S1** has an IP address of `172.16.1.1`, **S2** is `172.17.1.1`, and **S3** is `172.16.1.2`. The relevant portions of the earlier VLAN diagram are presented here for convenience's sake:



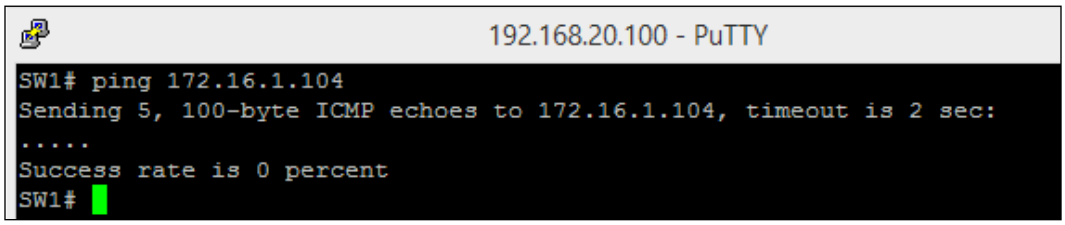
Network diagram showing nodes D1 and D4. In our example, D1 cannot communicate with D4.

We start our troubleshooting at the Physical Layer, so first we find out if there are any connectivity issues. Once we rule out any problems with the physical cabling, we observe that since **D1** and **D4** are on the same VLAN, this is a layer 2 issue, and we can focus on troubleshooting the connections between each node and their respective switches, and the trunk link between **S1** and **S3**.

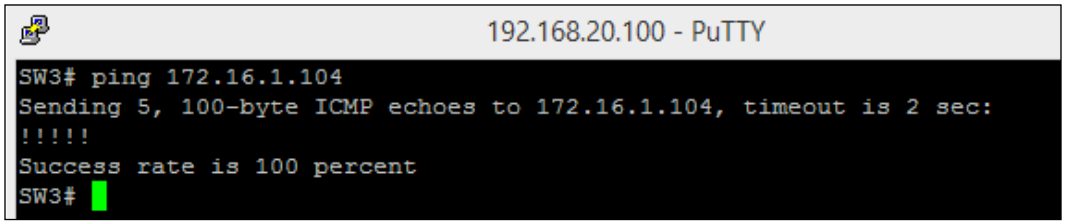
Our first goal will be to verify connectivity between **D1** and **S1**. This can be done by a simple `ping` command issued from **S1**, as shown in the following screenshot:



As you can see, we were able to successfully ping **D1** from **S1**; the interfaces between them are configured correctly, and we can now begin to look at the link between **S1** and **D4**, which we will do in the following screenshot:



Now we will try to ping **D4** from **S3**:

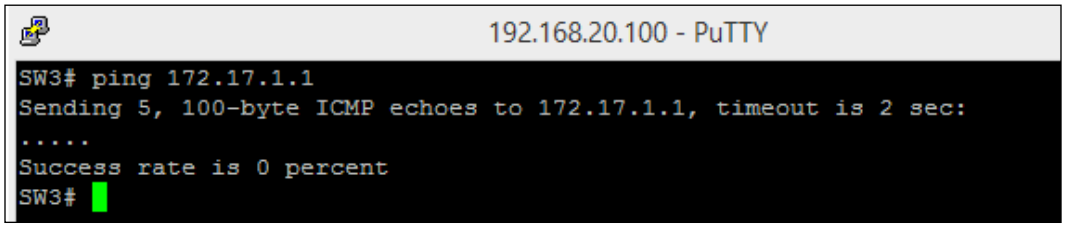


The link between **S3** and **D4** is good, so now it looks like the problem lies between **S1** and **S3**. If, however, the problem was between **S3** and **D4**, you should do the following:

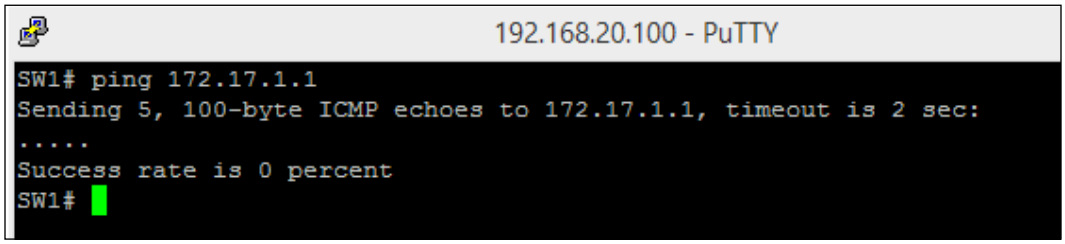
- Confirm the VLAN is active on **S3**
- Confirm the VLAN is assigned to the port to which **D4** is connected

If the `ping` between **S1** and **D1** failed, then obviously the same troubleshooting steps would apply: we would need to confirm the VLAN is active on **S1** and we need to confirm the VLAN is assigned to the port to which **D1** is connected.

If the link between **S1** and **D1**, and, **S3** and **D4** is good, then the problem is the link between **S1** and **S3** – in other words, the trunk. There is another switch (`S2`) between **S1** and **S3**, and we should test the connectivity between **S1** and **S2** and **S3** and **S2** by running the `ping` command between each of them. We start by pinging **S2** from **S3**, since we are already logged into **S3**:



It is starting to look like the problem might be the link between **S3** and **S2**, but to be thorough, we try to ping **S2** from **S1**:



If we had just assumed the problem was between **S3** and **S2**, we might have focused on the trunk ports that connect those two switches. But since both ping tests failed, there is a good chance that **S2** is not configured correctly to pass DEVELOPERS VLAN traffic at all, so we need to check this, and correct the configuration if necessary.

To resolve this issue, we need to consider the following:

- The trunk needs to be active and running with the correct encapsulation format. If it isn't, we aren't going to be able to send VLAN traffic over it.
- The VLAN must be active and all trunk ports must be configured to allow traffic for the DEVELOPERS VLAN.

Summary

In this chapter, we covered basic VLAN concepts while also considering an example in which it would be advantageous to implement VLANs. We then covered the configuration of that example network, both in pfSense and in the switch itself. Finally, we covered VLAN troubleshooting, and walked through a hypothetical VLAN problem and how to solve it.

The information contained in this chapter should be more than enough to enable you to set up your own VLANs. There is, however, much more to network design, configuration, diagnosis, and repair of VLAN-enabled networks than has been covered here. Cisco, for example, has five levels of certification covering everything from entry-level network support to network design. If the topics discussed in this chapter interest you, then you might consider further study of VLANs. There are numerous books, study materials, and instructional videos on the subject.

In the next chapter, we will cover *Chapter 4*, *pfSense as a Firewall*, which is one of the core functions of pfSense. The chapter will cover rule creation, NAT, scheduling, aliases, and virtual IPs. Traffic shaping, which is also part of pfSense's firewall functionality, gets its own chapter, and will be covered in *Chapter 5*, *Traffic Shaping*.

4
pfSense as a Firewall

In computing, a firewall can mean one of two things: it can refer to a network appliance that has as one of its functions the ability to filter incoming and outgoing traffic (hardware) or a service running on a computer that has the ability to filter traffic (software). In this chapter, we will be using the latter sense of the term. We will be focused primarily on the ability to use pfSense as a means of filtering traffic on your network, which is likely to be one of pfSense's primary functions, regardless of the deployment scenario.

In this chapter, we will cover firewall rules and rule methodology. We will also cover several services that are part of pfSense's core firewall functionality, such as NAT and scheduling. In fact, we will cover everything except traffic shaping, which will be covered in the next chapter. The topics covered in this chapter are:

- Firewall rules
- Firewall rule methodology
- Scheduling
- **Network Address Translation** (**NAT**)
- Aliases
- Virtual IPs
- Troubleshooting

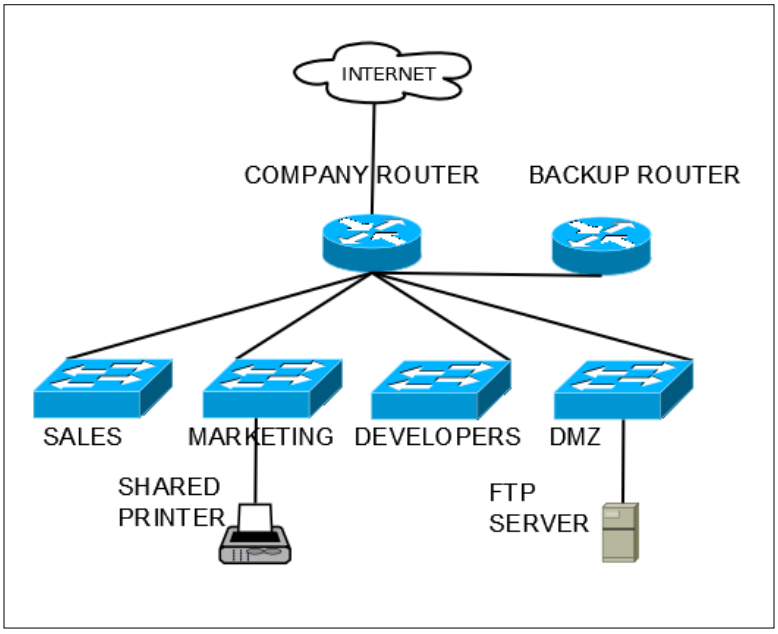
An example network

It often helps to use concrete examples to help illustrate concepts, so once again we will imagine a hypothetical network in order to understand how we would go about configuring firewall rules for a specific environment. Imagine a network with four subnets: **SALES**, **MARKETING**, **DEVELOPERS**, and a **DMZ**, and with the following requirements:

All subnets should be allowed to access the Internet, subject to the restrictions outlined as follows:

- **SALES** should not be able to talk to **MARKETING** and **DEVELOPERS**; **MARKETING** should not be able to talk to **SALES** and **DEVELOPERS**; **DEVELOPERS** should not be able to talk to **SALES** and **MARKETING**.
- **SALES**, **MARKETING**, and **DEVELOPERS** should be able to talk to the **DMZ**, but the **DMZ** should not be able to talk to any local subnets (other than **DMZ**).
- **SALES** and **MARKETING** share a printer that is on the **MARKETING** subnet, so **SALES** should have access to that printer, but not any other nodes on **MARKETING**.
- The company is cracking down on non company related Internet use that consumes excessive bandwidth, so YouTube should be blocked on all subnets.
- Developers waste too much time on Slashdot, so `https://slashdot.org/` should be blocked on the **DEVELOPERS** subnet, although access should be allowed during lunch hour (Noon-1 PM).
- The company wants to set up an FTP server for customers, which is to be placed in the **DMZ** subnet. For the FTP server to be accessible via the Internet, access to port `21` must be allowed and traffic to port `21` must be forwarded to the FTP server.
- The company also wants to incorporate some redundancy into the firewall configuration, so there should be two redundant firewalls, with one set up as the master firewall. The second firewall will only be used if and when the master firewall fails.

As you might imagine, these requirements will figure prominently in what firewall/NAT rules we will implement. We can tentatively diagram our network in the following way:



An example corporate network, with separate networks for different departments, and some shared resources.

pfSense's firewall capabilities are more than enough to meet the requirements of our network. We will revisit this scenario in subsequent sections.

Firewall fundamentals

The fundamental purpose of a firewall is to establish a barrier between trusted internal networks and untrusted external networks. We may sometimes also refer to personal firewalls, which are firewalls placed on individual nodes, primarily to filter outgoing traffic. All networking firewalls have the ability to perform packet filtering, which is the ability to inspect packets and determine if they conform to the packet filter's filtering rules. If they do not match the rules, the packets will be dropped.

pfSense's firewall has three options for filtering: **Pass** allows the packet to pass through the firewall. **Block** will drop the packet silently. **Reject** will also cause the packet to be discarded, but a **port unreachable** message will be returned to the sender (which will inform the sender that a firewall is blocking the traffic).

In pfSense, rules are evaluated on a top-down basis. Thus, if you read the ruleset (the list of rules) from the top to bottom, the first rule that matches the packet will be applied, and the remainder of the ruleset will not be applied for that packet. As a result, the order in which rules are placed within a list is significant, and the most permissive rules should be placed at the bottom of the list.

pfSense is a stateful firewall, which means that it records all packets passing through it, and determines whether the packet is part of a new connection, part of an existing connection, or neither of these. If the packet is part of an existing connection, the reply traffic is automatically allowed through the firewall. This is the case even if the packet uses a different protocol than the original connection, such as ICMP control packets. This is known as **stateful packet inspection**.

While stateful packet inspection has been an integral part of almost all firewalls since the early 1990s, it comes with a downside. Each connection represents a state, and each state requires an entry in the firewall's state table. In pfSense, each state requires about 1 KB of memory. The state table has a maximum size, which can be set under **System | Advanced** and clicking on the **Firewall & NAT** tab (**Firewall Maximum States**, which sets the maximum number of connections, and **Firewall Maximum Table Entries**, which sets the maximum number of entries, which includes entries for everything that creates entries, including proxy servers, are the relevant settings here). If the number of connections exceeds **Firewall Maximum States**, then unpredictable behavior will occur, such as connections being dropped. This creates a potential attack vector, as some **Denial of Service** (**DoS**) attacks are based on bombarding the firewall with so many fake connection packets that the state table becomes overwhelmed, and starts dropping connections and preventing new connections from being made.

The two basic types of packet filtering are ingress filtering, which blocks traffic coming into your network from the Internet, and egress filtering, which filters traffic initiated within your network whose destination is either the Internet or another interface/subnet on your local network. It is easy to see why you would want to have ingress filtering, as we tend to want to protect our networks from nefarious forces outside of our networks. In fact, the default setting for pfSense is to block all incoming traffic, and there are no allow rules on the WAN interface by default (although as mentioned earlier, replies to connections already allowed by pfSense are allowed through the firewall). It is not as easy to see why egress filtering is necessary, as we tend to assume that all other things being equal, our local networks can be trusted.

There are, however, valid reasons for employing egress filtering. In spite of your best efforts, it is possible that malware may find its way onto your local network, and if you do not have some form of egress filtering, this malware will be able to phone home. The objectives of the malware may differ: the goal may be to send data back to a location controlled by the malware writer. The goal may be to use your computer as a bot which the malware writer controls for some purpose (for example, to send spam). It is also possible that compromising your network's security is the ultimate goal of the malware. Many of these programs use commonly allowed ports (for example, port `80`, the default HTTP port) to circumvent egress filtering, but many do not. If you block port `6667`, which is the default IRC port, you can cripple many bots that rely on IRC to function. Whatever the purpose is of the malware, lack of egress filtering will allow malware that is already running on your local network to achieve its purpose. Moreover, any reply traffic to the malware will also be allowed through the firewall. Thus, lack of egress filtering can result in harm being done to our networks.

Lack of egress filtering can also harm networks beyond our control. If malware or another party gains access to your local network, then your network can be used as a springboard to launch attacks on other networks. This includes attacks that involve IP spoofing, such as **Distributed Denial of Service** (**DDoS**) attacks, or spam or phishing campaigns. This can become especially problematic if you have several connections to the Internet. If you are running a DNS server on your network, someone might use it to host the zone data for a malicious domain. In short, you could unwittingly be an accomplice to criminal activities, which is definitely something we want to avoid doing.

Although in most cases egress filtering will only minimize damage done once a network is compromised, in some cases it can prevent a network from being compromised at all. Some malware requires outbound access in order to succeed at all, and by using egress filtering judiciously, you can stop it in its tracks. The **Code Red** worm is a good example of this, and any malware that requires downloading a file from an external site controlled by the malware writer can be stopped in such a manner.

Another reason for employing egress filtering is to prevent use of unauthorized software on our own network. Many peer-to-peer programs use atypical ports, which can easily be blocked via egress filtering. Some of these programs have become more sophisticated and will hop from port to port until they find one they can use, but by blocking all ports except those which are essential, we can minimize the use of these programs. In addition, egress filtering can, in many cases, prevent users from using VPN software, which otherwise could be used to bypass firewall rules and access unauthorized sites.

Finally, egress filtering can be used to prevent traffic from passing through your firewall that should never have outbound access. SMTP traffic on ports `161` and `162` come to mind; not only should SMTP traffic never pass through to the Internet, but allowing it to do so could compromise the security of your network by revealing information about what exists behind your firewall. You may also consider blocking DHCP traffic on ports `67` and `68` and SQL queries on port `118`.

Firewall best practices

From these fundamental principles we can distil a set of best practices for implementing our firewall. Some of these practices are fairly obvious; some may not be quite so obvious:

- When you create your firewall rules, the principle of least privilege should apply. In many cases, firewall rules have been too permissive. You should try to avoid creating pass-through rules which have **any** in the destination field, or at least limit the range of ports to which these rules apply. pfSense blocks all network traffic by default, and you'll want to take advantage of that.
- You should periodically check your firewall rules and delete rules that are out of date. For example, in our example network, we had a printer on the **MARKETING** subnet that was to be shared, and therefore a firewall rule would have to be created granting access to this printer. If the printer is subsequently decommissioned or moved to another subnet, then the rule granting access to the printer's IP address should be removed. In a corporate environment, finding out what rules should be removed may require network admins being proactive, as different departments may not make an effort to communicate this information. Still, it is an important practice, as deleting unnecessary firewall rules eliminates potential attack vectors.
- An important corollary to these two practices is that all firewall rule changes should be documented. Even if you remember why a rule change was made, others may not remember, especially if the rule change was made in response to an emergency. Documenting rule changes makes firewall management easier and can be helpful in a troubleshooting scenario.
- Firewall rules should be backed up on a regular basis. In a corporate environment, such backups should be maintained offsite. Such backups may prove to be of value if you ever have to recover from a firewall crash or some other catastrophe.
- You should create your rules in such a manner that makes them consistent with your organization's security policy, and when you are done creating them, you should review them to make sure they are consistent with such policy.

- Eliminate redundant and unnecessary firewall rules, and try to keep your ruleset as simple as possible.
- Patch the firewall with the latest updates on a regular basis.
- You should limit the number of applications running on the firewall in order to maximize CPU cycles and increase network throughput. Any applications that can be run on a dedicated machine (for example, a proxy server) should be moved to another system either behind or in front of the firewall.
- It's a good idea to perform regular security tests on your firewall; new exploits are being found and the firewall should be tested on a regular basis. This should include testing every interface on both sides of the firewall.
- If your organization is required to comply with the **Payment Card Industry Data Security Standard** (**PCI DSS**), you will want to review your policies to make sure you are in compliance with this standard. For example, PCI requirement 1.1.6 requires a complete firewall review every six months. PCI DSS is constantly being updated – at the time of writing, Version 3.2 was scheduled for release in March or April of 2016 – so you need to review the latest version of the standard to see if there are any new requirements that affect firewall implementation.
- Enable logging, but only if you are going to actually look at the logs; otherwise, maintaining logs is a waste of both disk space and CPU usage.
- If you have remote users, you should require that they run a personal firewall and/or intrusion detection system on their computer.
- You may also consider running a remote syslog server for logging, to make it more difficult for potential hackers to modify the log files and thus cover their tracks.

Obviously, some of these suggestions may be overkill for a home or SOHO user, so you'll have to decide how many of these suggestions you implement, but avoiding overly permissive rules, deleting outdated rules, and documenting rule changes are definitely good practices that we will want to employ even on home networks. Implementation of the other suggestions will depend on your security needs and level of paranoia.

Best practices for ingress filtering

Based on what we have already covered, we can articulate some best practices for ingress filtering. We want the default of block all traffic to stand. We need to allow access to ports and nodes for certain services that we are providing. For example, in our example network, we are operating an FTP server. This requires leaving port `21` open on the FTP server's network. In addition, we want to use ingress filtering as a means of preventing DDoS attacks. The best practices for ingress filtering are described in the following **Internet Engineering Task Force** (**IETF**) documents:

- **Network Ingress Filtering:** Defeating DoS attacks which employ IP source address spoofing (`https://tools.ietf.org/html/bcp38`)
- **Ingress Filtering for Multihomed Networks**: Discusses different strategies for ensuring that incoming packets are from the networks from which they claim to originate, both in general and from a multihomed (meaning the network has multiple points of access to the Internet) perspective (`https://tools.ietf.org/html/bcp84`)

The aforementioned documents are not particularly long, and reading them in their entirety can be instructive. However, the most pertinent findings of these documents are as follows:

- Traffic which employs IP spoofing should be blocked by firewalls. Ingress filters should thus be configured to only allow traffic from valid source addresses.
- Automatic filtering should be used on remote access servers. If, for example, a user connects to a remote access server through an ISP, the only valid IP address for traffic from that user is the IP address assigned by the ISP.
- If DHCP or BOOTP is used, provision must be made on the relay agent for packets with a source IP address of `0.0.0.0` and a destination IP address of `255.255.255.255`.
- BCP 84 is aimed at ISPs and edge network operators, and describes different methods of **reverse path forwarding** (**RPF**) which can be used to thwart DDoS attacks. If RPF is employed, the router will check the source IP address of a packet, which will only be forwarded if they come from the router's best route to the source of the packet. Otherwise, the packet will be dropped.

Best practices for egress filtering

If you are configuring a home network or SOHO network, determining your egress filtering requirements begins with compiling a list of services to which you need access (this might include such services as DNS, SMTP, POP and/or IMAP, NTP, and HTTP/HTTPS). If you are configuring a corporate network, you probably want to begin by consulting your organization's security policy. You may also want to consult with those in charge of network security and perhaps other stakeholders within the organization.

You should make a list of remote servers that services running on your network have to access, and allow them through the filter. For example, if you are running a DNS server, it will undoubtedly have to communicate with other DNS servers. You may find it helpful to organize your interfaces into interface groups, with access being granted based on the interface group settings.

As mentioned previously, egress filtering should begin with a *deny all* outbound policy. From here, add access for the services identified when you first compiled a list of services. Then add rules that allow the admins access to network/security systems they need to get to in order to do their jobs. Finally, you should add rules to allow any servers you operate on your local network to communicate with externally hosted services.

You should also use your egress filtering policy to prevent IP spoofing. This means only allowing source addresses from the IP addresses you assign to nodes on your local networks to pass through the firewall. This will include addresses assigned via DHCP or statically, and subnets routed to the Internet through the firewall, including VPN clients (if VPN is enabled). If you are only using a portion of the subnet to assign addresses (for example, you have `172.16.0.0` as one of your networks, and you are only using `172.16.1.0`), then allow only the addresses you are actually using and not the rest of the subnet.

You should block all connections from internal servers or workgroups that have no business establishing connections with external servers. Also, you should consult lists such as those maintained by **The Spamhaus Project** to determine which domains and IPs are used by spammers and botnets, and therefore should be blocked. Spamhaus's **Don't Route or Peer** (**DROP**) list is particularly helpful, as it identifies IP blocks that have been hijacked or are otherwise totally controlled by spammers, and therefore should be blocked.

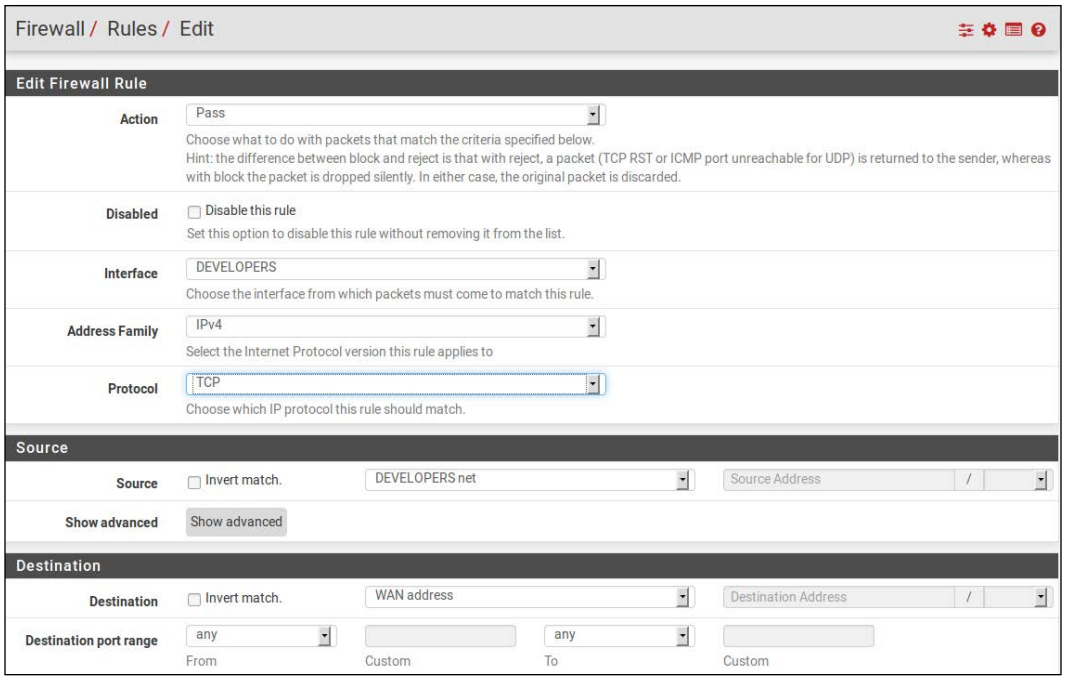
Creating and editing firewall rules

Now that we have covered some basic firewall principles, we can begin our firewall configuration. To create and/or edit firewall rules, log in to pfSense and navigate to **Firewall | Rules**. This should present you with a list of interfaces across the top of the page; you can see the ruleset for each interface by clicking on its name (initially, you will see the ruleset for the **WAN** interface). Typically, we will click on the interface for which we want to create/edit rules first, although you can create rules for any interface from any tab, since the Rule Edit page will provide an **Interface** option that allows you to choose the interface to which the rule applies. Click on the interface for which you want to add a rule and use one of the two **Add** buttons at the bottom of the page to create a rule. The **Add** button with the up arrow will place the newly created rule at the top of the table, while the **Add** button with the down arrow will place the newly created rule at the bottom of the table. Another helpful option is to use the **Copy** button, which can be seen on the right side of a table listing of a current rule. The **Copy** button (represented by an icon showing two sheets of paper) allows you to create a new rule based on an existing rule. When you press the **Copy** button, you will generate a new rule in which all the options are initially identical to the old rule.

Choosing any of the options outlined earlier will launch the **Edit** page for firewall rules. The first section of the page is **Edit Firewall Rule**, and the first option is the **Action** drop-down box, which allows you to select what happens to packets that meet the rule criteria. The options for the rule are as follows:

- **Pass**: Let the traffic pass
- **Block**: The packet is dropped silently
- **Reject**: The packet is returned to the sender with a TCP RST or ICMP port unreachable message (TCP RST is for TCP traffic, ICMP port unreachable is for UDP traffic)

There is a split of authority on whether the best practice is to block traffic or reject it. The advantage of **Reject**, of course, is that the sender knows right away that access to the resource is not allowed, whereas with block, the connection eventually times out:



Creating a rule in pfSense. The rule allows TCP traffic to pass from the DEVELOPERS network to a WAN address.

This **Disabled** checkbox, if checked, will result in the rule being disabled without removing it from the ruleset. The **Interface** drop-down box allows you to select the interface to which this rule applies (the interface from which packets must come in on for the rule to apply). The **Address Family** drop-down box lets you select which Internet protocol version to which the rule applies: the choices are **IPv4**, **IPv6**, or both (**IPv4+IPv6**). Finally, the **Protocol** drop-down box allows you to select which IP protocol the rule should match. You should try to avoid using the any option here, and only allow the protocol or protocols you need to allow.

The next section of the page is **Source**, which allows you to specify where the packets must originate if they are to match the rule. In the **Source** drop-down box, you can specify several options: **any** will result in any packet on the interface matching the rule; **Single host or alias** enables you to enter a single IP address or alias (we will cover how to create an alias later in the chapter). **Network** allows you to enter a subnet (if you select it, you must enter the network portion of the address and the CIDR). You can also select **PPPoE clients** (PPPoE stands for Point-to-Point over Ethernet) or **L2TP clients** (L2TP stands for Layer 2 Tunnelling Protocol). The remaining options allow you to select as the source either an entire interface you previously created (for example, LAN) or an address on that interface. The **Invert match** checkbox, if checked, will result in the rule being applied to the opposite of what is selected for the source. For example, if you select **LAN net** and check **Invert match**, the rule will apply to everything but the **LAN net**. Clicking on the **Show advanced** button will reveal the **Source port range** options. You can select ports from the drop-down boxes or type them directly into the edit boxes.

The **Destination** section allows you to select the destination the packets must match for the rule to apply. It mirrors the **Source** section, with the exception of the fact that the **Destination port range** field is always visible and showing/hiding this option is not possible. As with **Source**, you can invert the match.

The next section is called **Extra Options**. The **Log** checkbox, if checked, will log packets that are handled by the rule. Usually you won't want to turn on logging for rules, since that's a good way to use up all remaining disk space, but if you need to log packets for an individual rule, you can do it here. You can also enter a brief description for future reference. Clicking on the **Advanced Options** button will show the **Advanced Options** section of the page.

The **Source OS** drop-down box allows you to select the operating system from which the packets must come if the rule is to be applied. There are many options (including **Any**), although there does not seem to be options for newer versions of Windows (there are no options for Windows 7, 8 , or 10, although there are options for older versions as well as a generic **Windows** option). The **Diffserv Code Point** option allows you to apply the rule only to certain **Diffserv Code Point** values; different Diffserv values are used for traffic filtering or queue assignments. Traffic shaping must be enabled for this option to work.

By default, pfSense blocks packets with IP options set; checking the **Allow IP options** checkbox allows these packets to pass. The **Disable reply-to** checkbox is designed for setups in which a non-WAN interface is the gateway for part of our network. If this is the case, reply-to traffic for a packet will be routed through the defined gateway rather than through the interface on which the packet arrived. This can result in the gateway forwarding the packet to the firewall, and the firewall sending it back, resulting in an eventual timeout. In cases such as this, we should enable the **Disable reply-to** option.

The **Tag** edit box allows you to mark a packet matching the rule. You can then use the mark to match on NAT and/or filter rules. The next option, **Tagged**, allows you to match a packet if a mark was placed on it by another rule.

The following options may be of some help in mitigating a DoS attack. **Max. states** defines the maximum state entries the rule can create, while **Max. src nodes** defines the maximum number of unique source hosts. **Max. connections** defines the maximum number of established connections per host. It only works on TCP (you have to have a connection for this rule to apply, so obviously it would not work with a connectionless protocol such as UDP). **Max. src. States** sets the maximum state entries per host. **Max. src. Conn. Rate** sets the maximum new connections per host. **Max. src. Conn. Rate** and **Max. src. Conn. Rates** together control the number of connections allowed per host per second(s). The first edit box specifies the number of connections and the second edit box specifies the time interval. For example, setting **Max. src. conn. Rate** to `25` and **Max.src. conn. Rates** to `60` will allow 25 connections per host per minute (60 seconds). Finally, **State timeout** specifies the amount of time before a state entry will expire. Obviously, this can help prevent the state table from filling up, thus potentially thwarting DoS attacks, but if the timeout is set for too short a time, legitimate traffic could be dropped. **Max src. Conn. Rate**, **Max.src. Conn. Rates,** and **State timeout** only apply to TCP connections.

The next setting, **TCP Flags**, can be used to choose which TCP flags need to be set or cleared in order for the rule to match. Check the flag in the **set** row to require that the flag be set; check the flag in the **out of** row to require that it be cleared. Check the **Any flags** checkbox for the rule to match if any flag is set or cleared.

The **No pfSync** checkbox, if checked, will result in states created by the rule not being synced over pfSync if **Common Address Redundancy Protocol** (**CARP**) is being used. The **State type** drop-down box allows you to choose which type of state tracking mechanism to use. The **Keep** option is the default option, and it works with all protocols. **Sloppy** also works with all protocols. It invokes a less stringent form of state tracking. This can be useful if asymmetric routing is used (like the situation with multiple gateways described earlier). **Synproxy** will automatically proxy incoming TCP connections. This is useful, because if it is invoked, pfSense will not create a new state table entry for a new TCP connection until it receives a `SYN ACK` packet. This will help protect your network from spoofed `SYN` flood attacks. As you probably have guessed, it only works on TCP connections. Finally, **None** results in no state entries being created for this rule.

The **No XMLRPC Sync** checkbox, if checked, will prevent this rule from syncing to other CARP members. Note that this only works between two or more master CARP members; it does not prevent the master from overwriting the rule on a slave CARP member. The **VLAN Prio** option allows you to choose an **802.1p** priority level that must be set for on a VLAN packet for the rule to match. These priority levels (which were discussed in *Chapter 3*, *Working with VLANs*) are represented in the drop-down box as acronyms. The following table describes each acronym:

Acronym	**Description**
BK	Background
BE	Best Effort
EE	Excellent Effort
CA	Critical Applications
VI	Video with less than 100 ms latency
VO	Voice with less than 10 ms latency
IC	Internetwork Control
NC	Network Control

The **VLAN priority set** drop-down box allows you to choose an **802.1p** priority to apply to the packets that match this rule. The abbreviations in this drop-down box are identical to the ones in the **VLAN Prio** drop-down box.

The **Schedule** drop-down box allows you to apply the rule only during a predefined time range. You can't create the time range on this page; you need to do this from **Firewall | Schedules**. The process will be detailed later in this chapter. The **none** option leaves the rule enabled all the time.

The **Gateway** drop-down box allows you to select a gateway for traffic matching the rule. If **default** is selected, then the system routing table is used. Otherwise, the traffic goes out on the selected gateway. This is useful if you want to set up policy based routing.

The next option is **In/Out pipe**. This allows you to pipe traffic coming from a selected interface (the **In** interface), and send traffic leaving the interface to another interface (the **Out** interface). The **Ackqueue/Queue** option allows you to pipe traffic coming from a specific traffic shaping queue and send the `ACK` traffic to a specific `ack` queue.

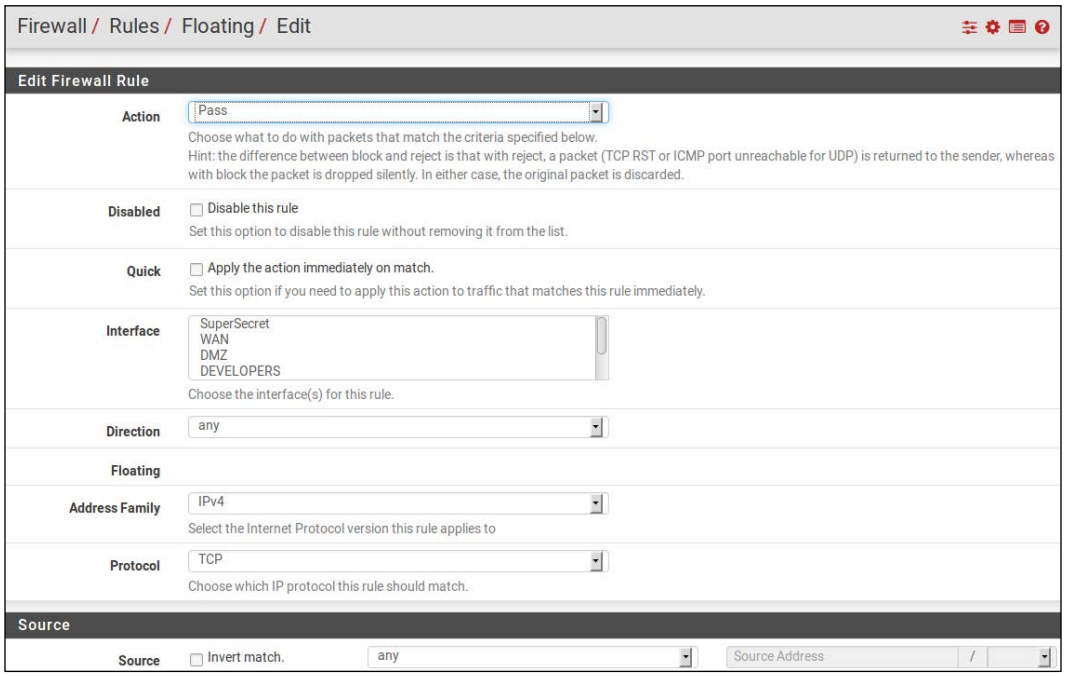
When you are finished making changes, click on the **Save** button at the bottom of the page. This will return you to the main **Rules** page.

Floating rules

Floating firewall rules are rules that are different from other firewall rules in two significant ways:

- They can be applied in any direction
- They can be applied to more than one interface

The following screenshot shows how to configure a floating rule:



Configuring a floating rule. Floating rules have the Quick option, and more than one interface can be selected.

Floating rules can be created by clicking on the **Floating** tab on the **Rules** page and clicking on one of the **Add** buttons. The options are similar to those in the conventional rule **Edit** page, with the following exceptions:

- The **Quick** checkbox, if checked, will cause pfSense to apply the rule to packets matching the rule and pfSense will not attempt to filter the packets against any other rules
- In the **Interface** listbox, more than one interface may be selected
- In the **Direction** drop-down box, you can choose to apply the rule to traffic coming into the interface (**in**), traffic leaving the interface (**out**), or both (**any**)

Keep in mind that floating rules are parsed before other rules, so even if the **Quick** option isn't enabled, a misconfigured floating rule could easily defeat the purpose of rules on individual interfaces.

An example rule

To demonstrate the rule creation process, we will create one of the rules needed for our example network. Each subnet requires a rule to allow access to the Internet, so we will create such a rule for the **DEVELOPERS** subnet. The process, which is relatively simple, is outlined as follows:

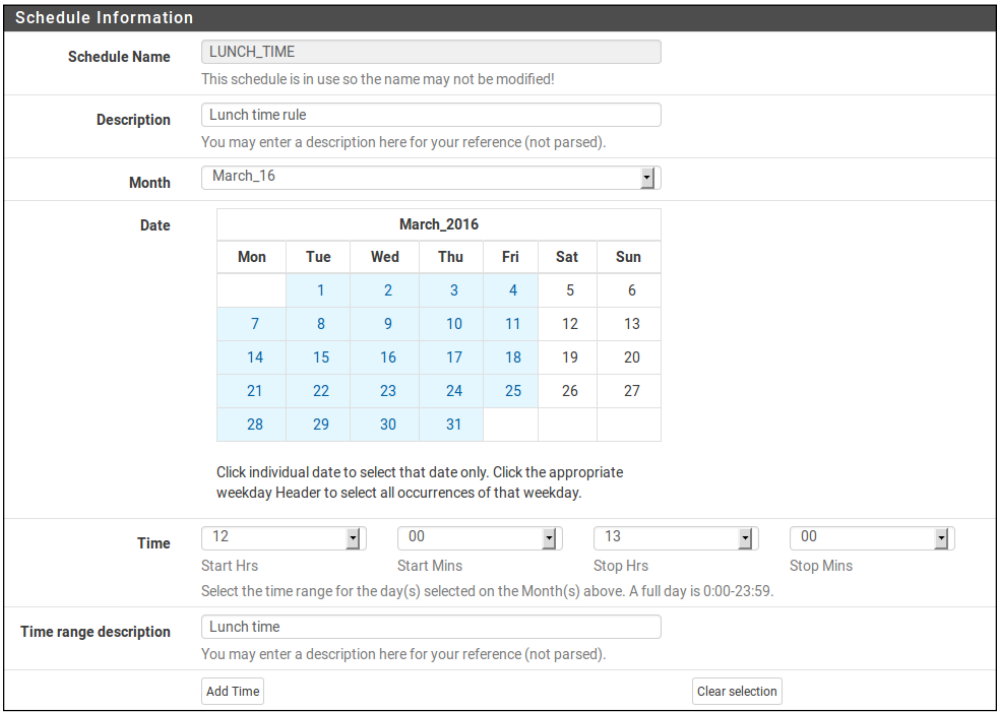
1. We navigate to **Firewall | Rules**, and click on the **DEVELOPERS** tab. Then we can click on either **Add** button below the table to add a new rule.
2. On the **Edit** page, many of the default values can be used; the default **Action** value of **Pass** is kept. For **Interface**, we select **DEVELOPERS** as the interface from which packets must come in on to match this rule. We can set the **Address Family** field to **IPv4**, **IPv6**, or **IPv4+IPv6**, depending on whether or not our network supports IPv4 addresses, IPv6 addresses, or both. We only need to allow TCP traffic, so we leave **Protocol** set to **TCP**.
3. The packets must come from the **DEVELOPERS** subnet for the rule to apply, so we set **Source** to **DEVELOPERS net**. We don't need to set a port range for this rule, so we will not click on the **Show Advanced** button.
4. For this rule to apply, the traffic must be destined for the Internet, so for **Destination**, we select **WAN net**. We leave **Destination port range** unchanged, since we don't need to set a port range.
5. For **Description**, we type **Allow DEVELOPERS to WAN rule** for future reference. Then we click on the **Save** button. Once we are returned to the main **Rules** page, we need to click on the **Apply Changes** button to reload the firewall rules.

That's all there is to it – nodes on the **DEVELOPERS** subnet should now be able to access the Internet. Keep in mind we still need to create similar rules for the other subnets, and we can do that easily by just clicking on the **Copy** button in the right side of the table next to that rule. Once we do that, we change **Interface** to the new interface (for example, **ENGINEERING**), and we change **Source** to match what we set in **Interface**. We change **Description** accordingly (for example, **Allow ENGINEERING to WAN rule**) and click on **Save**. We have now made a duplicate rule for another subnet. Another option would be to set up a floating rule to allow Internet access to all subnets that require it.

Scheduling

Rules don't have to take effect all the time; we can define time ranges during which the rules apply, and the process is even easier than creating rules. Each schedule can have multiple time ranges, and, once defined, it can be applied to a rule. To get started with scheduling, navigate to **Firewall | Schedules**. There will be a table displaying all the previously created schedule entries; clicking on the **Add** button below the table allows you to create a new entry.

The **Edit** page for schedules has two sections: **Schedule Information**, in which you can configure options, and **Configured Ranges**, in which the already defined ranges for this rule appear. You must create at least one time range per schedule, although you can create more. The first option on the page is **Schedule Name**, where you enter the name, which can consist only of letters, numbers, and the underscore character. You may also enter a non-parsed, free-form description in the next field. In the **Month** drop-down box, you can select the month that will appear in the **Date** section. **Time ranges** can consist of individual dates (for example, April 15), or to days of the week (for example, Tuesdays). You can click on an individual date on the calendar to select only that date, or you can click on a weekday header to select all occurrences of that weekday.



Creating a schedule. The schedule entry will apply to all weekdays.

In the **Time** section, you can select a time range for the days selected on the calendar. The fields are **Start Hrs**, **Start Mins**, **Stop Hrs**, and **Stop Mins**, and time is in 24-hour time. You can also enter a non-parsed **Time range description**. When you are done defining a time range, you can click on the **Add Time** button. Alternatively, you can click on the **Clear selection** button to clear the selection. Once you click on the **Add Time** button, the time range should appear in the **Configured Ranges** section of the page. You can create additional time ranges by selecting the appropriate dates/days of the week and time ranges, adding a description, and clicking the **Add Time** button again. You can also delete existing ranges by clicking on the **Delete** button to the right of each entry. When you are done configuring time ranges and editing other options, click on the **Save** button at the bottom of the page.

An example schedule

To illustrate the process of creating a schedule and using it in a rule, we will create a schedule for lunchtime (Noon-1 PM) and create a rule using this schedule. This will allow us to implement a rule which allows access to Slashdot only during Noon to 1 PM on weekdays. To do this, we perform the following steps:

1. Navigate to **Firewall** | **Schedules**, and click on the **Add** button at the bottom of the page.
2. Set **Schedule Name** to **LUNCH_TIME** and add a brief description.
3. On the calendar, select **Mon**, **Tue**, **Wed**, **Thu**, and **Fri** by clicking on the top of each column.
4. Set the time range in the **Time** fields to begin at **12:00** and end at **13:00**. Enter a brief description (for example, *Lunchtime*), and click on the **Add Time** button. Then click on the **Save** button at the bottom of the page.
5. Now that the schedule has been added, we can navigate to **Firewall** | **Rules** and add a rule that utilizes it. From the **Rules** page, we click on the **DEVELOPERS** tab and click on the **Add** button that shows an up arrow to the right of **Add**, to add a rule to the top of the list.
6. On the **Edit** page, we can keep all the options in the **Edit Firewall Rule** section the same, unless we need to support IPv6 addresses (we will assume we do not have to support such addresses). We set **Source** to **DEVELOPERS net** and leave the port options unchanged. We set **Source** to **Single host or alias** and enter `216.34.181.45` (the Slashdot IP address) in the **Source Address** field. We can also enter a description for this rule (for example, *Allow Slashdot during lunchtime*).

7. To configure scheduling options, we need to click on the **Advanced options** button. Once we do, the advanced options will appear on the page, and we can scroll down to the **Schedule** drop-down box. In this box, we can now select the **LUNCH_TIME** schedule we just created.
8. Now we can scroll to the bottom of the page and click on the **Save** button. Our new rule is now created. We still need to click on the **Apply Changes** button on the main **Rules** page to reload the firewall rules.

You may have noticed that we have created a rule to allow access to Slashdot during the lunch hour, but we have not created a rule to block access to Slashdot yet. Thus, with our current ruleset, the new rule has no practical effect, because access to Slashdot was already enabled via the **Allow DEVELOPERS to WAN** rule. We can easily create a rule to block Slashdot, however, by clicking on the **Copy** button to the right of the new rule in the table, and creating a new rule based on the previously created rule. We just need to change the **Action** from **Pass** to either **Block** or **Reject** (**Reject** is probably the better option), and change the **Schedule** option so the rule applies at all times. We should also change the **Description** field to reflect its purpose. After we click on the **Save** button, a new rule will be created after the **Allow Slashdot during lunchtime** rule, which is the order we need. Remember, rules are evaluated on a top-down basis, so we want the **Block Slashdot** rule to come before to the **All DEVELOPERS to WAN** rule and we want the **Allow Slashdot during lunchtime** rule to come before both of these rules.

NAT/port forwarding

NAT, in its most commonly used form, is a means of connecting multiple computers to the Internet through a single Internet connection. But it can do more than that, and can accommodate networks with multiple IP addresses. There are two forms of NAT: inbound NAT (port forwarding), which controls where incoming traffic is sent, and outbound NAT, which controls outgoing traffic. We will cover both of these categories in this section.

Inbound NAT (port forwarding)

To configure inbound NAT settings, navigate to **Firewall | NAT**, and click on the **Port Forwarding** tab. Port forwarding allows you to forward a specific port, range of ports, or protocol to a node on your internal network.

By default, pfSense does not leave any ports open on the WAN interface, which blocks any traffic initiated on the Internet. This provides protection against malicious parties looking to attack your system. If you add a port forward, pfSense will create a corresponding firewall rule, and it will allow any traffic matching the corresponding rule through. Thus, if you allow port forwarding to a node, you will have to rely on that node's security to protect it from attack.

To create a new port forwarding rule, from the **Port Forward** tab on the **NAT** page, click on one of the **Add** buttons to add a new rule. The first option is **Disable**, which allows you to disable a rule without deleting it. **No RDR (NOT)** negates the rule, thus disabling redirection. This option is rarely used, but may be useful if you have a transparent proxy running. It could also be used if you want to exclude a subset of ports from a larger range of ports.

The **Interface** drop-down box allows you to select the interface the rule applies to (in most cases, you want to leave this as **WAN**, since with inbound NAT, we are concerned with traffic originating on the Internet). The **Protocol** drop-down box allows you to select which protocol to which the NAT rule applies. **Source** allows you to match a packet from a specific source address or network, but in most cases, you can leave it set to **Any**. You can also set a **Source** port range, but this is also usually set to **Any**, since the source and destination port are rarely the same.

For **Destination**, you probably want to leave this set to **WAN address**, since users on the Internet will be targeting your WAN address, not one of your private network IP addresses. If you have a multi WAN setup, you may want to change the destination to one of your other WAN interfaces. **Destination port range** is the port, or range of ports, you want to forward to one of your private IP addresses.

In the **Redirect target IP** edit box, you enter the internal IP address of the node to which you want to map the port or range of ports. The **Redirect target port** option specifies the port to which you want to map the port specified in the **Destination** port range. This is usually identical to the port specified in the **Destination** port range, but you can specify a different port or ports here. This can be useful in some circumstances. For example, you may want to set up a private web server which is accessible from the Internet on your home Internet connection. However, most ISPs block port `80` (the default HTTP port) and port `443` (HTTPS). Using **Port Redirection**, you can choose a port other than ports `80` and `443` for **Destination** (for example, `1234`) and redirect traffic coming in on that port to your web server (which likely would be accepting traffic on port `80`).

In the **Description** edit box, you can enter a non-parsed description for future reference. The **No XMLRPC Sync** checkbox, if checked, will result in this rule not being synced to other CARP members (this does not apply to CARP slaves, which can still have their NAT rules overwritten by a CARP master). The **NAT Reflection** drop-down box allows you to access the service to which port forwarding is enabled using the public IP address of your network. The **Use system default** option allows you to use whatever NAT reflection option was chosen in **System | Advanced** under the **NAT** tab. The **Enable (NAT + Proxy)** option will set up a proxy daemon which will receive and reflect connections, but it will only work with TCP connections, and only with single port forwards, or with ranges of less than 500 ports. **Enable (Pure NAT)** just creates automatic NAT redirect rules to accomplish redirection without using an external daemon. Finally, **Disable** will disable NAT reflection.

The **Filter rule association** drop-down box allows you to select what type of firewall rule is created corresponding to the NAT rule. **Add associated filter rule** generates a new firewall rule that is updated whenever the NAT rule is updated. **Add unassociated filter rule** generates a new firewall rule that is not automatically updated. **Pass** will pass traffic that matches the NAT rule through the firewall, but does not create a new firewall rule for it. Finally, if the **None** option is selected, no firewall rule is created and, unless an existing firewall rule allows the traffic from this NAT rule to pass, the traffic will not pass. When you are done making changes, you can click on the **Save** button at the bottom of the page and then click on the **Apply Changes** button on the main **Port Forwarding** page.

1:1 NAT

1:1 NAT allows you to map one public IP to one private IP; all traffic from that private IP to the Internet will then be mapped to the public IP specified in the 1:1 NAT mapping. This will override the **Outbound NAT** settings. Conversely, all traffic initiated on the Internet which is destined for the specified public IP address will then be translated to the private IP. Then it will be evaluated according to the WAN firewall ruleset, and if the traffic is permitted by the WAN rules, it will be passed to the internal node specified in the mapping.

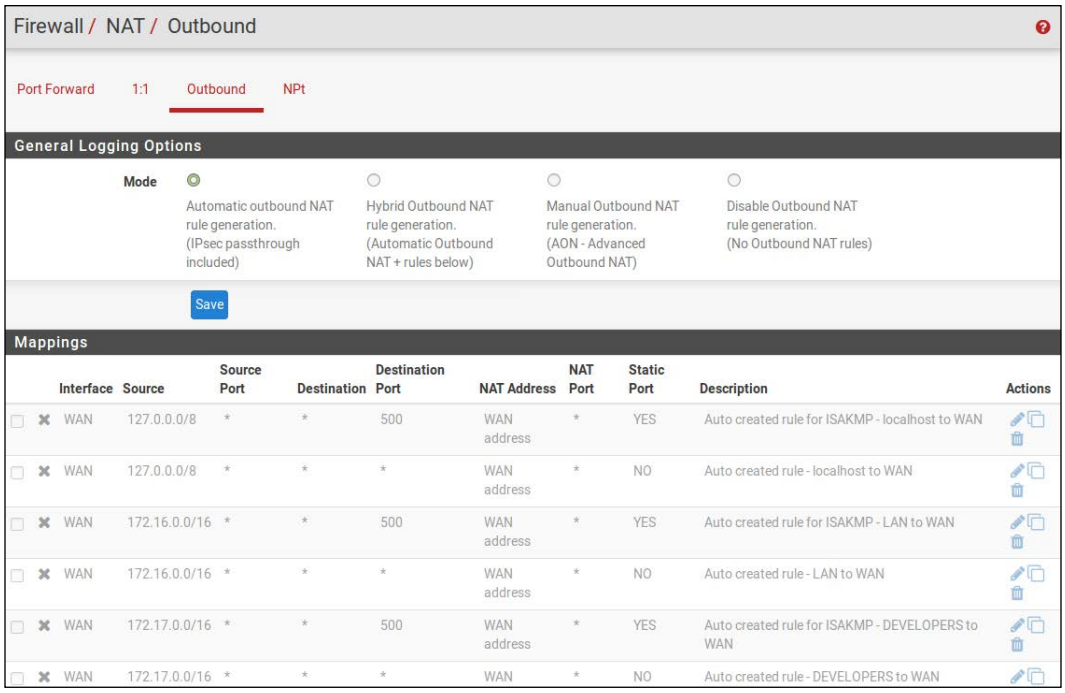
To create a NAT 1:1 mapping, click on the **1:1** tab on the **NAT** page and click on the **Add** button below the table. Many of the options are similar to the options we covered in the **Port Forwarding** section. **Negate** allows you to exclude the rule from the NAT, which could be useful if you are redirecting a range of addresses, and need to exclude a subset of the range. **No BINAT** disables redirection for any traffic matching the rule. This way, you can exclude a subset of addresses from a larger range of translated addresses. The **Interface** dropdown allows you to specify the interface to which this mapping applies; usually, you can leave it set to **WAN**. The **External subnet ID** edit box is where you enter the external subnet's starting IP address for the 1:1 mapping.

In the **Internal IP** section, you specify the internal subnet for the 1:1 mapping. The subnet size for the internal subnet determines how many IP addresses are mapped. For example, assume we have set **External subnet IP** to `10.1.1.1` and **Internal IP** to `192.168.1.100/30` (with **Network** as the type specified in the **Type** drop-down box). This will map `10.1.1.1` to `192.168.1.100`, `10.1.1.2` to `192.168.1.101`, and so on up to and including `10.1.1.3/192.168.1.103`. **Destination** allows us to use the 1:1 mapping only for connection to or from the specified destination; usually, this is set as **Any**. Both **Internal IP** and **Destination** have **Not** checkboxes allowing us to invert the sense of the match.

You can enter a non-parsed description for future reference in the **Description** field. The **NAT reflection** drop-down box allows you to access the mapped nodes on the local network from the public IP address. Unlike **Port Forwarding**, where there were several options for reflection, there are only two options here: **Enable** and **Disable**. Click on the **Save** button when you are done making changes to the 1:1 entry and click on the **Apply Changes** button on the main **NAT** page to reload the rules.

Outbound NAT

Outbound NAT configuration, as the name applies, covers traffic from our internal networks whose destination is an external network. The default NAT configuration in pfSense automatically translates outbound traffic to the WAN IP address. If there are multiple WAN interfaces, traffic leaving any WAN interface is automatically translated to the address of the WAN interface which is being used. Thus, you may find configuring outbound NAT rules unnecessary.



The main outbound NAT page, with Automatic outbound NAT rule generation selected. Rules in the Mappings section are automatically generated rules.

If you do need to create or edit outbound NAT rules you can do so by clicking on the **Outbound** tab on the **NAT** page. There are four options (represented by radio buttons) in the **General Logging Options** section, which control how the outbound rules are generated:

- **Automatic outbound NAT rule generation** is the default option and is suitable if all you want to do is forward outbound traffic to the WAN, while translating the internal IP address to the external IP address
- **Hybrid Outbound NAT rule generation** will still automatically generate outbound NAT rules for each non-WAN interface, but you will also be able to create your own outbound NAT rules

- **Manual Outbound NAT rule generation**, if selected, will not automatically create any rules, although any previously created automatic rules will remain
- **Disable Outbound NAT rule generation**, if selected, will result in no outbound NAT rules being allowed

If you have **Automatic outbound NAT rule generation** selected, you should also see a section on the page called **Automatic Rules** which will contain two rules: a rule for non-static ports to pass outgoing traffic on internal interfaces to the WAN address, and a rule for static ports to send ISAKMP traffic. To create or edit outbound NAT rules, click on one of the **Add** buttons below the **Mappings** section.

The first section of the page is **Edit Advanced Outbound NAT Entry**. The **Disabled** option just disables the rule, while **Do not NAT** completely disables NAT processing for traffic matching the rule. The **Interface** drop-down box allows you to select with **Interface** (as with almost every rule in which NAT is involved, this is usually set to **WAN**). **Protocol** allows you to specify the protocol the outbound rule applies to (usually we can keep it set to **any**, but you may want to create a more restrictive rule). **Source** is where you define where the traffic originates. This is almost always a subnet on your local network. For example, if we want to create an outbound rule for the **DEVELOPERS** network, and its subnet is `172.17.0.0/16`, we would choose **Network** in the **Type** drop-down box, and enter `172.16.0.0` in the adjacent edit box and set the **CIDR** in the dropdown box to **16**. Finally, **Destination** allows us to set a destination network for the outbound NAT mapping. Since we typically do not know the destination ahead of time, we usually set this to **Any**. The **Not** checkbox, if checked, inverts the sense of the destination match.

The **Translation** section of the page allows us to translate the IP address from the original internal address to another IP address. The default setting in the **Address** drop-down box is **Interface Address**, which just uses the IP address of the interface selected in the **Interface** drop-down box. We can also select **Other Subnet**, which will make additional options available. If we choose this option in the drop-down box, we can enter a different subnet in the **Other subnet** edit box; if we use this option, we need to define virtual IPs first, and use a subnet of virtual IPs.

The **Pool options** dropdown allows you to select how the subnet pool is used. The following options are available:

- **Round Robin**: This goes through the virtual IP addresses in a round-robin fashion; in other words, in a loop. It is the only option that works with host aliases.
- **Random**: This option will result in pfSense selecting an address from the virtual IP subnet randomly.

- **Source Hash**: This option will take the source IP address, hash it, and use the hash to determine the translation IP address. This guarantees that as long as the source IP address remains the same, the translation IP address will also remain the same.
- **Bitmask**: This option applies the subnet mask defined in the **Other** subnet and keeps the last portion identical. So if we choose a virtual IP pool of `10.1.1.0/24` and the source IP is `192.168.1.12`, the translated address will be `10.1.1.12`.
- **Round Robin with Sticky Address/Random with Sticky Address**: These options invoke either **Round Robin** or **Random** addresses, but once an address is selected for a source IP address, it remains the same.

In the **Port** edit box, you can set the source port for the outbound NAT mapping. The **Static port** checkbox, if enabled, will prevent pfSense from rewriting the source port on outgoing packets. Rewriting the source port prevents other parties from finding out the original source port and thus thwarts fingerprinting nodes behind the firewall. Rewriting the source ports, however, breaks some applications, and in such cases we can enable static ports for the rule.

The **No XMLRPC Sync** checkbox in the **Misc** section, if checked, will prevent the rule from syncing to other CARP members. You can also enter a brief description for future reference. When you are done, click on the **Save** button at the bottom of the page and the **Apply Changes** button on the main **NAT** page.

Network Prefix Translation

Network Prefix Translation (**NPT**) allows us to map an internal IPv6 prefix to an external IPv6 prefix. Normally, we try to avoid using NAT when we use IPv6, but there are some cases where being able to translate IPv6 prefixes is helpful (for example, in multi WAN setups). It functions similarly to 1:1 NAT for IPv4 addresses, only in this case, we are translating prefixes, not complete addresses.

To create an NPT entry, click on the **NPT** tab and click on one of the **Add** buttons on the page. There is only one section on the page: **Edit NAT NPT Entry**. Checking the **Disable** checkbox will disable the rule. The **Interface** drop-down box allows you to select the interface to which the rule applies (once again, it's usually **WAN**).

The first **Address** edit box is where you enter the internal ULA IPv6 prefix which will be selected. You also need to select the CIDR for the prefix. In the second **Address** checkbox, you enter the external, global unicast routable IPv6 prefix (you must specify the CIDR of the prefix here as well). Both the internal and destination (external) prefixes have corresponding **Not** checkboxes you can use to invert the sense of the match.

The last option is the **Description** edit box, where you can enter a non-parsed description. Once you have entered all the information, click on the **Save** button and the **Apply Changes** button on the **NAT** page.

An example NAT rule

To illustrate NAT rule creation, we'll create a NAT rule for our example network. We want to set up an FTP server which will be accessible from the Internet. The FTP server will reside on the DMZ interface; its internal IP address will be `172.16.1.100`. The procedure for setting up a NAT rule for this server is as follows:

1. Navigate to **Firewall | NAT**, and click on one of the **Add** buttons.
2. Leave **Disabled**, **No RDR (NOT)**, **Interface**, **Protocol**, and **Source** unchanged. In **Destination**, leave **Type** as **WAN address**, and in **Destination port range**, select **FTP** in the first drop-down box as the **From** port.
3. Set the **Redirect target IP** to `172.16.1.100`.
4. In **Redirect target port**, select **FTP** in the drop-down box.
5. Enter a brief description in the **Description** field (for example, `FTP port forward rule`).
6. Leave the remaining options unchanged. Leaving the **Filter rule association** set to **Add associated filter rule** will ensure that a corresponding firewall rule will be created to allow traffic to port `21` of the FTP server. Click on the **Save** button at the bottom of the page, then click on **Apply Changes** on the **NAT** page.

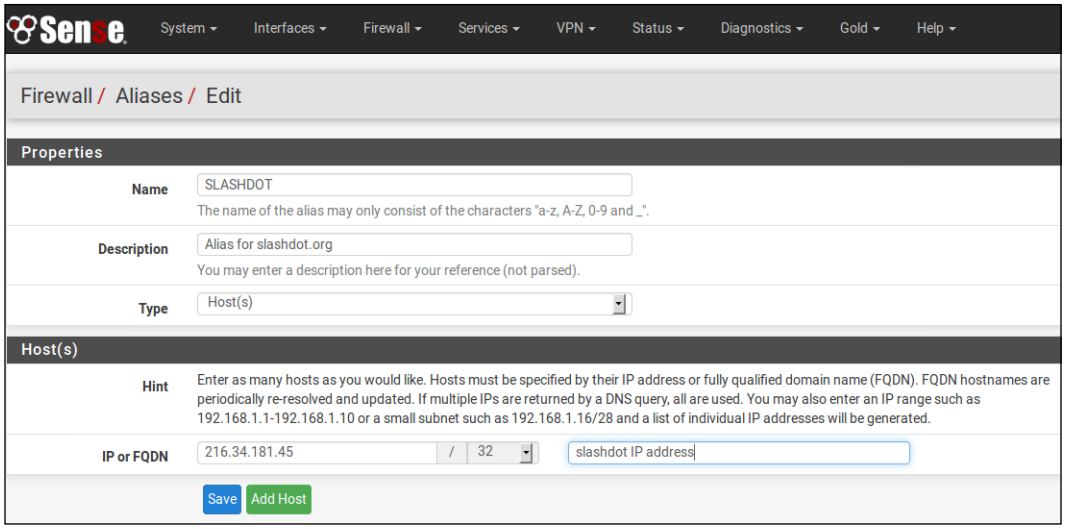
We have now created a port forwarding rule (and an automatically generated firewall rule) for the FTP server.

Aliases

Aliases enable you to group ports, hosts, or networks into named entities, which you can then refer to in firewall and NAT rules and traffic shaper configuration. This allows you to create more manageable rules; in addition, changes in IP addresses, ports, or networks will not necessitate multiple configuration changes – you may be able to just change an alias.

Not all options available in the pfSense web GUI allow you to use aliases, but you will always know when you can use aliases. An edit box that is alias-friendly will have a red background, and if you start to type the alias name, pfSense's autocomplete functionality can complete the name.

To create an alias, navigate to **Firewall | Aliases**. The **Aliases** landing page has four separate tabs: **IP**, **Ports**, **URLs**, and **All**. Clicking on one of the tabs will show a table with all of the previously created aliases in that category (for example, the **IP** tab displays a table with IP aliases). If you want to create an alias of a specific type, you can click on the corresponding tab and then click the **Add** button below the table. But selecting the right tab before clicking **Add** is not necessary – you can create an alias for any supported type from any tab, because selecting the corresponding tab before clicking on **Add** only changes the default value in the **Type** drop-down box. Clicking on the **Add** button on any of the tabs will launch the **Aliases Edit** page.



Creating an alias in pfSense.

There are two sections on the **Edit** page. The first section is called **Properties**; the second section's name changes depending on what you select in the **Type** drop-down box. The first option in **Properties** is **Name**, where you enter the name which pfSense will use to identify the alias. It may only consist of letters, numbers, and the underscore character. You may also enter a free-form, non-parsed description in the next field. In the **Type** drop-down box, specify the type of alias you want. The options for **Type** are:

- **Host(s)**: Selecting this option enables you to enter one or more hosts. The hosts must be specified by either their IP address or **fully qualified domain name** (**FQDN**). If you use an FQDN, the hostnames will periodically be re-resolved and updated. If you use IP addresses, you may specify an IP range or a subnet. You can add more than one entry.

- **Network(s)**: Selecting this option allows you to specify one or more networks. The network prefix for each entry must be specified, along with the CIDR mask.
- **Port(s)**: Selecting this option allows you to specify one or more ports. Port ranges can be specified by separating the first and last port with a colon.
- **URL (IPs)**: Allows you to specify one or more URLs which point to text lists of IP addresses for which an alias will be created. Using this option causes pfSense to download the list,or lists, once and then convert it into a conventional alias. You can enter as many URLs as you wish, but each file should be limited to 3000 IP addresses/ranges or less.
- **URL (Ports)**: Allows you to specify one or more URLs which point to text lists of ports for which an alias will be created. As with URL (IPs), the list or lists are downloaded once and then converted into a conventional alias. You can enter as many URLs as you wish, but each file should be limited to 3000 IP ports/ranges or less.
- **URL Table (IPs)**: Similar to **URL (IPs)**, but with this option, you can only specify a single URL containing IPs/ranges of IPs/subnets, and this list is downloaded and refreshed periodically. This option will work with large numbers of addresses/ranges/subnets (30,000 or more). With this option, in the second section of the page, you enter the URL of the list, the update frequency in days (selected in the drop-down box), and you can also enter a brief description in the rightmost edit box.
- **URL Table (Ports)**: Similar to **URL (Ports)**, but you can only specify a single URL containing ports/ranges of ports, and this list is downloaded and refreshed periodically. As with **URL Table (IPs)**, in the second section of the page, you enter the URL of the list, the update frequency in days, and you may also enter a brief description.

As you may have surmised from our description of the different alias types, the second section of the page is where you enter information about what the alias stands for, which is one of the following:

- An FQDN
- An IP address/range of IP addresses/network
- A port or range of ports
- A URL

For all the types except the two **URL Table** options, multiple entries are allowed. You can add more than one entry by clicking on the green **Add** button at the bottom of the page after each new entry is defined (it will have the label **Add Host/Add Network/Add Port/Add URL**, depending on which option you choose). When you are done adding entries, click on the **Save** button at the bottom of the page and click on the **Apply Changes** button on the main **Aliases** page.

There is another way of generating aliases that may be helpful in certain circumstances. Sometimes we want to create an alias for a website; however, that website may use multiple IP addresses (for example, Amazon uses six different IP addresses at the time of writing). Rather than find out what these IP addresses are and input them manually, we can do this much more easily in pfSense.

To create an alias for a website, navigate to **Diagnostics | DNS Lookup**. On the **DNS Lookup** page, enter the hostname in the **Hostname** field and click on the **Lookup** button. When the results of the lookup are returned, there should be a button next to the **Lookup** button (before the **Results** section) labeled **Add Alias**. Click on the button, and an alias should be created, with any dots in the hostname converted to underscores (for example, if you did a DNS lookup on `www.amazon.com`, the corresponding alias would be `amazon_com`). Navigate back to **Firewall | Aliases**, and the newly created alias should be there.

An example alias

In this section, we will walk through the process of creating an alias. Assume that we want to create an alias to make implementation of our policy of blocking Slashdot easier. We proceed as follows:

1. Navigate to **Firewall | Aliases**, and click on the **Add** button.
2. Enter **Name** for the rule (for example, `SLASHDOT`) and a brief description (for example, `Alias for slashdot.org`).
3. In the **Type** drop-down box, select **Host(s)** as the type.
4. Enter `216.34.181.45` (the IP address for `slashdot.org`) in the **IP or FDQN** edit box. Enter a brief description to the right (for example, `slashdot IP address`).
5. Since we do not need to enter multiple IP addresses, click on the **Save** button. Click on the **Apply Changes** button on the main **Aliases** page.

Now we have an alias named `SLASHDOT`, and we can use it in any rule that requires us to allow/block access to the site. The site's IP address might change, but if it does, we will only need to change it once (in the alias entry). Since in this case we have already defined rules that refer to this IP address, we will want to edit these rules so they refer to the alias. We can do this as follows:

1. Navigate to **Firewall | Rules** and click on the **DEVELOPERS** tab.
2. Click on the **Edit** button (represented by a pencil) for **Block Slashdot rule**.
3. Change the **Destination** field to **SLASHDOT**.
4. Scroll down and click on the **Save** button.
5. Repeat every step except the first for the **Allow Slashdot during lunchtime** rule.
6. Click on the **Apply Changes** button on the main **Rules** page.

With these steps completed, we have our alias, and all rules that use it refer to the alias. To make knowing what aliases stand for easier, when we hover our mouse over an alias in the **Rules** table, pfSense provides a text popup that tells us to what the alias refers.

Virtual IPs

Virtual IPs (**VIPs**) refer to a situation where an IP address does not correspond to a single physical interface. They are used in many scenarios, including the following:

- NAT (including one-to-many NAT)
- Scenarios where fault tolerance is needed (for example, CARP)
- Mobile usage scenarios, which allows a mobile user to maintain a consistent virtual IP address even as their actual IP address changes

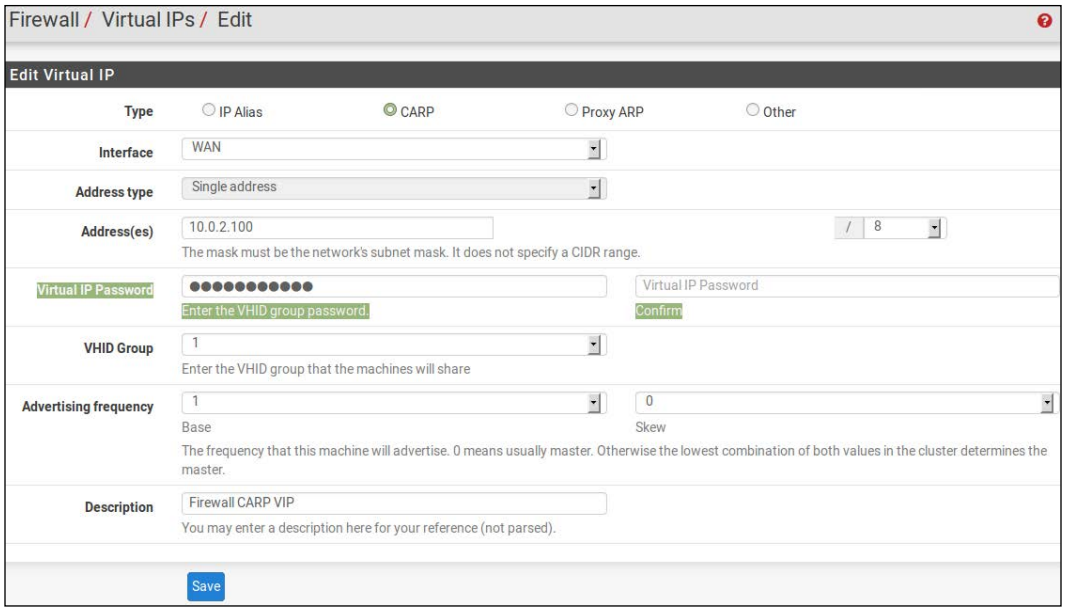
To add a VIP, navigate to **Firewall | Virtual IPs** and click on the **Add** button at the bottom of the table. pfSense offers four options for virtual IPs:

- **IP Alias**
- **CARP**
- **Proxy ARP**
- **Other**

Of these four options, we can state the following:

- **CARP**, **Proxy ARP**, and **Other** were available with the earliest versions of pfSense. **IP Alias** is available with version 2.0 and higher.
- All current options can be used with NAT.
- **CARP** and **IP Alias** can be used by the firewall to bind and/or run services. **Proxy ARP** and **Other** cannot be used in such a way.
- All options except **Other** generate ARP (Layer 2) traffic. This makes the **Other** option useful in scenarios where ARP traffic is not needed.
- All options except **Proxy ARP** can be used for clustering. However, if **IP Alias** VIPs are used as part of a **CARP** VIP, then they must be inside the same subnet as the **CARP** VIP upon which they are placed.
- As of version 2.2, all available options allow you to generate a VIP that is in a different subnet than the real interface IP. However, **CARP** VIPs did not support this feature prior to version 2.2, and it is recommended that you keep **CARP** VIPs on the same subnet for better connectivity and fewer potential issues.
- For **CARP**, the subnet mask must match the interface IP's subnet mask. For **IP Alias**, the subnet mask should match the interface IP or be `/32`. If the IPs are in different subnets than the original IP address, then at least one **IP Alias** VIP must have the correct mask for the new subnet.
- **CARP** and **IP Alias** will respond to ICMP ping attempts if the firewall rules allow it; **Proxy ARP** and **Other** will not respond to ICMP ping attempts.
- **CARP** and **IP Alias** VIPs must be added individually; **Proxy ARP** and **Other** may be added individually or as a VIP subnet.

To create a VIP, first select one of the four options. Then select a physical interface in the **Interface** drop-down box. In the **Address type** drop-down box, you may select either **Single address** or **Network** with **Proxy ARP** or **Other**. If you selected **CARP** or **IP Aliases**, you can only add a VIP individually, so this option will be disabled. In the **Address(es)** edit box, you enter the VIP or virtual subnet. You also need to specify the CIDR here.



Creating a CARP Virtual ID.

What follows are several options that are only available if you selected **CARP**. For CARP VIPs, you must enter a **Virtual IP Password**, which can be whatever you like. The next option is the **VHID Group** drop-down box. Each VIP which is to be shared on multiple nodes must use a unique **Virtual Host ID group** (**VHID**), and it must also be different from any VHIDs in active use on any directly connected network interface. If you are not currently using CARP or Cisco's **Virtual Router Redundancy Protocol** (**VRRP**) on any other nodes, you can use **1** as your VHID. The next option is the **Advertising Frequency** drop-down box. The **Advertising Frequency** value should correspond to this node's role in the network. The master should be set to `1`; a backup should be set to `2` or higher. The next parameter is the **Skew** dropdown, which controls how often (in seconds) the node advertises that it is a member of the redundancy group. Specifying a lower number tends to ensure that this node, if it isn't a master already, will become a master if the master node fails. This is the final option on the page that only applies to CARP VIPs.

In the **Description** edit box, you can enter a brief, non-parsed description. When you are done, click on the **Save** button at the bottom of the page and then click on **Apply Changes** on the main **Virtual IPs** page. We will cover CARP in greater depth in *Chapter 7*, *Redundancy and High Availability*.

An example VIP

In this example, we will use a VIP to begin implementation of a CARP failover group for our firewall, with one firewall that will act as a master, and a second which will act as a backup, in case the master fails. The virtual IP will be `10.0.2.100`; the subnet is `10.0.0.0/8`. We will set up the master firewall first. To do this, we perform the following steps:

1. Navigate to **Firewall** | **Virtual IPs** and click on the **Add** button at the bottom of the page.
2. Select **CARP** in the **Type** radio buttons.
3. Leave the **Interface** field set to **WAN**. Set **Address** to `10.0.2.100`. Set the **CIDR** in the adjacent drop-down box to `8`.
4. Enter a password at **Virtual IP Password** (you have to type it in twice). We don't have any other VHID groups on this network yet, so we can leave **VHID Group** set to `0`.
5. Leave **Advertising Frequency** set to `1` and **Skew** set to `0`.
6. Enter a brief description (for example, `Firewall CARP VIP`) and click on **Save**, then click on **Apply Changes** on the main **Apply Changes** page.

Configuration of the backup firewall will be similar, but **Advertising Frequency** should be set to 2 or higher, and **Skew** should also be set to a higher number.

Troubleshooting

At some point, there will be a situation where your firewall rules aren't doing what you think they should be doing, and our firewall troubleshooting skills are put to the test. The first step is to diagnose the problem (for example, nodes on the **DEVELOPERS** network cannot access the Internet). If we can easily identify the interface or interfaces which are affected, then we can focus on that interface's ruleset.

It is probably a good idea to check the **Floating Rules** tab first, since floating rules take precedence over rules for an individual interface, and if the problem is a misconfigured floating rule, then we can save a lot of time that we otherwise would spend double-checking an interface's rule set. If you are running a proxy server on your firewall, you may want to check the settings on that, since a proxy server's allow and deny lists tend to supersede firewall rule settings.

The next step is to check the firewall rules for the affected interfaces, keeping in mind that firewall rules are evaluated from the top down. If warranted, check the allowed/blocked protocols. For example, if a rule is set up to allow only TCP traffic to pass through to an interface, a video streaming client that uses UDP will not work.

If you still cannot figure out what the problem is, it might be a good idea to enable logging for the rules you suspect may be causing the problem. This is usually not recommended, as enabling logging for rules tends to quickly use up disk space, but sometimes looking at the logs can be helpful. Once you have enabled logging for the rules, navigate to **Status** | **System Logs** and click on the **Firewall** tab. You can use the filtering options at the top of the page to help focus on the relevant log entries.

If logging doesn't provide enough information about the source of the problem, you might consider using `tcpdump`, a command-line utility included with pfSense. `tcpdump` is a packet analyzer usable which prints the contents of network packets. It is extremely useful, albeit somewhat difficult to use at first. It is beyond the scope of this chapter to provide a tutorial on `tcpdump`, but you should be aware that it is available. We will cover `tcpdump` in greater depth in the final chapter.

If you have made a recent change to the firewall rules, and some traffic is getting through that seems to violate the firewall rules, it is possible that the state table entries for the connections pre-date the rule change. Therefore, if you want the connections to be dropped, you will have to reset the state table. To do this, navigate to **Diagnostics** | **States** and click on the **Reset States** tab. Click on the **Reset** button, which will remove all entries from the state table. This will also reset any active connections, so take that into account.

If the problem involves a remote user who is unable to access shared resources, the problem may not be a firewall rule misconfiguration, but a NAT rule misconfiguration. For IPv4 networks, we need both a NAT port forwarding rule to forward traffic from the WAN to the target system and a firewall rule to allow the traffic through. pfSense makes it easy to create a corresponding firewall rule with the Add associated firewall rule option, but if you have any doubts as to whether a firewall rule exists, check the ruleset for the relevant interface.

Also, keep in mind that for inbound NAT, typically we only need to configure the destination IP address and port. The source could be virtually anywhere, so we can usually leave this set to **any**. Make sure that these options are configured correctly.

One possible problem with NAT is that incoming traffic may be reaching the target node, but the host may have a different default gateway. The outbound traffic will thus go out on a different router than the pfSense router from which the incoming NAT traffic came. As a result, the gateway for outgoing traffic may drop the connection, since there is no corresponding state in the state table, or it might send the outgoing traffic to the system originating the request, but the system will ignore the reply traffic because it has a different IP address than the WAN address of the pfSense router to which the request was sent. Therefore, you need to make sure that the incoming and outgoing gateway are the same.

It may be the case that pfSense is configured correctly, but the target node is running a firewall which blocks the request. If the system is running a firewall and you suspect the firewall may be blocking the connection, check the logs for the firewall and check the firewall settings.

Another possibility is that the target system does not have a service that is listening on the target port. This could happen if the target system does not have any service listening, or perhaps the service is listening, but on the wrong port. You can confirm that the target system is not listening on the right port by using **telnet** to access the port. If you get a **Connection refused** message from the target system, it's a good sign that the target system is not listening on the port.

If the incoming traffic does not even reach pfSense, you should check to see if your ISP blocks the target port. Many ISPs block well-known ports; it is not likely, for example, that your ISP will allow incoming traffic on port `80`. This is much more commonplace with residential connections than it is with business connections. If in doubt, you may want to contact your ISP and find out. If the port is being blocked, you could change the target port to one that is not blocked.

Outbound NAT options are typically less problematic, since in most cases, you can leave **Automatic Outbound NAT rule generation** enabled. If you switch to **Manual Outbound NAT rule generation**, however, and add new interfaces, then unless you explicitly add rules to forward traffic from the new internal interface to the WAN interface, those interfaces will not have access to remote networks. **Use Hybrid Outbound NAT rule generation** to avoid this problem.

Summary

In this chapter, we began by considering a hypothetical network that had some specific firewalling requirements. We then introduced some basic firewall concepts and saw how our example network could be implemented using pfSense's firewall capabilities, as well as NAT, scheduling, aliases, and virtual IPs. Creating and editing firewall rules is definitely something you will use in the future. NAT may become less commonplace as IPv6 gains ascendancy, but it's not going to go away anytime soon, so you will want to have a clear understanding of how it works and how it is implemented. Schedules and aliases are tools that make our lives easier, and while you may never have occasion to use virtual IPs if you are in a home or SOHO environment, this knowledge will definitely be of value in a corporate environment.

There is one entry on pfSense's **Firewall** menu that we did not cover here. Traffic shaping is important enough and complex enough to warrant devoting an entire chapter to it, and we will cover it in *Chapter 5*, *Traffic Shaping*.

5
Traffic Shaping

Traffic shaping, also known as **Quality of Service** (**QoS**), is a means of prioritizing network traffic which meets certain criteria. Without traffic shaping, network traffic is processed on a **first-in, first-out** (**FIFO**) basis. While in many cases, processing network traffic in such a way may be adequate, in other cases, it may lead to links becoming saturated, which in turn can lead to buffering and increased latency. Traffic shaping provides us with a means of prioritizing certain network traffic, which guarantees that it will receive available bandwidth before lesser priority traffic.

pfSense has its own traffic shaper which is not only useful, but is also extremely easy to use. The pfSense traffic shaper wizard is easy and quick to configure, and the process of setting up traffic shaping can be done in a matter of minutes. In this chapter, however, it is our objective to provide a basic understanding of traffic shaping before delving into the specifics of how to implement traffic shaping in pfSense. The topics covered in this chapter are as follows:

- Traffic shaping essentials, including a summary of different queuing disciplines
- Configuring traffic shaping in pfSense, including using the pfSense traffic shaping wizard, as well as manual queue and rule configuration
- Some real-world traffic shaping examples
- Troubleshooting traffic shaping

An example network

To illustrate how traffic shaping might be implemented on a network, we will again revisit our hypothetical network, which again is divided into several subnets: **DEVELOPERS**, **ENGINEERING**, **SALES**, and **DMZ**. The company's main Internet connection provides 150 Mbps of bandwidth for downloading and 50 Mbps of bandwidth for uploading. The company also has a backup DSL connection with 7 Mbps down/1 Mbps up. The network has some requirements that require implementing traffic shaping, including the following:

- **DEVELOPERS** and **ENGINEERING** should have 100 Mbps of guaranteed download bandwidth, with 60 Mbps of download bandwidth going to **DEVELOPERS**. For upload bandwidth, 25 Mbps will go to **DEVELOPERS** and **ENGINEERING**, with 15 Mbps going to **DEVELOPERS**. As with download bandwidth, excess will go first to **ENGINEERING** and then to **SALES** and **DMZ**.
- All subnets use Skype for videoconferencing, which requires a low-latency connection. The **SALES** subnet utilizes videoconferencing the most, so we need to take that into account.
- If possible, all peer-to-peer traffic should be eliminated; if it cannot be eliminated entirely, it should not use more than 5% of the total bandwidth.

We have now outlined some fairly specific requirements for our network. We will implement some of these measures with the pfSense traffic shaper later on in this chapter.

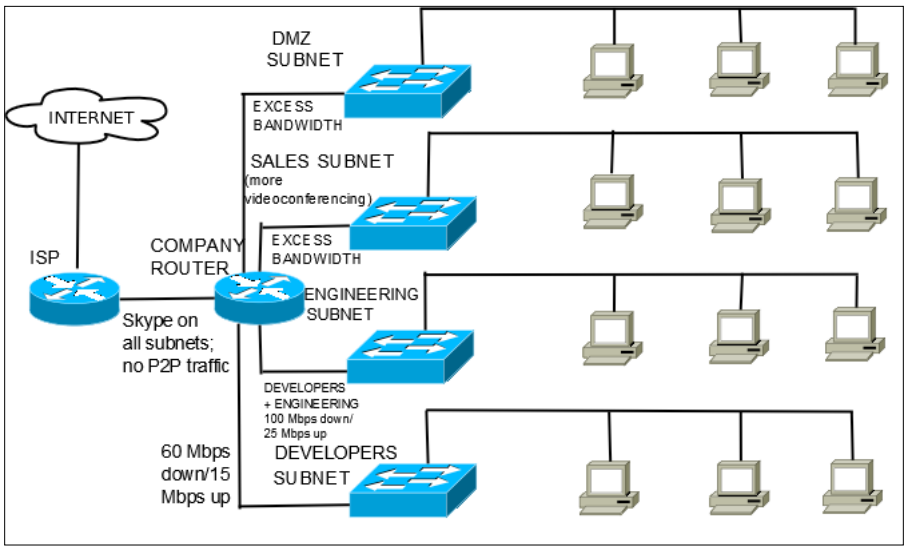


Diagram of our example network showing bandwidth and other requirements.

Traffic shaping essentials

Traffic shaping allows us to prioritize some traffic over other traffic, in order to optimize/improve network performance, and in some cases, lower latency. The purpose of traffic shaping is to make network traffic conform to certain predefined constraints, generally known as either a traffic profile or contract. The traffic shaper is able to do this because it examines packets; if the packets meet certain criteria, they are handled differently. In this sense, traffic shaping bears similarities to firewall rules. In the case of firewall rules, packets that meet rule criteria are either allowed, blocked, or rejected. In the case of traffic shaping, packets that meet certain criteria (we can call them traffic shaping rules) are put into different queues. These queues are implemented as FIFO buffers. Priority traffic is typically sent immediately, while lower-priority traffic is held until the higher-priority traffic has passed.

Traffic shaping has to be implemented where the router can control the flow of data. Therefore, in pfSense, traffic shaping is always applied when packets are leaving the router. For example, traffic shaping of incoming traffic to the LAN is actually applied when the traffic is leaving the LAN interface. Similarly, traffic shaping of outgoing traffic is applied when traffic is leaving the WAN interface.

Traffic shaping can be used for a variety of purposes. This includes the following:

- It can be used in a number of different scenarios where low latency is required. This includes VoIP traffic, which, if it is given the same priority as other traffic, may be affected by uploads and downloads. Similarly, if you are playing an online game, you want the response time to be as fast as possible, even if you are simultaneously downloading a file. Other applications can tolerate a higher level of latency. For example, with video streaming using online services, such as Netflix or Hulu, a certain amount of buffering is tolerable.
- It can be used to limit the amount of bandwidth used by peer-to-peer applications. It can do this in two different ways. One is by lowering the priority of traffic coming to and from well-known peer-to-peer ports. The second is by actually examining the packets and finding out what application is generating them. The latter is known as Layer 7 inspection, or Deep Packet Inspection. Both approaches have strengths and weaknesses. A port-based approach is easy to implement and will work in most cases, but users may be able to circumvent such an approach by using different ports. Layer 7 inspection is generally more effective in identifying peer-to-peer traffic, but it is also CPU-intensive, and it is of no help on encrypted traffic. In addition, small changes to the peer-to-peer protocol can result in Layer 7 inspection not working.

- It can be used to make asymmetric Internet connections work more smoothly. If your download bandwidth is significantly larger than your upload bandwidth, the maximum download speed may seem unattainable because you won't be able to send enough `ACK` packets back to the target host to keep the traffic flowing. This is most likely as the connection becomes more saturated; for example, if you are downloading a file while simultaneously loading a web page. In these situations, pfSense can prioritize `ACK` packets, ensuring that traffic flows and that you are able to reach the maximum download speed.
- In business environments, traffic shaping can be used to prioritize business-related traffic.
- ISPs have sometimes used traffic shaping to limit bandwidth consumption of certain programs (for example, BitTorrent traffic) so they can take on additional customers. This is often controversial, because such connections are often advertised as *unlimited* connections. Nonetheless, it is yet another example of traffic shaping being used for a specific outcome.

Queuing policies

No discussion of traffic shaping would be complete without mentioning the different types of queues that can be utilized. The most basic queuing policy is a FIFO queue, sometimes also referred to as **first-come, first-served** (**FCFS**) queuing. With FIFO queuing, no packet is given priority; nor are there different classes of traffic. All packets are treated equally within the FIFO queue and packets are sent out in the order that they arrive.

Obviously, this makes for a very easy to implement policy. But when implemented, it can result in some users and applications consuming all the bandwidth. Even when they are not consuming bandwidth constantly, their usage may spike at inopportune times, delaying time-sensitive and important traffic. Worse yet, important traffic may be dropped because there is less important traffic in the queue.

Nonetheless, if you have congestion-free Internet connection on which users and applications have as much bandwidth as they need, FIFO queuing may be appropriate. It is easy to implement and also guarantees that your access to bandwidth is delay-free. If this is not the case, however, it is time to consider one of the many alternatives to FIFO queuing.

Fair queuing represented the first improvement over FIFO queuing. In it, each program process is given its own FIFO queue. This prevents a badly behaving process from monopolizing the bandwidth. A further refinement of fair queuing is **weighted fair queuing** (**WFQ**), which provides a form of priority management. Packets are ultimately classified into high-bandwidth traffic and low-bandwidth traffic, and low-bandwidth traffic is given priority over high-bandwidth traffic. In turn, high-bandwidth traffic shares the connection proportionally based on assigned weights. This ensures that low-bandwidth streams, which represent the bulk of network traffic, are transmitted in a timely manner. One of the drawbacks of WFQ is that it relies on examining the packets, so it does not work on encrypted connections.

There are three queuing disciplines supported by the current version of pfSense: **priority queuing** (**PRIQ**), **class-based queuing** (**CBQ**), and **Hierarchical Fair Service Curve** (**HFSC**). Each of these policies has advantages and disadvantages as we will soon see.

PRIQ is a queuing policy that divides traffic into different priority levels. Implementations differ in the number of levels, but in pfSense, there are seven levels, with seven being the highest priority. This is a flat hierarchy of priority levels. On each interface, priority queues are scanned for packets in descending order of priority. The highest priority queue is scanned first, then the next highest priority queue, and so forth. The packet at the head of the highest queue is chosen for sending. This procedure is repeated each time the traffic shaper chooses a packet to be sent.

A priority queue's behavior is defined by a set of rules that describe how packets should be assigned to priority queues. Packets can be classified by protocol or subprotocol type, which interface they come from, packet size, and so on. The advantage of PRIQ is that it is easy to configure and also easy to understand. It also ensures that absolute priority is given to traffic that is in the highest priority queue. The main disadvantage is that because priority always goes to higher-level traffic and there is no way of circumventing this policy or for moving traffic to a higher level once it has been assigned a lower level of priority, lower priority traffic can be completely starved of bandwidth. In addition, having only seven priority levels limits the granularity of traffic shaping; an interface which relies solely on priority queuing can have at most seven separate queues.

CBQ allows a bit more control than PRIQ. In CBQ, each class gets a percentage of bandwidth, after being grouped by classes. It divides traffic into a hierarchy of classes and thus allows you to classify traffic into a hierarchy. Criteria for prioritization can include protocol, the application being used, the IP address of the sender, and many other factors. It operates at the IP network layer (Layer 3). An additional appeal of CBQ is that it is in the public domain.

Each class is assigned a bandwidth limit, and packets within the class are processed until the bandwidth limit for the class is reached. This tends to ensure that even low-priority packets get some bandwidth. The first goal of CBQ is quantitative bandwidth sharing, but a secondary goal is that when some class is not using its allocated bandwidth, the distribution of excess bandwidth should not be arbitrary. Rather, the distribution of such bandwidth should follow a set of guidelines.

As an example of how PRIQ and CBQ differ, consider the case of the example network presented earlier. We want to assign the bulk of the bandwidth to the **DEVELOPERS** and **ENGINEERING** subnets. With priority level queuing, there is really no way of implementing such an arrangement. We could assign higher priority levels to **DEVELOPERS** and **ENGINEERING** than **SALES** and **DMZ**, with **DEVELOPERS** receiving a higher priority than **ENGINEERING**, but this could result in **SALES** and **DMZ** not receiving an adequate slice of bandwidth.

With CBQ, however, each subnet could be assigned a percentage of bandwidth. Even better, CBQ can be hierarchical, so that **DEVELOPERS** and **ENGINEERING** share a percentage of bandwidth, with **ENGINEERING** being assigned a greater portion of their shared bandwidth.

The third queuing discipline supported by pfSense is HFSC. An HFSC can be thought of as a form of bandwidth allocation in which guarantees are made about latency. An HFSC queue is defined by a nonlinear curve with two parts. The first part, *m1*, determines the amount of bandwidth the queue gets up to *p* milliseconds. After *p* milliseconds, the second part of the curve (*m2*) determines the behavior of the queue. This is the amount of bandwidth guaranteed to the queue.

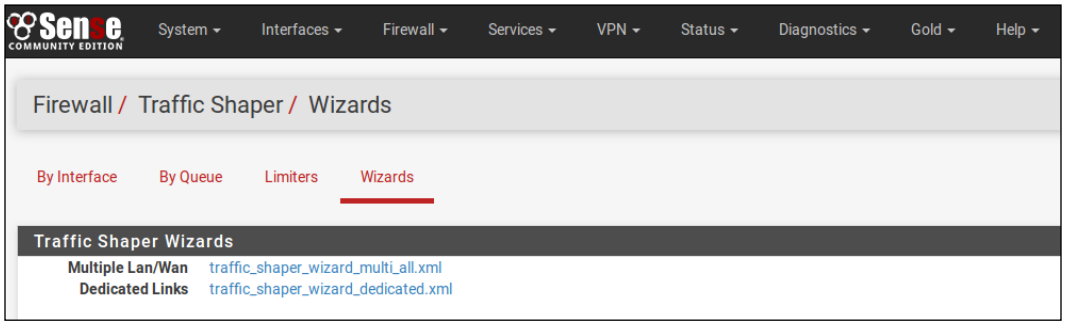
To illustrate HFSC, imagine two services competing for bandwidth: a VoIP connection and a file download. Assume a linear service curve such that the VoIP connection requires that a packet be sent every 30 ms, while for the file download, a packet must be sent every 9 ms. Assume that it takes 7 ms to transmit a packet. If packets are sent according to these deadlines, the delay for a video packet will be approximately 21 ms. Such a policy ensures that the deadlines are met, but the latency for VoIP packets is high.

Now imagine a different service curve such that the VoIP connection gets the bulk of the bandwidth up until 10 ms (for example, 75% of available bandwidth). The inflection point is at 10 ms, and after that the VoIP connection only gets 25% of the available bandwidth. With this policy, the delay for any VoIP is no more than 10 ms. The result is a lower latency for VoIP traffic, but a higher latency for the file download traffic, but this is acceptable, since throughput is more important than latency with respect to file downloads.

The main drawbacks of HFSC is that unlike PRIQ and CBQ, which are defined by very simple criteria (priority levels in the case of priority queuing, and amount of bandwidth allocated to a class in the case of CBQ), HFSC queues are defined by nonlinear curves, and therefore are inherently more complex. There will be times when the traffic shaper cannot guarantee service to all curves at the same time, and/or it cannot do so fairly. Nonetheless, HFSC is a good choice for an algorithm if we are utilizing services that benefit from decoupling latency from bandwidth.

Configuring traffic shaping in pfSense

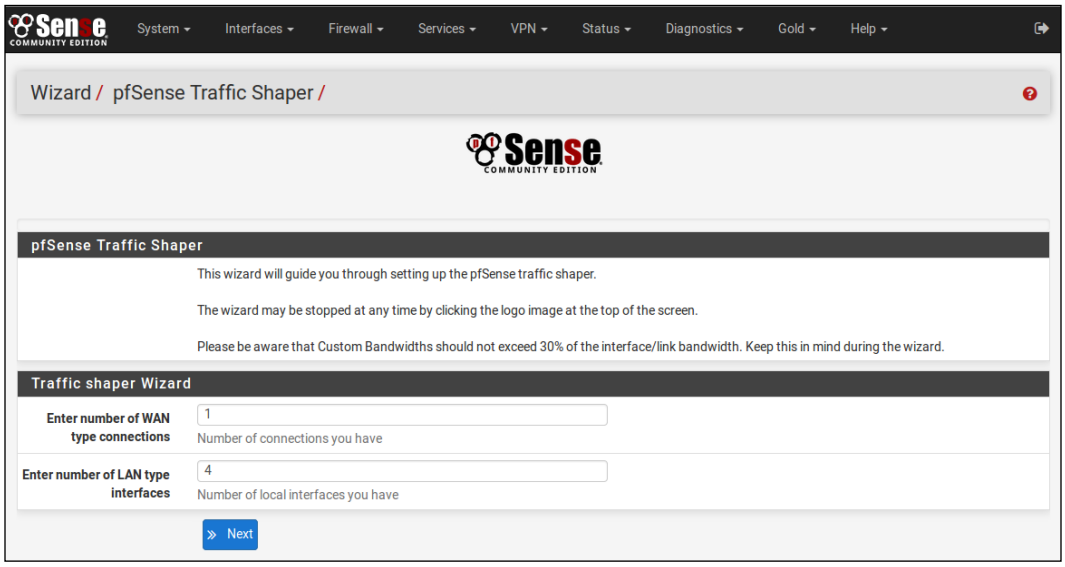
Traffic shaping in pfSense can be a challenge to configure, partially because of the number of options and the complexity of the shaper rules and shaper queues. It is generally recommended that you begin with the web GUI's traffic shaper wizard. You can access the wizard by clicking on **Firewall | Traffic Shaper** and then clicking on the **Wizards** tab. There are currently two wizards available: **Multiple Lan/Wan** and **Dedicated Links**. **Multiple Lan/Wan** can be used in a variety of scenarios in which there are one or more LAN-type interfaces, and one or more WAN interfaces. **Dedicated Links**, on the other hand, is designed for cases in which specific LAN/WAN pairings do not mix with other traffic. For example, users on one subnet may have a different Internet connection than users on another subnet. Therefore, there are two separate WAN interfaces (one for each Internet provider). Traffic from one LAN interface goes to WAN, while traffic from another LAN interface goes to WAN2. Each LAN-WAN link has its own traffic shaping requirements, and this is where the **Dedicated Links** wizard helps. In most cases, however, you will not have dedicated WAN links, so **Multiple Lan/Wan** will be the correct choice.



The main Wizards tab, where we can choose between the two available wizards.

The Multiple LAN/WAN Configuration wizard

The first page on the **Multiple Lan/Wan Configuration** wizard asks for the number of WAN-type connections and the number of LAN-type connections in two separate edit boxes. Since the wizard detects the number of each type of interface automatically, you can usually leave these numbers unchanged, and click on the **Next** button at the bottom of the page. You may not want to apply the traffic shaper to all interfaces, however, in which case you will want to enter fewer than the total number of WAN and LAN interfaces. You cannot, however, enter more than the total number of interfaces, or you will receive an error message. When you are done making changes, press the **Next** button.



Entering the number of WAN and LAN connections in the Multiple Lan/Wan Configuration wizard.

The next page, **Shaper configuration**, is where you set up each of the individual interfaces. The page will have different sections, each labeled **Setup connection and scheduler information for interface X** where X is LAN #1, LAN #2, and so on, or WAN #1, WAN #2, and so on. In each section for the LAN interfaces, there are two drop-down boxes. In the first drop-down box, you select the interface; in the second drop-down box, you select the queuing discipline. Note that in subsequent pages of the wizard, the interfaces will not be specified by name, but instead will be identified based on the assignments made on this page (for example, if you have a DMZ interface, and you specified it as the LAN #1 connection on the previous page, then on subsequent pages, connection LAN #1 will refer to the DMZ interface). This is an aspect of the wizard that is not very user-friendly, and you want to make note of the assignments you make here. Otherwise, you will find yourself constantly hitting the **Back** button on your browser to remind yourself what the assignments are.

The different queuing disciplines have been discussed previously in this chapter, so we won't discuss them in detail here, but here is a summary of their advantages and disadvantages:

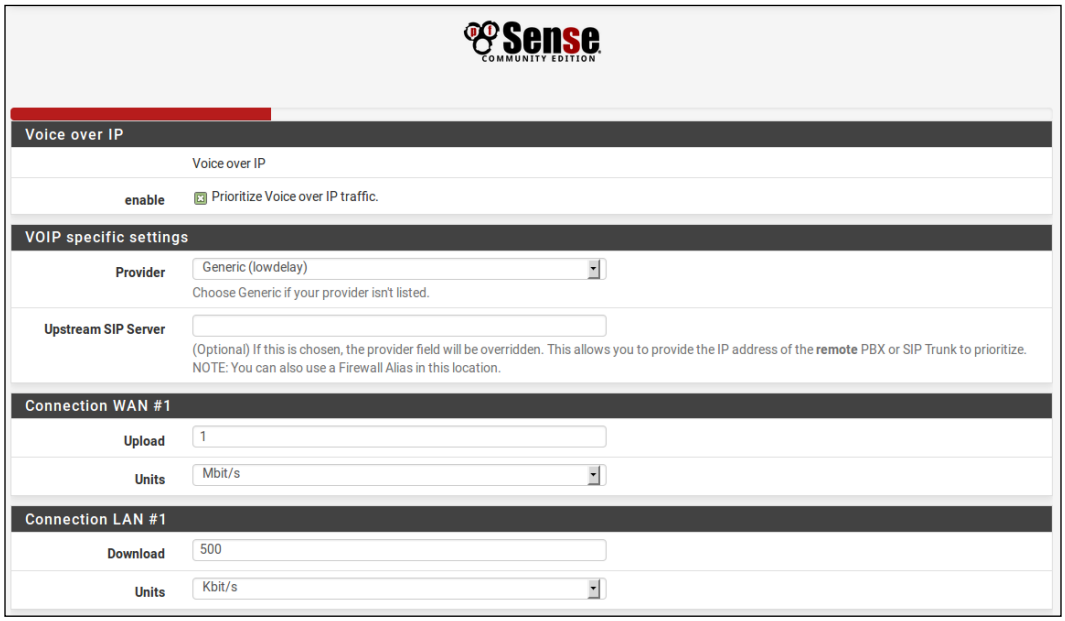
- **PRIQ**: Stands for priority queuing, the simplest of all queuing algorithms. Packets are assigned different priority levels, with higher priority levels always being favored over lower priority levels. This guarantees lower latency for higher priority packets, but it also means packets with a lower level of priority can get starved for bandwidth.
- **CBQ**: Stands for class-based queuing. Packets belong to classes, and each class is assigned an upper and lower bound for bandwidth. Classes can be hierarchical; therefore a class can be divided into subclasses. This is a good queuing discipline for guaranteeing a minimum bandwidth, but no guarantees are made regarding latency.
- **HFSC**: Stands for Hierarchical Fair-Service Curve, a queuing discipline in which each queue has a curve with two portions: a fairness curve and a service curve. The fairness portion of the curve is designed to provide a minimum level of latency for each queue. There is no guarantee that all the goals of HFSC will be met under all circumstances, but HFSC is the best option for many purposes.

Once you have selected the queuing discipline for each of the LAN-type interfaces, you can set up your WAN connections. For each WAN interface, you can also select the queuing discipline (the same three options – **PRIQ**, **CBQ**, and **HFSC** – are offered). In addition, the wizard will prompt you for the upload and download bandwidth of each WAN interface. The numbers entered in these edit boxes should be a close approximation for your upload and download speeds, in order to ensure the traffic shaper works properly. When you are done making changes, click on the **Next** button at the bottom of the page.

The next page of the wizard, **Voice over IP**, allows you to configure VoIP settings. The options on this page will be grayed out unless you check the **Prioritize Voice over IP traffic** checkbox. The next section of the page, **VOIP specific settings**, allows you to select a provider from the **Provider** drop-down box. The choices are as follows:

- **VoicePulse**: A company that offers VoIP services to residential and business customers. They also offer trunking using the **Session Initiation Protocol** (**SIP**) for VoIP gateways and PBX systems.

- **Asterisk/Vonage**: You have probably heard of Asterisk, which provides you a means of setting up a PBX with software that has both an open source (GNU GPL) and a proprietary component. With Asterisk, you can implement many features previously only available in proprietary PBX systems, such as voice mail and conference calling. Asterisk also supports such VoIP protocols as SIP, the **Media Gateway Control Protocol** (**MGCP**), and H.323. Vonage is a VoIP company that offers both residential and business plans, as well as cloud services for enterprise-level customers.
- **PanasonicTDA**: The Panasonic KX-TDA series of phones supports both H.323 and SIP trunking, with the KX-TDA600 supporting up to 640 trunks.
- **Generic**: Use this option if your VoIP service does not fall into any of the aforementioned categories.



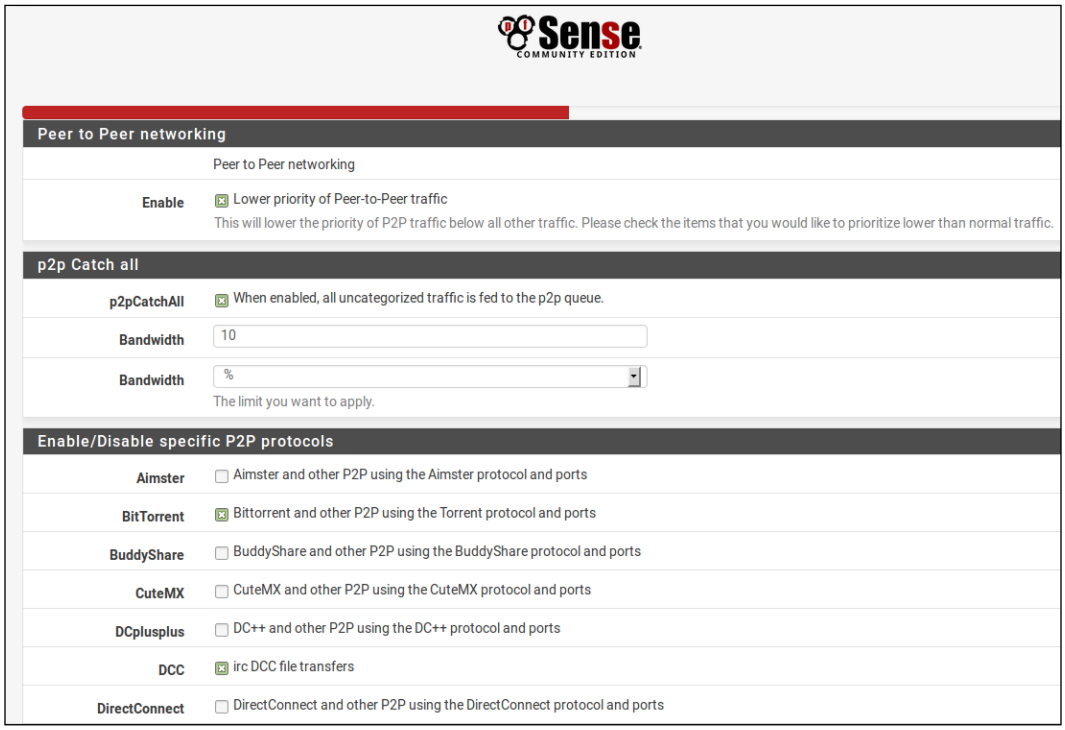
Configuring VoIP settings in the traffic shaping wizard.

The next option, **Upstream SIP Server**, allows you to enter the IP address of a remote PBX or SIP trunk to prioritize. If this option is used, the **Provider** field will be ignored. The value entered in this field can be an alias.

The rest of the page, **Connection WAN #1**, **Connection LAN #1**, and so on, allows you to enter the upload bandwidth for your WAN connections and the download bandwidth for your LAN connections. This allows you to specify the minimum bandwidth to be allocated to VoIP traffic. This will vary, based on the amount of bandwidth required per VoIP connection, and the total number of VoIP phones/devices, so you'll want to do your homework before entering this information. When you are done making changes, click on the **Next** button on the bottom of the page.

The next page, **Penalty Box**, contains two sections: **Penalty Box** and **Penalty Box specific settings**. The **Penalty Box** section has one option: the **Penalize IP or Alias** checkbox. If enabled, the priority of traffic from the IP (or alias) specified in the **Address** field in **Penalty Box specific settings** will be lowered. You must also specify a bandwidth percentage to which the specified host will be limited (only values between 2 and 15% are allowed). Note that although the drop-down box in this section allows you to select different options (percentage, bits/s, kilobits/s, megabits/s, and gigabits/s), if you select anything other than percentage, the entry will not be validated – when you click on **Next**, you will get a **Only percentage bandwidth specification is allowed** error message.

The next page, **Peer to Peer networking**, allows you to configure the peer-to-peer (commonly known as **P2P**) networking options. P2P networking protocols are designed to utilize all available bandwidth, unless you set limits. Often P2P clients allow you to set limits on the amount of bandwidth to be used, but if you expect P2P traffic on your network, you should ensure that other traffic will not be degraded as a result. Checking the **Lower priority of Peer-to-Peer traffic** checkbox at the top of this page allows you to configure other P2P options on the page.



Configuring peer-to-peer settings in the traffic shaping wizard.

The next option is the **P2P Catch All** checkbox, which, if checked, will feed all uncategorized traffic into the p2p queue. This addresses a common problem with traffic shaping with respect to P2P traffic. Many P2P protocols and technologies try deliberately to avoid detection, often by utilizing non-standard or random ports, or even ports associated with other protocols. The **P2P Catch All** option deals with this problem, sending all unrecognized traffic to the p2p queue, where its priority is accordingly lowered. As with **Penalty Box**, you must specify a percentage of bandwidth to allocate to the P2P queue, and once again, you are limited to specifying a value between 2 and 15%.

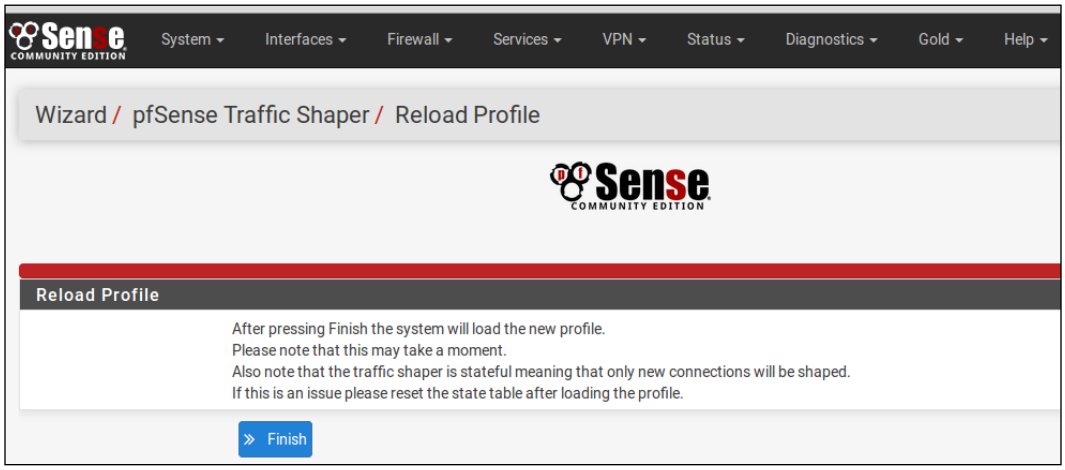
The next section, **Enable/Disable specific P2P protocols**, allows you to specify which P2P protocols will be recognized by pfSense. Check the corresponding checkbox for each service you want to be recognized. There are over 20 in total, including many well-known protocols, such as **BitTorrent**, **DCC**, **Gnutella**, and **Napster**. When you are finished making your selections on this page, click on the **Next** button.

The next page of the wizard, **Network Games**, allows you to specify settings for network games. Since many online games rely on low latency for a good experience, you will want to check the **Prioritize network gaming traffic** checkbox if you or other users are going to play online games. Gaming can be affected by other users downloading large files, or even by gamers downloading game patches while playing. Enabling the prioritization of network gaming here raises the priority of network gaming so that game traffic will be transferred first and also given a guaranteed chunk of bandwidth.

The next section of the page, **Enable/Disable specific game consoles and services**, allows you to enable the game consoles/services you will be using. All the major game consoles are represented here (**PlayStation**, **Wii**, and **Xbox**), and a few popular gaming services (such as **Games for Windows Live**). The last section of the page is **Enable/Disable specific games**. Quite a few popular games are represented here, including **Doom 3**, **Minecraft**, and **World of Warcraft**. If a game you play is not on the list, you may want to choose a game (preferably a similar one) so you can configure a reference rule later on. When you are done selecting games, click on the **Next** button.

The next page of the wizard, **Raise or lower other Applications**, provides a list of over 25 applications/services for which you can raise or lower the priority level. Each application or service has its own drop-down box with three options: **Default priority**, which keeps the priority level the same, **Higher priority**, and **Lower priority**. Your specific network configuration and requirements will dictate which applications, and services, for which you manipulate the priority levels. The applications and services are generally grouped with those that would need a higher priority closer to the top of the page and those whose priority can be lowered closer to the bottom of the page. For example, the **Remote Service / Terminal emulation** section of the page has **VNC** (**Virtual Network Computing**) listed. If you are using **VNC**, you probably want to choose **Highest priority**, since a poor quality network connection will make it difficult to remotely control another computer (keep in mind that not just bandwidth but latency is a factor here, with keyboard and mouse events needed to be transmitted to the remote computer for it to work).

On the other hand, there are services where nobody will notice if the priority level is lowered. Mail services such as SMTP, POP3, and IMAP come to mind, as well as applications such as MySQL Server. If you enabled **p2p Catch All** earlier in the wizard, you want to specify protocols here, so they are not penalized by the **p2p Catch All** rule. When you are done making changes, click on the **Next** button.



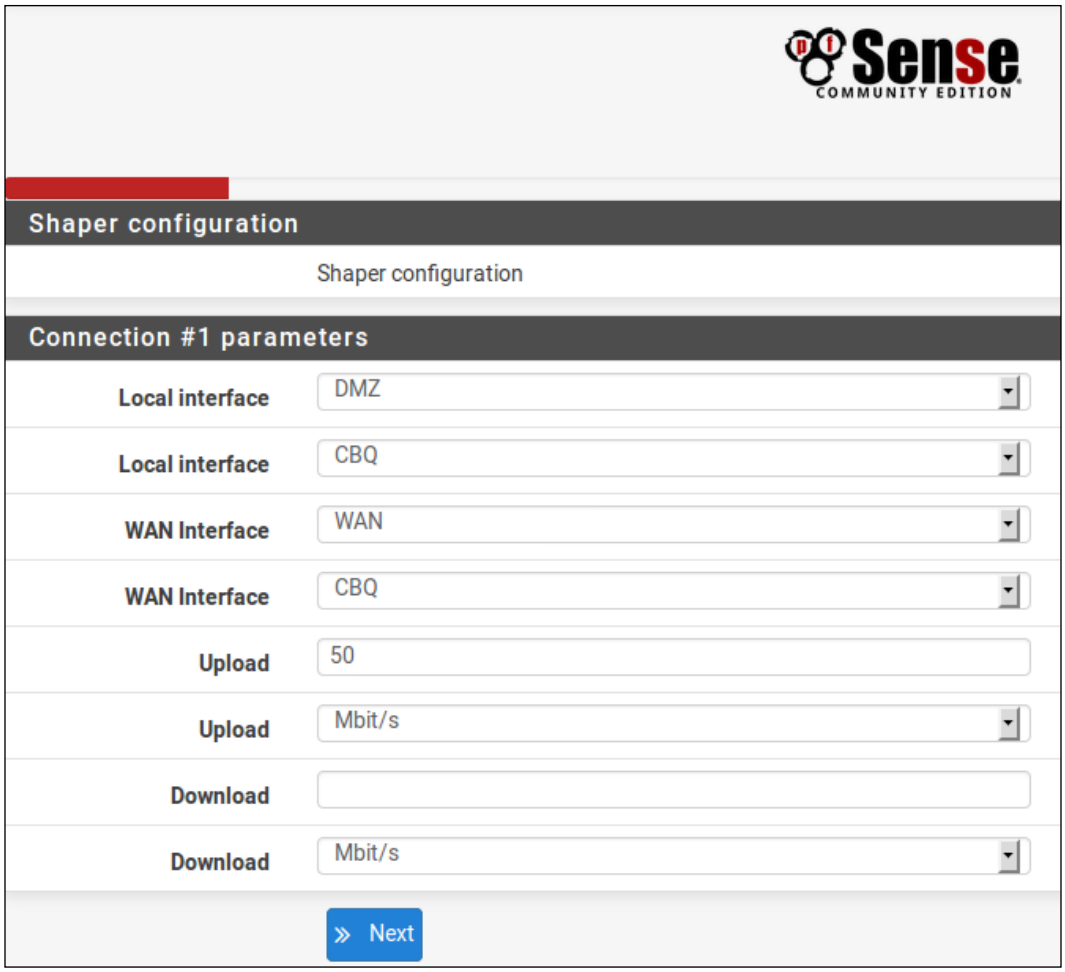
The last page of the wizard.

Once you click on the **Next** button, you will be on the final page of the wizard. At this point, all the rules and queues are created, but not yet in use. By clicking on the **Finish** button at the bottom of the page, the new rules will load and will be active.

Traffic shaping will now be active, but it will only be applied to new connections. In order for the traffic shaper to take effect on all connections, you must clear the state table. To do this, navigate to **Diagnostics** | **States**, click on the **Reset States** tab, and then click on the **Reset** button at the bottom of the page.

The Dedicated Links wizard

pfSense also provides a wizard for setting up dedicated links. To use this wizard, navigate to **Firewall** | **Traffic Shaper**, click on the **Wizards** tab, and click on the second option (**traffic_shaper_wizard_dedicated.xml**). On the first page, **pfSense Traffic Shaper**, you will be warned that custom links should not exceed 30% of the interface link/bandwidth. There is also an edit box where you must enter the number of WAN connections. As with the **Multiple Lan/Wan** wizard, the wizard will automatically fill in the number of WAN connections, so unless you want to use this traffic shaper on less than the total number of WAN interfaces, you can leave this value as it is and click on the **Next** button.



Entering parameters for Connection #1 in the Dedicated Links wizard.

In the next few pages, the **Shaper configuration** pages, you will enter the parameters for each connection. There are two **Local interface** drop-down boxes. In the first drop-down box, you will specify the interface which will use this connection, and in the second drop-down box, you will specify the queuing discipline (again, the choices are **PRIQ**, **CBQ**, and **HFSC**). The two **WAN Interface** drop-down boxes are set up in the same way, with the actual interface specified in the first drop-down box and the queuing discipline specified in the second one. The next options on the page are **Upload**, where you specify the upload bandwidth for the connection, and **Download**, where you specify the download bandwidth.

Both options have an edit box and a drop-down box; in the edit box you specify the bandwidth, and in the corresponding drop-down box, you specify the unit of measure for the edit box (**Kbit/s**, **Mbit/s**, or **Gbit/s**). When you are done, click on the **Next** button at the bottom. This page will repeat itself for as many WAN connections as you specified on the first page of the wizard. So if you entered 3 on the first page, the next page will prompt you for the settings for **Connection #2**, and the next page after that will prompt you for the settings for **Connection #3**.

The next page, **Voice over IP**, allows you to configure the VoIP settings. Since the options here are identical to the options in the **Multiple Lan/Wan** wizard, we will not cover them in detail here, but instead refer to the **Voice over IP** subsection in the previous section. In fact, the next few pages of the wizard (**Penalty Box**, **Peer to Peer Networking**, **Network Games**, and **Raise or lower other Applications**) are all identical to corresponding pages in the **Multiple Lan/Wan** wizard, so refer to the previous section for those options as well.

As with the **Multiple Lan/Wan** wizard, at the end of the process, you will be presented with a final page. The rules and queues have been created, but will not be loaded until you click on the **Finish** button. Once you have done this, the traffic shaper will be active, but will only apply to new connections. If you want it to apply to all connections, you have to empty the state table using the **Reset States** option in **Diagnostics | States**.

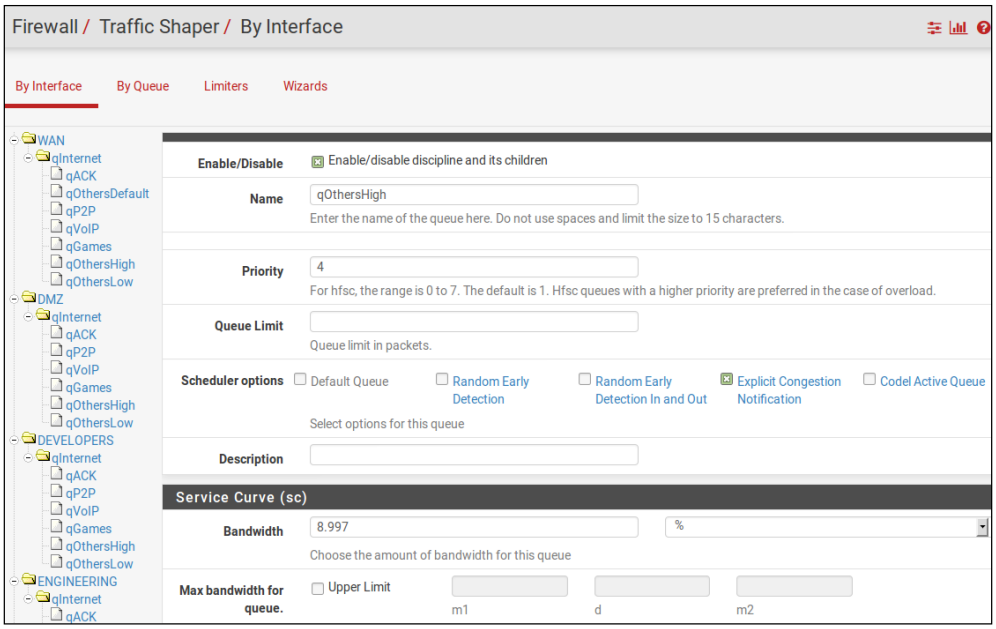
Advanced traffic shaping configuration

After the initial traffic shaping configuration using the traffic shaper wizard, you may find that the rules the wizard do not entirely fit your needs. This may be as a result of issues you knew about when you were using the wizard (for example, you are using a game not on the list of games) or there may be other issues, such as a service or application that needs to be limited. This should not be a major problem: now that the basic rules have been created, you can edit or copy those rules and create custom rules that suit your needs. There are two broad categories of changes you might want to make: changes to queues and changes to traffic shaping rules.

Changes to queues

To begin configuration, navigate to **Firewall | Traffic Shaper** and click on either the **By Interface** or **By Queue** tab. If you choose **By Interface**, you will see a list of interfaces at the root level, along with a list of queues available on each interface. If you choose **By Queue**, you will instead see a list of queues at the root level, and when you click on each queue, you will see a list of interfaces, which utilize that queue. You can edit queues from either tab; which tab you use for such editing is a matter of preference. If you are creating queues, you will find that the easiest way to do so is to create a queue on a single interface on the **By Interface** tab, and then make the queue available on other interfaces by clicking on the **By Queue** tab and using the **Clone Shaper to this Interface** button.

Once you have selected a queue on an interface to edit, you will be presented with several options. The **Enable/Disable** checkbox, if unchecked, will disable the queue and any children queues. The **Name** edit box allows you to change the name, assuming you would want to do that. The **Priority** edit box allows you to set a priority level from `0` to `7`. Higher-numbered priority levels take precedence over lower-numbered priority levels. Keep in mind, however, that if the queue is a HFSC queue, the priority field will be ignored. HFSC queues are identifiable by the fact that their configuration pages have a section called **Service Curve (sc)**. We will cover HFSC configuration later in this section.



Editing a queue. Note that since this is a HFSC queue, there is a section of the configuration page for configuring the service curve.

The **Queue Limit** edit box allows you to enter the queue limit (expressed in terms of packets). The next options are the **Scheduler options** checkboxes. These checkboxes allow you to apply additional traffic shaping algorithms to the queue. Checking the **Default Queue** checkbox will make this queue the default queue for the interface (it can only be selected on one queue per interface). The other options are as follows:

- **Random Early Detection**: A traffic shaping queue is essentially a buffer. Once the buffer is full, packets will be dropped (often referred to as tail drop). This can be problematic, as during times when the network is congested, all buffers can become full, and might alternate between being flooded and being under-utilized. **Random Early Detection** (**RED**) attempts to avoid this problem by randomly dropping packets as the buffer fills up. If the buffer is almost empty, all packets are accepted, but as the buffer fills up, the probability of a packet being dropped increases.
- **Random Early Detection In and Out**: This is a variation of RED. The RED algorithm is still employed, but there are separate in and out queues on the interface. The out queue is much more aggressive in dropping packets than the in queue. The advantage here is that the out traffic can be controlled before the queue grows to the point that any in traffic is dropped. We call this scheme **RED with In and Out**, or RIO.
- **Explicit Congestion Notification**: This is an extension to TCP/IP which provides for end-to-end notification of network congestion without dropping packets. It is defined in RFC 3168 (2001) and is supported by most modern network hardware.
- **CoDel Active Queue: CoDel**, or controlled delay, was developed to address perceived shortcomings in RED. Whereas RED/RIO are based on the assumption that average queue length is a sign of network congestion, CoDel is based on the assumption that average queue length actually tells us nothing about network conditions, and that a better metric is the minimum amount of delay experienced by any packet in the running buffer window. CoDel seeks to minimize this delay and keep it below 5 milliseconds. If the minimum delay rises to a higher value, packets are dropped from the window until the delay drops below this value. It is also based on the assumption that there are good queues (queues that handle bursts of traffic with only minor increases in delay) and bad queues (queues for which a burst of traffic causes them to fill and stay filled, with larger increase in delay), and that CoDel can safely ignore the good queues.

All of these algorithms are designed to deal with the problem of bufferbloat, an occurrence of excess buffering of packets, which causes high latency and packet delay variation. Network equipment manufacturers began to incorporate larger buffers into their routers. The problem with larger buffers is that the TCP algorithm uses the number of dropped packets to determine when a connection is saturated. But with large buffers, it may take several seconds for the buffers to fill and packets to drop. Thus, the buffer becomes a bottleneck until TCP adjusts. Then the buffer drains, the TCP connection ramps up again and floods the buffer. In other words, large buffers can actually break TCP's congestion avoidance algorithms and thus queues can be constantly congested unless appropriate countermeasures are taken.

The last option in the top section is the **Description** edit box. In this field, you can enter a description for your own reference, which is not parsed.

This covers options that are available for queues that employ PRIQ or CBQ. If **HFSC** was selected for the queue, however, there are additional options provided on a section of the page called **Service Curve (sc)**. The first option, **Bandwidth**, allows you to choose the amount of bandwidth of the queue. The remaining options allow you to configure the service curves for the queue. Each service curve has three parameters: **m1**, **d**, and **m2**. **m1** and **m2** represent two portions of the service curve, and **d** represents the dividing point between the two portions. For the first *d* milliseconds, the queue gets the bandwidth given as **m1**. After *d* milliseconds, the queue gets the value given in **m2**. You can configure three different service curves for each queue: **Max bandwidth for the queue**, **Min bandwidth for the queue**, and **B/W share of a backlogged queue**. The significance of these three curves is as follows:

- **Max bandwidth for the queue (Upper Limit)**: The upper limit service curve limits HFSC bandwidth to bandwidth available on the upstream router/interface
- **Min bandwidth for the queue (Real Time)**: The real-time service curve ignores any class hierarchy and guarantees precise bandwidth as well as delay allocation
- **B/W share of a backlogged queue (Link Share)**: The opposite of the real-time service curve, link share distributes bandwidth according to a class hierarchy

When you are done making changes, click on the **Save** button at the bottom of the page. You can also choose **Add new queue** or **Delete this queue**. **Add new queue** allows you to create a brand new queue (the options are the same as those outlined earlier) while **Delete this queue** results in the deletion of the currently selected queue.

Limiters

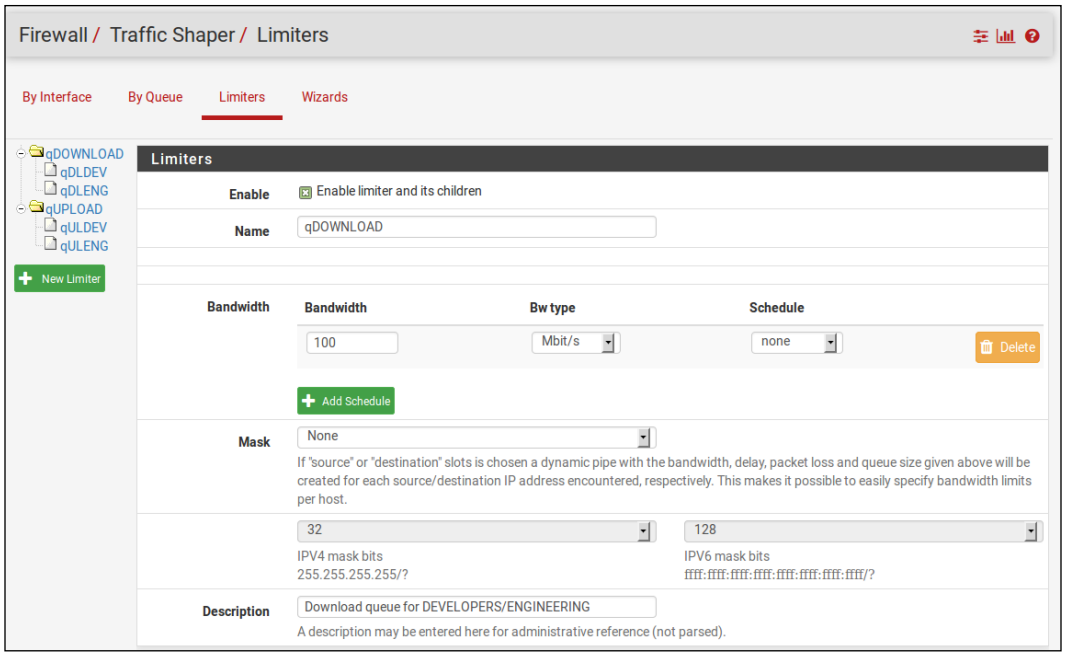
Another option for traffic shaping in pfSense is using limiters. The **Limiters** option allows you to set up a series of dummynet pipes; *dummynet* is a FreeBSD traffic shaper that was designed to simulate different types of connections. Bandwidth and queue size limitations can be imposed, as well as scheduling and queue management policies and delay/loss emulation.

To set up a limiter, navigate to **Firewall | Traffic Shaper,** and click on the **Limiters** tab. If you have set up limiters previously, you will see a tree showing the different queues. Otherwise, the page will be mostly blank, but there will be a **New Limiter** button on the left of the page. Click on this button to set up a new limiter.

There are some things to consider when creating a new limiter:

- It is generally considered a good idea to create separate queues for the in and out traffic. *In* and *out* are always from the perspective of the interface. Thus, the in queue is for upload traffic, and the out queue is for download traffic.
- Keep in mind that the newly created limiter will have no effect until a rule is created which assigns traffic to the limiter. We will cover creating rules that assign traffic to a queue later in this chapter.

The configuration page for limiters has two sections: **Limiters** and **Advanced Options**. The first option on the page is the **Enable** checkbox. If checked, the limiter (and its children) will be enabled. Next, there is also a **Name** edit box where you must enter a name for the limiter.



Configuring a limiter.

The next section of the page is called **Bandwidth**. Here, you enter the upper limit for the bandwidth. The amount of bandwidth is entered in the **Bandwidth** edit box, and the unit of measurement (**bit/s**, **Kbit/s**, or **Mbit/s**) can be selected in the **Bw type** drop-down box. The third option is **Schedule**. In this drop-down box, you can select a time frame in which the bandwidth limit will be imposed. The schedule has to be one that was defined by using the pfSense **Schedule** option, which can be found at **Firewall | Traffic Shaper** (detailed information about how to create a schedule can be found in *Chapter 4*, *pfSense as a Firewall*). If you do not want to use a schedule on this limiter, you can select **none** in the drop-down box. You can also create multiple bandwidth schedule entries by clicking on the **Add Schedule** button.

The next field is the **Mask** drop-down box. In this box, you can set up the limiter so that it only applies to either source or destination traffic. If you select either **Source addresses** or **Destination addresses**, then a dynamic pipe will be created for each source or destination IP address encountered. This dynamic pipe will have the bandwidth, delay, packet loss, and queue size specified for the limiter. As a result, you can easily specify bandwidth limits per host with this option. If you utilize this option, you must specify the IPv4 mask or IPv6 mask in the appropriate drop-down boxes. You may also enter a brief non-parsed description in the **Description** field.

The next section is **Advanced Options**. These options are mainly useful if you want to simulate certain network conditions, and are not particularly useful in real-world situations. **Delay (ms)** allows you to specify a delay. **Packet loss rate** allows you to specify a rate of packet loss, expressed as a fraction of 1. For example, a value of 0.001 means that one packet in 1000 is dropped; 0.01 will drop one in 100, and so on. If a number is specified for **Queue size (slots)**, then the limiter will create a fix-sized queue into which packets in the pipe will be placed. They will then be delayed by the amount specified in **Delay (ms)**, and then they will be delivered to their destination. Finally, **Bucket size (slots)** allows you to specify the number of slots in the bucket array used for source or destination hashing. When you are done making changes, click on the **Save** button at the bottom of the page.

What is a limiter good for? You can use it for anything for which you would use a traffic shaper. One possible use of limiters is to set up a guaranteed minimum bandwidth queue. To do this, create two queues (one for uploading and one for downloading) with the upper bandwidth limit set to the amount you want as the guaranteed minimum bandwidth (for example, 1 Gbps up and 1 Gbps down). Then create two more queues with the upper bandwidth limit set to whatever bandwidth is left (for example, if your connection is 10 Gbps up and 20 Gbps down, set the upload queue limit to 9 Gbps and the download queue to 19 Gbps. Direct guaranteed service traffic into the 1 Gbps queues, and everything else into the other two queues). This will have the effect of guaranteeing bandwidth to an application or service using the 1 Gbps queues, since it will be able to have sole use of the queues.

An example limiter

For a demonstration of how to add a limiter, we will create two limiters for a shared connection. Assume that we have a shared broadband connection for our company. We only have 300 Mbps down / 50 Mbps up, and this connection has to be shared among about 500 users. Therefore, when it comes to allocating bandwidth, we need to get a bit creative. We will create an upload queue and a download queue; each user of the upload queue will be limited to 256 Kbps, while each user of the download queue will be limited to 1.5 Mbps.

To do this, from the **Limiters** tab we click on **New Limiter**. For the upload queue, we click on the **Enable/Disable** checkbox, enter the name (`qUPLOAD`), and the bandwidth (**256 Kbit/s**). We do not need to use any schedule options. We choose **Source addresses** in the **Mask** drop-down box, and we set the **IPv4** mask to **32**. Having configured the upload queue, we can click on the **Save** button. Now there should be a tree on the left sidebar of the main **Limiters** page with **qUPLOAD** in it. We go through the same steps to create a download queue, clicking on the **New Limiter** button, and creating a queue named `qDOWNLOAD`, with **Bandwidth** set to **1.5 Gbit/s**. We choose **Destination addresses** in the **Mask** drop-down box, set the **IPv4** mask to **32**, and click on the **Save** button.

As of now, the newly created queues will have no effect, because we are not directing traffic into them. We will do that when we cover changing and creating traffic shaper rules.

Layer 7 traffic shaping

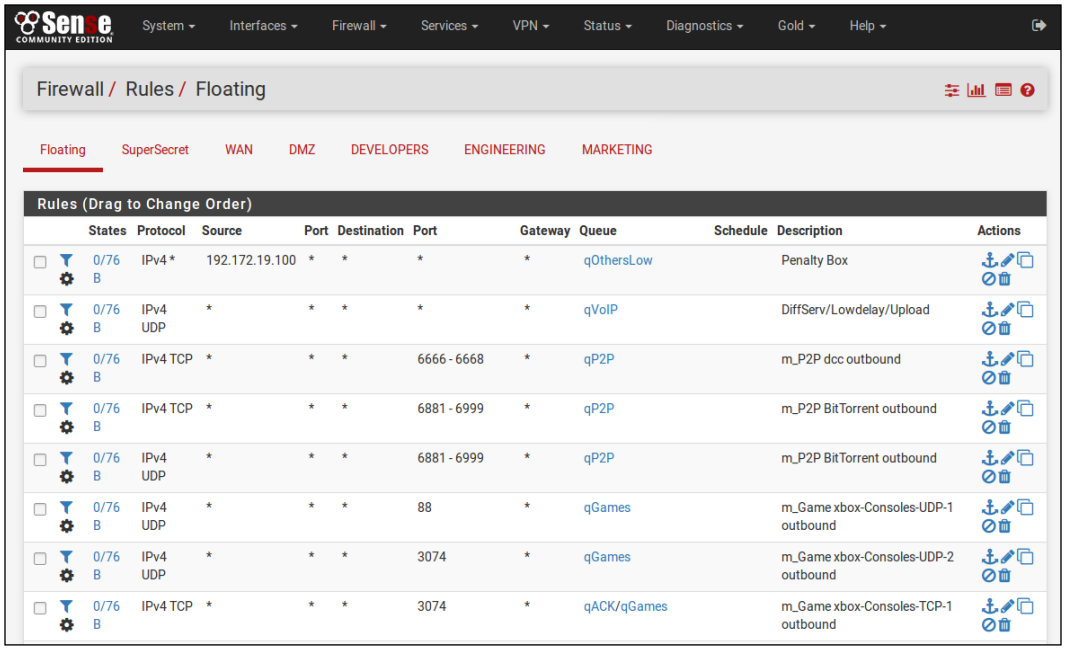
You probably noticed that the majority of traffic shaping rules use ports and/or protocols as matching criteria. This is an imperfect solution, since many applications use random ports, or have the ability to select different ports, and the protocol alone usually isn't enough to identify the traffic.

Layer 7 traffic shaping, also known as **Deep Packet Inspection** (**DPI**), attempts to address this shortcoming by identifying traffic based on the contents of the packets. Prior to version 2.3, pfSense had Layer 7 traffic shaping available as an option. As of version 2.3, however, Layer 7 support has been removed from pfSense. According to the release notes for 2.3, Layer 7 traffic shaping had been broken for all of 2.2.x and had high CPU usage. Instead, the notes recommend that we use Snort filters instead. Snort is a third-party package which we will cover in *Chapter 9*, *Extending pfSense with Packages*.

Changes to rules

We have demonstrated how queues can be added and how existing queues can be edited, but the traffic shaping rules control how network traffic is assigned into these queues. If a packet matches a rule, it will be assigned into the queue that the rule specifies. So traffic shaping rules are essentially a subset of the firewall rules covered in *Chapter 4*, *pfSense as a Firewall*.

In older versions of pfSense, traffic shaper had a separate tab called **Rules**. This tab showed all the rules generated by the traffic shaper. This is no longer the case. To see the traffic shaper rules, navigate to **Firewall | Rules** and click on the **Floating** tab. The traffic shaper rules will be listed here, mixed in with any other floating rules that you created yourself. Nonetheless, you should be able to distinguish the traffic-shaper rules from the nontraffic-shaper rules by their description. In addition, all traffic-shaper rules will have a value specified for **Queue** (for example, **qOthersLow**, **qVoIP**, and so on), whereas other rules may not have a queue specified.



The Floating Rules tab, showing some of the rules generated by the Multiple Lan/Wan wizard.

To edit a rule, click on the **Edit** icon (represented by a pencil); to delete a rule, click on the **Delete** icon (represented by a trash can). Both options can be found in the **Actions** column (the right most column in the table). You can also change the order of rules in two different ways. You can click on a rule in the table and drag it to a different position. If you need to move more than one rule, it may be more convenient to check the rules (the checkbox for each rule is in the left most column) and then click on the **Move checked rules above this one** icon in the **Actions** column for the rule, which the checked rules are to be moved ahead of. To add a new blank rule, click on one of the **Add** buttons at the bottom of the list (the **Add** button with the up arrow creates a new rule at the top of the list, while the one with the down arrow creates a new rule at the bottom of the list). To create a rule based on an existing rule, click on the **Copy** icon (represented by two sheets) in the **Actions** column of the rule you want to copy.

Each rule will have several matching criteria. These criteria are what ensure that traffic is fed into the proper queue. Traffic shaping rules can have separate inbound and outbound queues, but most of the rules generated by the pfSense traffic shaper wizard have the same queue for inbound and outbound traffic. This is because the wizard generates floating rules, which apply to traffic in both directions. This saves having to generate separate rules for inbound and outbound traffic, but it also means that inbound and outbound traffic must be fed into the same queue, since each rule can only assign traffic into one queue.

If we click on the **Edit** option for any traffic shaper rule, we can see that such a rule has much in common with any other firewall rule, although there are some significant differences. The first field is the **Action** drop-down box. Traffic shaping rules do not utilize the **Pass**, **Block**, or **Reject** options used by most other firewall rules, but instead use the **Match** option. This option allows pfSense to match traffic without affecting its pass/block status. The interface selected in the **Interface** listbox is usually the **WAN** interface. The **Direction** drop-down box determines whether the rule applies to inbound traffic, outbound traffic, or both. As aforementioned, most of the rules generated by the pfSense traffic shaper wizard appear to take advantage of the fact that floating rules can apply to traffic in both directions; therefore, the traffic shaper rules are generally set to **any**.

The aforementioned settings are the same for all the auto-generated rules, but the elements that differentiate traffic are the core of traffic shaping rules. The two factors that seem to be used most often to filter traffic are protocol (TCP is most commonly used, but many VoIP and gaming services use UDP) and port number. Consider, for example, an auto-generated rule to divert DCC traffic into the P2P queue. **TCP** is selected as **Protocol** (which is not unusual), and **Destination port range** is set to **6666 to 6668**. This rule might not be that effective, since the end user can easily circumvent it by changing the port range on their DCC client. On the other hand, our traffic shaper rules should work pretty well with services that always use the same ports. For example, our rule to send all port `25` traffic into the low-priority queue should be effective in ensuring that all SMTP traffic is given a lower priority.

A good example of a rule which uses both protocol and port as matching criteria is an auto-generated rule created by pfSense to assign a higher priority to Ventrilo voice traffic. Here, the protocol is UDP, so **UDP** is selected in the **Protocol** drop-down box. Port `6100` is also used, so it is specified as **Destination port range**.

Although they seldom seem to be used by the pfSense auto-generated rules, another way of matching traffic is to use the TCP flags. The TCP flags indicate various states of a connection, and they can be matched on whether or not they are set, cleared, or we can leave the checkboxes unchecked if we don't care whether they are set. Since we covered the TCP flags in detail in *Chapter 4*, *pfSense as a Firewall*, we won't cover it here, other than to be aware that they may be used as matching criteria.

The last option in the **Advanced Options** section is **Ackqueue/Queue**, and this is where the matching traffic is assigned to a queue. The first drop-down box selects the queue for ACK traffic; the second drop-down box selects the queue for all other traffic. In practice, **Ackqueue** is often left undefined (set to **none**) and **Queue** is the only selection made.

Armed with this information, we should now be able to make changes to traffic shaping rules if necessary. As always, you may want to make a backup before making any rule changes, in case the changes lead to unfavorable results and you want to revert back to your old ruleset.

Example rule changes/rule creation

As an example of how we can change rules generated by the pfSense traffic shaper wizard to suit our needs, let's revisit the penalty box rule. As you might recall, the traffic shaper wizard lets us assign a single IP address to the low-priority queue (**qOthersLow**). But what if we want to assign a range of IP addresses to the so-called penalty box? The traffic shaper wizard does not allow us to do this.

Fortunately, changing the existing penalty box rule is relatively easy to do. In our example, the IP address `172.19.1.10` is assigned to the penalty box. Assume that we want to assign `172.19.1.1` to `172.19.1.15` to the penalty box. Rather conveniently, the IP addresses all fall within a subnet that is defined by the subnet mask `255.255.255.240`, or a CIDR of `28`. Thus, we click on the **Edit** icon for the penalty box rule and make the necessary changes:

1. **Source** is currently set to **Single host or alias** and to an **IP address** of `172.19.1.10`. Select **Network** from the **Source** drop-down box.
2. Set the network to `172.19.1.0`, and set the CIDR in the corresponding drop-down box to `28`.
3. Click on the **Save** button at the bottom of the page, and when the main **Floating rules** page loads, click on the **Apply Changes** button at the top of the page.

Now the entire subnet from `172.19.1.1` to `172.19.1.15` will be in the penalty box. But what if we want to assign an arbitrary set of IP addresses to the penalty box? For example, assume that we want to assign `172.18.1.10`, `172.19.1.12`, and `172.19.1.17` to the penalty box. Obviously we cannot use the approach outlined earlier, since the nodes are on different networks. We could create three separate rules (one for each IP address), but we should try to avoid duplication when possible. So we revisit the concept of *Aliases* introduced in *Chapter 4*, *pfSense as a Firewall*, and utilize the following approach:

1. Navigate to **Firewall** | **Aliases** and click on the **Add** button.

2. In the **Name** edit box, type `PENALTYBOX`. You may also enter a brief description in the **Description** edit box (for example, `Nodes assigned to the low priority queue`). In the **Type** drop-down box, select **Host(s)**.
3. In the **Host(s)** section of the page, enter each IP address. Click on the **Add Host** button after entering the first and second IP address. The CIDR will be updated automatically.
4. Click on the **Save** button at the bottom of the page, then click on the **Apply Changes** button on the main **Aliases** page.
5. Now that we have an alias we can use, we will return to **Firewall** | **Rules** and click on the **Floating** tab. Click on the **Edit** icon on the penalty box rule.
6. For **Source**, select **Single host or alias** in the drop-down box. In the edit box, type `PENALTYBOX` (as soon as you start typing, the autocomplete feature should do the rest).
7. Click on the **Save** button at the bottom of the page, and click on the **Apply Changes** button on the main **Floating rules** page.

Now we have a traffic shaping rule which sends traffic to and from the three specified IP addresses into the low-priority queue, and if we want to alter the IP addresses affected by this policy, we just need to edit the **PENALTYBOX** alias. This demonstrates how in editing and creating traffic shaping rules, it helps to utilize what we already know about pfSense's firewall options such as aliases.

We can also create rules for applications not covered by pfSense's traffic shaper wizard. For example, we may want to create a rule to prioritize traffic from EchoLink, a VoIP application that allows radio amateurs to communicate with each other. EchoLink uses ports `5198` to `6000`, and uses UDP on ports `5198` and `5199`, and TCP on port `6000`. As a result, we will have to create two rules for EchoLink, but the process is still fairly simple:

1. From the **Floating** tab on the **Rules** page, click on one of the **Add** buttons at the bottom of the page.
2. In the **Action** drop-down box, select **Match**.
3. In the **Interface** listbox, select **WAN**.
4. Leave **Direction** set to **any**, so that the rule will be a bidirectional rule.
5. Change **Protocol** to **UDP**.
6. Set **Destination port range** to `5198` to `5199`. You may also enter a brief description (for example, `Prioritize EchoLink UDP rule`).
7. Click on the **Show Advanced** button and scroll down to **Ackqueue/Queue**.
8. Set **Queue** to **qOthersHigh**.

9. Click on the **Save** button. This will take you back to the main **Floating rules** page.
10. To save time, we'll copy this rule and make a rule for port `6000`. Click on the **Copy** icon on the newly created rule to make a new rule based on this rule.
11. In the new rule, change **Protocol** to **TCP**.
12. Change **Destination port range** to `6000`. You may also enter a brief description (for example, `Prioritize EchoLink TCP rule`).
13. Click on the **Save** button. On the **Floating rules** page, click on the **Apply Changes** button.

You'll probably want to check the firewall rules to make sure no existing rules conflict with the newly created ones. But as this example demonstrates, generating your own rules without the wizards is not necessarily difficult.

Traffic shaping examples

In the beginning of the chapter, we outlined an example network with some basic traffic shaping requirements. Now we will attempt to implement traffic shaping using pfSense in a manner that matches these requirements as closely as possible.

Example #1 – adding limiters

Although it is generally recommended that you use the traffic shaper wizards when getting started with traffic shaping, for this exercise we will avoid using them, since the rules the wizard will implement would require significant modification. We will begin by navigating to **Firewall** | **Traffic Shaper** and selecting the **Limiters** tab.

We require that **DEVELOPERS** and **ENGINEERING** receive 100 Mbps of downstream bandwidth, with 60 Mbps going to **DEVELOPERS**. We also will give **DEVELOPERS** and **ENGINEERING** 25 Mbps of upstream bandwidth, with 15 Mbps going to **DEVELOPERS**. To do this, we will set up two limiters: a limiter for download bandwidth and one for upload bandwidth. Each of these limiters will have two children (one for **DEVELOPERS** and one for **ENGINEERING**). We proceed as follows:

1. Click on the **New Limiter** button.
2. Check the **Enable** checkbox.
3. In the **Name** edit box, type `qDOWNLOAD`.
4. For **Bandwidth**, enter `100` in the edit box and select **Mbit/s** in the drop-down box.

5. We can leave **Mask** unchanged. You can enter a brief description (for example, `Download queue for DEVELOPERS/ENGINEERING`).
6. Click on the **Save** button; then click on the **Apply Changes** button.
7. Click on the **qDOWNLOAD** queue on the left sidebar; then click on the **Add new Queue** button to create the first of the child queues.
8. Click on the **Enable** checkbox.
9. In the **Name** field, type `qDLDEV`.
10. Again, **Mask** can be left unchanged; you may enter a brief description (for example, `Download queue for DEVELOPERS`).
11. Under **Advanced Options**, in the **Weight** field, type `60` (so that **DEVELOPERS** gets a 60% share of 100 Mbps, or 60 Mbps).
12. Click on the **Save** button and then click on **Apply Changes**.
13. Click on the **qDOWNLOAD** queue on the left sidebar and click on the **Add New Queue** button. Create a new child queue named `qDLENG` by checking the **Enable** checkbox and specifying `qDLENG` in the **Name** field.
14. Under **Advanced Options**, in the **Weight** field, type `40` (so that **ENGINEERING** gets a 40% share of 100 Mbps, or 40 Mbps).
15. Click on the **Save** button; then click on **Apply Changes**.
16. Follow the same procedure to create a queue called `qUPLOAD` with a total bandwidth of 25 Mbit/s. Create two child queues called `qULDEV` with a 60% share of bandwidth, and `qULENG` with a 40% share of bandwidth.

We now have a set of queues for the **DEVELOPERS** and **ENGINEERING** networks, but they are of no use until we create rules to send traffic to them. Navigate to **Firewall** | **Rules** and click on the **Floating** tab. We need to create four rules: an upload and download queue for each interface:

1. Click on one of the **Add** buttons at the bottom of the page.
2. In the **Action** drop-down box, select **Match**.
3. In the **Interface** listbox, select **DEVELOPERS**.
4. In the **Direction** drop-down box, select **out**.
5. All traffic to and from the interface is going to the queue, so in the **Protocol** drop-down box, select **any**.
6. You may enter a brief description in the **Description** edit box (for example, `DEVELOPERS download queue rule`).
7. Click on the **Show Advanced** button.

8. In **Advanced Options**, scroll down to the **In/Out** pipe drop-down boxes and select **qDLDEV** as the **In** pipe.
9. Click on the **Save** button at the bottom of the page; when the main **Floating rule** page reloads, click on the **Apply Changes** button.
10. Create a rule for the **DEVELOPERS** upload queue by clicking on the **Copy** icon for the previously created rule, changing the **Direction** to **in** and changing the **In** pipe to **qULDEV** (you may also enter a brief description in the **Description** field). Click on the **Save** button when done and then click on the **Apply Changes** button on the main **Floating rules** page.
11. Create rules for the **ENGINEERING** download and upload queues. Both queues should have **ENGINEERING** set as the **Interface** and **any** selected in the **Protocol** drop-down box. The download queue should have the **Direction** set to **out** and the **In** pipe set to **qDLENG**. The upload queue should have the **Direction** set to **in** and the **In** pipe set to **qULENG**.

We now have queues for both **DEVELOPERS** and **ENGINEERING** that meet our traffic shaping requirements for both networks.

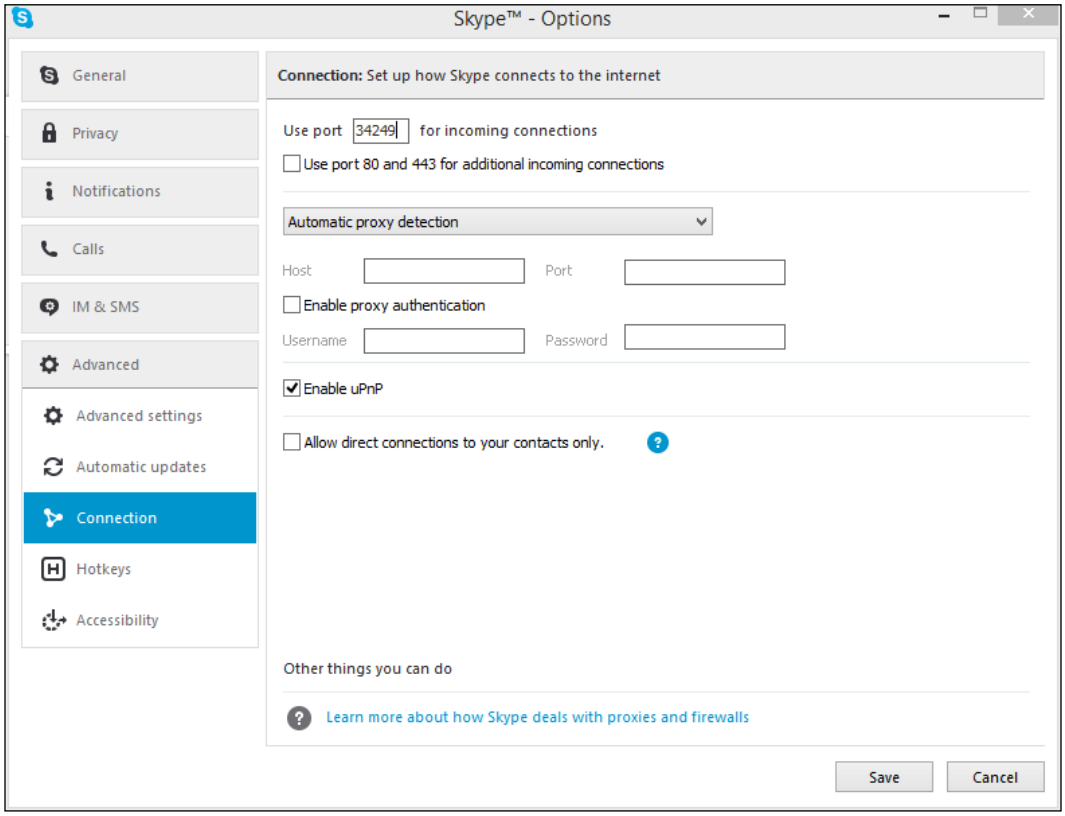
Example #2 – prioritizing Skype

Another one of our traffic shaping requirements was that we wanted to prioritize Skype traffic. This is not easy to do, and this is probably one of the reasons the pfSense traffic shaper wizard does not have prioritizing Skype traffic as an option. One of the reasons for this is that the wizard relies heavily on using ports to differentiate applications and services; however, by default, Skype uses TCP on a random port above `1024` for incoming connections. If a port above `1024` is not available, by default Skype uses ports `80` and `443`.

Obviously, we are going to have to look for a different way of configuring Skype if we are going to get it to work with the traffic shaper. Fortunately, one of Skype's options is to configure Skype to use a single port for incoming connections. This is not an ideal option, for several reasons:

- It requires us to open up a separate port for each Skype user, and to make a corresponding NAT entry/firewall rule.
- It requires us to configure each individual Skype client and set the port in each one.
- Even if we set a port for incoming traffic, testing reveals that it only works for Skype TCP traffic. Skype calls also have a UDP component that will not be affected by altering the port setting in the Skype client.

As a result, implementation of this prioritization scheme will require a good deal of work, and will likely only leave us marginally better off than we would be if we just directed all UDP traffic into the VoIP queue. Nonetheless, we will walk through the process of implementing this scheme. First, we should take a look at the Skype client to see where we can set the incoming port, and we can find it in **Tools** | **Options** in the **Advanced** section under **Connection**:



This is where we need to set the incoming port in Skype. In addition, the port 80/443 option should be unchecked.

For purposes of this exercise, assume that we have chosen a range of `34000` to `35000` as the selected port range for incoming Skype traffic. We will begin by creating a VoIP queue. Navigate to **Firewall** | **Traffic Shaper** and click on **By Interface**. The following steps will create the VoIP queue on all interfaces: on the left sidebar, click on **WAN**. The right-hand side of the page will show options for this queue:

1. Check the **Enable/Disable** checkbox for this queue.
2. In the **Scheduler Type** drop-down box, select **PRIQ** for priority queuing.

3. For **Bandwidth**, specify the upstream bandwidth of the WAN interface. **Queue Limit** and **TRB Size** can be left blank.
4. Click on the **Save** button, and when the page reloads, click on **Apply Changes**.
5. The VoIP queue will now be created as a child queue of the WAN queue. Click on **WAN** on the left sidebar once again, only this time, click on **Add new Queue**.
6. Check the **Enable/Disable** checkbox for the new queue.
7. In the **Name** edit box, enter `qVoIP`.
8. Set **Priority** to **7** (the highest priority level). If you already have a queue with this priority level, you may have to select a slightly lower value.
9. You can leave **Queue Limit** blank. For **Scheduler** options, it is generally recommended that you check **Random Early Detection In and Out**, but you may select a different option for this queue if necessary. Do not check the **Default Queue** checkbox – we do not want the high-priority queue to be the default queue on this interface. You may enter a brief description in the **Description** edit box.
10. Click on the **Save** button and then click on the **Apply Changes** button. qvoIP should now appear as a child queue of the WAN queue.
11. We need to create a default queue. Click on **WAN** on the left sidebar and then click on the **Add new Queue** button.
12. Check the **Enable/Disable** checkbox for the new queue.
13. In the **Name** edit box, enter `qDefault`.
14. Set **Priority** to **3**. Once again, you can leave **Queue Limit** blank.
15. For **Scheduler** options, check **Default Queue** and **Explicit Congestion Notification**. You may enter a brief description.
16. Click on the **Save** button, and when the page reloads, click the **Apply Changes** button.
17. We need to replicate qVoIP on the remaining interfaces. To make this process as easy as possible, click on the **By Queue** tab. The **qVoIP** queue should be there.
18. Click on **qVoIP** on the left sidebar. A list of interfaces should appear on the right side of the page. Every interface that does not have the **qVoIP** queue (which should be every queue except WAN) will have a **Clone Shaper to this Interface** button next to it. Click on each of these buttons to clone **qVoIP** to each interface. Then click on the **Apply Changes** button.

19. Click on the **By Interface** tab. **qVoIP** should now appear as a child queue of each interface.
20. Now we have to create a firewall rule for Skype traffic (fortunately, this time, it's only one rule). Navigate to **Firewall | Rules** and click on the **Floating** tab.
21. At the bottom of the table, click on one of the **Add** buttons.
22. On the configuration page for the new firewall rule, select **Match** in the **Action** drop-down box.
23. In the **Interface** listbox, select **WAN**.
24. In the **Direction** drop-down box, leave **Direction** set to **any**.
25. In the **Protocol** drop-down box, leave **Protocol** set to **TCP**.
26. Under **Destination**, set **Destination port range** to `34000` to `35000`.
27. Under **Extra Options**, you may enter a brief description in the **Description** field.
28. Also under **Advanced Options**, click on **Display Advanced**. Scroll down to **Ackqueue/Queue** and select **qVoIP** in the **Queue** drop-down box.
29. Click on the **Save** button and on the main **Floating rules** page, click on the **Apply Changes** button.
30. You also want to add a rule to catch all other UDP traffic and also place it in the qVoIP queue. Click on the **Add** button again, and create another rule. Select **Match** in the **Action** drop-down box, select **WAN** as **Interface**, leave **Direction** set to **any**, and set **Protocol** to **UDP**.
31. In **Advanced Options**, click on **Display Advanced**. Scroll down to **Ackqueue/Queue** and select **qVoIP** in the **Queue** drop-down box. You may also enter a brief description.
32. Click on the **Save** button and on the main **Floating rules** page, click on the **Apply Changes** button.
33. You still need to unblock any ports in the range from `34000` to `35000` that are being used for Skype clients, so navigate to **Firewall | NAT** and click on **Add** to add a new rule. Adding NAT rules was covered in depth in *Chapter 4*, *pfSense as a Firewall*, so we won't cover it in depth here, but each port forward rule should have **TCP** set as **Protocol**, the **Redirect target IP** as the IP of the Skype client, and the **Destination port range** as the port to be used by the Skype client at the specified IP address. Leave **Add associated filter rule** set under **Filter rule association** in order to create a matching firewall rule. You may also enter a brief description. Click on **Save** when done, and then click on **Apply Changes**.

We now have a rule(s) that prioritizes Skype traffic, or at least Skype traffic that uses port `34000` to `35000`. All Skype TCP and UDP traffic should now go to the qVoIP queue. Since rules are evaluated from the top down, we want to move this rule closer to the top than the rules we created for the limiters in the previous example. This will ensure that the Skype rule is applied to traffic on the **DEVELOPERS** and **ENGINEERING** networks. We will likely want to confirm that the newly created rule works, a process we will cover in the next section.

Example #3 – penalizing P2P traffic

Dealing with P2P traffic is a bit more challenging. We are unlikely to be able to categorize every protocol and port used by P2P applications, and finding other matching criteria may be difficult. But if we can assume a certain range of ports is being used, we can create a rule. Moreover, we can at least create a queue for future use.

Once again, we begin by navigating to **Firewall** | **Traffic Shaper** and clicking on the **By Interface** tab. We then proceed as follows:

1. Click on **WAN** on the left sidebar.
2. If you have been following the examples sequentially, you won't have to create the parent queue for the WAN interface. Otherwise, see the previous example to see how to configure the parent queue on the WAN interface. If the WAN parent queue already exists, click on the **Add new Queue** button.
3. Check the **Enable/Disable** checkbox for the new queue.
4. In the **Name** field, type `qP2P`.
5. Set **Priority** to **1**. You can leave **Queue Limit** blank.
6. In **Scheduler** options, check **Explicit Congestion Notification**. You may enter a brief description in the **Description** field.
7. Click on the **Save** button, then when the page reloads click on the **Apply Changes** button.
8. Click on the **By Queue** tab. The **qP2P** queue should be listed on the left sidebar.
9. Click on **qP2P**. The right side of the page should display all interfaces, with a **Clone Shaper to this Interface** button for each interface. Click on each button to clone **qP2P** to each interface. Then click on the **Apply Changes** button at the top of the page.
10. Click on **By Interface** to confirm that the **qP2P** queue is available on all interfaces.

11. Navigate to **Firewall | Rules** and click on the **Floating** tab; we will now create a rule for P2P traffic. Assume that we are going to send traffic on ports `6881` to `6999` to **qP2P**.
12. Click on one of the **Add** buttons at the bottom of the page.
13. On the **Rule Configuration** page, select **Match** in the **Action** drop-down box.
14. In the **Interface** list, select **WAN**.
15. Leave **Direction** set to **any**. In the **Protocol** drop-down box, change the protocol to **TCP/UDP**.
16. In the **Destination** section, set **Destination** port range to `6881` to `6999`. Under **Extra Options**, you may enter a brief description.
17. Also under **Extra Options**, click on the **Display Advanced** button.
18. Scroll down to **Ackqueue/Queue** and set **Queue** to **qP2P**.
19. Click on the **Save** button, and on the main **Floating rules** page, click on the **Apply Changes** button.

We now have a queue for P2P traffic, and a corresponding rule. If our requirements change with respect to ports and/or protocols, we can always update the ruleset.

Troubleshooting traffic shaping

There's no doubt that troubleshooting traffic shaping issues can be challenging. Even if we set up the queues and rules the way we think they should be set up, it may not work the way we think it should, and in many cases, we might not get it to work right the first time. Often we must fall back on the tried and true troubleshooting steps: diagnosing the problem, forming a hypothesis, testing it, implementing a solution, verifying that the system works, and documenting the solution. But there are some common issues that we should also cover.

We may have problems keeping P2P traffic in the P2P queue. The main reason for this is that for the most part, pfSense relies on ports as matching criteria for the traffic shaping rules. Many P2P applications, including BitTorrent, rely on non-standard or random ports. There are several possible solutions to this. You could try to use Layer 7 DPI, which does not rely on ports but instead looks at the packets. However, Layer 7 traffic shaping is not available with the base pfSense installation; it is only available through third-party packages such as Snort.

If you don't want to use Layer 7 traffic shaping, another possibility is to make the default queue for all interfaces a low-priority queue. This approach, however, would require you to create rules for every type of traffic you don't want to be relegated to this queue.

If traffic is not being shaped correctly, there are several tools available to help you diagnose the problem. To get an overview of traffic on all queues, navigate to **Status | Queues**. This will reveal how much traffic is on each queue, both graphically (each queue has its own bar graph), and numerically in the form of **PPS** (**packets per second**), bandwidth, borrows (indicating whether bandwidth has been borrowed from a parent queue), suspends (indicating how many times a queue has been suspended), and drops (dropped packets). Also, **Length** indicates how many packets are currently in the queue as well as the queue length (the default queue length is 50 slots, although the queue length can be changed). At the very least, this page will indicate what traffic, if any, is in the queues, which might be all you need to know to diagnose the problem.

The **Queues** page only shows traffic interactively, so what you see is a snapshot of the current traffic, rather than a summary of all the traffic in the queues. To see a cumulative summary of all traffic on the queues, navigate to **Diagnostics | pfTop** and select queue in the **View** drop-down box. This will provide similar information to that provided on the **Queues** page, only they are expressed in raw totals.

If you are using limiters, you can find information about their configuration by navigating to **Diagnostics | Limiter Info**. This will show configuration information and statistics for all limiters and any child queues they may have.

Finally, if none of these diagnostic tools are adequate, navigate to **Status | System Logs**. The **Firewall** tab is most likely to yield relevant results, so you'll want to click on that. Once you do, you can filter the results by clicking on the **+** button on the **Advanced Log Filter** bar. This will display the advanced filtering options. You can filter the logs by port, which can be helpful in finding out whether certain traffic is being passed into queues. If necessary, you can enable logging on the relevant rule. Generally, we try not to log every rule we create, since logging consumes disk space, but if you think enabling logging might help with troubleshooting, temporarily enable logging is always an option.

If your system is not deployed in a production environment and you can experiment with different settings, you might want to try different configurations and see what results you get. For example, it is generally recommended that you not alter the queue size settings (this is why in the examples, we left **Queue Limit** blank, which leaves the queue size at its default of 50). Some users have reported better results with larger queues, although too large of a queue will likely lead to bufferbloat. But often the only way to find out is to test it on your router. Therefore, if you think that altering a setting might help optimize performance, and you can do it without breaking your network, feel free to make the changes and document the results.

Summary

In this chapter, we covered different forms of traffic shaping and introduced the pfSense traffic wizard. While the wizard is helpful in getting started using traffic shaping, this chapter showed some of the limitations of the traffic shaper. It also showed that creating queues and editing/creating our own traffic shaper rules is not that difficult. We also saw that limiters can sometimes be helpful in allocating bandwidth. We provided some concrete examples of implementing traffic shaping; finally, we covered what to do when traffic shaping doesn't work as it should.

In the next chapter, we will continue to build on our knowledge base and cover a subject that you are likely to encounter repeatedly, both with pfSense and in networking in general: **virtual private networks** (**VPNs**).

6
Virtual Private Networks

Virtual private networks (**VPNs**) provide a means of accessing a private network over a shared public network such as the Internet. Access to the private network is provided via an encrypted tunnel, and connecting to the network in such a way emulates a point-to-point link between the remote node and the network. Since the tunnel is encrypted, any packets that are intercepted are indecipherable without the encryption keys. Thus, VPNs provide a secure means of accessing a private network remotely.

Prior to the advent of VPNs, the only way of providing remote connections to a private network was through private WAN circuits. These circuits provided point-to-point dedicated circuits, and were based on such technologies as frame relay and ATM; later on came, **Multiprotocol Label Switching** (**MPLS**), using Ethernet over copper and fiber media. Private WAN circuits provide low latency, and in some cases they may still be the best solution for connecting to a private network, but they also have high monthly costs. VPN solutions have grown in popularity, in spite of the fact that they often have somewhat higher latency than private WAN circuits, because they provide the same point-to-point connectivity at a much lower cost.

pfSense is one such means by which you can implement low-cost VPN connectivity. While establishing and maintaining a VPN tunnel is somewhat CPU-intensive – a computer that barely meets the minimum specifications for pfSense will be hard-pressed to maintain a VPN connection – with pfSense, you will be able to set up VPN connections much more cheaply than you would be able to with commercial equipment.

In this chapter, we will cover the following topics:

- VPN fundamentals
- Configuring a VPN tunnel in pfSense (IPsec, L2TP, and OpenVPN)
- Troubleshooting VPNs

VPN fundamentals

VPNs enable a remote user to securely connect to a private network or server over a remote connection. To the end user, it is as if data sent is being sent over a dedicated private link. Another common usage is for network-to-network communication. For example, a branch office of a corporation may need to connect their local network with the network at corporate headquarters. In this case, the Internet is logically equivalent to a WAN. In both cases, those using the VPN benefit from the fact that the connection is implemented as an encrypted tunnel. This enables end users to use the public Internet as a private tunnel for a virtual point-to-point connection.

As noted earlier, private WAN circuits were the only way of connecting to a private network securely before there were VPNs, and in some cases such private circuits may still be the only way to meet bandwidth and/or latency requirements. Latency is a big factor. A private WAN circuit will usually provide latency of 3 ms or less, whereas with VPNs you will get that much latency just with the first hop through your ISP. Running ping tests will allow you to get a better idea of the latency of VPN connections, but in general VPN connections have latencies of 30-60 ms. This can vary greatly based on two factors: the type of connection being used, and the distance between the remote node and the private network being accessed. One of the ways of minimizing latency is to use the same ISP on both ends of the connection, although this is not always possible. In some unusual cases, using a VPN may decrease latency rather than increase it. For example, if your ISP employs traffic shaping, encrypting traffic may result in the ISP not throttling it, and therefore latency will decrease.

Otherwise, you may find it necessary to research the types of applications you are likely to use over a VPN connection and find out how well they perform over connections with latency. Online games, for example, can be affected by higher latency. Microsoft file sharing (SMB) and Microsoft **Remote Desktop Protocol** (**RDP**) are also latency-sensitive. Obviously there is a cost-benefit analysis involved. You may find that the performance improvement justifies spending money on a private WAN circuit. Or you may find that the performance degradation involved in using a VPN is justified by the savings. In addition, it may be possible to alter your network settings to improve VPN performance.

If you decide to implement a VPN, you can choose from several different forms of VPN deployments. The most common ones are the following:

- **Client-server**: In this scenario, a VPN tunnel is used to connect one or more mobile clients to the local networks. The encryption provided by the VPN guarantees that data privacy is maintained. This is probably the most likely deployment scenario you will be using if you configure a VPN with pfSense.

- **Peer-to-peer**: In this scenario, a VPN tunnel is created between two networks; for example the main corporate office and a satellite office location. The general idea is that setting up a VPN is cheaper than a leased line between the two locations. Instead of having a router on one end and a mobile client on the other end, there is a router on each end of the tunnel.
- **Hidden network**: This is not as common a deployment scenario, but is nonetheless worth mentioning. In some cases, data may be too sensitive to place on the main corporate network, and this data may reside on a subnet that is physically disconnected from the rest of the network. If this is the case, a VPN can provide us with a means of connecting to this subnet.

We can also use VPNs to provide an additional level of security on wireless connections. By requiring wireless clients to log in through a VPN, we can force these clients to provide additional authentication, and the VPN connection itself will provide another layer of encryption in addition to the encryption that the wireless protocol provides.

There are several VPN protocols that can be used, and each VPN technology has its own advantages and disadvantages. In this section, we will focus on the VPN protocols currently supported by pfSense: IPsec, L2TP, and OpenVPN.

IPsec

IPsec, as the name implies, is a protocol suite that operates on the Internet layer of the four-layer network model (and the Network layer of the OSI model). It is the only protocol of the three discussed here that operates on this layer. Because it operates on the Internet/Network layer, it is capable of encrypting and authenticating the entire IP packet, thus not only ensuring privacy for our data, but also ensuring that the packet's final destination is kept private as well. Thus it differs from both OpenVPN (which offers encryption, but operates on the Application layer) and the Layer 2 Tunneling Protocol (which does not encrypt data at all).

As a protocol suite, IPsec is actually a group of protocols that in combination provide the functionality we require. These protocols can be divided into three groups:

- **Authentication Headers (AH)**: This header is 32-bit long and provides authentication and connectionless data integrity.
- **Encapsulating Security Payload (ESP)**: This portion of the IPsec protocol suite provides authentication, as well as encryption and data integrity. It also exists in authentication-only and encryption-only modes, which provide either authentication or encryption but not both. ESP is responsible for encrypting at least the payload (transport mode), and in some cases, the entire packet (tunnel mode).

- **Security Association (SA)**: Security Association is the set of security attributes (for example, encryption algorithm, encryption key, and other parameters) that are used in a connection.

SAs are established through the **Internet Security and Key Management Protocol** (**ISAKMP**). Key exchange is typically done through **Internet Key Exchange** (**IKE**) versions 1 or 2, but other protocols are available, such as **Kerberized Internet Negotiation of Keys** (**KINK**), which uses the Kerberos protocol for key negotiation. Currently, the only methods supported by pfSense are IKE and IKEv2.

There are two different modes for establishing an IPsec connection:

- **Transport mode**: In this mode, the payload of the IPsec packet is encrypted, but not the header. This mode does not support NAT traversal, so if you are configuring an IPsec connection that must traverse more than one router, it is not a good choice.
- **Tunnel mode**: In this mode, the entire packet is encrypted. This mode supports NAT traversal.

IPsec supports a number of encryption algorithms. Advanced Encryption Standard with a key size of 256 bits (AES-256) is the most commonly used option, but other options are available. Since some systems only support DES, 3DES is offered as an option. If you need a bigger key, SHA-2 (with a 512-bit key size) is available. For more information about the cryptographic options available with IPsec, see RFC 7321 (`https://tools.ietf.org/html/rfc7321`).

L2TP

L2TP, or **Layer 2 Tunneling Protocol**, is a tunneling protocol that (not surprisingly) operates on the Link layer of the seven-layer OSI model. Unlike IPsec, it does not provide any encryption or confidentiality by itself, but instead relies on whatever encryption protocol is passing through its tunnel. As a result, it is often used in conjunction with IPsec.

The client end of an L2TP tunnel is known as the **L2TP Access Concentrator** (**LAC**). The server end is known as the **L2TP Network Server** (**LNS**). The LNS end, once configured, waits for new connections. A connection is established through the exchange of several control packets, for which L2TP provides reliability. No reliability is provided for data packets, although reliability may be provided by protocols running within the L2TP tunnel.

Because L2TP does not have any confidentiality or encryption, it is often implemented in conjunction with IPsec. This combination is known as L2TP/IPsec. Establishing an L2TP/IPsec connection involves negotiation of an IPsec security association (usually with IKE or IKEv2), establishment of ESP communication in transport mode, and negotiation of an L2TP tunnel. L2TP uses UDP; the default port is `1701`.

L2TP, without any other protocols nested within it, is generally referred to as native L2TP. You are unlikely to implement L2TP in native mode; however, L2TP/IPsec is a common option for VPN tunnels, and L2TP can be combined with other protocols to provide confidentiality and encryption (for example, L2TP/PPP).

OpenVPN

OpenVPN is an open source VPN protocol (published under the GNU General Public License, or GPL). Since it is based on SSL, and SSL operates just above the Transport layer, we can say that it exists between the Application and Transport layers in the four layer network model, and between the Session and Transport layers in the OSI model. OpenVPN client software is now available for Linux, Windows, and Mac OS.

OpenVPN uses the OpenSSL library for encryption. Thus, all the cryptographic algorithms available in OpenSSL are available in OpenVPN. It can also use HMAC packet authentication, and support for the mbed TLS (formerly PolarSSL) SSL library has been added.

Authentication in OpenVPN can be accomplished through certificates, a user/password combination, or both. Another one of the advantages of using OpenVPN is that it can be implemented with TCP or UDP. In either case, the official IANA assigned port number for OpenVPN is port `1194`. Version 2.0 and later of OpenVPN support several simultaneous tunnels per process.

OpenVPN uses the universal TUN/TAP driver for networking. Thus, it can create either a layer 3 (the Network layer of the OSI model) TUN tunnel, or a layer 2 (Data link layer of the OSI model) TAP connection.

Although OpenVPN seems to be most heavily supported with Linux (not to mention UNIX variants such as FreeBSD), there are clients available for Windows (XP and later), as well as Mac OS X. Mobile devices are also supported, with clients available for iOS and Android.

Choosing a VPN protocol

Which VPN protocol you choose will likely be based on a number of factors. Interoperability is one factor to consider. If you need a VPN solution that is interoperable with another firewall or router, especially one from another vendor, then IPsec may be the ideal protocol to use, since it is included with every VPN-capable device. Using IPsec will also prevent you from being locked into a particular product or vendor. OpenVPN is gaining acceptance, but its usage is not quite as widespread as IPsec.

Another consideration is what type of authentication the protocol uses. IPsec allows you to use a pre-shared key or certificates, as well as username/password combinations. L2TP does not provide for any authentication, while OpenVPN supports pre-shared keys and certificates.

Ease of configuration is another consideration. All of the VPN protocol options available under the current version of pfSense (IPsec, L2TP, and OpenVPN) are fairly easy to configure, but some are easier than others. OpenVPN requires the use of certificates for remote access in many environments, but is otherwise relatively easy to configure. IPsec, on the other hand, can be somewhat difficult for the uninitiated, although IPsec may be preferable because of its near-universal acceptance.

If you have a multi-WAN setup, this may prove to be a factor in your choice. In this case, both IPsec and OpenVPN can be used.

More often than not, your choice will be dictated by what operating systems you will be supporting and what clients are available for these operating systems. If your network is Windows-centric, you may consider using IPsec. Support for IPsec is built directly into Windows, and has been since Windows Vista. As a result, connecting to a VPN with IPsec under Windows can be as easy as navigating to **Settings** | **Control Panel**, clicking on **Network and Sharing Center**, clicking on **Set up a new connection or network**, and using the wizard to set up an IPsec/L2TP connection. You can also use third-party VPN clients, such as the Shrew Soft VPN Client.

On the other hand, most Linux distributions do not have built-in VPN support. Third-party clients are available, and in some cases can be downloaded from repositories, and these clients involve varying degrees of configuration. If your network is Linux-centric, you should be able to support IPsec, although OpenVPN is probably a better option in such cases.

Mac OS X has had IPsec support for years, and now even has a user-friendly interface for IPsec. OS X 10.6 (Snow Leopard) and later have a built-in Cisco IPsec VPN client that provides an easy-to-use graphical interface for connecting to a network that supports IPsec. Earlier versions of Mac OS X do not have the Cisco built-in VPN client, but you can install the Cisco Remote Access IPsec client on them. You can also use the Cisco AnyConnect Secure Mobility Client on earlier versions, although you should be aware that support for Mac OS X 10.5 (Leopard) was dropped with version 3.1 of AnyConnect.

For a network that is likely to have a variety of platforms, L2TP is a good choice. Because of the inherent lack of encryption and confidentiality in L2TP, it is usually implemented in conjunction with IPsec. Still, there are several clients on different platforms that support L2TP without IPsec. Beginning with Windows Vista, Windows has built-in support for L2TP without IPsec. One of the utilities provided for L2TP configuration is a **Microsoft Management Console** (**MMC**) snap-in called **Windows Firewall with Advanced Security (WFwAS)** and can be found in **Control Panel** | **Administrative Tools**. The other is a command-line tool called **netshadvfirewall**.

Support for L2TP is not built in to Linux, but there are third-party clients available. They are available for most popular distributions such as Arch Linux and Ubuntu, and configuration for most of these clients is relatively easy.

The Cisco IPsec client for Mac OS X supports L2TP, but it appears that it supports only L2TP over IPsec. As of this writing, there does not appear to be a third-party client for Mac OS that supports native L2TP without IPsec. Thus L2TP is a poor choice if your network must support computers running Mac OS.

OpenVPN has been ported to several operating systems. Windows does not have built-in support for OpenVPN, but there are several third-party clients for Windows. In fact, the OpenVPN project has a client for Windows that works on XP or later, and is easy to install and configure.

Linux not only supports OpenVPN, but OpenVPN support is built into many popular Linux distributions. OpenVPN configuration through the Network Connections applet in Ubuntu and its variants is rather easy, and it supports authentication with both certificates and with a pre-shared key. This makes OpenVPN an excellent choice if you are mainly supporting Linux clients.

If you are running Linux and the ability to create an OpenVPN connection does not appear as one of the VPN options, you may have to install OpenVPN. In most cases, you should be able to install OpenVPN from you distribution's repositories with the following command:

```
sudo apt-get install openvpn
```

This should install OpenVPN and all dependencies. If this does not work, consult the official OpenVPN site at `http://openvpn.net/` or your distribution's documentation.

Mac OS X does not have built-in support for OpenVPN. The OpenVPN project does not provide a Mac OS version of their client, and, to my knowledge, no one has successfully compiled the source code of the client under Mac OS. There is an open source project called **Tunnelblick**, which provides the necessary drivers for implementing OpenVPN under OS X. It has a graphical interface that provides a way to control either server or client connections. It can be used on its own or in conjunction with commercial software such as Viscosity. For more information, see the Tunnelblick website at `http://tunnelblick.net`.

If your network setup is fairly complex, your choice of protocol may be dictated at least in part by how well the protocol works behind multiple firewalls. Some of these firewalls may be beyond your control, and their configurations and capabilities may differ substantially.

IPsec uses both UDP port `500` (for IKE) and the ESP protocol. Not all firewalls handle ESP traffic well when NAT is used, because the ESP protocol does not have port numbers that make it easily trackable by NAT devices. IPsec clients behind firewalls may require NAT-T to function; it encapsulates ESP traffic over port `4500` using the UDP protocol. Versions 2.0 and later of pfSense support NAT-T, so you should be able to utilize NAT traversal with IPsec if necessary.

OpenVPN is generally more firewall-friendly than IPsec. It uses TCP or UDP and thus is not affected by NAT behavior such as the rewriting of source ports. As a result, it is rare that a firewall won't work with OpenVPN. One possible issue is that the protocol and port may be blocked. OpenVPN uses port `1194` by default; if that port is blocked, you may want to switch to a port commonly used for something else to evade egress filtering. For example, ports `80` and `443` are assigned for HTTP and HTTPS respectively, but any TCP traffic should pass through these ports, so you could use them.

Since L2TP uses UDP, it shouldn't create any especially challenging issues with firewalls. It is often used with IPsec, however, so all of the issues related to IPsec come into play when you are using L2TP/IPsec.

One of the justifications for using VPNs is cryptographic security, so this is another factor to consider. **Point-to-Point Tunneling Protocol** (**PPTP**), which has been removed from the current version of pfSense, has numerous security vulnerabilities, and thus became a poor choice for security-conscious administrator long ago. L2TP has no encryption capability; if you want encryption, you'll have to use it in combination with another protocol (usually IPsec). Therefore the choice essentially comes down to either IPsec or OpenVPN.

OpenVPN uses the SSL encryption library, which provides a number of different ciphers. To find out which ciphers the version of OpenVPN installed with pfSense supports, execute the following command, either at the pfSense console's command prompt or from **Diagnostics** | **Command Prompt**:

```
openvpn --show-ciphers
```

OpenVPN's default encryption algorithm is BF-CBC, or Blowfish, block cipher, with a 128-bit (variable) key size. While this is not a terrible cipher, it may be beneficial to choose a stronger cipher, such as AES-256-CBC.

OpenVPN also offers a number of different digests for message authentication, including many of the digests supported by IPsec (for example, SHA512). To see a list of digests supported by OpenVPN, use the following command:

```
openvpn --show-digests
```

One factor working against OpenVPN is that it seems that OpenVPN developers have generally given priority to backward-compatibility over security. This, and the fact that IPsec operates at Layer 3 of the OSI model and therefore provides encryption on the IP level, would seem to give IPsec a slight advantage over OpenVPN in cryptographic security.

It might prove useful to provide a summary of some of the features of each VPN protocol currently supported by pfSense, so with that in mind, here it is:

Protocol	Client included in OS	Client available for OS	Supports multi-WAN	Firewall-friendliness	Cryptographically secure
IPsec	Windows, Mac OS X.	Windows, Linux, Mac OS X	Yes	Only with NAT-T	Yes

Protocol	Client included in OS	Client available for OS	Supports multi-WAN	Firewall-friendliness	Cryptographically secure
L2TP	None of the major desktop OSes have clients that support native L2TP. Both Windows and Mac OS X have clients that support L2TP/IPsec	Windows, Linux	Yes	Yes	No (no encryption at all)
OpenVPN	Linux.	Windows, Linux, Mac OS X	Yes	Yes	Yes

Configuring a VPN tunnel

Now that we have covered the basics of VPNs and considered the pros and cons of each of the pfSense-supported protocols, it's time to cover configuration of a VPN connection, both under pfSense and on the client side. IPsec is the most difficult to configure on both sides, and you may not get it to work on your first try. OpenVPN is probably the easiest to configure, in part because it does not have as many options as IPsec.

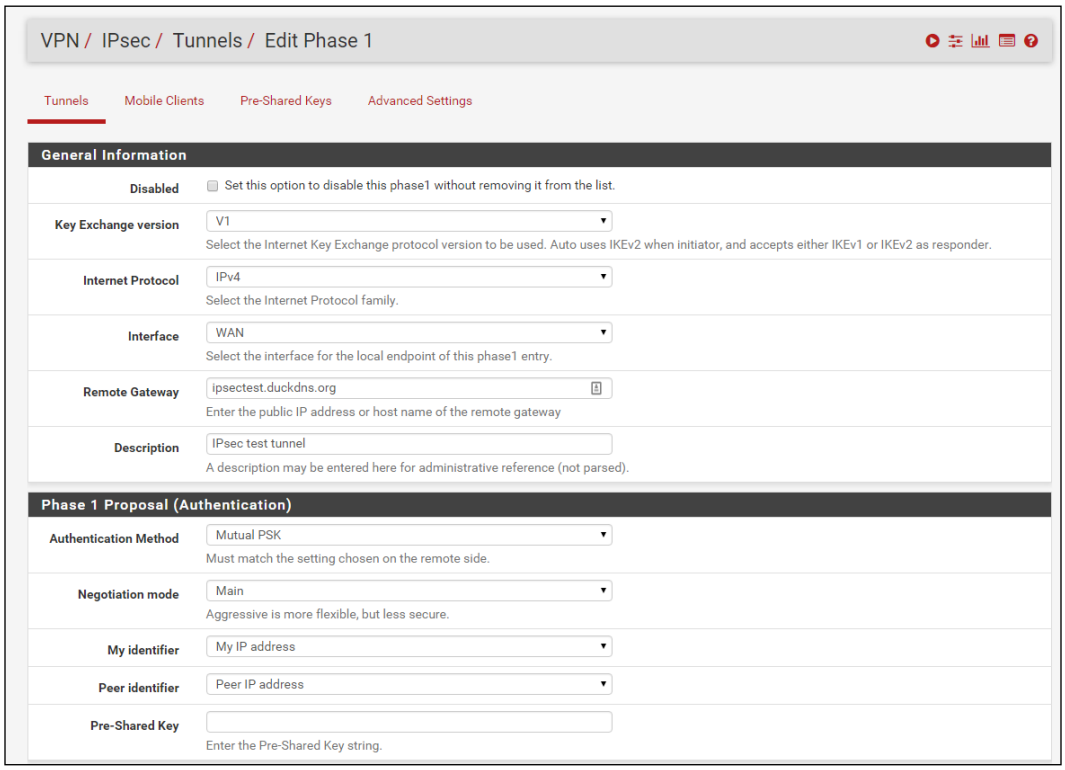
IPsec configuration

When you configure an IPsec tunnel in pfSense, you are likely envisioning one of two deployment scenarios. One is to configure IPsec as a peer that can connect to and/or accept a connection from another peer, establishing an IPsec tunnel between the two devices. Another is to set up an IPsec server as a server, and accept connections from remote clients. This section will cover both scenarios.

If you want to set up IPsec to act as a server with multiple mobile clients, you should begin at the **Mobile Clients** tab. The mobile clients configuration process will then autogenerate a **Phase 1 IPsec** entry, which you can then configure. If this is your IPsec deployment scenario, you might consider skipping to the *IPsec mobile client configuration* section.

IPsec peer/server configuration

To begin IPsec configuration, navigate to **VPN | IPsec**. You can configure an IPsec tunnel from the default tab, **Tunnels**. This tab displays a table of all existing IPsec tunnels. Each IPsec tunnel requires a Phase 1 configuration, and one or more Phase 2 configurations. To begin Phase 1 configuration, click on the **Add P1** button below the table on the right side.



Phase 1 IPsec configuration.

The Phase 1 configuration page has four sections: **General Information**, **Phase 1 Proposal (Authentication)**, **Phase 1 Proposal (Algorithms)**, and **Advanced Options**. The first option under **General Information** is the **Disabled** checkbox. If checked, the Phase 1 entry is disabled, but will still be in the table. The next option is the **Key Exchange version** drop-down box. This allows you to choose between IKEv1 (**V1**), IKEv2 (**V2**), or **Auto**. If **Auto** is chosen, IKEv2 will be used when initiating a connection, but either IKEv1 or IKEv2 will be accepted when pfSense is responding to a request to initiate a connection.

Next is the **Internet Protocol** drop-down box. This allows you to choose between IPv4 and IPv6. In the **Interface** drop-down box, you select the interface that is the local endpoint of the tunnel. Typically, you'll want to leave this as **WAN** since you will be accepting connections from the WAN side, but you can set it to any interface. In the **Remote Gateway** edit box, you must enter the public IP address or host name of the remote gateway. If you are configuring IPsec on a pfSense box that sits at the boundary between the Internet and your local network, then the value entered here should match the IP address of the WAN interface, or the domain name that matches that IP address. If you are configuring IPsec on a router that is behind one or more other routers, however, the value entered here may be different. You may enter a brief, non-parsed description in the **Description** edit box.

The first option in the next section is the **Authentication Method** drop-down box. The options are **Mutual PSK** and **Mutual RSA**. **Mutual PSK** allows for authentication using a **pre-shared key** (**PSK**), whereas **Mutual RSA** allows for authentication using certificates. The **Negotiation Mode** drop-down box allows you to choose the type of authentication security that will be used. What differentiates the two is what happens when the VPN tunnel needs to be rebuilt. **Main** will force the peer to re-authenticate, which is more secure but will take longer, while **Aggressive** will rebuild the tunnel quickly, sacrificing security. The **Aggressive** mode is generally recommended, since it will ensure that if the VPN tunnel is down, it will be able to rebuild itself quickly. **My identifier** identifies the pfSense router to the far side of the connection. It can usually be left as **My IP address**. **Peer identifier** identifies the router on the far side; this can usually be left as **Peer IP address**.

If you selected **Mutual PSK** as your **Authentication Method**, then the next field will be **Pre-Shared Key**, where you enter the PSK string. You should choose a long key (at least 10 characters); since special characters are supported, it might be a good idea to use them as well. If you chose **Mutual RSA**, then the next two options will be the **My Certificate** drop-down box, where you select a certificate previously configured in the pfSense certificate manager, and the **Peer Certificate Authority** drop-down box, where you select a **Certificate Authority** (**CA**) (also previously configured in the certificate manager).

The next section deals with encryption options. The **Encryption Algorithm** drop-down box allows you to choose an encryption method. Both **AES** and **Blowfish** allow you to choose between **128 bit**, **192 bit**, and **256 bit** encryption using an adjacent drop-down box, while **3DES** and **CAST128** do not have this option. The default option is **AES-256**, which is a good choice, but if a peer on the other end can only support DES encryption, you can choose **3DES**. IPsec employs a hash function to ensure the integrity of its data, and the **Hash Algorithm** drop-down box allows you to choose which one is used. **SHA1** is considered stronger and more reliable than **MD5**, but some devices only support MD5, so it is included as an option. If you require a more secure hash function, several are available (for example, **SHA512**).

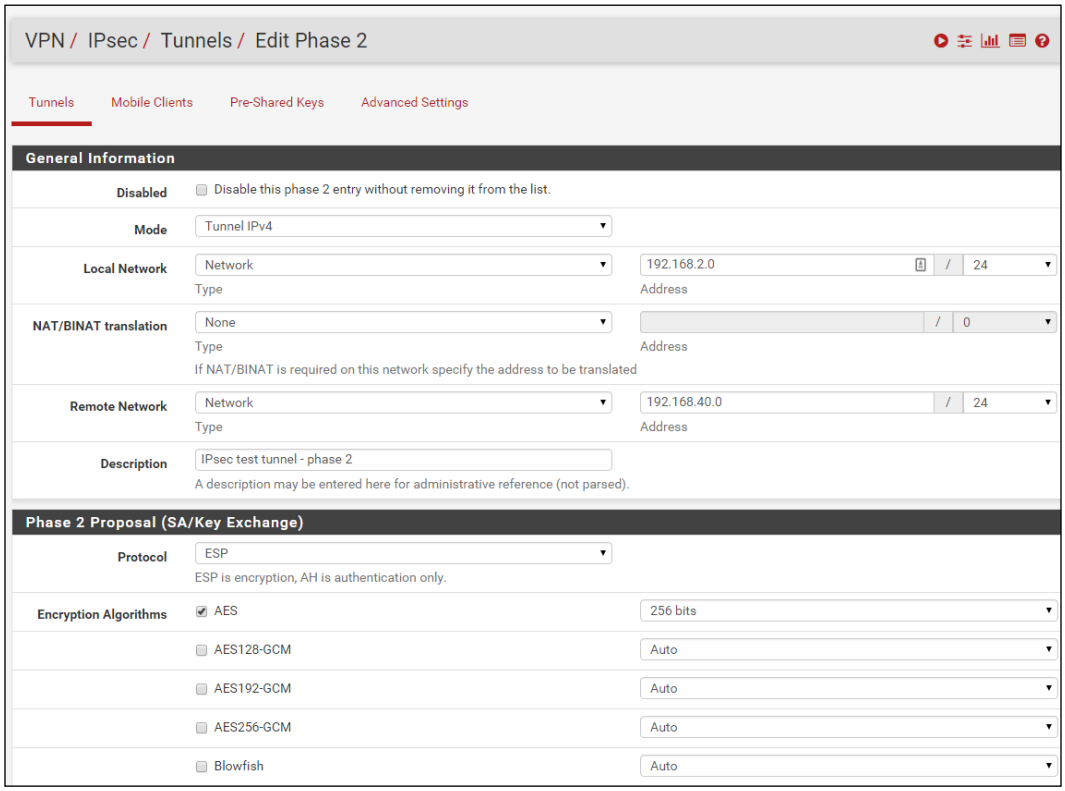
The **DH Group** drop-down box allows you to select the **Diffie-Hellman** (D-H) group used to generate session keys. The default value is **1024 bits**, which is generally considered safe, especially for keys that have a relatively short lifetime. You can use a greater number of bits, but this potentially comes at a cost in performance. The **Lifetime (Seconds)** edit box allows you to choose how long pfSense will wait for Phase 1 to complete. The default value is **28800** seconds, but you may want to increase this value.

The **Advanced Options** section's first option is the **Disable Rekey** checkbox. By default, pfSense will renegotiate an IPsec connection if it is about to expire, but checking this box disables this behavior. The **Responder Only** checkbox, if checked, will cause pfSense to only respond to incoming IPsec requests, and never initiate a connection.

The **NAT Traversal** drop-down box allows you to enable the encapsulation of ESP in UDP packets on port `4500`, also known as NAT-T. This should only be set if one side or both sides of the connection are behind restrictive firewalls. If necessary, choose **Force** to enable NAT-T.

The **DPD (Dead Peer Detection)** checkbox, if checked, will help detect if the other side is having a problem, and if so will try to rebuild the tunnel. If this option is checked, you must also set values in the **Delay** (the delay between requesting for each acknowledgement) and **Max failures** (the number of consecutive failures allowed before disconnect). The default values of **10** and **5** are suitable in most cases, although you may need to change these later. Click on **Save** when you are done making changes, and then click on **Apply Changes** on the main IPsec page.

You have now configured Phase 1, but you have to create one or more Phase 2 entries to complete the process. In the table on the main IPsec page, there should be an entry for the Phase 1 connection you just configured. Click on the **Show Phase 2** Entries to show any Phase 2 entries; this subsection should be empty, but there should be an **Add P2** button. Click on this button to begin Phase 2 configuration.



Phase 2 IPsec configuration.

There are three sections on the Phase 2 configuration page: **General Information**, **Phase 2 Proposal (SA/Key Exchange)**, and **Advanced Configuration**. The first option in **General Information** is the **Disabled** checkbox, which allows you to disable this entry without removing it from the table. The **Mode** drop-down box allows you to choose between **Tunnel IPv4**, **Tunnel IPv6**, and **Transport.** The tunnel mode encrypts the entire IP packet and adds a new IP header, whereas the transport mode encrypts the payload but not the IP header. If you choose tunnel mode, your choice between IPv4 and IPv6 will be dictated by what you set in the **Internet Protocol** drop-down box during Phase 1 configuration.

The **Local Network** drop-down box allows you to define which subnet or host can be accessed from the other side of the VPN tunnel. For example, if you select **LAN subnet**, the entire LAN will be accessible from the other side of the VPN tunnel. The other end of the tunnel's VPN settings will have the same setting, but the setting will be **Remote Network** or **Remote Subnet**. The settings must match on both sides for it to work.

The next setting is the **NAT/BINAT translation** drop-down box. This allows you to specify the settings that will be presented to the other side of the tunnel in cases where the actual local network is hidden. If you choose **Address or Network**, you can specify the IP address or subnet in the adjacent edit box. Next is the **Remote Network** dropdown. Here you specify the network or address on the other side of the tunnel that will be accessible from this side of the tunnel. It must match the setting in the **Local Network** setting for the peer, or the connection will fail. You may enter a brief non-parsed description in the **Description** field.

The next section is **Phase 2 Proposal (SA/Key Exchange)**. The first option is the **Protocol** dropdown, where you can select the protocol (for key exchange only). The options are **ESP** and **AH**. The de facto standard is **ESP**, and it is the recommended setting. ESP uses port `50` and AH uses port `51`. pfSense should autogenerate a rule to allow ESP or AH to the endpoint of the IPsec tunnel (the rules should appear under the **Floating** tab). If it does not, you will have to create a rule.

The next option is **Encryption Algorithm**. The default is **AES**, but you can choose more than one algorithm. It is recommended, however, that you only check the one that is to be used. The algorithm must match the setting of the remote peer. The recommended algorithm is **AES-256**.

Next are the **Hash Algorithms** checkboxes. You can choose more than one hash algorithm, although it is recommended that you only select the one being used. As mentioned before, some devices only support **MD5**, so check that if the remote peer is such a device. **SHA1** is the default setting.

The **PFS Key Group** is similar to the DH group in Phase 1. The default setting is **off**; as with the Phase 1 DH Group setting, there is a trade-off between security and performance. The **Lifetime** edit box sets the lifetime of the negotiated keys. The value should not be too high, or hackers will have more time to crack the key.

The last section, **Advanced Configuration**, has only one setting. The **Automatically ping host** edit box allows you to enter an IP address for a remote Phase 2 network to ping to keep the tunnel alive. When you are done changing settings, click on the **Save** button at the bottom of the page, then click on **Apply Changes** when the main IPsec page loads.

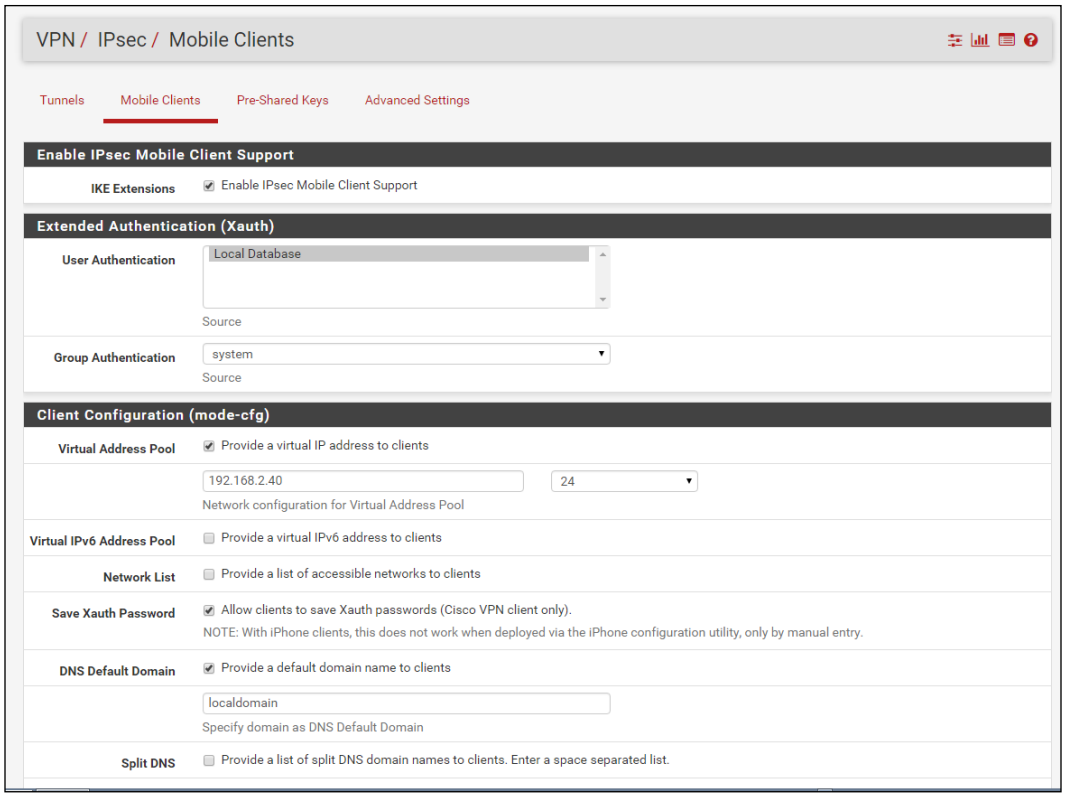
Now that Phase 1 and Phase 2 configuration is complete, you may still need to add firewall rules (although there should be automatically-generated rules for most of these). IPsec requires the following ports to be open, so navigate to **Firewall** | **Rules**, click on the **Floating** tab, and confirm that the following rules (or at least the ones necessary for your configuration) exist:

Port	Protocol	Notes
`50`	ESP	Required if ESP is used for Phase 2 key exchange
`51`	AH	Required if AH is used for Phase 2 key exchange
`500`	UDP	For IKE
`4500`	UDP	Required if NAT traversal is used

Port `500` must be open in all configurations. The other rules may or may not have to be created, depending on which options you use. If you use NAT-T, port `4500` must have a NAT rule and the corresponding firewall rule. For Phase 2 key exchange, you are going to use either **ESP** or **AH**. If you choose **ESP**, you don't need to open port `51`; if you use **AH**, you don't need to open port `50`. The NAT entry must be created on the WAN interface, to allow port forwarding from the WAN to the IPsec tunnel.

IPsec mobile client configuration

In the previous section, we configured an IPsec tunnel in which authentication is done though either a PSK or certificates. This is acceptable for connecting two routers, but what if there are multiple mobile clients? In such scenarios, it makes sense to configure settings for each individual user, and we can do that via the **Mobile Clients** tab.



The mobile client configuration page.

The first option on the **Mobile Clients** tab is the **IKE Extensions** checkbox. If checked, IPsec mobile client support will be enabled. The next section is **Extended Authentication (Xauth)**. The **User Authentication** listbox allows you to choose what database is used for authentication. The only option seems to be **Local Database** and this will allow for authentication through the pfSense user manager. Next is the **Group Authentication** drop-down box; select **system** for user manager authentication.

The last section is **Client Configuration (mode-cfg)**. The first option is the **Virtual Address Pool** checkbox, which, if checked, provides virtual IP addresses to clients. If it is checked, you must enter a network mask (and the corresponding CIDR) in the edit box that will appear below the checkbox. The **Virtual IPv6 Address Pool** option also allows you to provide virtual IP addresses, but they will be IPv6 addresses instead of IPv4 addresses.

The **Network List** checkbox, if checked, will provide a list of accessible networks to mobile clients. The **Save Xauth Password** option will allow clients to save Xauth passwords if checked, but will only work if the mobile user is using a Cisco VPN client. The **DNS Default Domain** checkbox will, if checked, cause pfSense to provide a default domain to clients; if checked, you must specify a DNS domain in the edit box that will appear below the checkbox. **Split DNS**, if checked, will enable you to provide a list of split DNS domain names to the mobile clients; this allows you to provide different sets of DNS information based on the source address of the DNS request. The domain names should be entered in the edit box below the checkbox and should be separated by commas.

The **DNS Servers** checkbox, if checked, allows you to provide a DNS server list to clients, which you will then have to enter in edit boxes below the checkbox. The **WINS Servers** checkbox is similar, only you are providing IP addresses to WINS servers. Checking **Phase 2 PFS Group** allows you to set a PFS group for mobile clients using the **Group** drop-down box. This will override whatever was set during Phase 2 configuration. Finally, the **Login Banner** checkbox, if checked, will allow you to provide a login banner to clients, which you can then enter in the edit box below the checkbox. When you are done, click on the **Save** button and click on the **Apply Changes** button on the main IPsec page.

The next tab under IPsec is **Pre-Shared Keys**. This tab allows you to add new keys and edit existing ones. If you click on this tab, you will see a table containing any previously entered keys. To add a new key, click on the **Add** button below the table on the right side.

The first option on the **Pre-Shared Keys** configuration page is the **Identifier** edit box. You can enter an IP address here, a **FQDN** (**fully qualified domain name**), or an e-mail address. The next option is the **Secret type** drop-down box; you can select **PSK** or **EAP** (Extensible Authentication Protocol, a protocol commonly used for wireless networks) here. Finally, in the **Pre-Shared Key** edit box, you can enter a PSK. Note that you can create a PSK that can be used by anyone by entering `any` in the **Identifier** field. When you are done, click on the **Save** button and then click on **Apply Changes** on the main IPsec page.

The last tab is **Advanced Settings**, which presents a single page divided into two sections: **IPsec Logging Controls** and **Advanced IPsec Settings**. **IPsec Logging Controls** allows you to set different levels of logging for different components of IPsec (for example, **Daemon**, **SA Manager**, **Job Processing**, and so on). Each component has a corresponding drop-down box that allows you to set the levels of logging. These are:

- **Silent**: There will be no logging.
- **Audit**: Logs audit events, which are generated when a service is accessed.

- **Control**: Logs access control events. This is the default logging level.
- **Diag**: Logs all diagnostic messages.
- **Raw**: Displays the contents of log files as-is without any parsing from the GUI.
- **Highest**: Display all logs.

The next section of the page is **Advanced IPsec Settings**. The first option in this section is the **Configure Unique IDs as** drop-down box. This value determines whether a participant IKE ID should be kept unique.

The **IP Compression** checkbox, if checked, will enable IPComp compression of content. The **Strict interface binding** checkbox will enable strong Swan's interface use option to bind specific interfaces only. The **Unencrypted payloads in IKEv1 Main mode** checkbox allows you to enable unencrypted ID and HASH payloads in IKEv1 Main Mode. Some implementations send the third Main Mode message unencrypted; if you need to send unencrypted ID and HASH payloads to maintain compatibility with them, you can enable this option, but you should only do so if absolutely necessary.

The **Enable Maximum MSS** checkbox enables MSS clamping if checked. This is useful if you are having problems with **Path MTU Discovery** (**PMTUD**), which can be the case if large packets have problems being transmitted over the IPsec tunnel. **Enable Cisco Extensions**, if checked, will enable the Cisco Unity plugin, which provides Cisco extension support.

The **Strict CRL Checking** checkbox will, if checked, require the availability of a fresh **Certificate Revocation List** (**CRL**) for peer authentication. If the **Make before Break** checkbox is checked, pfSense will create new SAs during re-authentication before deleting the old SAs. This is the reverse of the default behavior, in which SAs are deleted before new ones are created. This is advantageous in that it can help avoid connectivity gaps, but it must be supported by the peer if it is to work.

Finally, the **Auto-exclude LAN address** checkbox is designed to address cases in which the remote subnet overlaps with the local subnet. If this box is checked, traffic from the LAN subnet to the LAN IP address will be excluded from IPsec. Click on **Save** when done and then click on **Apply Changes** on the main IPsec page.

Client configuration

In order to create an IPsec client, configuration must be done at both ends of the tunnel. Although we cannot cover all the different deployment scenarios or every possible combination of platform and client software here, it should be helpful to see how we can configure some of the more popular VPN clients to set up an IPsec tunnel.

IPsec configuration using the ShrewSoft VPN Client

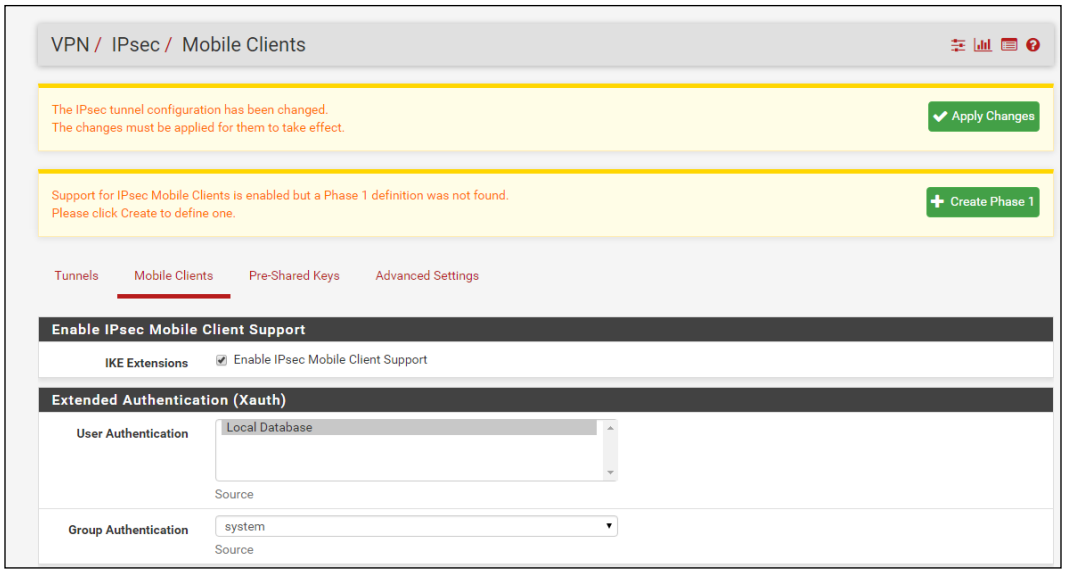
One of the more popular IPsec VPN clients for Windows is the ShrewSoft VPN Client. Although it hasn't been updated in a while (the last stable release of the client is 2.2.2, released in July 2013), it is a stable client with many options. You can download the client at `https://www.shrew.net/download/vpn`.

To show the ShrewSoft VPN Client in action, we will step through the process of setting up an IPsec tunnel, which we will then connect to as a mobile client using ShrewSoft's VPN Access Manager. We begin by navigating to **VPN** | **IPsec** and clicking on the **Mobile Clients** tab. To enable mobile clients, check the **Enable IPsec Mobile Client Support** checkbox.

The **Extended Authentication (Xauth)** section has two settings: **User Authentication** and **Group Authentication**. **User Authentication** has one option, **Local Database**, so we won't make any changes here. For **Group Authentication**, we will select **system**.

In the **Client Configuration (mode-cfg)** section, we will configure a virtual address pool for the remote client. Thus, we check the **Provide a virtual IP address to clients** checkbox, and enter a subnet and CIDR below the checkbox. For this exercise, we will set the network to `192.168.40.0/24`.

The next setting that we will alter is **Save Xauth Password**. We will check this checkbox. We will also check the **DNS Default Domain** checkbox, and enter `localdomain` as the default domain name. We will also check the **Provide a DNS server list to clients** checkbox. For **Server #1**, we will enter `8.8.8.8`, and for **Server #2**, we will enter `8.8.4.4`. We will also check the **Login banner** checkbox and enter a login banner to clients. We then click on the **Save** button at the bottom of the page. Once we do, the screen will reload and it will look like this:



After completing the mobile client configuration, you will be prompted to create a Phase 1 IPsec entry.

As you can see, pfSense is prompting us to create a corresponding Phase 1 entry for the mobile client configuration. The Phase 1 and Phase 2 entry we create in this manner will be designated as the mobile client IPsec tunnel, which is why you want to complete mobile client configuration before creating an IPsec tunnel – it will make the process much easier. We click on the **Create Phase 1** button to begin IPsec tunnel configuration.

In the **Key Exchange version** drop-down box, we want to select **V1**, as the ShrewSoft Client will not work with **V2**; I was unsuccessful in getting it to work on the **Auto** setting as well. We will leave **Internet Protocol**, **Interface**, and **Description** unchanged. Since we are going to require mobile user authentication, we set the **Authentication Mode** dropdown to **Mutual PSK + Xauth**. We will leave the **Negotiation** mode set to **Aggressive** and **My identifier** set to **My IP address**. We will change **Peer identifier** to **User distinguished name** and enter `vpnuser@ipsectest.duckdns.org` in the corresponding edit box. In the **Pre-Shared Key** box, we will enter `betterthannothing`.

In the **Phase 1 Proposal (Algorithms)** section, the default values are acceptable, so we will not change them. In the **Advanced Options** section, we will change one setting: we will change the **NAT Traversal** setting to **Force** to force the use of NAT-T on port `4500`. Once we are done, we will press the **Save** button, which will take us back to the main IPsec page.

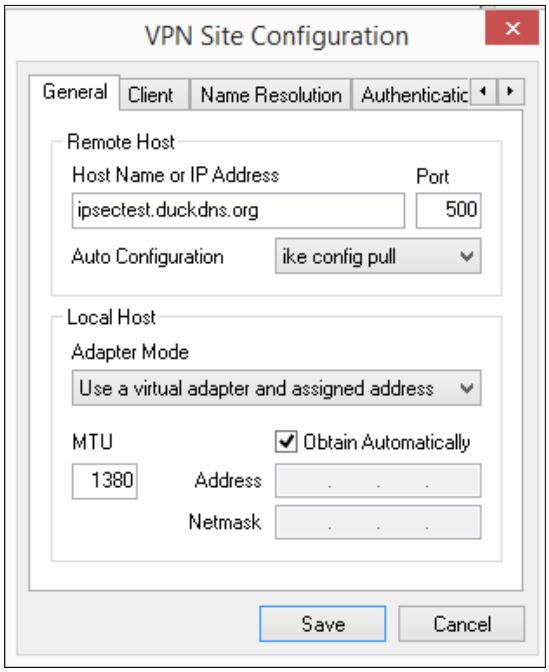
From the main IPsec page, we click on **Show Phase 2 Entries** in the mobile client entry. Then we click on the **Add P2** button to add a Phase 2 entry for this tunnel. In the **General Information** section, we will keep the default settings. In **Phase 2 Proposal (SA/Key Exchange)**, we will keep **Encryption Algorithms** as **AES**, but we will change the value in the drop-down box from **Auto** to **256**. **3600** is a bit short for **Lifetime**, so we will change this value to **28800**. When done, we will click on the **Save** button; then we will click on the **Apply Changes** button on the main IPsec page.

We still haven't created a user group and users for the VPN tunnel, so we will next navigate to **System | User Manager** and click on the **Groups** tab. Then we click on the **Add** button below the table to the right to add a new group. We enter the group name as `vpnusers`, and in the **Scope** drop-down box we set the scope to **Remote**. Then we click on the **Save** button.

We must assign privileges to **vpnusers**, so we click on the **Edit** icon for **vpnusers** in the table. On the configuration page for the group, there will now be a section called **Assigned Privileges**, and we click on the **Add** button. In the **Assigned Privileges** listbox, we select **User – VPN: IPsecxauthDialin** and click on **Save**. From the main configuration page, we click on **Save** again. The group is now configured.

Now all we have to do on the local side is create at least one user for the newly created group. We click on the **Users** tab and click on the **Add** button to create a new user. We set the **Username** to `remoteuser` and the **Password** to `suPerseCret01`. Under **Group Memberships**, we make **remoteuser** a member of vpnusers. For the **IPsec Pre-Shared Key**, we re-enter the key we entered earlier (`betterthannothing`). Then we click on the **Save** button.

We are now done with configuration on the local side, and only need to configure the remote client. We launch the ShrewSoft VPN Access Manager, and then click on the **Add** button on the toolbar to add a new configuration profile. The **General** tab has two sections: **Remote Host** and **Local Host**. Keep in mind that the remote host and local host are now the reverse of what they were when we were configuring the other end of the connection. For **Host Name or IP Address**, we generally want the WAN IP of the router on which the IPsec tunnel was set up in the previous step, unless this router is behind another router, in which case you would enter the Internet IP address of your network. If you set up dynamic DNS, you can enter the DDNS hostname here. In this case, we created the domain name `ipsectest.duckdns.org`, which provides a domain name for the pfSense router. For **Auto Configuration**, we want to select **ikeconfig pull** from the drop-down box. Finally, since the remote peer will be assigning virtual IP addresses to clients, we select **Use a virtual adapter and assigned address** in the **Adapter Mode** drop-down box. The **Obtain Automatically** checkbox should be checked, since the remote peer will be assigning the IP addresses. **MTU** can be kept at `1380`.



ShrewSoft Client configuration.

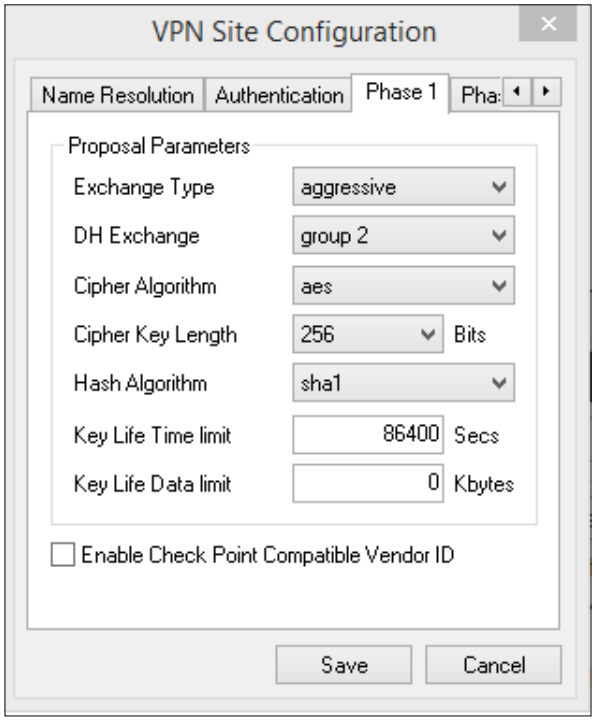
The next tab is the **Client** tab. Here, we want to set **NAT Traversal** to **enable** to match the setting on the remote end; **NAT Traversal Port** should be set to `4500`, which is the default value. The default values for **Keep-alive packet rate**, **Ike Fragmentation**, and **Maximum packet size** should be fine. We will check the **Enable Dead Peer Detection**, **Enable ISAKMP Failure Notifications**, and the **Enable Client Login Banner** checkboxes.

The next tab is **Name Resolution**. It has two tabs of its own: one is called **DNS** and the other is **WINS**. Since we are not dealing with WINS servers, we will focus only on the **DNS** tab and check the **Enable DNS** checkbox. We also check the **Obtain Automatically** checkbox for DNS, and the **Obtain Automatically** checkbox for **DNS Suffix**.

Next we move to the **Authentication** tab, which has three of its own tabs: **Local Identity**, **Remote Identity**, and **Credentials**. The method selected in the **Authentication Method** drop-down box must match what we set during Phase 1 configuration of the IPsec tunnel in pfSense, so we set it to **Mutual PSK + XAuth**. **Local Identity** must match **Peer Identifier** in Phase 1, so we select **User Fully Qualified Domain Name** (meaning user + FQDN).

For **UFQDN String**, we enter `vpnuser@ipsectest.duckdns.org`, just as we did for **Peer Identifier** in pfSense. On the **Remote Identity** tab, we can keep the default **Identification Type** at **IP Address** and move on to the **Credentials** tab. We are using a PSK, and the PSK must match the one we entered during Phase 1; thus, in the **Pre Shared Key** edit box, we enter `betterthannothing`.

The last two tabs we must configure are **Phase 1** and **Phase 2**. Moving to **Phase 1**, we must match the settings with those entered during Phase 1 configuration on the other end, so we set **Exchange Type** to **aggressive** and **DH Exchange** to **group 2** (1024 bits). The next three options you could set as **auto**, but the software seems to work better if you match the settings on the other end of the tunnel exactly. Therefore, we set **Cipher Algorithm** to **aes**, **Cipher Key Length** to **256**, and **Hash Algorithm** to **sha1**. We set **Key Life Time limit** to `28800` secs, and we leave **Key Life Data limit** at `0` Kbytes.

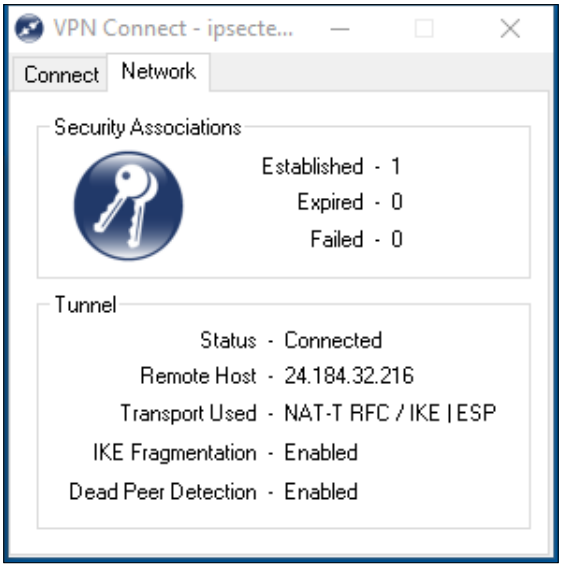


Phase 1 configuration.

Moving on to the **Phase 2** tab, we set **Transform Algorithm** to **esp-aes** and **Transform Key Length** to **256**. **HMAC Algorithm** should be set to **sha1**, and **PFS Exchange** and **Compress Algorithm** should be kept at the default value: disabled. We set **Key Life Time limit** to `28800` secs and **Key Life Data limit** is kept at `0` Kbytes. On the **Policy** tab, we do not need to make any changes, so we click on the **Save** button at the bottom.

Our client configuration is complete, so we can now click on **Connect** on the menu bar to try it out. We will be presented with a dialog box that states **config loaded for site <this_site>**. Click on the **Connect** button to start connecting. The VPN Access Manager will prompt us for a username/password combination, so we enter the username and password for the user we created in the previous step (`remoteuser`, `suPerseCret01`). We click on **Connect** again. The client should take a minute or less to connect to the tunnel.

Once we are connected, we will be able to access the LAN subnet on the remote end as if the LAN is a local resource. The next screenshot shows the ShrewSoft VPN Client with an active connection.



A successful connection using the ShrewSoft VPN Client.

IPsec configuration using vpnc

If you are using Linux, IPsec support is not built into the operating system, but you have a few options if you need to set up an IPsec tunnel between a Linux node and pfSense. One option is **vpnc**, which is both easy to install and easy to use. If you are using Ubuntu or any of its variants, vpnc is available from the repositories. At the command line, type the following:

```
sudo apt-get install vpnc
```

Once vpnc is installed, you can run it with the following command:

```
sudovpnc
```

vpnc does not have a graphical interface, but you shouldn't have much trouble getting it to work. Here's how we would connect to the IPsec tunnel we created in the previous section:

```
Enter IPSec gateway address: ipsectest.duckdns.org
Enter IPSec ID for ipsectest.duckdns.org: vpnuser
Enter IPSec secret for vpnuser@ipsectest.duckdns.org: betterthannothing
Enter username for vpnuser@ipsectest.duckdns.org: remoteuser
Enter password for vpnuser@ipsectest.duckdns.org: suPerseCret01
Connect Banner:
| Welcome to ipsectest.duckdns.org, set up to demonstrate an IPsec
tunnel.
```

As you can see, entering the connection information is considerably easier than it is using the ShrewSoft Client under Windows. There doesn't seem to be a command for disconnecting from the tunnel, but you can resort to the following:

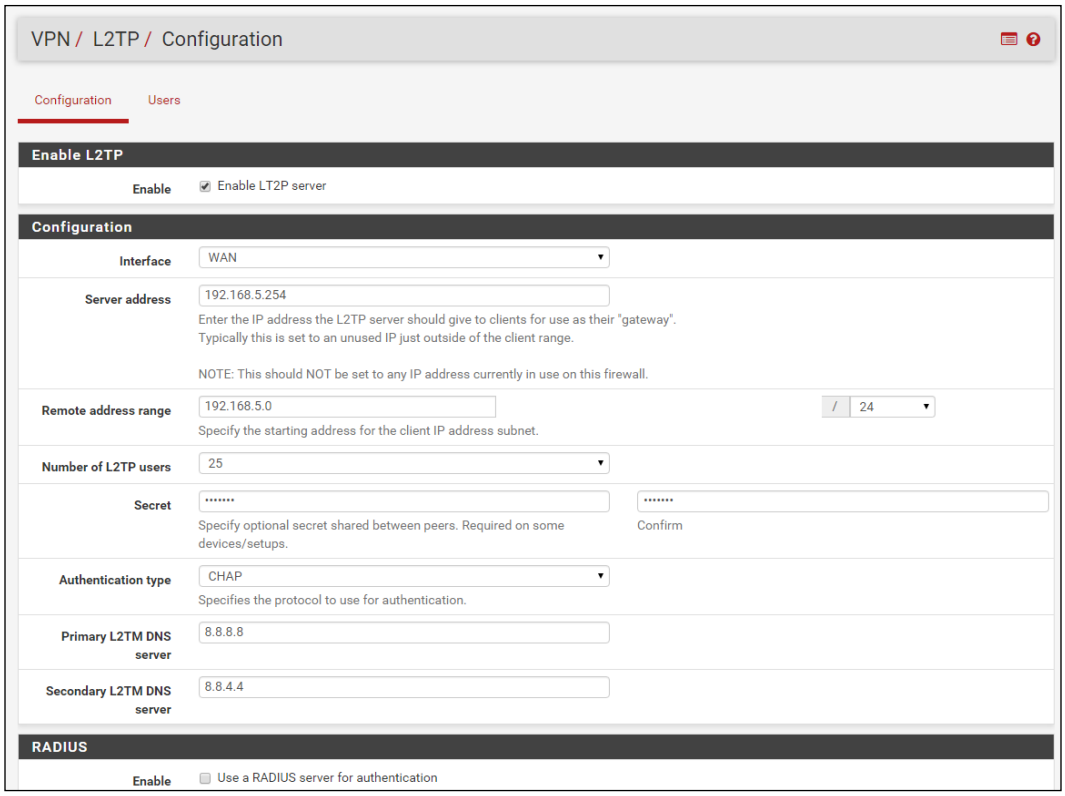
```
sudo kill -9 <PID>
```

where `<PID>` is the process ID of vpnc.

L2TP configuration

Owing to the fact that L2TP lacks both authentication and encryption, it is unlikely you will ever set up L2TP as a standalone VPN protocol. A more likely scenario is setting up an L2TP/IPsec tunnel in which users can connect to the IPsec tunnel directly, or via L2TP, with IPsec traffic taking place within the L2TP tunnel. Fortunately, L2TP configuration is much easier than IPsec configuration, and implementing it should ensure that our VPN will be accessible to a greater number of users.

To begin L2TP configuration, navigate to **VPN | L2TP**. This should take you to the **Configuration** tab. The **Enable** checkbox, when checked, enables the L2TP server. In the **Configuration** section, the **Interface** dropdown allows you to select the interface on which the L2TP server is listening for connections (almost always **WAN**).



The main L2TP configuration page.

In the **Server address** field, you must enter the gateway IP address of the L2TP server. It should be an unused IP address, usually on the same subnet as the client IP address subnet. The **Remote address range** field is where you enter the starting IP address of the client subnet. There is a drop-down box labeled **Number of L2TP users** where you select the number of clients allowed. The starting IP address plus the number of L2TP users minus 1 will be the ending IP address.

The **Secret** field is where you can enter a shared secret (there are two edit boxes, as the secret must be entered twice). Next is the **Authentication type** drop-down box; there are currently three different options for the protocol to use for authentication:

- **Challenge-Handshake Authentication Protocol (CHAP)**: When a peer tries to establish a connection, the authenticator sends a challenge message to the peer. The peer replies with a value calculated using a one-way hash function in which the challenge and the secret are inputs to the function (the handshake). The authenticator checks the response, based on its own calculation of what the hash value should be, and if there is a match, the peer is authenticated. This is the default choice and is considered relatively secure because the secret (or password) is encrypted before it is sent.
- **MS-CHAPv2**: This is Microsoft's version of CHAP and differs from standard CHAP in several ways (for example, it uses the CHAP Algorithm 0x80, and provides authenticator-control mechanisms for password change and authentication retry). It is also considered weak, since it uses 56-bit DES encryption, which is vulnerable to brute-force attacks using modern hardware, so take that into account.
- **Password Authentication Protocol (PAP)**: The least secure of all the protocols, this authentication protocol transmits unencrypted passwords over the network.

The next section, **RADIUS**, has a checkbox that allows you to enable RADIUS authentication. If you check this box, then you will have to enter a series of **RADIUS** options, including **server IP address** and **shared secret**. When you are done making changes, click on the **Save** button.

There is also a **Users** tab for adding L2TP clients. To add a user, click on this tab and click on the **Add** button below the table (which lists users already added). The **User** configuration page is pretty self-explanatory. You enter the username in the **Username** edit box and the password in the **Password** edit boxes (the password must be entered twice). The **IP Address** edit box is optional and you can use it to assign the user a specific IP address. When you are done, click on the **Save** button.

OpenVPN configuration

The third VPN protocol supported by the current version of pfSense is OpenVPN. It is an excellent choice if you require a protocol that has cross-platform support, is relatively secure, and is easy to configure. A relative newcomer (OpenVPN was initially released in 2001), it has been gaining in acceptance in recent years.

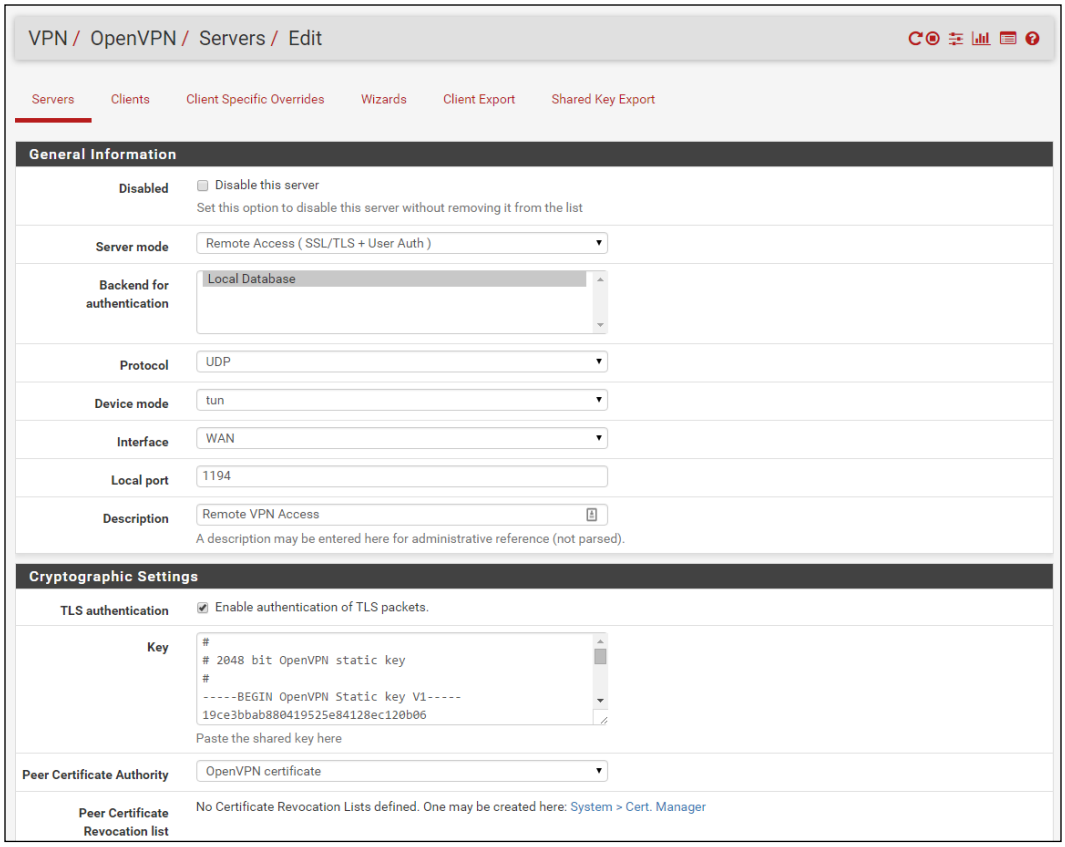
To begin OpenVPN configuration, navigate to **VPN** | **OpenVPN**. There are four tabs: **Servers**, **Clients**, **Client-Specific Overrides**, and **Wizards**. Note that, whereas in IPsec both ends of the tunnels can be configured as peers, OpenVPN tunnels always have one end defined as a client and the other as a server.

OpenVPN server configuration

To begin server configuration, click on the **Server** tab, and from there click on the **Add** button below the table (listing already configured servers). The first option on the configuration page, the **Disable** checkbox, allows you to disable the server entry without removing it if checked. The **Server mode** drop-down box allows you to choose between several modes:

- **Peer-to-Peer (SSL/TLS)**: Either side can initiate the connection. A certificate will be used for authentication.
- **Peer-to-Peer (Shared Key)**: Either side can initiate the connection. A shared key is used for authentication.
- **Remote Access (SSL/TLS)**: The remote client initiates the connection. A certificate is used for authentication.
- **Remote Access (User Auth)**: The remote client initiates the connection. User authentication is through a username/password combination.

- **Remote Access (SSL/TLS + User Auth)**: The remote client initiates the connection. User authentication involves both a certificate and username/password.



The OpenVPN server configuration page.

In the **Protocol** drop-down box, you can choose the protocol for this connection; both **UDP** and **TCP** are supported, as well as **UDP6** and **TCP6** for IPv6 connections. The **Device mode** drop-down box allows you to choose between **tun** and **tap**. A TAP device is a virtual Ethernet adapter; a TUN device is a virtual point-to-point IP link. This setting must match on both sides of the connection.

The **Local port** edit box lets you set the port for this OpenVPN connection. The default port for OpenVPN is `1194`. You may also enter a brief non-parsed description in the **Description** edit box.

Under **Cryptographic Settings**, you can configure a number of options for certificates. There are two checkboxes: **Enable authentication of TLS packets** and **Automatically generate a shared TLS authentication key**. **Peer Certificate Authority** will allow you to choose from any defined certificate authorities. Similarly, if any certificate revocation lists have been created, you can choose one from the **Peer Certificate Revocation list**. The **DH Parameter** drop-down list allows you to set the size of the D-H key. You can also select the **Encryption Algorithm** and **Auth** (entication) **Digest Algorithm** (although you should leave the latter set to **SHA1**, since **SHA1** is the default for OpenVPN). You can enable hardware crypto acceleration in the **Hardware Crypto** drop-down box (the only option currently supported seems to be **BSD cryptodev engine**).

You can select the **Certificate Depth** as well; pfSense will not accept certificate-based logins from clients whose certificates are below the set depth. The certificate depth is the maximum number of intermediate certificate issuers that are allowed to be followed when verifying the client certificate. If the depth is set to `0`, then only self-signed certificates will be allowed. If the depth is set to `1`, the certificate may be self-signed or signed by a CA known to the system. Setting the certificate depth to a number higher than 1 allows for more intermediate certificate issuers.

Tunnel Settings determines what happens to the OpenVPN clients once they are authenticated. **IPv4 Tunnel Network** and **IPv6 Tunnel Network** allow you to set the IPv4 and IPv6 virtual networks, which will provide the address pools for the clients. For example, an **IPv4 Tunnel Network** setting of `192.168.3.0/24` will result in clients being assigned addresses of `192.168.3.1`, `192.168.3.2`, and so on. **Redirect Gateway**, if checked, will force all client-generated traffic through the VPN tunnel. **IPv4 Local network(s)** and **IPv6 Local networks** allow you to set what local networks will be accessible from the remote end. These should be expressed as comma-separated lists of one or more CIDR ranges. **IPv4 Remote network(s)** and **IPv6 Remote network(s)** allow you to set what remote networks will be accessible from the remote end of the VPN.

The **Concurrent connections** edit box allows you to specify the maximum number of clients allowed to connect to the server concurrently. The **Compression** drop-down box allows you to set the compression option for this channel; the choices are: **No Preference**, **Disabled (no compression)**, **Enabled with Adaptive Compression** (dynamically disable compression for a time if OpenVPN determines compression is not being done efficiently), or **Enabled without Adaptive Compression** (compression always on). **Disable IPv6** will result in IPv6 traffic not being forwarded.

The **Advanced Configuration** section has two options. In the **Custom options** listbox, you can enter any additional options to add to the OpenVPN server. The **Verbosity** level drop-down box allows you to select the logging level (2 through 11, with 5 outputting R and W characters to the console for each read and write, and 6 through 11 providing debugging info) for OpenVPN. When you are done making changes, click on the **Save** button at the bottom of the page and the **Apply Changes** button on the main OpenVPN page.

Server configuration with the wizard

One way you can set up an OpenVPN server easily is to use the server configuration wizard. To do so, click on the Wizards tab. The first option is the **Type of Server** drop-down box. The options are as follows:

- **Local User Access**: OpenVPN access with authentication through certificates, managed through the pfSense Certificate Authority Manager
- **LDAP**: Authentication through an **LDAP** (**Lightweight Directory Access Protocol**, a vendor-neutral protocol for directory services) server
- **RADIUS**: Authentication through a **RADIUS** (**Remote Authentication Dial-In User Service**) server

If you choose **Local User Access**, the wizard allow you to choose an existing CA/server certificate (if any exist), or you can create a new CA in this step. If you opt for the latter, you must enter a non-parsed descriptive name, the **Key length** (in bits), **Lifetime** (in days), as well as the **Country Code**, **State** or **Province, City**, **Organization**, and **E-mail**. When you have entered all this information, click on the **Add new CA** button. On the next screen, the wizard will prompt you to create a new server certificate. The fields will be auto-filled with the information you entered in the previous step. If you do not need to make any changes, you can click on the **Create new Certificate** button and move on to the next screen.

The final screen is the **Server Setup** screen. This screen mirrors the server configuration page we covered in the previous section, although it does have some options not available from that page. The **Inter-Client Communication** checkbox, if checked, allows communication between clients connected to the server. The **Duplicate Connections** checkbox, if checked, allows multiple concurrent connections using the same common name.

The **Client Settings** section has several more options not available on the server configuration page. The **Dynamic IP** option allows connected clients to retain their connections if their IP address changes. If you want to force reauthentication if the client changes IP addresses, uncheck this option. The **Address Pool** option provides a virtual IP address to clients (the IP subnet is defined in **Tunnel Network** in the previous page section. The **Topology** dropdown allows you to choose the method used to supply a virtual IP address to clients when using TUN mode on IPv4. There are two modes available:

- **Subnet – One IP address per client in a common subnet**: This is the default option.
- **net30 – Isolated /30 network per client**: This gives each client a subnet with two IP addresses (2^2 – 2 = 4 – 2 = 2). This may be necessary for older versions of OpenVPN (before 2.0.9) or some older clients.

In the **DNS Default Domain** edit box, you can provide a default domain to clients. There are four edit boxes where you can enter DNS server IP addresses. There are also two edit boxes where you can enter IP addresses for NTP servers. The **Enable NetBIOS over TCP/IP** checkbox, if checked, allows you to use NetBIOS over a TCP/IP network (if you intend to do so, you should choose TCP as your protocol). The **NetBIOS Node Type** allows you to select the way pfSense resolves NetBIOS names to IP addresses. The options are:

- **b-node**: Broadcast
- **p-node**: Point-to-point, or peer, queries to a WINS server
- **m-node**: Mixed; broadcast first, then WINS
- **h-node**: Hybrid; WINS first, then broadcast

NetBIOS Scope ID allows you to provide an ID for an extended naming service, which isolates NetBIOS traffic onto a single network to only those nodes with the same scope ID. Finally, there are two edit boxes for WINS servers. You can click on the **Next** button when you are done making changes.

The next step of the wizard covers configuration of the firewall rules. You need two rules for an OpenVPN tunnel: a rule to permit connections on the OpenVPN port, and a rule to allow traffic to pass inside the VPN tunnel. This page enables you to easily create both rules, simply by checking the appropriate checkboxes. If you previously set up an OpenVPN tunnel, you probably don't need to create these rules. When you are done making changes, click on the **Next** button. You should see a message on the next page acknowledging that the configuration is complete; click on the **Finish** button on this page.

LDAP configuration with the wizard

If you instead choose LDAP for authentication in the first step of the wizard, you will have different options. The **Name** field allows you to enter a descriptive name. In the **Hostname or IP address** field, you must enter the LDAP server's hostname/address. In the **Port** field, you can enter the LDAP server port, or leave it blank for the default port. In the **Transport** dropdown, you can choose **TCP** or **SSL**. If you leave the port set blank, setting the protocol will also affect the default port (`389` for TCP and `636` for SSL).

In the **Search Scope Level** drop-down box, you can select the scope of an LDAP search. **One Level** specifies that the search operation should only be performed against entries that are immediate subordinates of the search base DN (the subtree to be searched). The base entry itself will not be considered, nor will any entries that are below the immediate subordinates of the search base DN. If **Entire Subtree** is selected, the search operation will be performed against the entry specified as the search base DN and all of its subordinates to any depth. In the **Search Scope Base DN** edit box, you can specify the subtree to be searched.

The **Authentication Containers** edit box allows you to specify the actual units within the active directory in which users reside. These differ based on your configuration. In the **LDAP Bind user DN** edit box, you may specify a username for LDAP searches. You can leave it blank to allow anonymous searches. If you specify a username here, you should also specify **LDAP Bind Password** in the next field.

The **User Naming Attribute**, **Group Naming Attribute**, and **Member Naming Attribute** fields should be set to the LDAP server's user, group and member naming attributes so LDAP queries work. When you are done you can click on the **Add new Server** button

RADIUS configuration with the wizard

On the first screen of the wizard, you can also choose to use a RADIUS server for authentication. Configuring a RADIUS server is the easiest of the three options. In the **Name** field, you can enter a descriptive, non-parsed name for the server. In **Hostname or IP address**, you specify the hostname/address of the server. **Authentication port** is where you specify the port, and **Shared Secret** is for entering a shared key. Click on the **Add new Server** button when you're done.

OpenVPN client configuration

The **Client** tab under **OpenVPN** is for configuring pfSense to act as a client so it can connect to a remote OpenVPN server. This is an ideal option if you want to connect to a VPN service. Instead of connecting individual computers to a VPN, you can connect at the firewall, thus encrypting all traffic from nodes on your local network to the Internet. To begin configuration, click on the **Clients** tab and click on the **Add** button below the table.

Most of the options on the client configuration page are similar to options found on the server configuration page, with some notable exceptions. The **User Authentication Settings** section is where you set the username and password for the remote server. In the **Tunnel Configuration** section, the **Don't pull routes** checkbox, if checked, will bar the server from adding routes to your routing table. The **Don't add/remove routes** checkbox, if checked, will pass routes using environmental variables. Click on the **Save** button at the bottom to save the new client configuration and click on the **Apply Changes** button on the main **OpenVPN** page.

Client-specific overrides

If you are running an OpenVPN server and you need special settings for one or more clients, then the **Client Specific Overrides** tab is the place to configure such settings. To begin, click on **Client Specific Overrides** and click on the **Add** button below the table.

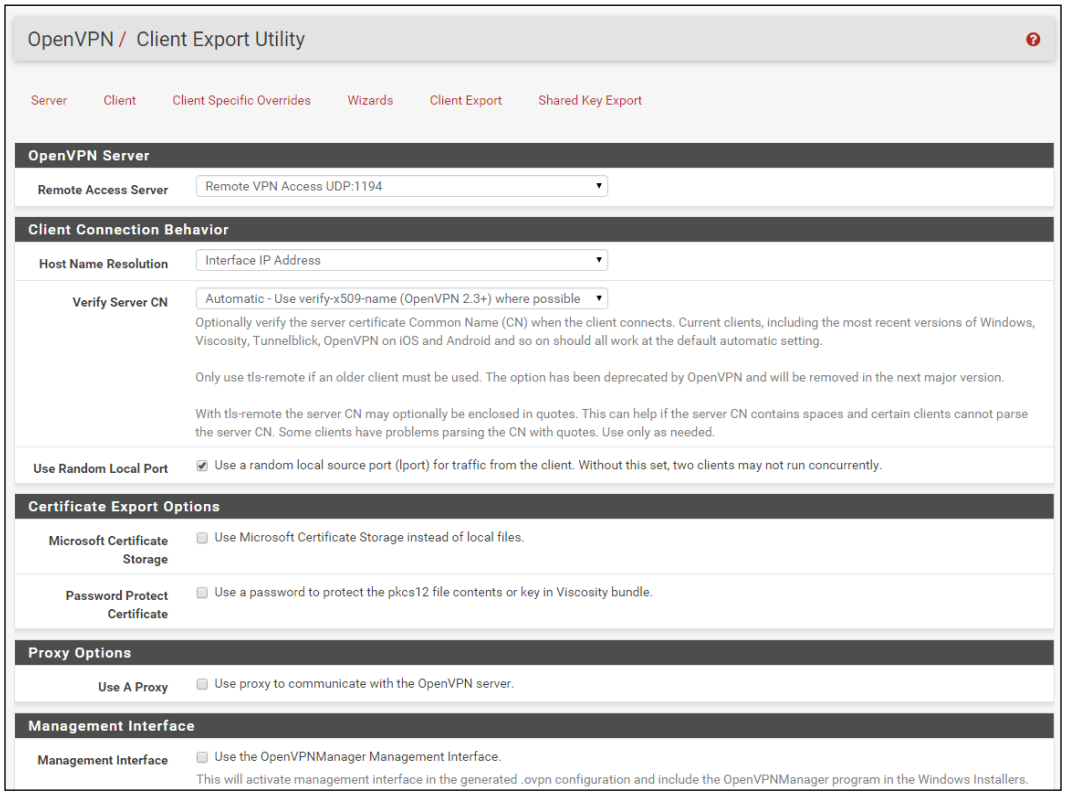
In the **General Information** section, you must specify both the server to which the override applies and the name of the client. In the **Server List** listbox, select a server for which the override will apply. Not selecting any servers will result in the override being applied to all servers. The **Disable** checkbox, if checked, will disable the override without removing it from the list. In the **Common name** edit box, you must enter the client's X.509 common name. In an X.509 certificate, the common name, or **CN**, is the field that must match the host being authenticated, and is typically used to identify a given user. You can enter a non-parsed description in the **Description** edit box. The **Connection blocking** checkbox will, if checked, block this client connection based on its common name.

In the next two sections, **Tunnel Settings** and **Client Settings**, most of the settings are similar to settings that are available on the server configuration page. The difference is, of course, that setting them here will cause them to be applied to the override only. For example, in **Tunnel Network**, you can define a virtual network to be used only by this client. In the **Client Settings** section, you can make changes such as providing a different DNS server list to this client. The **Server Definitions** checkbox, if checked, will prevent this particular client from receiving any server-defined client settings. Click on the **Save** button when you are done configuring the client-specific overrides for the client.

OpenVPN Client Export Utility

One of the advantages of using OpenVPN is that it has gotten so popular there are third-party packages available to make the process of using OpenVPN easier. One of these packages is the OpenVPN Client Export Utility, which allows a pre-configured OpenVPN Windows client or Mac OS X's Viscosity configuration bundle to be exported directly from pfSense.

To install the OpenVPN Client Export Utility, navigate to **Packages | OpenVPN** and click on the **Available Packages** tab. Scroll down to **openvpn-client-export** and click on the **Install** button. The next page will prompt you to confirm installation; click on the **Confirm** button to complete the process. This will install **openvpn-client-export** and all its dependencies. The process should take less than a minute.



OpenVPN Client Export Utility.

Installation of the OpenVPN Client Export Utility will result in two additional tabs becoming available when you navigate back to **Protocols** | **OpenVPN**: **Client Export** and **Shared Key Export**. The **Client Export** tab allows you to generate configuration files for clients that can be used on various platforms, whereas **Shared Key Export** is geared towards peer-to-peer connections (for example, connecting two networks with an OpenVPN tunnel). The **Client Export** tab has a number of options. The **Remote Access Server** dropdown allows you to choose to which OpenVPN server the client will be connecting. Typically, the only available option will be the OpenVPN server on port `1194` using UDP, but if you have other OpenVPN servers configured on other ports (and possibly using TCP instead of UDP), these servers should appear in the drop-down box.

The **Verify Server** CN dropdown allows you to select how the server certificate **Common Name** (**CN**) is verified. The default selection, of **Automatic**, should work in most cases (it is compatible with OpenVPN v.2.3 and most modern clients), but there are other options available for backward compatibility. The **Use Random Local Port** checkbox allows you to enable using a random local source port, which is likely something you will want to enable, since the client end can send and receive on any port (but the server must send and receive on the same pre-defined port), and enabling this option allows more than one client to run on the same system. There are two options in **Certificate Export Options**: **Microsoft Certificate Storage** (instead of local storage) and **Password Protect Certificate** (for password-protecting a certificate when using Viscosity with Mac OS X).

The **Use A Proxy** checkbox, if checked, will allow the client to use a proxy to communicate with the OpenVPN server. If this option is enabled, you must select **Proxy Type** (**HTTP** or **SOCKS**), **Proxy IP Address**, and **Proxy Port**. You can optionally choose a **Proxy Authentication** method. The options are **None**, **Basic**, and **NTLM** (NT LAN Manager).

The **Use the OpenVPN Manager Management Interface** option, if selected, will result in the management interface being activated in the generated configuration, allowing OpenVPN to be used by non-administrator users on Windows systems. Finally, the **Advanced configuration options** edit box allows you to add any additional options you require, separated by a line break or semicolon.

In the **OpenVPN Clients** section, there will be download links for different client configurations, assuming that you have added at least one client that uses the same CA as the OpenVPN server. There are configuration files available for Android, iOS, Windows XP and Vista, and Viscosity (both Mac OS X and Windows).

If you click on the **Shared Key Export** tab, you can export a shared key configuration. These are generally for site-to-site tunnels with other routers. To generate a shared key configuration, you must select a server in the **Shared Key Server** drop-down box. You must also select a resolution method in the **Host Name Resolution** drop-down box, and a hostname/address in the **Host Name** edit box.

In the **Proxy Options** section, you can opt to use a proxy to connect to the OpenVPN server and enter the proxy information. If so, you need to check the **Use a Proxy** edit box, and select a **Proxy Type** (**HTTP** or **SOCKS**), **Proxy IP Address**, **Proxy Port**, **Authentication Method** (again, the choices are **None**, **Basic**, and **NTLM**), and a username/password combination.

Troubleshooting VPN connections

Troubleshooting VPN connections can be challenging, because the process of establishing a VPN tunnel involves multiple steps, and a failure at any one of these steps will result in a failure to establish a tunnel. For that reason, it might be helpful to adopt a step-by-step approach in troubleshooting:

1. Is the remote client (or peer) able to connect to pfSense (acting either as a server or peer)? If not, then it's possible that either the VPN service is not running at the pfSense end, or, more likely, ports may be blocked that need to be unblocked. IPsec's port requirements differ depending on your configuration; consult the table included in the section of this chapter on IPsec configuration for more information. OpenVPN normally accepts connections on port `1194`; you can change this port, but if you are using OpenVPN, whichever port you use must be unblocked. If you are using IPsec, port `500` must be open for ISAKMP key exchange traffic, and port `50` or `51` must be kept open depending on your configuration (but not both); if NAT traversal is required, port `4500` must be open. L2TP uses UDP on port `1701`, so if you are using L2TP, make sure that port is open. Keep in mind that autogenerated rules created by pfSense are floating rules, so check the **Floating** tab to confirm that the necessary rules exist. If you are using OpenVPN, keep in mind that the autogenerated firewall rule for OpenVPN only allows UDP traffic. Therefore, if you are using OpenVPN over TCP, you may have to modify the rule to allow OpenVPN traffic on the WAN interface to allow TCP traffic.

2. If the remote client is able to make an initial connection to the server, but the connection ultimately fails, then often the best source for information as to why the connection failed is the log file. You can find the logs by navigating to **Status | System Logs**. Click on the **IPsec** tab to find IPsec log entries and click on the **OpenVPN** tab to find OpenVPN log entries. Very often, the source of the problem is a mismatch between the settings required by the server and the settings specified by the client in the client configuration.
3. For example, assume that there has been a failure of a mobile client to establish an IPsec connection, and you see the following log entry:

   ```
   Charon: 13[IKE] Aggressive Mode PSK disabled for security reasons
   ```

   Such an entry is a good sign that there was a mismatch in the negotiation mode between the client and server. The **Aggressive Mode PSK disabled** message indicates that the negotiation mode on the server is set to **main**. Sure enough, we discover that the client has set **Negotiation mode** to **Aggressive**, which is why the connection failed. Changing the setting on the client to **main** does not guarantee it will work, but at least we know a negotiation mode mismatch won't be the problem.

Some log entries are a little more cryptic. For example, a **pre-shared key** (**PSK**) mismatch may appear in the logs as follows:

```
charon: 09[ENC] invalid HASH_V1 payload length, decryption failed?
```

This doesn't exactly give us a clear indication of a PSK mismatch; still, if you see such a message, it's a good idea to check the PSK entry.

In addition, many of the IPsec log entries indicate whether the failure was at Phase 1 of the connection or Phase 2. Such an indication can help clue us in as to where we should be focusing our troubleshooting efforts. When the connection fails at Phase 2, often the problem is mismatched encryption methods.

Very often, the client side has **Auto** as an option for some settings – in other words, autonegotiate settings. For example, the ShrewSoft VPN Client has an Auto setting for Cipher Algorithm and Hash Algorithm. Sometimes a setting of Auto will work; however, I have generally found that the connection is more likely to succeed if all settings are set to match the settings on the other end of the tunnel. For example, I was unable to connect to an IPsec tunnel with **Auto** settings for **Cipher Algorithm** and **Hash Algorithm**, but by setting these to **AES-256** and **SHA1** (the IPsec server settings for these two parameters), I was able to successfully establish an IPsec tunnel.

There may be some cases where, even though the parameters match on both ends of the tunnel, you are unable to establish a tunnel. In many cases, this is because the client only supports one method of connecting. For example, the ShrewSoft VPN Client seems to require IKEv1 and **Negotiation mode** of **Aggressive**, while the Windows built-in VPN Client requires IKEv2. In such cases, consulting the client software documentation may help, and looking online for additional information is always a good idea.

One thing that is worth noting is that, if you switch from IKEv1 to IKEv2 and then back to IKEv1, **Negotiation mode** will be set to **main**, even if you originally set it to **Aggressive**, so be sure you have the correct setting for **Negotiation mode** before saving your settings.

Summary

In this chapter, we began with some basic VPN concepts, with our focus being primarily on the three VPN protocols currently supported by pfSense: IPsec, L2TP, and OpenVPN. We weighed the advantages and disadvantages of each protocol with respect to security, cross-platform support, ease of configuration, and firewall-friendliness. We emphasized that, since L2TP lacks confidentiality and encryption, you are not likely to ever implement L2TP in native mode; rather, it is more likely to be implemented in combination with IPsec, making your choice one between IPsec, L2TP/IPsec, and OpenVPN.

We then covered IPsec, L2TP, and OpenVPN configuration in some depth. We covered the OpenVPN Client Export Utility, which makes the process of generating OpenVPN configuration files for different platforms much easier. Finally, in the troubleshooting section, we covered what to do when we are unable to establish a tunnel between the remote and local ends.

In the next chapter, we will cover how to implement redundancy and high availability with pfSense. This is accomplished by implementing load balancing as well as the **Common Address Redundancy Protocol** (**CARP**).

7
Redundancy and High Availability

One of the primary selling points of pfSense is that deploying pfSense routers on our network enhances the overall reliability of the network. A single network component, however – for example, a single router or a single web server – still represents a single point of failure. Even in the absence of hardware failure, a single network component may not be adequate in accommodating the level of traffic on our network. For that reason, we need to consider eliminating single points of failure from our network whenever possible. This process is two-pronged, and involves incorporating both redundancy and high availability:

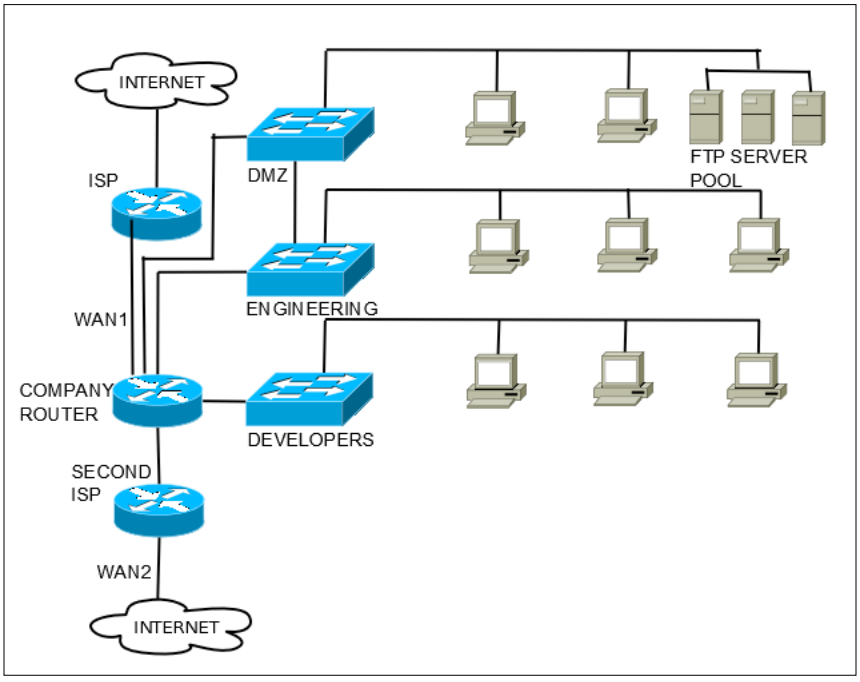
- **Redundancy** is defined as the duplication of critical components. Redundancy can be both active and passive. With passive redundancy, we incorporate excess capacity into the network, so that when an individual component fails, resources are still available. An example of this would be having two or more redundant web servers. If one server fails, the website should still be available. Active redundancy involves monitoring components and doing an automatic reconfiguration if a component fails. This might involve, for example, having a spare, inactive web server on the network. When the primary web server goes down, the failure is detected and the spare becomes active. As you may have guessed, both forms of redundancy are implemented in pfSense.
- **High availability** is defined as ensuring a specified level of operational performance over a prolonged period of time. In practice, it means incorporating some of the same elements as redundancy. Single points of failure are eliminated when possible, and we seek to detect failures when they occur and provide for reliable switchover to the redundant components. Again, we can use pfSense to provide high availability.

pfSense incorporates redundancy and high availability through load-balancing and **Common Address Redundancy Protocol** (**CARP**). Both of these topics will be covered in this chapter. This chapter will cover the following:

- An example network
- Basic load balancing and CARP concepts
- Configuring load balancing
- CARP configuration
- An example load balancing and CARP configuration
- Troubleshooting

An example network

To illustrate load balancing and CARP, we will reintroduce our example network from *Chapter 3*, *Working with VLANs*, and *Chapter 4*, *pfSense as a Firewall*. As you might recall, our example network had multiple segments; one of these network segments was the **DMZ** (**de-militarized zone**), to which we added an FTP server. The FTP server is accessible on the Internet; therefore, we isolated in on a separate segment.



Our example network, with two WAN connections and an FTP server pool.

Let's also assume that we have added a second WAN connection to the example network, in order to ensure Internet availability when one of the ISPs goes down. There are three distinct issues we seek to address through the use of load balancing and CARP on our network:

- We recognize that the pfSense firewall/router that resides at the boundary between the Internet and our local network represents a single point of failure. Therefore, we want to introduce at least one redundant firewall, which will be invoked in the case of failure.
- We want to distribute outbound traffic evenly between our two WAN connections. This will require some form of load balancing.
- We also recognize that the FTP server represents a single point of failure. We want to have at least one additional FTP server, and create a server pool containing all the available physical servers.

We thus have a fairly clear idea of what needs to be done on our example network. As we take a closer look at load balancing and CARP, we will get a clearer idea as to how these elements might be implemented within our network.

Basic concepts

In networking, load balancing is designed to distribute workloads across multiple network resources. Load balancing in pfSense is of two types: **gateway load balancing** and **server load balancing**:

- The purpose of gateway load balancing is to distribute Internet-bound traffic over more than one WAN interface. Thus, the configuration is separate from server load balancing, and is done by configuring gateway groups by navigating to **System** | **Routing** and clicking on the **Gateway Groups** tab.
- The purpose of server load balancing is to distribute traffic among multiple internal servers. In some cases, we may also want to have redundant servers available for failover, and this is supported in pfSense as well.

There are two broad methods of achieving load balancing. *Client-side load balancing* allows the client to choose which internal server they connect to. Although it might seem this would be an unreliable method of load balancing, it is surprisingly effective. Over time, clients will connect to different servers, and the load will be evenly distributed over the different servers. Moreover, this is a very simple method of configuration, since it doesn't require us to set up server pools.

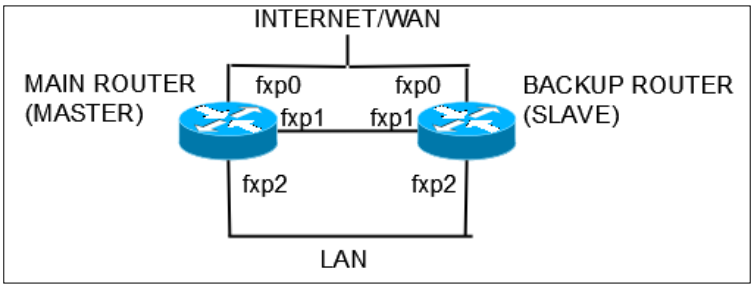
Server-side load balancing uses software to listen on the port/IP address to which external clients connect. When a client connects, the software forwards the request to one or more backend servers. There are multiple advantages to this approach:

- Since the software decides which backend server the client is forwarded to, server-side load balancing tends to be able to guarantee effective load balancing at all times.
- The load balancing process is transparent to the client, which has no idea of our network configuration.
- Since the client doesn't get to connect directly to the backend server, it tends to be more secure than client-side load balancing. For that matter, since the client doesn't know that we are utilizing backend servers, there is an added *security through obscurity* benefit.
- We can present a special message to users when all backend servers are down.

The method used in pfSense is server-side load balancing, so all the benefits of this method are available to us. This requires us to set up load balancing pools (containing the backend servers), and one or more virtual servers (to which clients will connect). We will also be required to set up firewall rules to allow traffic to pass to the backend servers, as we shall see when we configure load balancing.

CARP has a single purpose: to allow multiple hosts to share the same IP address or group of IP addresses. To understand how this works, we have to reintroduce a concept originally introduced in *Chapter 4*, *pfSense as a Firewall*. As you may recall, virtual IPs allow multiple devices to share the same (virtual) IP address. We can configure two routers to share the same virtual IP address (each must also have a unique non-virtual IP address). One of these routers is designated as the master, and the other is designated as the slave. The master router is the one that handles traffic and ARP requests for the shared virtual IP address, under normal circumstances. When the master goes down, the slave takes over. This ensures that the network is able to function normally even when there is a hardware failure.

CARP itself provides a means of ensuring that the slave router knows when the master is down. When the slave router stops receiving CARP advertisements from the master (or, in some configurations, when the CARP advertisements from the master become less frequent than advertisements from the slave), then the slave router begins handling traffic for the CARP virtual IPs. There are also two protocols to ensure synchronization between the two routers. pfsync is for state synchronization, and **XML-RPC** (**Extensible Markup Language – Remote Procedure Call**) is for configuration synchronization. The pfsync connection between the two routers is achieved via a crossover cable on a dedicated network interface. The accompanying diagram shows this setup:



Example CARP setup. fxp0 is the WAN interface; fxp2 is the LAN interface, and fxp1 is the pfsync interface.

On each router, **fxp0** is the WAN interface, and **fxp2** is the LAN interface. The two routers are connected to each other or **fxp1** using a crossover cable. Each router has three interfaces and thus three unique interfaces. They also share virtual IP addresses for the WAN and LAN interfaces. Assume the following IP assignments:

Router	**fxp0**	**fxp1**	**fxp2**
Main router	`172.16.1.1`	`192.168.2.1`	`192.168.1.1`
Backup router	`172.16.1.2`	`192.168.2.2`	`192.168.1.2`

We want to use virtual IPs to ensure that the two routers have the same LAN and WAN addresses. The **fxp1** interfaces do not require a virtual IP, since these are not shared interfaces, but we also want to ensure that the routers use their **fxp1** interfaces to exchange information so that, when the main router goes down, the backup router takes over. In the section of this chapter on CARP configuration, we will see how to use pfSense's CARP capabilities to implement this setup.

It should be noted that CARP does not have an official IANA-assigned port number. As a result, CARP's developers chose a port that would not conflict with anything of value: `112`. **pfsync** is used on an unused and open port.

Load balancing configuration

As mentioned earlier, there are two types of load balancing supported by pfSense: gateway load balancing and server load balancing. We will consider gateway load balancing first.

Gateway load balancing

Gateway load balancing is accomplished by setting up gateway groups, which consist of two or more WAN interfaces. Configuring gateway load balancing involves several steps:

1. Adding and configuring additional WAN interfaces.
2. Configuring DNS servers for each for the new WAN interfaces.
3. Adding gateway groups that include the new interfaces.
4. Adding firewall rules for each of the new gateway groups.

The first step, adding and configuring additional WAN interfaces, is a fairly simple process. When you initially set up pfSense, the WAN interface was automatically configured, but configuring additional WAN interfaces isn't much different than configuring any other interfaces. Navigate to **Interfaces | (assign)**, and on the **Interface Assignments** tab, there should be a tab showing all the existing interface assignments (which should be, at a minimum, the WAN and LAN interfaces). To add the second WAN interface, select an unused network interface in the **Available network ports** drop-down box and click on the **Add** button on the right side of the row. This will add the new interface (which will initially have a generic name such as **OPT1**). Click on the new interface's name in the leftmost column in the table. Alternately, you can select it from the **Interfaces** drop-down menu to begin configuration.

On the interface configuration page, check the **Enable** checkbox, and enter an appropriate description in the **Description** field (for example, `WAN2`). In the **IPv4 Configuration Type** and **IPv6 Configuration Type** drop-down boxes, you must select the appropriate configuration type for the interface IP. If the interface will be receiving an IP address from your ISP, then the correct selection is **DHCP** (**DHCP6** or **SLAAC** for IPv6). If you choose **DHCP** and/or **DHCP6** or **SLAAC**, then there isn't much more you have to do for interface configuration. pfSense will automatically set up the interface as a gateway, so you don't have to do this.

If you chose **Static IPv4** and/or **Static IPv6** as **Configuration Type**, however, you will have to manually configure this interface as a gateway. Fortunately, all we have to do is scroll down to the **Static IPv4/IPv6 Configuration** section of the page and click on the **Add new gateway** button. This will launch a dialog box that will allow you to configure the most basic options for the gateway. You should leave the **Default gateway** checkbox unchecked, as the first WAN interface is already the default gateway. Give the gateway an appropriate name in the **Gateway name** edit box (for example, `GW2`), and enter a gateway IP address in the **Gateway IPv4** (or **Gateway IPv6**) edit box. This should be an address different from the interface's IP address, but on the same subnet. Finally, you may enter a non-parsed description in the **Description** edit box. Click on **Add** when done.

Adding a gateway from the interface configuration page.

There isn't much more you have to do for interface configuration, unless you have some other options you need to enter for your connection (for example, if you need to configure advanced DHCP options, or if you have a PPP or PPPoE connection and must enter a username or password). You probably should check the **Block bogon networks** checkbox to block non-IANA-assigned networks. Otherwise, you can click on the **Save** button at the bottom of the page and, when the page reloads, click on the **Apply Changes** button at the top of the page. Repeat this process for as many WAN-type interfaces as you have.

The next step is DNS configuration for each of the new gateways. In order to do this, navigate to **System | General Setup** and enter a DNS server for each of the new gateways. There should be at least one unique DNS server per gateway in a multi-WAN step. You enter the DNS server information by entering a DNS server IP address in one of the edit boxes (for **DNS Server 1-4**), and then selecting one of the gateways in the adjacent drop-down box. This process should be repeated for each of the gateways. When you are done, click on the **Save** button at the bottom of the page.

Now that we have completed DNS configuration, we can navigate to **System | Routing** and begin gateway configuration. On the **Gateway** tab, the newly created gateways should be listed in the table. If you configured the gateways manually in the previous step, they will have whatever names you assigned to them; otherwise, they will have names such as **WAN2_DHCP** or **WAN2_DHCP6**, and so on.

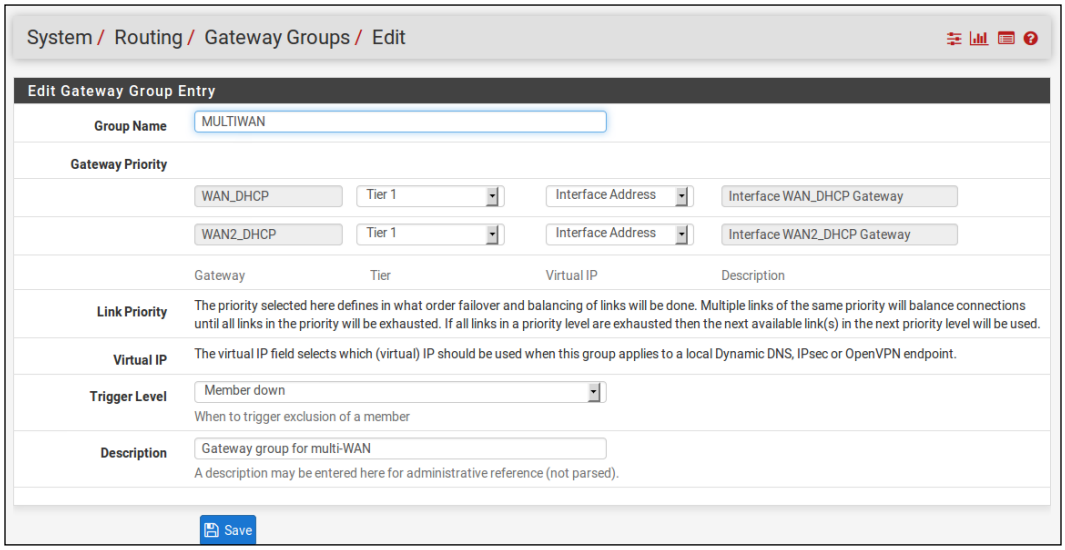
One thing you will notice if you click on the **Edit** icon (the pencil) for any of the gateways is that you have many more options than were presented in the dialog box that appears when you click on **Add new gateway** on the interface configuration page. There is a **Disable Gateway Monitoring** checkbox, which, if checked, will cause pfSense to consider the gateway to always be up. There is also a **Monitor IP** edit box, in which you can enter an alternative IP address to monitor the gateway. To determine whether a gateway is up or not, pfSense will first ping the gateway. Sometimes, however, having the gateway ping a remote address is a better measure of whether the gateway is actually up; thus, if the gateway fails to respond to a ping and a monitor IP is specified, pfSense will have the gateway ping the monitor IP. You should probably configure this option. To configure Monitor IP, enter a non-local IP address to ping (you can enter the DNS server IP address for the gateway if you can't think of another reliable site to ping).

The **Mark Gateway as Down** checkbox, if checked allows you to force pfSense to consider the gateway to be down. There is also a **Description** field. Also of interest are the options available in the **Advanced** section (you need to click the **Display Advanced** button for these options to appear). The **Weight** drop-down box allows you to select the weight for the gateway within a gateway group. Higher numbers mean the gateway has more weight. For example, if one gateway has a weight of 2 and another gateway has a weight of 1 the gateway with a weight of 2 will have twice as many connections going through it as the other gateway.

The **Latency thresholds** edit boxes determine the low and high thresholds for latency (in milliseconds) in cases where latency is one of the criteria for determining if a gateway is up or down. The **low threshold** value sends an alarm, while the **high threshold** value signifies the gateway is down. The defaults of **200/500** should be fine, although you may want to adjust this if you have a high latency connection (for example, a satellite connection). The **Packet Loss** thresholds specify the low and high thresholds for how much packet loss is acceptable before the gateway is considered down in cases where packet loss is one of the criteria for determining if a gateway is functional. Again, **low threshold** sends an alarm and **high threshold** signifies the gateway is down. The **Probe Interval** edit box allows you to specify how often (in milliseconds) an ICMP (ping) probe is sent. The default is **500** ms. The **Alert interval** edit box allows you to specify the time period between checking for an alert condition; the default is 1 second. There is also a **Use non-local gateway** checkbox which, if checked, allows use of a gateway outside the interface's subnet.

Most of the settings in **Advanced** can be kept at their default values. The value you will most likely have to adjust is **Latency thresholds**, and even then only for certain types of connections. Click on the **Save** button when you are done making changes, and from the main **Routing** page click on the **Apply Changes** button.

Now we can set up the actual gateway group for our multi-WAN connection. Click on the **Gateway Groups** tab. This tab should display a table with all configured gateways. Click on the **Add** button at the bottom of the table on the right to add a new gateway.



Adding a gateway group.

There are only a few options when configuring a gateway group. In the **Group Name** edit box, enter the name of the group. Under **Gateway Priority**, there are two configurable options. **Tier** allows you to select the tier on which a gateway exists. With tiers, lower numbers have priority over higher numbers. Gateways on the same tier level are load-balanced with each other, while gateways on a higher tier level only become invoked when all gateways on lower tiers are down. Thus, if we set **WAN_DHCP** to **Tier 1** and **WAN2_DHCP** to **Tier2**, then **WAN_DHCP** will get all the traffic for this gateway group, and **WAN2_DHCP** will not be used at all unless **WAN_DHCP** is down. If both **WAN_DHCP** and **WAN2_DHCP** are set to **Tier1**, however, they will be load balanced. Since this is what we want, you should set all the gateways in the group to **Tier 1**. The **Virtual IP** drop-down box allows you to select which virtual IP to use for each gateway. As this only applies to cases where the gateway group is used as an endpoint for a local **Dynamic DNS** (**DDNS**), IPSec or OpenVPN connection, you can leave it set to **Interface Address**.

The **Trigger Level** drop-down box allows you to specify when to trigger exclusion of a gateway member. The choices are as follows:

- **Member down**: Member is excluded when it fails to respond to a ping attempt, or when it fails to ping the monitor IP
- **Packet Loss**: Member is excluded when packet loss is unacceptably high (the actual percentage value is set in **Advanced** in the gateway configuration)
- **High Latency**: Member is excluded when latency is unacceptably high (the actual threshold is set in **Advanced** in the gateway configuration)
- **Packet Loss or High Latency**: Member is excluded when either packet loss or high latency becomes unacceptably high

Finally, in the **Description** field, you can enter a brief non-parsed description. Click on **Save** when you are done making changes; on the main **Routing** page, click on **Apply Changes**.

You may also want to configure failover groups for each of the gateways. To do so, again click on the **Add** button on the **Gateway Groups** tab. Type an appropriate name in the **Group Name** field (for example, `FAILOVER1`). In the **Gateway priority Tier** drop-down box, set the first WAN connection to **Tier 1** and the second WAN connection to **Tier 2**. Set the desired trigger level in the **Trigger Level** drop-down box, type an appropriate **Description** (for example, `WAN1 failover`), and then click on the **Save** button.

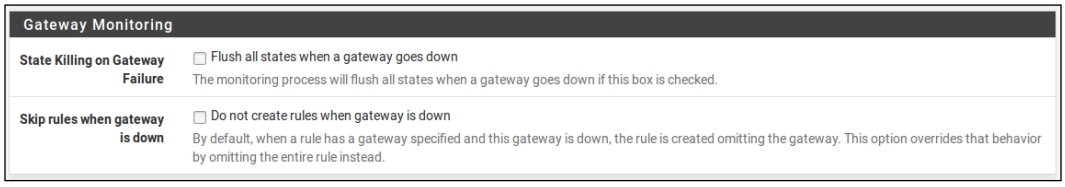
On the **Gateway Groups** tab, click on **Add** once again (or, to make life even easier, click on the **Copy** icon in the table entry for the first failover group, which will make a new gateway group with all values defaulting to the first failover group options), and configure another gateway group with an appropriate **Group Name**, only this time set the second WAN connection to **Tier 1** and the first WAN connection to **Tier 2**. When you are done making changes, click on the **Save** button. On the **Gateway Groups** page, click on **Apply Changes**.

The gateway group is now configured, but without the corresponding firewall rules no network traffic will be directed through the group. You could create a rule for each interface that will be using the group, but if the group is going to be used on more than one network, it will be easier to create a floating rule. To do so, navigate to **Firewall** | **Rules** and click on the **Floating** tab. Scroll down to the bottom of the table and click one of the **Add** buttons to add a new rule.

The objective of this rule is to pass traffic, so the **Action** drop-down box should be left at its default value of **Pass**. In the **Interface** listbox, you should select every interface that will be using the gateway group. In the **Direction** drop-down box, select **out** (rules involving gateways can only be one-way rules). In the **Protocol** drop-down box, select **any**. The **Source** field should be an alias that refers to all the interfaces selected in the **Interface** listbox; the **Destination** field can be left as **any**. Then scroll down to **Advanced Options** (in the **Extra Options** section) and click on the **Show Advanced** button. Scroll down further, and the third-from-last option will be **Gateway**. In the **Gateway** drop-down box, select the newly created gateway group. Then click on the **Save** button at the bottom of the page.

You still need to create rules for the two failover gateway groups. Click on the **Copy** icon in the table entry for the new rule, and create a new rule for each of the failover groups. All you need to change is the **Description** field and the gateway in the **Gateway** drop-down box. Click on **Save** when you are done creating each rule; when you have created all the necessary rules, click on **Apply Changes** on the main floating rules page.

Two options available from **System** | **Advanced** settings are of interest in configuring gateway groups. If you click on the **Miscellaneous** tab, there are two options in the **Gateway Monitoring** section. The **State Killing on Gateway Failure** checkbox, if checked, will cause all states to be flushed when a gateway goes down. Otherwise, active states from the gateway that is now down will be transferred to other gateways in the gateway group. This may be undesirable if you don't want persistent connections to be transferred in such a way. The **Skip rules when gateway is down** checkbox, when checked, will change the default behavior regarding what happens to a rule specifying a gateway when the gateway is down. By default, the rule will be created without the gateway that is down. This option changes that behavior so that, if a rule specifies a gateway which is down, the rule is not created at all.



Advanced gateway monitoring options.

If you completed these steps, your gateway group should be up-and-running, but you will probably want to check to make sure it is functioning correctly. To do so, navigate to **Status** | **Gateways**. There are two tabs on the **Gateways** page: **Gateways** and **Gateway Groups**. The **Gateways** tab has more useful information about configured gateways. On this tab, there is a table showing all configured gateways. The meanings of the **Name**, **Gateway**, **Monitor**, and **Description** fields are obvious, but there are also the following fields that convey crucial information about the gateways:

- **RTT (Round Trip Time)**: The ping round trip time in milliseconds, averaged over the calculation interval
- **RTTsd (Round Trip Time standard deviation)**: New to pfSense 2.3, this is the standard deviation of the round trip time over the calculation interval
- **Loss**: Packet loss over the calculation interval
- **Status**: Either online or offline

You can test the gateway group monitoring by unplugging each of the WAN interfaces in turn, and seeing how long it takes for this page to report the gateway as offline. If the amount of time it takes is unacceptably high, you may have to adjust the **Trigger Level** setting in **Gateway Groups** or **Latency threshold** or **Packet Loss threshold** in the gateway settings.

Load balancing outbound traffic with aliases

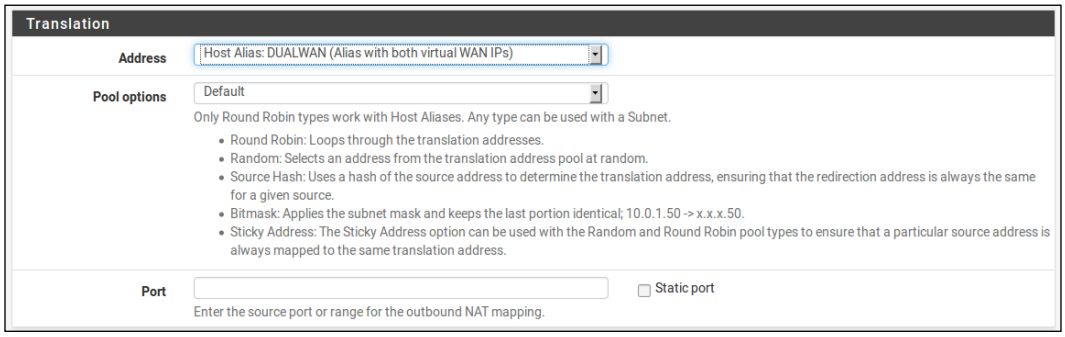
There is another way of load balancing outbound traffic that does not involve creating gateway groups. It does not have all of the functionality of a gateway group, but it is still worth a mention. This method entails the following:

1. Creating an alias consisting of two or more WAN interfaces.
2. Altering the manual outbound NAT settings to translate outbound traffic on one or more interfaces to the alias.

To begin configuration, navigate to **Firewall** | **Aliases** and click on the **Add** button. On the **Aliases** configuration page, enter an appropriate name in the **Name** field (for example, `GATEWAY`). In the **Type** drop-down box, select either **Host(s)** or **Network**. If the alias is a group of hosts, then you will be limited to round-robin load balancing using this method, while if the alias is a network or a group of networks, all load balancing options will be available. Therefore, if you use this form of load balancing, it helps if the interfaces are on the same network. You can add hosts or networks by entering them in the appropriate edit boxes and clicking the **Add Host** or **Add Network** button. Click on the **Save** button when you are finished, and then the **Apply Changes** button.

The next step is to navigate to **Firewall | NAT**. On the **Outbound** tab, select **Hybrid Outbound NAT rule generation** (which auto-generates NAT rules but also allows you to manually add rules) or **Manual Outbound NAT rule generation**. Once you have selected one of these, click on **Save**.

Then find the autocreated LAN to WAN1 rule and click on the **Edit** icon for this rule. In the **Translation** section, select the newly created alias in the **Address** drop-down box. Once you do that, a new option will appear beneath **Address** called **Pool options**. In the drop-down box, select the load balancing options you want. Four of the options (**Round Robin**, **Random**, **Round Robin with Sticky Address**, and **Random with Sticky Address**) will send traffic from one node to different addresses in the pool, whereas two of the options (**Source Hash** and **Bitmask**) will send traffic from an IP address to the same address in the pool. When you have made your selection, click on the **Save** button. Repeat the same process for the autocreated LAN to WAN2 rule. When you are done, click on the **Apply Changes** button on the main **NAT** page.



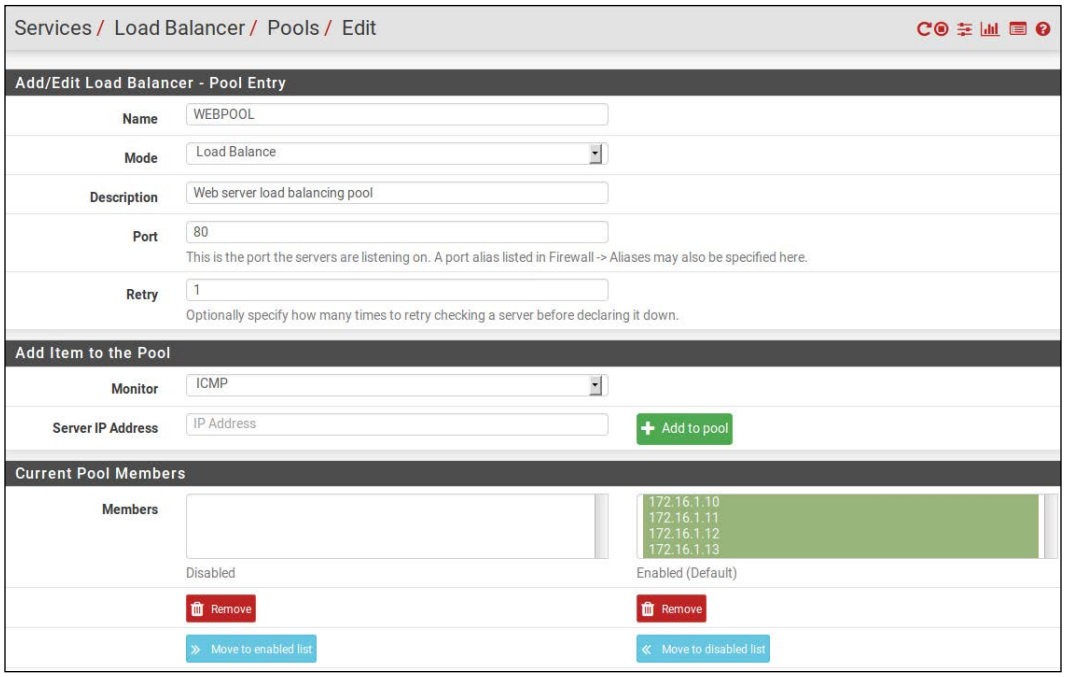
Load balancing with manual outbound NAT.

Implementing gateway load balancing in this way is easier than implementing gateway load balancing with gateway groups, but it doesn't have as many options as gateway groups. For example, there is no support for multiple tiers and there doesn't seem to be any way to configure the method to determine whether a gateway is down. Still, this provides other options for implementing a multi-WAN setup.

Server load balancing

Configuring server load balancing in pfSense involves two steps. First, you must create one or more virtual-server pools. Second, you must create one or more virtual server (the server to which clients will actually connect).

To begin server load balancing configuration, navigate to **Services | Load Balancer**. There are four tabs available: **Pools**, **Virtual Servers**, **Monitors**, and **Settings**. Configuration begins on the **Pools** tab; on this tab, click on the **Add** button to add a server pool.



Configuring the load balancing pool.

On the pool configuration page, enter an appropriate name in the **Name** edit box. The next field is the **Mode** drop-down box; the choices are as follows:

- **Load Balance**: This will balance the load across all servers in the pool
- **Failover**: The first server in the pool is used unless it fails; then it fails over to other servers in the pool

You may enter a brief, non-parsed description in the **Description** edit box. In the **Port** edit box, you must type the port on which the servers are listening (for example, port `80` for a web server). In the **Retry** edit box, you can specify how many times a server is to be retried before declaring it is down.

In the **Add Item to the Pool** section, you can add servers to the pool. The **Monitor** drop-down box allows you to choose the protocol used for monitoring the server, while the **Server IP Address** edit box is where you enter the IP address of each of the servers. Click the **Add to pool** button to add servers to the pool. As you do, the **Enabled** listbox under **Current Pool Members** will become populated with servers. You can move pool members from the **Enabled** box to the **Disabled** box by selecting a server and clicking on the **Move to disabled** list button. Selecting a server in the **Disabled** box and clicking on the **Move to enabled** list button does the opposite. You can remove a server from either list by selecting it and clicking on the **Remove** button underneath the corresponding box. When you are done configuring the server pool, click on the **Save** button.

The next step is virtual server configuration. Click on the **Virtual Server** tab, which will display a table with all of the configured virtual servers. Click on the **Add** button beneath the table to the right to add a new server.

On the virtual server configuration page, you must assign a name to the server in the **Name** edit box. The **Description** field allows you to enter a non-parsed description. The **IP Address** edit box is where you specify the address on which the server listens; this is normally the WAN IP address, but your configuration may be different. You can also specify an alias in this field.

The **Port** edit box is where you specify the port to which clients will connect. If it is blank, listening ports from the pool will be used. All connections made to this port will be forwarded to the server pool. As with the **IP address** field, you can specify an alias here.

The **Virtual Server Pool** drop-down box is where you specify the pool to which clients will be directed. You should specify the server configured during the first step. The **Fall-back Pool** allows you to specify a fall-back in the event all the servers in the main server pool are down. It could contain another list of servers that serve the same content as servers in the main pool, but more likely it will contain a server (or servers) that relay a **This server is down** message. Finally, the **Relay Protocol** drop-down box determines the protocol with which the virtual server communicates with the backend. **TCP** is the default choice, but **DNS** is also an option. Click on the **Save** button when you're done configuring the virtual server and click on the **Apply Changes** button on the main **Load Balancer** page.

Clicking on the **Settings** tabs reveals some global settings. The **Timeout** field represents the global timeout for checks (in milliseconds). If the field is left blank, the default value of one second is used. The **Interval** field allows you to set the interval at which a pool member will be checked (in seconds). The default is **10** seconds. Finally, **Prefork** allows you to set the number of processes forked in advance by the relayd daemon. The default is five processes.

Now the server and server pool are configured, but you still need to create firewall rules to allow access to each of the servers in the server pool. This rule should be placed on whatever interface the server is waiting for connections on (usually the WAN interface). To make the process easier, you can create an alias for all the servers and then create a single rule for the entire server pool.

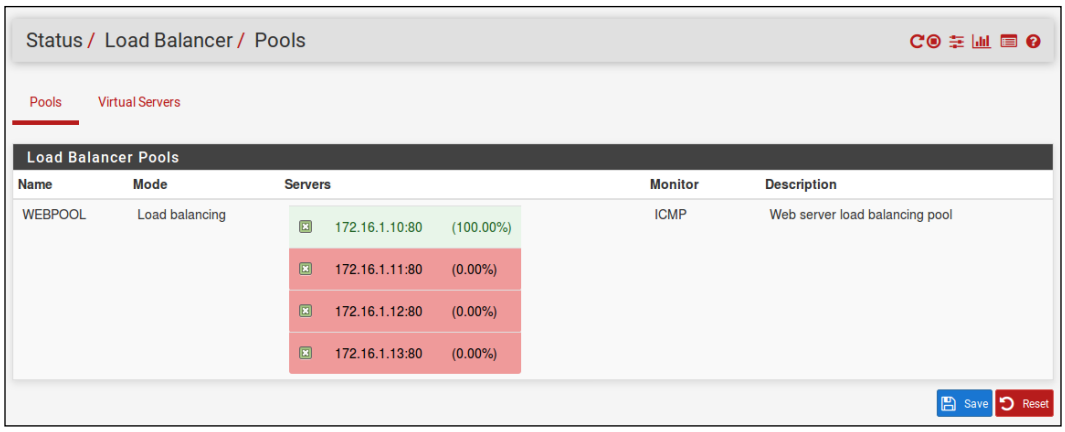
To do this, navigate to **Firewall | Aliases** and click on the **Add** button. Enter a name for the alias in the **Name** field (for example, `SERVER_POOL`) and in the **Description** field enter a brief description. Leave the type in the **Type** dropdown at its default value of **Host(s)**. Then begin entering the server IP addresses in the **IP or FQDN** field along with the CIDR, clicking on the **Add Host** button to add each server. Click on the **Save** button when you are done adding servers. Then click on **Apply Changes** on the main **Aliases** page.

You still need to create a firewall rule, which you can do by navigating to **Firewall | Rules** and adding a rule for the interface that will accept incoming connections. The destination, for this rule, of course, should be the alias defined in the previous step (I used `SERVER_POOL`).

There are two options relevant to load balancing that can be found by navigating to **System | Advanced**. Both options are on the **Miscellaneous** tab. **Use sticky connections**, if checked, will alter the default behavior of pfSense when there are successive connections from the same client. Normally, these connections would be directed to different servers in the server pool in round robin fashion, but if this option is checked, successive requests will be directed to the same server as the first. The adjacent edit box determines the timeout period for sticky connections, in seconds. The default is zero, in which case the sticky connection expires as soon as the last state that refers to the connection expires. Changing this option restarts the load balancing service. This is not a perfect solution for cases in which all requests from the same client must go to the same server; a request that takes place at a long enough interval (longer than the timeout period) after the last state expired will be directed to the next web server. As a result, pfSense may not be the ideal solution for these cases.

The second option is the **Enable default gateway switching** checkbox. If this is checked, then if the default gateway goes down the default gateway will be switched to another available one. This is not necessary in most cases, as gateway groups ensure another gateway is available if the default gateway goes down.

If you want to monitor your load balancing pool, navigate to **Status | Load Balancer**. The **Pools** tab will show any configured load balancer pools. The table shows the name and mode (load balancing or failover) of each pool, the IP addresses of each server in the pool under **Servers**, the **Monitor type**, and the **Description** that was entered. The listing of servers under the **Servers** column will also show the percentage of the load covered by each server in the pool. There is also a checkbox corresponding to each server; unchecking the checkbox corresponding to a server and clicking on **Save** will remove the server from the pool, while clicking on **Reset** will result in connections to the server pool being reset.



A load balancing pool in pfSense. The first server (172.16.1.10) is up; the others are down.

Clicking on the **Virtual Servers** tab will display a different table. The table lists the name of each virtual server, the address of each virtual server, and the IP address of each of the servers in the server pool under **Servers**. The **Status** value of the virtual server will be displayed in the table (up or down), as well as the description.

CARP configuration

Whereas pfSense's load balancing capabilities may leave something to be desired, pfSense's high availability capabilities are quite good, and pfSense offers an enterprise class CARP solution that provides for stateful failover. We will first consider a basic CARP group for firewall failover, but we will also consider other scenarios involving CARP, such as multi-WAN deployments.

CARP with firewall failover

This is probably the most common deployment scenario in which CARP is involved. The most common scenario involves a two firewall failover group with a dedicated pfsync interface on each and both pfsync interfaces connected with a crossover cable. Setting up a CARP failover group involves several steps:

1. Configuration of virtual IP addresses.
2. Configuration of a dedicated pfsync interface.
3. Enabling pfsync and XML-RPC Sync.
4. Manual outbound NAT configuration.
5. DHCP server configuration.
6. Secondary firewall configuration.

You likely will want to give consideration to your CARP setup (sometimes a network diagram helps), and possibly compile a list of hardware requirements. A typical two-firewall CARP setup, for example, would involve two pfSense firewalls, a router on the WAN side, and a switch on the LAN side. One interface on each of the firewalls would be devoted to pfsync; they can be connected with a crossover cable. If your CARP setup involves three or more firewalls, then you'll likely need another switch for the pfsync subnet.

Once you have a concept of what your setup will look like and you have the required hardware, you can begin by determining what the virtual IP addresses will be. Keep in mind that each interface will require a virtual IP address, and the physical interface on each of the *N* firewalls will have its own IP address, for a total of *N* + *1* IP addresses for each interface. Thus, in the case of a two-firewall CARP group, each interface will have three IP addresses. It is generally a good idea to have a consistent convention for IP address assignment. One way to do this is to assign the first address on an interface's subnet to the virtual IP address for that interface, with subsequent addresses being used for the interfaces on each firewall. For example, if we have a LAN subnet of `192.168.1.0`, then `192.168.1.1` will be the LAN interface's virtual IP, while the LAN interface's IP on firewall #1 will be `192.168.1.2` and the LAN interface's IP on firewall #2 will be `192.168.1.3`.

To begin configuration, we will make sure that everything is functioning on the primary firewall. Additional firewalls should be offline until this point. Configuring virtual IPs is the first step, so navigate to **Firewall** | **Virtual IPs**. Then click on the **Add** button below the **Virtual IP** table on the right to add a new virtual IP entry.

On the **Virtual IP** configuration page, set **Type** to **CARP**. Set the interface in the **Interface** drop-down box to whichever interface you wish to configure. You are going to have to create virtual IPs for both the WAN and LAN interfaces, so you will likely be starting with one of these two. In the **Address(es)** edit box, enter the virtual IP address. The mask specified in the adjacent drop-down box should be the network's subnet mask.

In the **Virtual IP Password** edit boxes, you need to enter a VHID group password, which can be whatever you want. You won't have to enter this on the other firewalls, as it will automatically propagate to them via the pfsync interface. You do need to enter the password a second time for confirmation, however.

In the **VHID Group** drop-down box, you need to select the VHID group for this interface. The only requirement is that the VHID must not already be in use, and the VHID must be unique on the entire interface's subnet. If there is no CARP or VRRP traffic on your network, you can set this to `1`; otherwise set it to the next available VHID.

The **Advertising frequency** drop-down boxes allow you to set the frequency with which the machine will advertise its presence. The lowest combination of both values (**Base** and **Skew**) determines which firewall is the master. For this reason, you will want to set **Base** to `1` and **Skew** to `0` on the master firewall (the lowest allowed values for these fields). Keep in mind that the XMLRPC process will automatically add 100 to each skew when syncing virtual IPs to secondary nodes. Thus, if *x* is the skew on the master firewall, the first slave will have a skew of *x + 100*; the second slave will have a skew of *x + 200*, and so on. In addition, the skew has a maximum value of 255, and XMLPRC will keep adding 100 to each skew when syncing VIPs to secondary nodes even if it results in values over 255, which it will if there are 3 or more slaves. In such cases, you should uncheck the **Virtual IPs** checkbox in the **Select options to sync** subsection of **XMLPRC sync** (which can be found under **High Availability Sync**). In the **Description** field, you may enter a brief non-parsed description. When you are done making changes, click on **Save** at the bottom of the page.

From the main **Virtual IPs** page, click on the **Add** button again and repeat the process for each interface that requires a virtual IP address. At a minimum, you will have to create virtual IPs for both the WAN and LAN, but you may have multiple other interfaces on your firewall that will have virtual IPs. Just change **Interface** to the interface you want to configure, and enter the virtual IP address for the new interface. The **VHID group password** will be for a different VHID group, so it can be different from the VHID password you entered previously. The **VHID Group** should be set to the next available VHID; this is likely the previously entered value plus 1. Finally, since this system is the master, in **Advertising Frequency**, **Base** should be set to `1` and **Skew** to `0`. Enter a brief description and click on the **Save** button. When you have entered all the required virtual IPs, click on the **Apply Changes** button on the main **Virtual IPs** page.

The next step is to set up a dedicated pfsync interface. Setting up a dedicated interface for synchronization is not strictly required, but there are benefits to such a configuration:

- **Increased security**: In a typical two-interface (WAN and LAN) configuration, the alternative is to transmit sync data to between the primary and secondary firewalls via the LAN. Although it is less likely to happen in the era of switched ports, this traffic is potentially vulnerable to interception. Isolating pfsync traffic onto a separate network to which only other firewalls are connected eliminates this vulnerability.
- **Improved resource utilization**: The secondary firewalls must sync to the primary firewalls often to ensure their configuration is up-to-date, and the traffic generated can be considerable. Placing this traffic on a separate network thus reduces congestion on the LAN.

To set up an interface for pfsync, navigate to **Interfaces | (assign),** select an unused interface in the **Available network ports** drop-down box, and click on the **Add** button. Then click on **interface name** and begin configuration. There isn't much required for the pfsync interface, except that all the pfsync interfaces should be on a shared subnet. Give the interface an appropriate name (for example, `SYNC`). Click on the **Save** button at the bottom of the page when you are done configuring the pfsync interface and, when the page reloads, click on **Apply Changes**.

Next, you must create a firewall rule for the pfsync interface. Navigate to **Firewall | Rules**, and click on the tab for the newly created interface. Click on the **Add** button to add an **allow pfsync interface to any** rule. The **Action** column should be set to **Pass** and the **Interface** should be kept set to the **pfsync** interface. The protocol in the **Protocol** drop-down box should be set to **PFSYNC**. The **Source** field should be set to the **pfsync** network and **Destination** should be set to **any**. Enter a brief description in the **Description** field, and click on the **Save** button. When the main **Firewall** page reloads, click on the **Apply Changes** button.

The next step is enabling pfsync and XML-RPC. Navigate to **System | High Availability Sync**. In the **State Synchronization Settings** section, make sure the **Synchronize states** checkbox is checked. In the **Synchronize Interface** drop-down box, select the **pfsync** interface. If you set up a dedicated interface, select it as the interface; otherwise, select whichever interface you are using to synchronize the firewalls (the most likely alternative is **LAN**). By default, pfsync data is sent via multicast, but by specifying an IP address in the **pfsync Synchronize Peer IP** edit box, you can force pfsync to synchronize its state table to the specified IP address. If we are setting up the primary firewall, this field should be set to the secondary firewall's IP address. For example, if we have a primary firewall on which the dedicated pfsync interface has an IP address of `192.168.2.1` and the secondary firewall's pfsync interface is `192.168.2.2`, this field should be set to `192.168.2.2` on the primary firewall (to sync the secondary firewall) and `192.168.2.1` on the secondary firewall.

Next, we must enable configuration synchronization for XML-RPC. On the same configuration page, scroll down to the **Configuration Synchronization Settings (XMLRPC Sync)** section. In the **Synchronize Config to IP** edit box, enter the IP address of the firewall to which the firewall should be synchronized. This should match the IP address entered in pfSync's **Synchronize Peer IP**. The **Remote System Username** edit box should be set to admin (other usernames will not work) and then enter the password in the **Remote System Password** edit box (it should match on all firewalls). In the **Select options to sync** subsection, you should check all the checkboxes for items you want to synchronize. By default, only **Firewall schedules** and **Virtual IPs** are selected, but if you want to have truly redundant secondary firewalls, all checkboxes should be checked (the **Toggle All** button at the bottom of this section allows you to do just that). When you are done making changes, click on the **Save** button at the bottom of the page.

The next step is configuration of manual outbound NAT. Navigate to **Firewall | NAT** and click on the **Outbound** tab. If you haven't already, set **Mode** to either **Hybrid Outbound NAT rule generation** or **Manual Outbound NAT rule generation** and click on the **Save** button. In the **Mappings** table, find the autocreated LAN to WAN rule, and click on the **Edit** icon for that rule. If you did not have any virtual IPs configured, then in the **Translation** section **Address** is likely set to **Interface Address**. Change this setting to the WAN virtual IP that was added earlier for CARP. Then click on the **Save** button; click on **Apply Changes** on the main **NAT** page. If you configured everything correctly, connections leaving the WAN interface should be translated to the new WAN CARP IP. If you want to confirm this, one possible method is to access a website that displays the IP address from which the site is being accessed. Also, if you look at the **Mappings** table, the address in the NAT address column should be the virtual IP of the WAN interface. You should repeat this process for any local interfaces (non-WAN/non-pfsync) you have on the firewall.

Now you need to update the DHCP settings. Navigate to **Services | DHCP Server** (these options are not available for DHCPv6) and scroll down to **Servers**. In the **DNS servers** subsection, set the first DNS server to the LAN virtual IP created earlier on in the process. In the **Other Options** section, set the **Gateway** field to the LAN virtual IP. Finally, enter the actual LAN IP address of the secondary firewall in the **Failover peer IP** edit box. This will allow the two firewalls to maintain a common set of DHCP leases. Then click on **Save** at the bottom of the page. Repeat this process for however many local interfaces you have on the firewall that are using DHCP.

This completes configuration of the primary firewall; we can now begin configuration of the secondary one. For the first phase of the secondary firewall configuration, keep the firewall offline. Assuming that pfSense is already installed and is working, you need to go through the interface assignment process. Set the LAN IP to whatever you previously designated as the backup LAN IP (for example, if we set the primary firewall's LAN IP to `192.168.1.1`, we might set the backup LAN IP to `192.168.1.2`). You need to assign an interface to **pfsync**, and set an IP address for that as well. The DHCP settings should be the same as they are on the primary firewall. Note that all of these configuration steps do not require use of the web GUI and can be done from the pfSense console. Once you have completed these steps, you should be able to put the secondary firewall online.

You can now log in to the secondary firewall via the web interface. If you haven't done so already, configure the WAN IP address (again, set it to the IP address you previously designated as the WAN IP). The admin password on the backup firewall must be set to the same value as that of the primary firewall, or synchronization will not work.

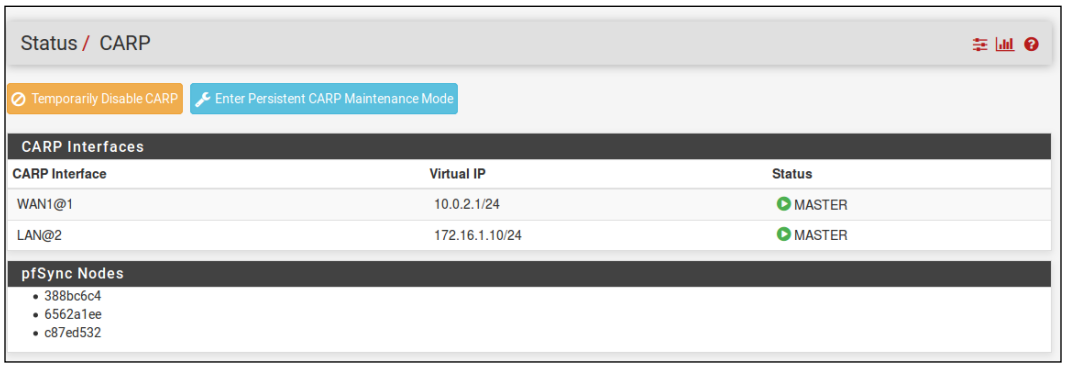
You need to create a firewall rule for the **pfsync** interface of the secondary firewall. This rule has two purposes. First, it will allow the initial synchronization data to pass from the pfsync interface to the primary firewall. Second, it will (hopefully) be overwritten by firewall rules from the primary firewall during the synchronization process, and thus will confirm that synchronization was successful. With this in mind, navigate to **Firewall | Rules** and create an *allow any to any* rule (**Source** should be set to **any** and **Destination** should be set to **any**). It may be helpful to use the **Description** field to flag this rule as one that will be overwritten.

It will be necessary to set the CARP LAN virtual IP address as the gateway, and to set the primary firewall's LAN IP address as the failover peer. As with the primary firewall, this process must be repeated for each secondary firewall.

Now all that is left to do is to activate CARP. Navigate to **Status | CARP (failover)** on both the primary and secondary firewall. If there is a button called **Enable CARP** on either firewall, click on it. Also, verify that the virtual IP for each interface is correct and that they show the correct status. On the primary firewall, the status should be **MASTER**. On the secondary firewall, the status should be **BACKUP**.

There are two additional buttons on this page that are useful, especially when troubleshooting. The **Temporarily Disable CARP** button disables CARP on the firewall on which it is invoked by removing the CARP virtual IPs from the system. If the firewall's status is **MASTER**, then the next available firewall whose status is **BACKUP** will take over. This setting is not remembered through a reboot, and if you reboot a firewall that had been master before CARP was temporarily disabled, the firewall will regain its status as **MASTER**. The button toggles to **Enable CARP** when you press it, and pressing **Enable CARP** also enables a temporarily disabled master firewall to become master again.

Sometimes, you may need to keep CARP disabled through a reboot. This is where the other button, **Enter Persistent CARP Maintenance Mode**, comes in. If pressed, this button will disable CARP on the firewall, and this condition persists through a reboot, thus preventing the firewall from prematurely regaining the **MASTER** status. The button toggles to **Leave Persistent CARP Maintenance Mode**, and pressing this button is the only way to exit maintenance mode from within the web GUI.



The CARP status page.

If you have followed these steps, synchronization should take place. If not, you may want to navigate to **System | High Avail**. Sync on the primary firewall and confirm that the **Synchronize States** checkbox is checked. If not, you should check this box and save the settings. You may also want to navigate to **Status | System Logs** and check the logs to see if synchronization occurred. Successful synchronization will generate a series of log entries such as these (as indicated in the log entries shown in the following screenshot, synchronization takes about 30 seconds to complete):

May 23 20:40:31	check_reload_status: Syncing firewall
May 23 20:40:33	php-fpm[42315]: /rc.filter_synchronize: Beginning XMLRPC sync to http://192.168.4.4:80.
May 23 20:40:40	php-fpm[42315]: /rc.filter_synchronize: XMLRPC sync successfully completed with http://192.168.4.4:80.
May 23 20:40:41	check_reload_status: Syncing firewall
May 23 20:40:42	php-fpm[20136]: /system_hasync.php: waiting for pfsync...
May 23 20:41:14	php-fpm[20136]: /system_hasync.php: pfsync done in 30 seconds.
May 23 20:41:14	php-fpm[20136]: /system_hasync.php: Configuring CARP settings finalize...

Log entries from a successful CARP synchronization.

In the event of failure, the log entries may provide a clue as to why the sync failed, or you can navigate to **Diagnostics | Ping** and try to ping the pfsync interface of the other firewall. If the ping fails, then you have a connectivity issue with the pfsync connection, and you can start your diagnosis there. Check to make sure that the crossover cable is good, and also check to see if there is a link light on the pfsync interface on both sides of the connection.

If the settings synchronized, the CARP group should be active. To ensure that this is the case, navigate to **Status | CARP (failover)**.

At this stage, if you look at the **Status** column, the primary firewall's status should be designated as **MASTER** and the secondary should be **BACKUP**. If the secondary firewall's CARP status is **DISABLED,** and there is an **Enable CARP** button on the status page, click on that button and it should activate CARP.

Once you have confirmed that CARP is running on both firewalls, you probably want to confirm that settings have been copied over from the primary firewall to the secondary firewall. Check the firewall rules, NAT rules, and DHCP settings; the temporary firewall rule created during configuration of the secondary firewall should be overwritten by now.

Finally, you probably want to confirm that your CARP failover group actually works in a real-world scenario. At a minimum, you'll want to power down the primary firewall and confirm that the secondary firewall takes over. You may also want to test the failover group in a variety of scenarios. In all cases, you should still be able to access the Internet.

At this point, we will have proven that the CARP group works, but depending on what your requirements are, you may want to test your CARP setup in different failure scenarios. For example, you may want to unplug the WAN or LAN cable and see what happens, or try downloading a file or streaming audio and/or video while one of the firewalls goes offline.

Multi-WAN with CARP

A modification of the basic CARP deployment scenario above involves deploying CARP for firewall redundancy in a multi-WAN configuration. It is somewhat more complex than the two firewall CARP setup outlined earlier.

The first step is to determine the IP assignments for the WAN interfaces on both firewalls. Each WAN IP needs at least three IP addresses: one for each of the WAN interfaces on each firewall, and one shared CARP virtual IP. You also need three IP addresses for the LAN interface.

One of the additional configuration steps with multi-WAN is that you must have a policy for the local network to route to the default gateway. This is to prevent traffic from going to the other WAN interface when it should be directed to the CARP WAN IP address. Rules must be added to all internal interfaces; the purpose of this rule will be to direct traffic to the CARP WAN IP address, which is the default gateway. Since rules are evaluated on a top-down basis, the rule should be placed at the top of the firewall rules for each interface.

To create this rule, navigate to **Firewall | Rules** and click on the **Floating** tab. In the **Interface** listbox, select all internal interfaces. In the **Direction** dropdown, select **in**. Set **Source** to **any**, and set **Destination** to either **LAN**, if LAN is the only internal interface, or an alias containing all local interfaces. This rule must be placed at the top of the firewall rules.

An example configuration – load balancing and CARP

To demonstrate how the concepts introduced might be implemented in a real-world scenario, we will return to the example network introduced in the beginning of the chapter. Some very specific requirements were outlined:

- We need redundant firewalls, and this requires implementing CARP.
- We wanted to balance outgoing traffic across two WAN connections, which requires gateway load balancing.
- Finally, we wanted to introduce some redundancy into our FTP server, and have at least two separate servers. This requires implementing server load balancing.

Assume that we have a LAN network for local traffic, and also assume that we have a separate **DMZ** network for the FTP server. Prior to implementing any of the aforementioned changes, our network looks like this:

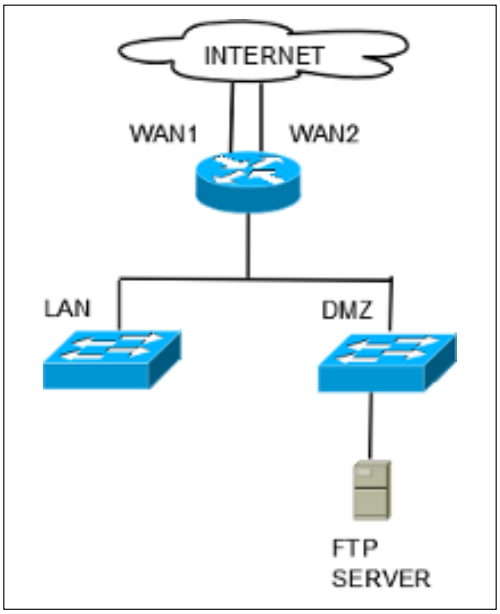


Diagram of our example network. There are two WAN connections that need to be load balanced, and an FTP server that also needs to be load balanced.

Assume we have a subnet of `192.168.1.0` for the LAN network, and a subnet of `192.168.2.0` for the DMZ network. The FTP server's IP address is `192.168.2.10`.

There are various ways we could go about implementing the changes we want, but implementing a CARP group is more difficult than implementing either gateway or server load balancing, so a case can be made for implementing the CARP group last. Gateway load balancing is likely the easiest to implement since it only involves configuration on the firewall itself, so we will do that first. Thus, we will implement the changes in the following order:

1. Gateway load balancing.
2. Server (FTP) load balancing.
3. CARP setup.

We begin by implementing gateway load balancing. Since we already have the additional WAN interface installed and configured, we can move straight ahead and configure the DNS server settings for WAN1 and WAN2. We navigate to **System | General Setup** and scroll down to **DNS Server Settings**. Since it is good practice to use different DNS servers for each WAN-type interface, we enter `208.69.38.170` (one of OpenDNS's DNS servers) in the **DNS server 1** listbox and then select **WAN1** in the corresponding drop-down box. We enter `8.8.8.8` (one of Google's DNS servers) in the **DNS server 2** listbox and then select **WAN2** in the corresponding drop-down box. We click on the **Save** button to save the settings.

Now we move on to gateway configuration. We navigate to **System | Routing,** and on the **Gateway** tab we click on the **Edit** icon for **WAN1**. On the **Gateway** configuration page, we enter `208.69.38.170` in the **Monitor IP** edit box (the same IP address that we entered for this interface's DNS server). We then click on the **Save** button. We repeat the same steps for **WAN2**, only this time we enter `8.8.8.8` in the **Monitor IP** edit box. When we are done, we click on **Apply Changes** on the main **Routing** page.

Next, we click on the **Gateway Groups** tab and click on the **Add** button. We give the gateway group an appropriate name (for example, `MULTIWAN`), and under **Gateway Priority** we assign both **WAN1** and **WAN2** to **Tier 1** so they will have equal weight. **Trigger Level** for this group will be set to **Member down**. We enter a brief description and click on **Save**.

It is good practice to create failover groups for each of the gateways, so we click on the **Add** button and add a group called `FAILOVER1`, which has **WAN1** on **Tier 1** and **WAN2** on **Tier 2**. Thus, WAN2 only becomes invoked if WAN1 fails. Again, **Trigger Level** is set to **Member down**. We click on **Save** and then create another failover group called `FAILOVER2`, which has **WAN2** on **Tier 1** and **WAN1** on **Tier2**. When we are done configuring all the groups, we click on **Apply Changes** on the main **Routing** page.

Next we must create firewall rules to pass traffic from the local interfaces to the gateway groups. In the section on load balancing, I described a floating rule which covered all local interfaces. Because of the configuration of the network, we cannot use floating rules here. The LAN network has access to all local networks and the Internet, but the DMZ, as its name suggests, only has access to the Internet and has no access to local networks. Therefore, we cannot create a universal rule. Fortunately, it is not too difficult to modify the existing firewall rules for our needs.

First, we navigate to **Firewall** | **Rules** and click on the **LAN** tab. There should be a **Default allow LAN to any** rule. We click on the **Edit** option for this rule and, keeping all other settings the same, we scroll down to **Extra Options**, click on the **Show Advanced** button, and then scroll down to **Gateway** under **Advanced** options. In the **Gateway** drop-down box, we select the **MULTIWAN** gateway we created earlier. We change the description to reflect the change, and then click on the **Save** button.

We also need to create rules for each of the failover groups, so we click on the **Copy** icon for the rule we just modified to create a new rule based on the old one. Again, keeping other settings the same, we scroll down to the **Gateway** drop-down box and set the gateway to **FAILOVER1**. We click on **Save** and repeat the process, but, instead of **FAILOVER1**, **FAILOVER2** will be the gateway. Once we have created the rules, we look at the table to make sure the rule that set **MULTIWAN** as the gateway is closer to the top of the table than the other two rules, since rules are evaluated from the top down and we want traffic to be directed to the **MULTIWAN** group if it is functional. Once we have confirmed that the rules are correct and are in the right order, we click the **Apply Changes** button.

Now we have to create rules for the DMZ, so we click on the **DMZ** tab. There won't be an **Allow DMZ to any** rule, but if whoever set up the system set it up correctly, there should be an **Allow DMZ to WAN** rule. When we find this rule, we click on the **Edit** icon for the rule and repeat the process outlined earlier for the LAN interface – namely, we keep all other settings the same, but set the gateway in the **Gateway** drop-down box to **MULTIWAN** and alter the **Description** field accordingly. Then we click on **Save** and repeat the process, clicking on the **Copy** icon for the modified rule and creating rules with **FAILOVER1** and **FAILOVER2**, making sure that the rule setting the **MULTIWAN** is closer to the top of the table than the other rules. When we are done making changes, we click on the **Apply Changes** button.

Now that we have created the firewall rules, our gateway load balancing setup is complete. We may want to reset states in order to force all outbound traffic to use the newly configured groups (to do so, we would navigate to **Diagnostics** | **States**, click on the **Reset States** tab, and click on the **Reset** button), but otherwise all we need to do is navigate to **Status** | **Gateways** and confirm that the gateways are up and running and that the gateway groups are working.

Our next step is to set up FTP server load balancing. As mentioned earlier, our DMZ has a subnet of `192.168.2.0` and the FTP server's IP is `192.168.2.10`. We have decided that the redundant FTP server will be assigned an IP of `192.168.2.11`, and additional redundant servers will be added as needed. We don't have to assign an IP address for the virtual server, as it will be the WAN IP address. Thus, our IP assignments look like this:

`192.168.2.10`	FTP Server #1
`192.168.2.11`	FTP Server #2
WAN IP Address	Virtual server

One issue we should consider before we move ahead with configuring load balancing is how we are going to synchronize the redundant FTP servers. We have two broad alternatives:

- Cluster the redundant FTP servers
- Run a utility on the FTP servers to ensure that the filesystems remain synchronized

Note that, if we cluster the FTP servers, the cluster will appear to other entities as a single server. There are many FTP servers that support clustering, and they have their own load balancing and high availability capabilities. In this case, pfSense can deal with the FTP cluster as if it was a single server, and we don't have to implement load balancing in pfSense.

If we choose not to cluster the server, however, then we have to find a means of synchronizing the servers. Fortunately, if we're using Unix or Linux, there is a widely-used utility called **rsync** that can be used; rsync has also been ported over to Windows, so if our FTP server is running on Windows, it's a potential solution, although there are many other file synchronization programs available for Windows. For this exercise, we'll assume we decided not to create an FTP server cluster and thus we will use pfSense's load balancing capabilities.

To begin load balancing configuration, navigate to **Services** | **Load Balancer**. On the **Pools** tab, click on the **Add** button. We enter an appropriate name in the **Name** field (for example, `FTPPOOL`). The **Mode** field should be set to **Load Balance**. The **Port** value will be set to `21` (the default port for FTP). Then, under **Add Item to the Pool**, we begin entering FTP servers in the **Server IP Address** edit box, clicking on **Add to pool** after we enter each IP address to add it to the pool. Since there are only two servers, `192.168.2.10` and `192.168.2.11`, this does not take long. After we have entered all the servers, we click on the **Save** button at the bottom of the page.

The next step is virtual server configuration. On the main **Load Balancer** page, we click on the **Virtual Servers** tab, and then click on the **Add** button. On the **Virtual Servers** configuration page, we type an appropriate name (for example, `FTP`), a brief description in the **Description** field, and we enter the WAN IP address in the **IP Address** field. We enter `21` in the **Port** field, and we specify `FTPPOOL` as the **Virtual Server Pool** (if `FTPPOOL` is the only pool, then it will be the default value and we don't have to change anything). Since we don't see any issue in using **TCP** as the **Relay Protocol**, we leave this unchanged and click on the **Save** button. Then we click on **Apply Changes** on the main **Load Balancer** page.

We now need to create a firewall rule to allow traffic to pass through the WAN interface to the FTP server pool. First, we create an alias for the FTP servers, which should help if we add servers in the future. We navigate to **Firewall | Aliases** and click on the **Add** button. On the **Aliases** configuration page, we enter an appropriate name in the **Name** field (for example, `FTPSERVERS`). We leave the **Type** set to **Host(s)** and, under the **Host(s)** section, we enter the IP addresses for the FTP servers. Then we click on the **Save** button, and from the main **Aliases** page we click on **Apply Changes**.

To create the firewall rule, we navigate to **Firewall | Rules**. On the **WAN** tab, we click on one of the **Add** buttons. All of the default values in the first section can be kept as they are (unless we have an IPv6 network and want to change the **Address Family** to **IPv6 or IPv4 + IPv6**). We keep **Source** as **any**, but in **Destination** we select **Single host or alias** in the **Destination** drop-down box and enter `FTPSERVERS` in the adjacent edit box. We enter a brief description in the **Description** field, and then click on the **Save** button and click on **Apply Changes** on the main **Rules** page.

This completes the pfSense portion of our FTP load balancing pool. We still need to implement synchronization so that the files (including user account data) are kept identical on both servers. It is beyond the scope of this discussion to cover this topic, but as mentioned earlier rsync is one possible solution. By utilizing rsync, implementing synchronization can be done as easily as entering the following line in our `crontab` file:

```
1 0 * * * rsync –az 192.168.2.10::ftp/   /var/ftp/
```

If entered into the `crontab` file on `192.168.2.11`, this will cause the cron scheduler to execute rsync at one minute past midnight every day, and copy the FTP tree on `192.168.2.10` to `/var/ftp`.

Even if we haven't yet implemented synchronization, we will want to verify that the FTP server pool is functioning, so we navigate to **Status | Load Balancer** and check both the **Pools** and **Virtual Servers** tabs to verify that both servers are up and running.

The final task is setting up a CARP failover group, and this requires some consideration. Four interfaces will require CARP virtual IPs: the WAN1, WAN2, LAN, and DMZ interfaces. We are going to have to add an interface for pfsync on each firewall. Assume also that we are going to make the CARP virtual IPs match the original interface IP assignments (`192.168.1.1` for the LAN and `192.168.2.1` for the DMZ) to make the transition easier. pfsync will be on its own network. We can summarize the IP assignments for our failover group as follows:

Interface	Firewall #1	Firewall #2	Virtual IP
WAN1	From ISP	From ISP	`10.1.1.1`
WAN2	From ISP	From ISP	`10.2.1.1`
LAN	`192.168.1.2`	`192.168.1.3`	`192.168.1.1`
DMZ	`192.168.2.2`	`192.168.2.3`	`192.168.2.1`
PFSYNC	`172.16.1.1`	`172.16.1.2`	None

As you can see, **PFSYNC** is the only interface on the failover group that doesn't get a virtual IP, as it is not accessible by the outside world, but is only there to allow the firewalls to exchange configuration data.

Since the virtual IPs for the LAN and DMZ are identical to the current IPs for those interfaces, we must change them before we create the virtual IPs, since pfSense will not allow us to create virtual IPs that match currently assigned IPs. Thus, we navigate to **Interfaces** | **LAN**, scroll down to the **IPv4 Address** edit box, and change this value to `192.168.1.2`, clicking on the **Save** button when we are done. Then we repeat this process with the DMZ interface, only we change the **IPv4 Address** to `192.168.2.2`.

Since we are going to have to add the PFSYNC interface anyway, we navigate to **Interfaces** | **(assign),** select one of the available interfaces in the **Available network ports** drop-down box, and click on the **Add** button. We select **Static IPv4** as the **IPv4 Configuration Type** and set the **IP address** to `172.16.1.1`. The **Enable Interface** checkbox also needs to be checked. Then we click on the **Save** button and, now that we are done configuring interfaces, we click on the **Apply Changes** button.

We begin configuration by navigating to **Firewall** | **Virtual IPs** and clicking on the **Add** button to add the first of our virtual IPs. We will set up the WAN IPs first, so for **Type** we select the **CARP** radio button, and then select **WAN1** in the **Interface** drop-down box. We type in `10.1.1.1` in the **Address(es)** edit box and select **8** for the subnet mask. We type in a password in **Virtual IP Password**; the **VHID Group** should be `1` if we haven't added any CARP virtual IPs before. The **Advertising Frequency** should be set to `1` and `0` for **Base** and **Skew** respectively. We enter a brief description in the **Description** field and click on the **Save** button.

We then repeat this process for the three remaining interfaces. The IPs entered in the **Address(es)** field for each interface must correspond to the virtual IP listed in the table (`10.2.1.1` for WAN2, `192.168.1.1` for LAN, and `192.168.2.1` for DMZ). The **Virtual IP Password** value can be different for each virtual IP, and the **VHID Group** must be unique for each one (it should automatically increment). On the primary firewall, the **Advertising Frequency Base** and **Skew** should always be `1` and `0`.

Next, we navigate to **System | High Availability Sync** to configure pfsync and XML-RPC. We make sure the **Synchronize states** checkbox is checked, and select **PFSYNC** as the **Synchronize Interface**. For the **pfsync Synchronize Peer IP**, we enter the LAN IP of firewall #2, or `192.168.1.3`. Under **XMLRPC Sync**, we enter this IP again, and in the **Remote System Password** fields we enter the admin password. In the **Select options to sync** section, we check everything and then click on **Save**.

The next step is configuration of the manual outbound NAT rules. We need to modify the outbound NAT rules for both WAN1 and WAN2 so they both translate to the CARP virtual IPs for those interfaces. We navigate to **Firewall | NAT**, click on the **Outbound** tab, and for **Mode** we select **Manual Outbound NAT rule generation**, and then press the **Save** button. When the page reloads, we find the autocreated LAN to WAN1 rule and click on the **Edit** icon. In the **Translation** section, we change the **Address** to the WAN1 virtual IP for CARP (`10.1.1.1`). We also alter the description in the **Description** field accordingly. Then we click on the **Save** button. We repeat the process for WAN2, but we change the translation address to `10.2.1.1`. When we are done making changes, we click on **Apply Changes** on the main **NAT** page.

Finally, we must alter the DHCP settings. Since the DMZ is primarily for resources that need to be accessible from the Internet, such as the FTP server, and those resources tend to have static IP addresses, there's a good chance the DHCP server won't be activated on the DMZ; thus, we only have to be concerned with DHCP settings for the LAN. Thus, we navigate to **Services | DHCP Server** and click on the **LAN** tab. Under **Servers**, we set the first DNS server to the CARP LAN virtual IP. Under **Other Options**, we set **Gateway** to the LAN virtual IP as well. We set the **Failover peer IP** to the actual LAN IP address of the other firewall (`192.168.1.3`). Then we click on the **Save** button at the bottom of the page.

Now we have completed configuration on the primary firewall, but we must repeat the process on the secondary firewall. We need to create a **PFSYNC** interface and create the same virtual IPs on the secondary firewall. When we configure pfsync, we set **pfsync Synchronize Peer IP** to the LAN IP of firewall #1, or `192.168.1.2` (this IP should also be used in the first field under **XMLRPC Sync**). The NAT manual outbound rules should not have to be changed, because the primary server should overwrite the NAT settings later. The DHCP settings will have to be changed; the first DNS server and the gateway should be set to the LAN virtual IP, and the **Failover peer IP** should match the IP address of the primary firewall (`192.168.1.2`).

Once we complete configuration of the second firewall and connect it to the network (and to the first firewall), our CARP setup is complete, and all that remains is to verify the CARP group's functionality, using the steps outlined in the section on CARP configuration. We navigate to **Status | CARP** and see CARP is up and running. There may be a button on one of the firewalls labeled **Enable CARP**. If so, we will need to click it to get CARP to run. If it is working, we will probably still want to test it in some likely failure scenarios. If it is not working, then we need to do some troubleshooting; this is the topic of the next section.

Troubleshooting load balancing and CARP

There are several problems that may arise when implementing a load balancing pool or a CARP group. The two broad possibilities are:

- The load balancing pool or CARP group may not be functioning at all – for example, traffic might not be passing to or from the gateway or server pool, or the CARP firewalls may not be syncing
- The load balancing pool or CARP group is functioning, but performance is suboptimal – for example, the load-balancing pool is not balancing, or a gateway which is down is still being reported as active, or the state table on the CARP group is not synchronized, resulting in lost connections when the group fails over to the backup firewall

If load balancing or CARP is not functioning at all, then there is a strong possibility that it was improperly configured. Double-checking the configuration is recommended, and confirming the functioning of each element of the configuration is a good idea. For example, if your CARP configuration is not functioning, you should check to make sure the virtual IPs are configured properly, then make sure that the pfsync interface is working, and then make sure that the firewall rules are configured properly.

Improper firewall rule configuration is a common error with both load balancing and CARP setups. Keep in mind that rules are evaluated from the top down and the first matching rule wins. If you have a policy-based rule that is below an **allow [interface] to any** rule, then the rule will never be invoked. If the rule ordering appears to be correct, but you still suspect the rules may be responsible for your setup not functioning, then it might help to enable logging on the relevant rules and then examine the logs.

The system logs, which can be found at **Status | System Logs**, are often useful in troubleshooting CARP problems, since these logs indicate whether CARP syncing was successful and, if syncing failed, they will usually indicate a reason. If you see an XMLRPC sync error, navigate to **System | High Avail**. Sync, and make sure the backup firewall (or firewalls) do not have any information entered under **XMLRPC Sync**. Implementing **Synchronize Config to IP**, **Remote System Username**, and **Remote System Password** on backup firewalls will cause synchronization to fail.

For load balancing, you should ensure that the firewall rules are directing traffic to the load balancing pool (or that you have a floating rule that directs traffic to the pool). If the rules appear to be correct, you should navigate to **Status | Load Balancer** and confirm that every server in the load balancing pool is online.

If you are load balancing a pool of web servers, one good way to verify that load balancing is working properly is to use cURL. The cURL computer software project produces two products: libcurl and cURL. libcurl is a client-side URL transfer library supporting many different protocols, while cURL is a command line tool for sending and receiving files using the URL syntax. For example, invoke cURL at the command line like this:

```
curl www.somerandomsite.com
```

This command will result in the source code of the site being sent to the standard output (usually the Terminal window). When testing load balancing with cURL, you will want to retrieve a page that displays the actual IP address of the site so you know which server you are hitting. Running cURL consecutive times should result in you retrieving pages from different servers, unless you have sticky connections enabled and the interval between each cURL command being executed is less than the sticky connections timeout.

Sometimes there is a failure with gateway load balancing where there is a gateway group and one of the WAN connections no longer has Internet connectivity, but still remains active. This may be because the monitor IP is still responding, so pfSense thinks the connection is still good. If so, ensure that the monitor IP is correct.

When troubleshooting CARP issues, you may reach a point where you have to disable CARP on one or more firewalls. If so, remember that you can disable CARP at **Status** | **CARP (failover)** with the **Temporarily Disable CARP** button and the **Enter Persistent Maintenance Mode** button. The former disables CARP until a reboot, while the latter disables CARP in such a way that CARP remains inactive even after a reboot.

One thing you probably should consider before you implement a load balancing pool or a CARP group is whether implementing load balancing and/or CARP may break something. This is especially important if it might cause a resource upon which users on your network rely to become non-functional. For example, if you have a firewall that is directly connected to the Internet and you are running a VPN server on pfSense, if you place pfSense behind a router, this will break VPN functionality unless you make changes to your VPN server configuration.

Summary

In this chapter, we covered the basic concepts of redundancy and high availability, discussed the two basic forms of load balancing (gateway and server load balancing), and introduced CARP. We then covered pfSense load balancing and CARP in detail, and then covered an example network in which both load balancing and CARP are implemented. We then considered some basic troubleshooting tips.

In the next chapter, we will consider one of the primary functions of a firewall: routing. Our look at routing will include several routing-related topics, such as static routes and routing protocols.

8
Routing and Bridging

Routing and bridging are functionally very similar, but they have significant differences. Both allow nodes on different interfaces to communicate with each other. With routing, however, the different interfaces reside on different subnets. In order for a packet to reach a node on a different subnet, the router must determine if the destination subnet is a local subnet. If not, the packet is sent to one of the router's gateways. If the destination is a local subnet, then the packet will still not be forwarded unless the rules allow it. Bridges are just connections between network segments. Hubs and switches are examples of bridges; hubs send packets out to every other port on the device, while switches learn which nodes are attached to it and send packets only to their destination.

Routing is one of the primary functions of a firewall, and most of them do a good enough job at it to make routing seem transparent. With a minimum of configuration, pfSense is able to route traffic between your local network (LAN) and the Internet (WAN). Little additional configuration is needed to add other local networks. Firewalls, however, initially only know how to route traffic to the networks directly attached to them. For example, if you have a router connected to one of pfSense's internal networks, pfSense will not know how to route traffic to any nodes attached to the router unless you define a static route for it.

Bridging is not something that is done in typical network configurations. Normally, each interface is its own broadcast domain. It is often useful or necessary, however, to combine (or bridge) two interfaces so that they are within the same broadcast domain, similar to the way they would be if they were on the same switch. However, the difference between two bridged interfaces and a switch is that with bridged interfaces, firewall rules still apply. Thus, if you want traffic to pass between the two interfaces, you need to make sure the rules allow it.

This chapter will cover the following topics:

- Basic concepts
- Routing
- Bridging
- Troubleshooting

Basic concepts

This chapter deals with both bridging (which involves intra-network communications) and networking (which involves inter-network communications). Since bridging is the simpler concept, we will address this concept first.

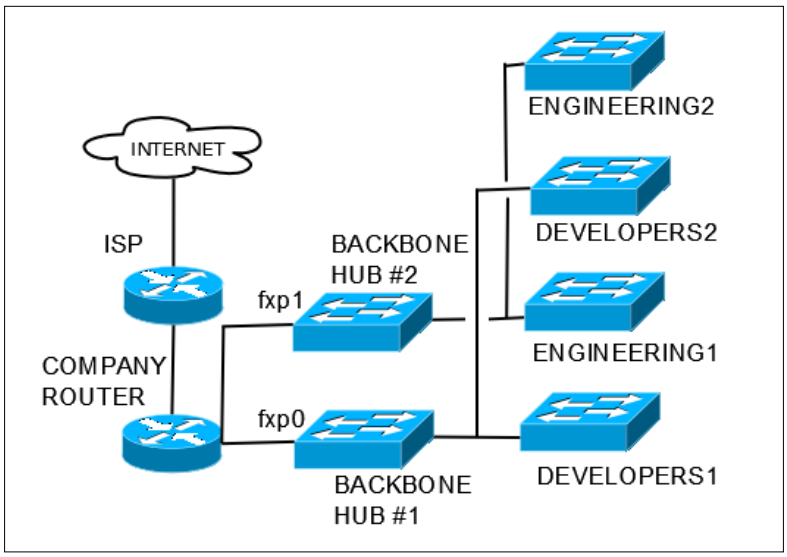
Bridging

Network bridging takes place at layer 2 (the Data link layer) of the OSI model. There are several different types of bridges. A simple bridge isn't much different than a repeater, except for the fact that the two network segments it connects may use different types of media (for example, one segment may use 100 Base-T cabling and the other may use 1000 Base-T) and the fact that bridges use a store-and-forward mechanism to forward packets, thus creating two separate collision domains.

A simple bridge forwards packets to the other side of the bridge, regardless of whether the destination host is on the other side. Bridges known as transparent bridges, however, are able to learn which side of the bridge hosts are on and use this information to decide whether or not to forward packets. Such bridges utilize a database that is initially empty. Packets are initially sent to both sides of the bridge regardless of the location of the target host. Gradually, however, a transparent bridge learns the location of hosts by observing which side of the bridge a hosts sends from, and as this information is entered into the database, the bridge will only forward packets to the other side of the bridge if the destination host is on the other side.

As an example of how a transparent bridge might work, imagine a bridge with three nodes: A, B, and C. The nodes A and B are on one side of the bridge, and C is on the other side. A begins a session with B. The bridge, not knowing initially that B is on the same side of the bridge as A, initially floods both sides of the bridge with B's packets. When B replies, the bridge *learns* that B is on the same side of the bridge as A, and traffic will not be forwarded anymore. If B begins a session with C, the bridge will initially flood both sides with B's packets again, not knowing where C is. Once the bridge learns C's location, traffic between B and C will be sent across the bridge.

Bridges, though somewhat limited, are, in the form of hubs and switches, still tremendously useful if we need to partition our networks. To demonstrate how this might work, let's revisit the example network from *Chapter 3*, *Working with VLANs*. You might recall that we had separate developers and engineering departments, and we wanted to partition them into separate networks. In that chapter, we implemented separate developer and engineering networks as VLANs, as this option seemed to provide the greatest amount of flexibility, scalability, and security. The following diagram shows how we might partition developers and engineering with stackable hubs or switches:



An example of using backbone hubs to partition a network.

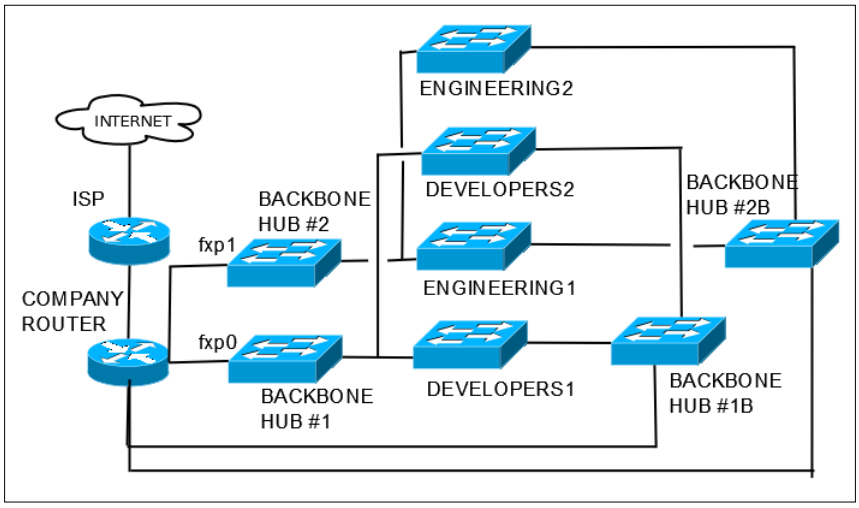
As you can see, the network has a multi-tier design. Instead of having **DEVELOPERS** and **ENGINEERING** on the same physical interface, but separate VLANs, in this setup **DEVELOPERS** and **ENGINEERING** are on separate physical interfaces (**fxp0** and **fxp1**, respectively). Each network gets its own backbone hub, and each floor gets its own hub (or switch), and thus each floor forms a separate network segment.

This configuration isn't quite as good as the VLAN configuration we used earlier, but it does have several advantages:

- It can be implemented with unmanaged switches instead of managed switches. Unmanaged switches are typically far less expensive.
- It provides communication with nodes in the same department on different floors. At the same time, by partitioning the network in this way, we ensure that traffic between two nodes on the same floor does not reach the backbone hub. Thus, it does not affect users on different floors, which would not be the case if each network shared a single switch.
- Giving each network its own backbone hub extends the total maximum distance between a node and the router. On a 1000BASE-T network, the maximum distance between devices is 100 meters. Thus, if a network has a single switch, and the switch connects to the router, then a node can be at most 200 meters from the router (100 meters to the switch and 100 meters between the switch and router). Adding a backbone hub extends the total possible distance between a node and the router by another 100 meters. Thus, it's like adding a repeater to the network.
- Another advantage of every network having its own hub is that, if a hub/switch fails other than one of the backbones, the backbone hub will detect the problem and disable the port on the backbone to which it is connected. Thus the malfunctioning switch will not affect the rest of the network, while nodes on the same floor will still be able to communicate with each other.
- This setup is somewhat scalable; to add another network segment to one of the networks, we could plug another switch into the backbone hub for that network.
- This setup is relatively secure; **DEVELOPERS** and **ENGINEERING** are on separate networks and won't be able to communicate with each other unless we create firewall rules to allow it.

Note that this setup still has its limitations. With VLANs, we could add another floor to our configuration simply by getting another managed switch and connecting it to one of the trunk ports on the previous floor's switch. In this setup, we can only add another floor if the total distance between the new switch and the backbone switch/hub is 100 meters or less. If not, we will have to add another backbone. Moreover, as you might recall, one of the advantages of VLANs is that we could make VLAN assignments based on MAC addresses, so we could move a node around, plug it into any available switch (as long as it's a managed switch), and the node will be assigned to the correct VLAN. With this setup, a node must be connected to a switch that is physically connected to the right interface for the network for the node to be assigned to the correct network. Still, it's a viable option if we don't anticipate much growth in our network and we don't have to move nodes around very often.

Note that our setup has a key weakness. The backbone hub for each network represents a single point of failure. For this reason, it is often desirable to introduce some redundancy into our network by adding backbones. The following diagram shows how this might work:

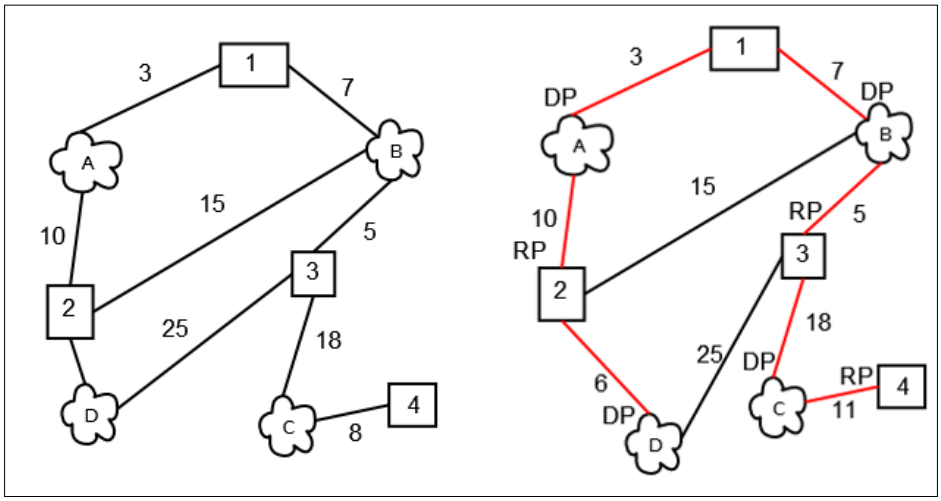


Adding a second set of backbone hubs creates redundancy, but now looping is a concern.

As you can see, we have added a redundant backbone hub to each network. This, however, creates a new problem. Assume that a node on **DEVELOPERS1** wants to start a session with a node on **DEVELOPERS2**. The switch for **DEVELOPERS1** generates two copies of each frame whose destination is the **DEVELOPERS2** node: one goes to **BACKBONE HUB #1** and the second to **BACKBONE HUB #1B**. Then each of these hubs sends the frame to **DEVELOPERS2**. If there are only two segments on each network, it won't be too bad, but what if we add another segment (**DEVELOPERS3**)? The backbone hubs will not know whether the destination resides on **DEVELOPERS2** or **DEVELOPERS3**, so each of them will send a copy to both switches, generating a total of four frames. The number of frames generated from the original frame thus can grow exponentially fast, crashing the network. Even if the backbones are intelligent devices that have the capability of learning where nodes reside (for example, a transparent bridge), initially they don't know anything, at least until the destination node replies, so this problem exists whether our backbone is a simple hub, a switch, or a bridge.

Since we want to introduce redundancy into our network, but we don't want our network to crash, we are in need of a solution, and the solution in this case is a spanning tree protocol. With a spanning tree protocol, bridges communicate with each other in order to determine a spanning tree, a subset of the original network topology with no loops. The spanning tree algorithm is run, and certain interfaces are disconnected to create the spanning tree. If at some point one of the network devices fails, the spanning tree algorithm can be run again to determine which interfaces need to be activated to create a new spanning tree.

Since implementing a spanning tree is something you are likely to do if you implement multiple bridges on your network, it might be instructive to describe how **Spanning Tree Protocol** (**STP**), the oldest spanning tree protocol for bridges, works. We will use the following network to illustrate the process:



A small network before and after the spanning tree calculation.

The figure on the left represents the network before the spanning tree calculation. As you can see, we have a network with several bridges (represented by boxes) and several network segments (represented by clouds). The numbers in the boxes are the bridge IDs. Assume that each network segment has a cost metric of 1. A spanning tree is formed as follows:

1. First, a root bridge is chosen. The root bridge is the bridge with the lowest bridge ID. In our example network, it is **Bridge 1**.
2. Second, each bridge determines the least-cost path to the root bridge. The cost of traversing a path is the sum of the cost metrics of each segment on the path. The port, which provides a path to the least cost path to the root bridge for each bridge, is designated the **root port** (**RP**).

3. Next, the bridges determine the least cost path from each network segment to the root bridge. The port connecting each segment to each path is designated as the **designated port** (**DP**) for that network segment.
4. Finally, each port that is not either a root port or a designated port becomes a blocked port, and thus is not part of the spanning tree.

The figure on the right of the preceding diagram illustrates the spanning tree after root ports and designated ports have been determined. The spanning tree is outlined in red. All ports not connected to a red segment are blocked.

Routing

Routing takes place on layer 3 (the Network layer) of the OSI model. Whereas switches are store-and-forward devices that use MAC addresses, routers are store-and-forward devices that use IP addresses. Routers (and layer 3 switches, which also act as routers but lack some of their advanced functionality) allow us to move data between networks. A router is responsible for maintaining tables of information about other routers on the network, and there are several different protocols available to enable a router to learn the topology of the network.

Often, the decision whether to use a hub/switch or a router is based on practical concerns. For example, in our hypothetical **DEVELOPERS/ENGINEERING** network, we could replace the backbone hubs with routers. Instead of dividing the networks into separate segments, now **DEVELOPERS1**, **DEVELOPERS2**, and **ENGINEERING1/2** are completely separate networks. A router can do everything a hub or a switch can, but it has some additional functionality, such as firewall capabilities and the ability to use the shortest path to a node. This can be useful in some cases. In our example network, we may want to allow traffic between **DEVELOPERS1** and **DEVELOPERS2**, but each floor may have a printer that should only be accessible to users on the same floor. We could create a rule that only allows users on **DEVELOPERS1** to access printers on **DEVELOPERS1**, and only allow users on **DEVELOPERS2** to access printers on **DEVELOPERS2**, something we couldn't do with switches.

There are two types of routing with which we are concerned:

- **Static routing**: A static route is a routing entry manually entered into the routing table. Sometimes, it is necessary to add a static route. For example, we may have a network that is not directly connected to pfSense, in which case pfSense will not know where to send traffic that has this network as its destination. A router that relies solely on static routes is not very fault-tolerant and cannot detect changes on the network. We thus seek something better, and that brings us to a second type of routing.
- **Dynamic routing**: As the name implies, this is implemented by dynamically configuring routing tables. The means by which this is done is through dynamic routing protocols such as **Routing Information Protocol** (**RIP**) and **Open Shortest Path First** (**OSPF**). Both of these protocols work on layer 3 of the OSI model. We can divide routing protocols into two categories:
    - **Distance-vector routing protocols**: This class of routing protocol requires that a router inform only its neighbors of topology changes. Paths are calculated using algorithms such as the Bellman-Ford algorithm, the Ford-Fulkerson algorithm, or DUAL FSM. This method is effective in finding the shortest path to another router. One of the problems with this method, however, is that some of the paths could be infinite loops, as with a distance-vector protocol; there is no way to know if a path includes the router itself. Two ways of dealing with this problem are split-horizon and split-horizon with poison reverse. Split-horizon simply prevents a router from advertising a route back to the router from which it learned the route. Thus if A is connected to B, and B is connected to both A and C, if the link between B and C is down, we don't have to worry about B using A's route to C (which runs through B), because A learned the route from B. Thus, we are spared from packets being caught in an infinite loop between B and A (B sends packets whose destination is C to A, A sends the packets back to B, and the process repeats, resulting in an infinite loop.) Another method is split-horizon with poison-reverse, in which a router advertises a route back to the router from which it learned the route, but sets the route metric to infinity. Examples of distance-vector protocols are RIPv1 and RIPv2, and **Interior Gateway Routing Protocol** (**IGRP**).

- **Link-state routing protocols**: This class of routing protocols involves every router constructing a map (in the form of a graph) of its connectivity to the network, not just its neighbors. Each router then independently calculates the best path from it to every other router, and these paths form the device's routing table. These protocols have some advantages over distance-vector protocols. Each router has a complete map of the network, so troubleshooting is much easier. Moreover, loops are less likely, since routers know which other routers a route runs through. Changes in the network tend to be detected more quickly. There are several disadvantages to link-state protocols as well. A database constructed of paths to other routers requires more memory and processor power than a distance-vector routing protocol table would, although the database's size can be minimized with careful design. Furthermore, the initial discovery process generates a great deal of network traffic, and can significantly degrade network performance during this period. An example of a link-state routing protocol is OSPF.

There are several protocols available for dynamic routing. These include:

- **RIP**: This is one of the oldest and one of the most popular distance-vector routing protocols. The original specification (RIPv1) used classful routing, and since the routing updates had no subnet information, all subnets had to be the same size within a network class. The distance between routers was called a **hop**, and RIPv1 allowed a maximum of 15 hops. 16 hops represented infinity (an unreachable route). There was also no support for router authentication. Updates were done through broadcast packets. RIPv2 improved upon the original protocol in many respects, introducing support for classless routing, and using multicasts to send the routing table. MD5 authentication was also introduced. The maximum hop count, however, remained at 15, in order to maintain compatibility with RIPv1. The latest version of RIP, **RIP next generation** (**RIPng**), supports IPv6 networking.
- **OSPF**: This is a link-state protocol that monitors the network for routers whose link state has changed (turned on, turned off, or restarted). It uses the link-state information to construct a topology map of the network.
- **IGRP**: A proprietary distance-vector protocol developed by Cisco to deal with the limitations of RIP. The maximum hop count is 255, and there can be multiple metrics for each route. Like RIPv1, it is a classful routing protocol, and all addresses within a certain address class must have the same subnet mask.

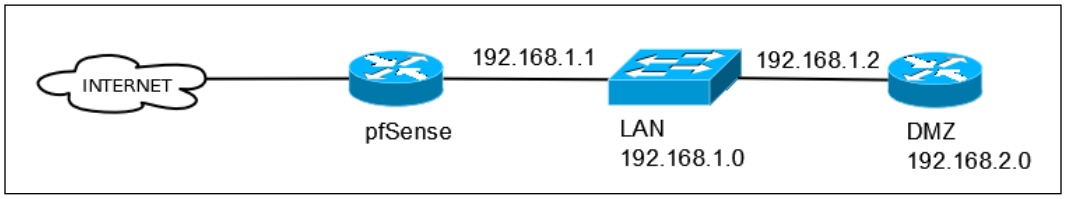
- **Enhanced Interior Gateway Routing Protocol (EIGRP)**: An update to IGRP that supports classless routing. In addition, rather than sending the entire routing table to neighboring routers, EIGRP only sends incremental updates. EIGRP started out as a proprietary protocol, but parts of it were converted to an open standard in 2013.
- **Border Gateway Protocol (BGP)**: A distance-vector protocol used for routing within an autonomous system. It uses TCP as its transport protocol.

Routing with pfSense

For the most part, pfSense does routing transparently. If a node on the local network is attempting to send a packet to a node on a local network, pfSense will send it to the right network, assuming that the network is directly attached to pfSense. If a node on the local network is attempting to send a packet to a remote network, pfSense will send it to a gateway. There are some special cases, however, and we will discuss them in this section.

Static routes

When we have local networks that are reachable through a router other than pfSense's default gateway, we need to configure a static route. A simple example of this situation is a router that is connected to a LAN network. The following diagram illustrates this scenario:

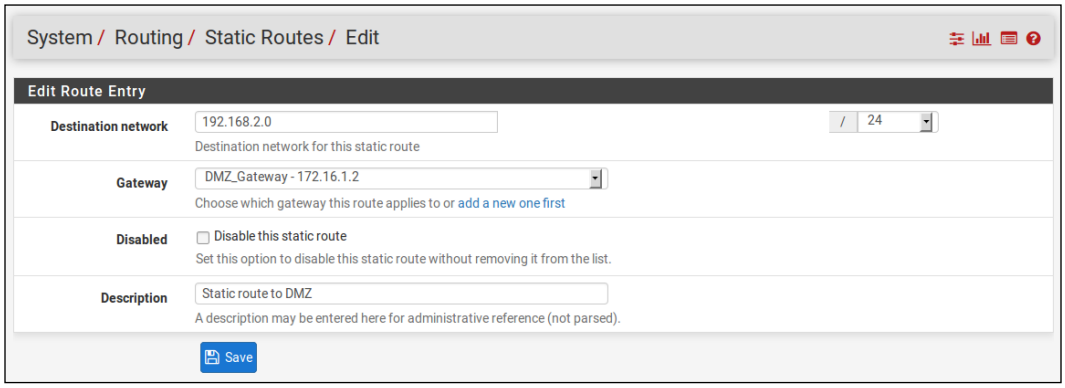


The DMZ router is not directly connected to the pfSense firewall and thus requires a static route configuration.

In this scenario, the LAN interface has a static IP address of `192.168.1.1`. The DMZ router is connected to the LAN switch and DMZ's WAN interface has an IP address of `192.168.1.2`. DMZ is not directly connected to pfSense, and the DMZ network is not reachable through pfSense's default gateway. Therefore, it is necessary to define a static route.

Setting up a static route for the `192.168.2.0` network involves first adding `192.168.1.2` as a new gateway, and then adding a new static route that has `192.168.1.2` as its gateway. To begin, first navigate to **System** | **Routing**. On the **Gateway** tab, click on the **Add** button. On the gateway configuration page, select the correct interface in the **Interface** drop-down box. This should match the interface on which the gateway resides (in our example, it would be **LAN**). You can type a name in the **Name** edit box. In the **Gateway** edit box, enter the gateway IP address (again, in our example, it would be `192.168.1.2`). Leave the **Default Gateway** checkbox unchecked. You may want to enter an IP for monitoring the gateway in the **Monitor** IP edit box; this way, the gateway can be marked as down if it does not respond to pings from this address. You can enter a brief description in the **Description** field; then click on **Save** and, on the main **Routing** page, click on the **Apply Changes** button.

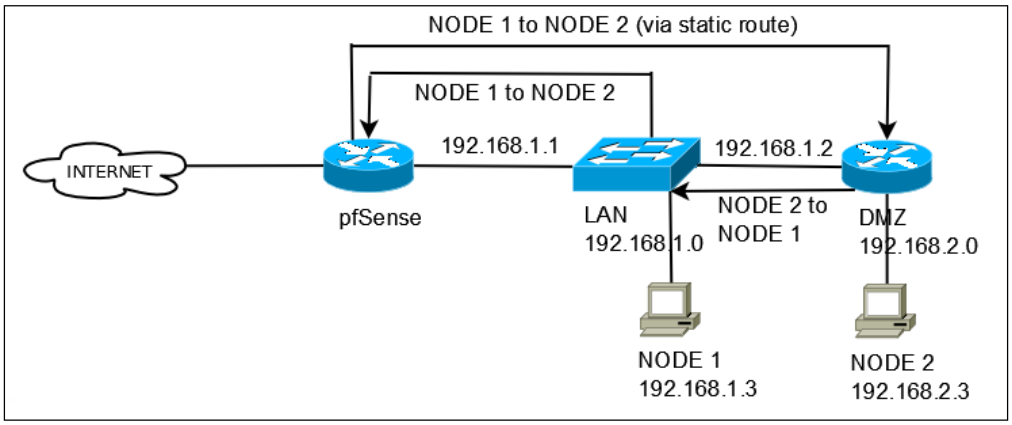
Next, click on the **Static Routes** tab and click on the **Add** button to add a new static route. In the **Destination network** edit box, enter the network that will be reached by this static route (in this example, it would be `192.168.2.0`). Don't forget to select the appropriate CIDR in the adjacent drop-down box (in this example, it would be **24**). In the **Gateway** drop-down box, select the gateway you created in the first step. You can enter a description in the **Description** field, and then click on the **Save** button.



Adding a static route in pfSense.

pfSense now knows a route to the DMZ router, but there is still a problem with our configuration. To illustrate this problem, imagine there is a node attached to the LAN switch. Assume that this node has an IP address of `192.168.1.3`. This node wants to establish a session with a node on the DMZ router (assume the destination node has an IP address of `192.168.2.3`).

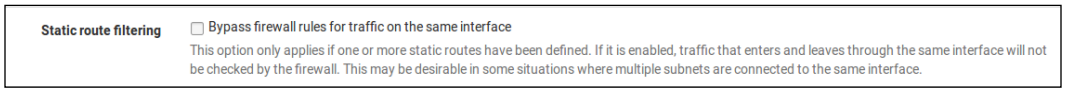
The LAN node's default gateway is `192.168.1.1` (the LAN interface IP), so it sends packets destined for the DMZ node to pfSense, which in turn uses the static route to send the packets to the DMZ network via the `192.168.1.2` gateway. pfSense also adds a state table entry for this connection. The DMZ node receives the packets from the LAN node, and sends a reply, which is sent out through the DMZ router's gateway (`192.168.1.2`). Since, the destination is on the LAN network, the return traffic is never filtered by pfSense, as pfSense only filters traffic between networks, not intra-network traffic. Since as far as pfSense is concerned, the connection was never completed, the entry gets dropped from the state table, and the connection between the LAN node and the DMZ node is dropped. The following diagram illustrates this asymmetrical routing:



An illustration of asymmetrical routing. pfSense requires a static route for DMZ traffic, but the DMZ router does not need a static route to reach pfSense.

Another scenario in which you may have a problem is with ICMP redirects, which are sent by a gateway when the gateway knows a more direct route to the destination host. If the sending node allows ICMP redirects, their routing table will temporarily add the new route. For example, **NODE 1** tries to establish a session with **NODE 2**. This request goes through its default gateway (`192.168.1.1`) and reaches the pfSense box. pfSense, realizing there is a more direct route to **NODE 2** via `192.168.1.2`, sends an ICMP redirect back to **NODE 1**, informing it of the more direct route, but sends the initial TCP `SYN` packet to **NODE 2** via the static route, and creates a state table entry for the connection. However, all subsequent communication between **NODE 1** and **NODE 2** takes place through `192.168.1.2`, and pfSense does not see this traffic, since it is intra-network traffic. The state table entry created for the connection expires and is deleted. If ICMP redirect learned route of **NODE 1** expires before the session ends, **NODE 1** will send the next packet destined for **NODE 2** to pfSense. Since it is not a packet establishing a new connection, pfSense will reject it, and the connection between **NODE 1** and **NODE 2** will be dropped.

There are two possible ways of dealing with these types of scenarios. The first is to navigate to **System | Advanced**, click on the **Firewall & NAT** tab, and, under **Firewall Advanced**, check the **Static route filtering** checkbox. If this option is enabled, and one or more static routes have been defined, then traffic that enters and leaves through the same interface will not be checked by pfSense. This applies to our example, since traffic between **NODE 1** and **NODE 2** enters and leaves through the LAN interface.

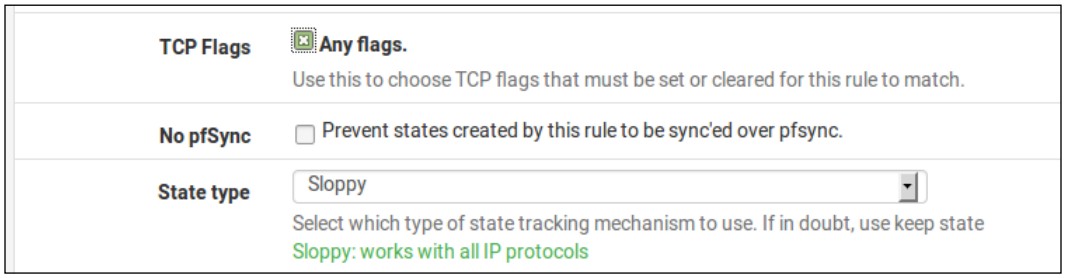


Checking this checkbox enables the static route filtering option.

Enabling this option will get the job done, but it will apply to all cases where traffic enters and leaves through the same interface, not just this one. We probably want a rule that only applies to interfaces that have static routes to them. In this case, we have to create two rules: a rule on the interface through which the static route passes, and a floating rule to cover the return traffic.

To create the first rule, navigate to **Firewall | Rules** and click on the tab of whichever interface the static route passes through (in the case of the example, **LAN**). Make sure the **Action** drop-down box is set to **Pass** and the **Protocol** drop-down box is set to **TCP**. **Source** should be set to match the setting in the **Interface** drop-down box (**LAN net**), since states only become an issue when the packets are sent and received through this interface. For **Destination**, choose **Single host or alias** in the drop-down box and in the adjacent edit box specify the IP address of the static route's gateway (in this case, `192.168.1.2`). Scroll down to the **Extra Options** section and click on the **Show Advanced** button.

In the **Advanced** section, set the **TCP Flags** option to **Any Flags** (the rule will match regardless of which TCP flags are set or not set). In the **State type** drop-down box, select **Sloppy** (this performs a less strict state match on return traffic). When you are done making changes, click on the **Save** button. This rule should be placed at the top of the firewall rules table for this interface to ensure it gets applied.



Creating a firewall rule to set the State type to Sloppy for traffic matching incoming traffic for the static route is another possible solution.

Next, you have to make a floating rule for the return traffic. Click on the **Floating** tab and click on the **Add** button. Make sure the **Action** column is set to **Pass** and in the **Interface** listbox make sure the same interface selected in the first rule is selected (in our case, **LAN**). The direction set in the **Direction** dropdown should be set to **out**, and **Protocol** should be set to **TCP**. Again, scroll down to **Extra Options**, click on the **Show Advanced** button, scroll down, set **TCP Flags** to **Any Flags,** and set **State type** to **Sloppy**. When you are done, click on **Save**, and on the main floating rules page, click on the **Apply Changes** button. You now have rules covering traffic in both directions.

There is another potential issue with this setup that we haven't addressed yet. Once we set up the static route and add appropriate rules to take into account the asymmetrical nature of traffic between **LAN** and **DMZ**, nodes on the two networks should be able to connect to each other. But if a node on **DMZ** tries to access the Internet, it will likely fail; because the default *allow LAN (or an alias with specifically defined networks) to any* rule only works for traffic whose source is the LAN net. While this result may be consistent with your intended policy (you may want to keep nodes on **DMZ** from accessing the Internet), if you want to allow this network to access the Internet, you will have to alter the Source setting on the default *allow LAN (or alias) to any* rule to allow traffic with the source as `any`.

Public IP addresses behind a firewall

Another scenario that is common enough to warrant discussion is when you have one or more public IP addresses on an internal interface. In this scenario, you will have at least two public IP addresses: one for the WAN interface of your firewall, and another for the internal interface. More commonly, you might have an entire subnet allocated to you by your ISP, but the steps discussed here apply whether you are assigned a single IP address or a subnet. This configuration has four steps:

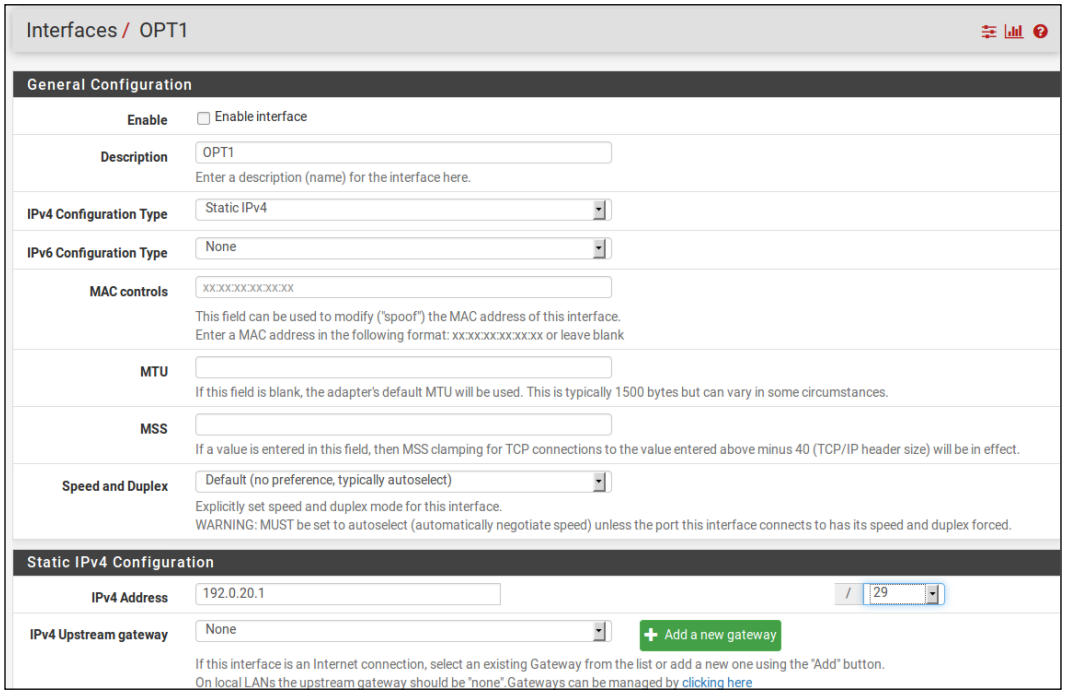
1. WAN configuration.
2. Internal interface configuration.
3. Outbound NAT configuration.
4. Firewall rule configuration.

As an example, assume that our ISP has assigned us several IPs: an IP for the ISP-provided router that is directly connected to the Internet, an IP for the WAN interface of pfSense, and a block of eight IPs (six of which are usable), which can be used by an interface that is internal to our network. The IP assignment is as follows:

IP address	Description
`192.0.10.10`	ISP router IP address
`192.0.10.11`	pfSense WAN interface IP
`192.0.20.0/29`	Public IPs on an internal interface

The first step is to set up the WAN interface, which you can do by navigating to **Interfaces** | **WAN**. Your WAN interface may be directly connected to the Internet, but more likely your ISP provided you a with router directly connected to the Internet. In this case, the IP address of this router will be your WAN gateway IP. If your ISP assigned an IP address for pfSense's WAN interface, choose **Static IPv4** (or **Static IPv6** if it is an IPv6 address) as your configuration type, and enter the assigned IP address in the appropriate edit box. Specify the upstream router's IP address in **IPv4 Upstream gateway** (and/or **IPv6 Upstream gateway**); you may have to use the **Add a new gateway** button if you have not yet added the upstream router as a gateway. If you haven't then press this button and enter the information in the corresponding dialog box.

Next, you need to configure the internal interface. If you haven't added it yet, navigate to **Interfaces | (assign)** and add an interface by selecting an available interface from the **Available network ports** drop-down box, and clicking on the **Add** button to the right of the dropdown box. Click on the name of the interface (for example, **OPT1**) and begin the configuration. If you have already added the interface, you can navigate directly to its configuration page.



Configuring the OPT1 interface for a range of public IP addresses.

On the interface's configuration page, you must check the **Enable** interface checkbox, and you can optionally change the name of the interface in the **Description** edit box. The configuration type should be set to **Static** (either **Static IPv4**, **Static IPv6**, or both). Enter one of the public IP addresses assigned by your ISP in the appropriate edit box. In our example, this would be `192.0.20.1/29`. We were assigned a `/29` subnet, which gives us six usable IP addresses (2^3 – 2 = 6). One IP address is assigned to the interface, and five IP addresses are available for internal hosts that require public IP addresses. When you are done making changes, click on the **Save** button at the bottom of the page and click on the **Apply Changes** button when the page reloads.

The next step is outbound NAT configuration. By default, outbound traffic on internal interfaces is translated to the WAN IP, and we want to disable this behavior. To do this, navigate to **Firewall** | **NAT** and click on the **Outbound** tab. Under **General Logging Options**, select the **Manual Outbound NAT** rule generation radio button, and click on the **Save** button. Now you should be able to add, edit, and delete the mappings. In the **Mappings** tab, look for an autocreated rule for the internal interface to which a public IP address has been assigned (for example, *Autocreated rule – OPT1 to WAN*). Since we don't want to map outbound traffic on this interface to the WAN IP, delete this rule. Then click on **Apply Changes** on the main **NAT** page.

The last step is firewall rule configuration. Since users on the Internet trying to reach the public IPs on the internal interface will be coming in through the WAN interface, at a minimum you will have to create a rule on the WAN interface to allow traffic to pass to one or more of the public IPs. For example, if we are hosting a web server on `192.0.20.2`, we create a rule on the WAN interface with **Action** set to **Pass**, **Protocol** set to **TCP**, **Source** set to **any**, and **Destination** set to **Single Host or alias** with the source address set to `192.0.20.2` and **Port** set to `80`. You will likely also want to create rules for the internal interface. For example, you'll probably want to block access to local networks, and possibly create a rule allowing access to the WAN interface, thus allowing connections to the Internet. You could also create a more restrictive rule (for example, only allowing outbound connections on port `80`).

Dynamic routing

Dynamic routing isn't natively supported in pfSense, but there are several third-party packages that provide dynamic routing capabilities. The following table lists those packages:

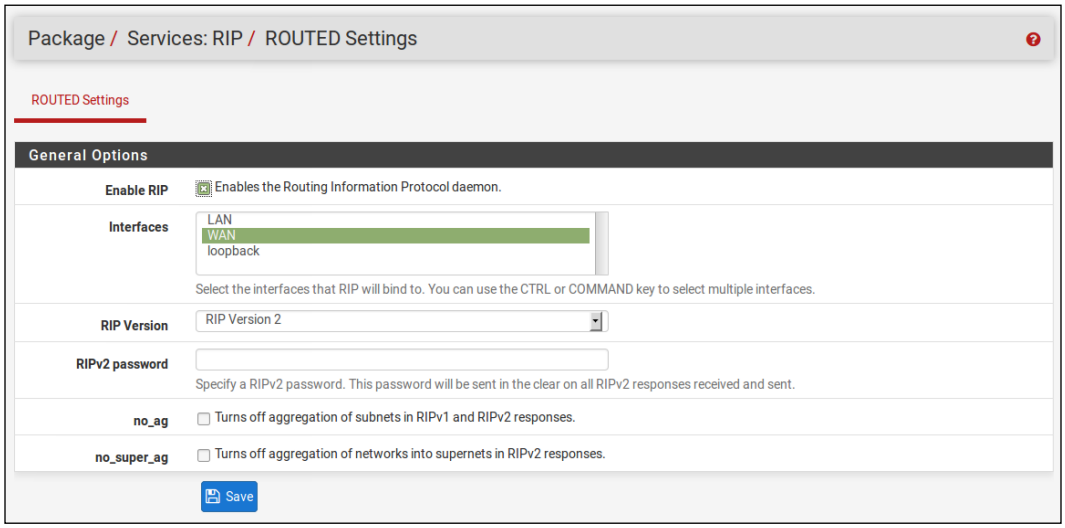
Package name	Routing protocol supported
OpenBGPD	BGP
Quagga OSPF	OSPF
routed	RIP v1 and v2

The Optimized Link State Routing Protocol had been available as a package, but it is no longer available as of version 2.3. Nonetheless, pfSense makes it possible to utilize both distance-vector protocols (OpenBGPD and routed) and link-state protocols (Quagga OSPF).

RIP

The `routed` package is actually just a frontend to the routed daemon for FreeBSD. To install routed in pfSense, navigate to **System | Packages**, scroll down to the table listing for routed, click on the **Add** icon for the package, and on the next page click on the **Confirm** button. Routed should install in about two minutes or less.

To begin using routed, navigate to **Services | RIP**. There you will find a number of configuration options for the RIP daemon. Checking the **Enable RIP** checkbox enables the RIP daemon. The **Interfaces** listbox allows you to select the interfaces to which RIP will bind, so any interfaces that provide a path to another RIP-enabled router should be selected. The **RIP Version** drop-down box allows you to choose between **RIP Version 1** and **RIP Version 2**; the RIP daemon will advertise and listen using whichever version is selected. The **RIPv2 password** edit box allows you to specify an RIP v2 password. The **no_ag** checkbox, if checked, turns off aggregation of subnets in RIP responses, while **no_super_ag** turns off aggregation of networks into super-networks. When you are done making changes, click on the **Save** button at the bottom of the page.



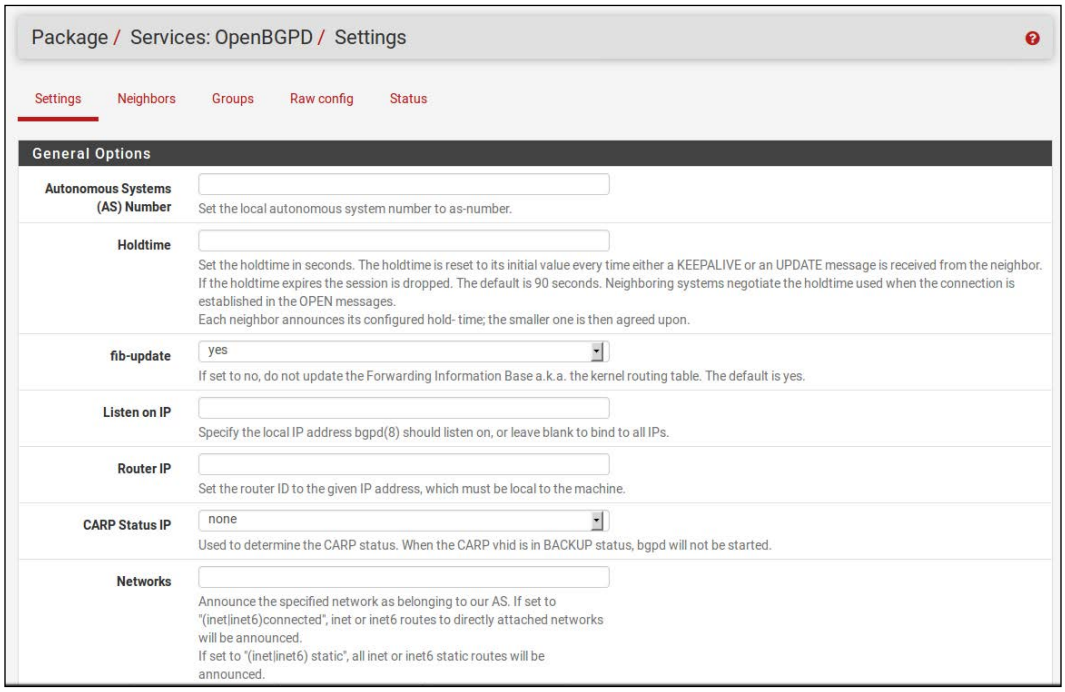
The routed configuration page.

OpenBGPD

OpenBGPD is a daemon that implements BGP. To install it, navigate to **System | Packages**, click on the **Add** icon next to the OpenBGPD entry, and click on the **Confirm** button on the next page.

You can begin OpenBGPD configuration by navigating to **Services** | **OpenBGPD**. You should see several configuration tabs. The first one is **Settings**. The **Autonomous Systems (AS) Number** edit box allows you to set the local autonomous system number. The **Holdtime** edit box allows you to define the time (in seconds) a session with a neighboring OpenBGPD router is kept active without receiving either a **KEEPALIVE** or **UPDATE** message from the neighbor. The **fib-update** drop-down box allows you to choose whether to update the Forwarding Information Base (the kernel routing table).

In the **Listen on IP** edit box, you can specify the local IP address the BGP daemon should listen on. Leaving this field blank causes the daemon to bind to all IPs. In the **Router IP** edit box, you can set the router IP (it must be local to pfSense). In the **CARP Status IP** edit box, you can specify the IP address for determining the CARP status. If your router is in **BACKUP** status for the interface to which the IP address corresponds, then the BGP daemon will not start. Finally, in the **Networks** edit box, you can specify a network to be announced as belonging to the AS. You can set this field to **(inet | inet6) connected** to announce all IPv4 or IPv6 directly attached networks, or **(inet | inet6) static** to announce all IPv4 or IPv6 static routes.



The Settings tab for OpenBGPD.

The next tab, **Neighbors**, allows you to add neighboring routers. Clicking on the **Add** button below the table to the right allows you to add another router. On the configuration page, you can enter a description in the **Description** edit box. The **Neighbor** edit box is where you enter the neighbor's IP address. In the **TCP-MD5** key edit box, enter the MD5 key for communicating with the peer. This does not work with Cisco routers, however; for Cisco routers, enter a value in the **TCP-MD5** password edit box. The **Group** drop-down box allows you to add the neighbor to a BGP group; such a group must be defined by adding a group at the **Group** tab. Finally, the **Neighbor** parameters setting drop-down box allows you to set parameters on the neighbor router. Some of the parameters have associated numeric values that can be set; if they do, the **Value** edit box will become enabled when they are selected. To add a parameter to set, click on the **Add** button; you can add more than one parameter this way. When you are done making changes, click on the **Save** button.

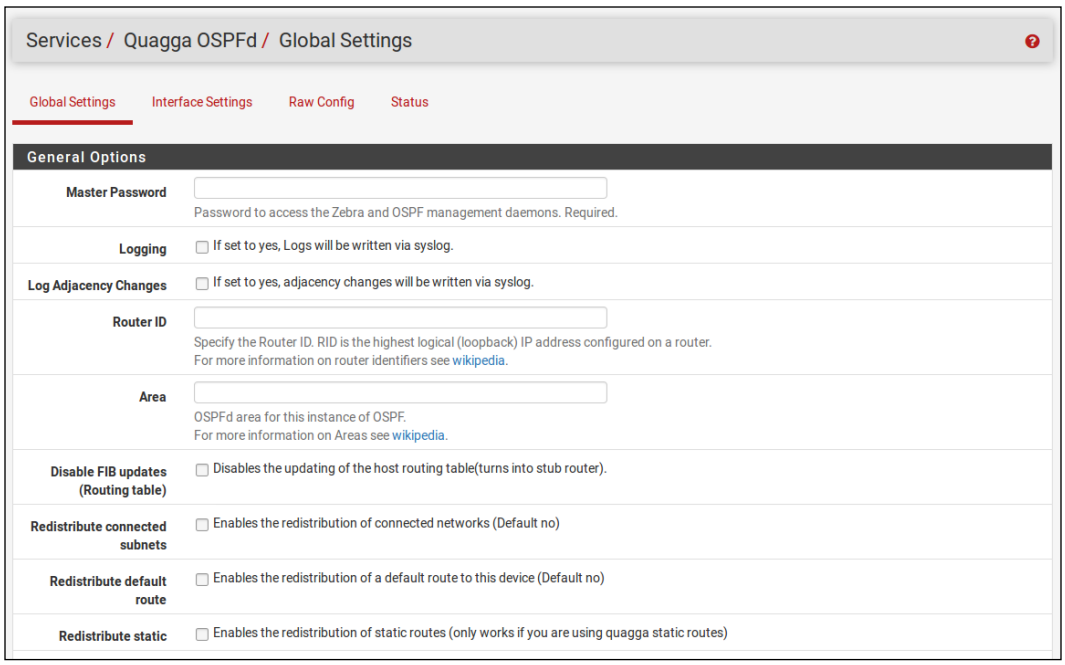
On the **Groups** tab, you can define groups into which neighboring routers can be placed. To add a group, click on the **Add** button below the table to the right. On the group configuration page, you must enter a name in the **Name** edit box. In the **Remote AS** edit box, you must enter an AS for the group. You can enter a brief non-parsed description in the **Description** edit box. Finally, there is a **Save** button for saving changes and a **Cancel** button for discarding changes.

The **Raw config** tab allows you to manually edit the `bgpd.conf` file. But be warned: whatever changes you make to `bgpd.conf` here will override any changes you make on the **Settings**, **Neighbors**, and **Groups** tabs. At the bottom of the page, there are two buttons: the **Save** button saves `bgpd.conf`, while **Cancel** discards any changes. Finally, the **Status** tab provides information about the OpenBGP daemon as it runs.

Quagga OSPF

Another way of adding link-state routing capabilities to pfSense is to install **Quagga OSPF**. This OSPF implementation is available as a package and can be installed via **System** | **Packages** in the same manner as the other packages described in this chapter. One warning included in the package description, however, is that Quagga OSPF is installed in the same location as OpenBGPD; installing both will break things. Therefore, it is recommended that you not install OpenBGPD if you have Quagga OSPF installed, and if you are going to install Quagga OSPF and you have OpenBGPD installed, you should uninstall OpenBGPD first.

Once you have it installed, you can navigate to **Services | Quagga OSPFd** and begin configuration. The first tab is **Global Settings**. You must enter the password for the Zebra and OSPFd daemons in the **Master Password** edit box. The **Logging** checkbox, if checked, will cause OSPF information to be written to the syslog. The **Log Adjacency Changes** checkbox allows you to have the OSPF daemon write adjacency changes to the syslog. The **Router ID** edit box is where you specify the router ID for this router. The router ID is customarily written in the dotted decimal format in which IP addresses are written (for example, `1.1.1.1`).



The Global Settings tab for Quagga OSPFd.

The router ID, although usually expressed in dotted decimal notation, does not represent an actual IP address. Moreover, expressing the router ID in dotted decimal notation is optional.

The **Area** edit box is where you enter the OSPFd area. What distinguishes an OSPF area is that it has its own link state database. Areas, like **Router ID**, are usually expressed in IPv4 (dotted decimal) format, but they do not have to be formatted in this way.

The **Disable FIB updates** checkbox, if checked, will turn the router into a stub router. Such routers only receive route advertisements within the **autonomous system** (**AS**).

Checking **Redistribute connected subnets** enables the redistribution of connected networks. The **Redistribute default route** checkbox, if checked, enables the redistribution of a default route to pfSense. Checking **Redistribute static** enables the redistribution of static routes if you are using Quagga static routes, whereas checking **Redistribute Kernel** enables redistribution of the kernel routing table and is required if you are using pfSense static routes.

The **SPF Hold Time** field is where you can specify the SPF hold time in milliseconds; this specifies the minimum time between two consecutive shortest-path-first calculations. The default value is 5 seconds. The **SPF Delay** field is where you can specify the SPF delay, also in milliseconds; this is the delay between receiving an update to the link state database and starting the shortest path first calculation. The default value is **1** second.

Checking the **RFC 1583 compatible** checkbox will cause decisions regarding AS-external routes to be evaluated according to RFC 1583. Without RFC 1583 compatibility, intra-area routes will always be favored over inter-area routes, regardless of the metric costs. Enabling RFC 1583 compatibility will cause OSPF to learn routes based on costs.

The next section allows you to generate rules for certain areas that will take precedence over any redistribute options otherwise specified on the page. You need to specify the subnet to route and the area ID, and for each entry you can disable redistribution and disable acceptance. Click on the **Add** button to add an entry. Finally, the **CARP Status IP** edit box allows you to specify the IP address used to determine the CARP status. This is similar to the identical setting in OpenBGPD, where, if the IP address specified has a status of **BACKUP**, then OSPF will be disabled. When you are done making changes, click on the **Save** button.

The **Interface Settings** tab is where you specify which interfaces will send and receive OSPF data. Click on the **Add** button below the table and to the right to add a new interface. On the **Interface Settings** configuration page there are several settings. The **Interface** dropdown is where you specify the desired participating interface. The **Network Type** dropdown allows you to specify the OSPF network type of the interface. The allowed values are:

- **Broadcast**: This is the most efficient way of making OSPF data available to a large number of routers. Running OSPF in broadcast mode requires the election of a **designated router** (**DR**) and **backup designated router** (**BDR**) with which all non-designated routers will form an adjacency. This keeps the number of adjacencies from becoming too large.
- **Non-Broadcast**: This router will be able to receive OSPF data, but won't make it available to other routers.

- **Point-to-Multipoint**: This sends OSPF data to a collection of point-to-point networks. It does not require having a DR or BDR.
- **Point-to-Point**: This sends OSPF data to one router at a time.

Note that non-broadcast and point-to-multipoint are the only two modes officially supported by OSPF (defined in RFC 2328); broadcast and point-to-point modes were defined by Cisco for use in **non-broadcast** (**NMBA**) networks.

In the **Metric** edit box, you can enter the cost for the OSPF interface. In the **Area** edit box, you can specify the area for this interface. You may enter a brief description in the **Description** edit box. Checking the **Interface is Passive** checkbox prevents the transmission and receiving of OSPF packets on the interface, thus making the interface appear as a stub network. Checking the **Accept Filter** checkbox will result in the OSPF daemon not adding routes for this interface subnet from OSPF into the routing table, which is helpful in multi-WAN environments. The **Enable MD5 password** checkbox, if checked, will enable the use of an MD5 password on this interface. If it is checked, you will have to specify a password in the next field.

In the **Router Priority** edit box, you can specify the router priority in a DR election. The default is **1**. In the **Hello Interval** edit box, you can specify the interval (in seconds) at which *Hello* discovery packets are sent out. The default is **10** seconds. In the **Retransmit Interval** edit box, you can specify the retransmit interval in seconds. The default is **5** seconds. Finally, in the **Dead Timer** edit box, you can specify the dead timer, which is the interval at which OSPF will check to see if a neighbor is still alive. The default is **40** seconds. There is a **Save** button for saving changes and a **Cancel** button to discard changes.

As with OpenBGPD, there is a **Raw Config** tab where you can edit OSPF config files manually. Finally, the **Status** tab aggregates information about the OSPF daemon as it runs.

Policy routing

Policy routing, also known as policy-based routing, refers to cases where the routing of traffic is based on criteria other than the destination network. A variety of criteria can be used to determine what route traffic takes, such as source or destination network, source or destination address or port, protocol, packet size, and many others. Basically, any criteria that can form the basis of a firewall rule can form the basis of policy routing. It is used often in multi-WAN setups, in cases where we want to direct traffic to a specific WAN interface based on certain criteria, but there are other cases where we might want to use policy routing as well.

You may recall in previous chapters we sometimes had occasion to create a rule that directed traffic to a gateway other than the default gateway. We can use this ability to choose a gateway to implement policy routing. The process can be summarized as follows:

1. Create one or more alternate gateways.
2. Create a firewall rule specifying certain criteria (the *policy* part of policy routing).
3. Select the gateway to which traffic matching the rule will be sent.

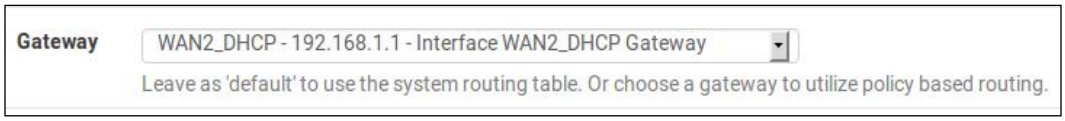
As an example, let's assume that we have a multi-WAN setup. **WAN** is our default gateway, but **WAN2** provides a gateway to a secondary Internet connection. We want to use **WAN2** for video streaming with the **Real-Time Transfer Protocol** (**RTP**) from the LAN network. The video streaming client will always be using port `554` to send video, and will utilize UDP only. We will also be using port `555` for the **Real-Time Control Protocol** (**RTCP**), which monitors the RTP session, but we do not need to re-route this traffic.

The first step is to navigate to **System** | **Routing** and confirm that **WAN2** is already configured as a gateway (on the **Gateways** tab). As you may recall from our previous discussion of gateway groups, WAN-type interfaces that are configured to get their IP address from an upstream DHCP server are automatically configured as gateways. If not, we must click on the **Add** button and create a **WAN2** gateway. The **Interface** dropdown should be **WAN2** and the interface's IP address should be entered in the **Gateway** edit box. You must also enter a name in the **Name** field; you may enter a brief description in the **Description** field as well. Click on **Save** when you are done making changes and click on **Apply Changes** on the main routing page.

Next, navigate to **Firewall** | **Rules** and click on the **LAN** tab. In cases where we need to implement policy routing on multiple interfaces and/or in both directions, then creating a floating rule would be more appropriate. Since we only need to redirect traffic in one direction and on a single interface, however, we will not create a floating rule. Click on the **Add** button on the **LAN** tab to create a new rule.

On the rule configuration page, keep the **Action** column as **Pass** and **Interface** as **LAN**. Change **Protocol** to **UDP**. Since the traffic's source will be the LAN net, choose **LAN net** in the **Source** drop-down box. Set **Destination port range** to `554`.

We have correctly set the matching criteria; now we just have to select a gateway. Click on the **Show Advanced** button, then scroll down the page and, in the **Advanced Options** section, the **Gateway** option should be third from the bottom. Select the **WAN2** gateway in the drop-down box. You could also use **Ackqueue/Queue** to assign the traffic to a high-priority queue if you have traffic shaping configured. You can enter a description in the **Description** field for your own reference (for example, `Policy routing for video streaming client`), and click on the **Save** button). On the main rules page, make sure the newly created rule appears in the table before the *default allow LAN to any* rule, as well as any other rule that would match the traffic. If it does not appear before these rules, drag it above them, then click on the **Apply Changes** button. We have now implemented a form of policy routing for our video streaming client.



Setting WAN2 as the default gateway.

This is but a single example of policy routing; there are many other real-world applications for such routing. Another example might be if we had a web cache proxy on another router, and directed all of our HTTP and HTTPS traffic on ports `80` and `443` to this router. Also, our example demonstrated how to use pfSense for policy routing, but in a real-world scenario such tasks might be delegated to a policy-based routing-aware level three switch.

Bridging with pfSense

In some cases, a single broadcast domain is formed by combining two or more interfaces. Two ports on your pfSense router act as if they are on the same switch, except that the firewall rules are used to control the traffic between the interfaces. This can be achieved using bridging, but you need to be careful to avoid loops when employing bridging As mentioned earlier, the primary means of preventing looping on bridges is to use the STP, which is employed by managed switches and routers (including pfSense).

It should be noted that, in the current version of pfSense, bridged interfaces are treated no differently than non-bridged interfaces. Therefore, firewall rules are applied to each interface that is a member of the bridge on an inbound basis. Older versions of pfSense had filtering turned off on bridges by default, and it had to be enabled to work. In the current version of pfSense, there is no way to selectively disable filtering on bridges; the only way to do so is to use the **Disable Firewall** checkbox in **System** | **Advanced**; this disables all packet filtering.

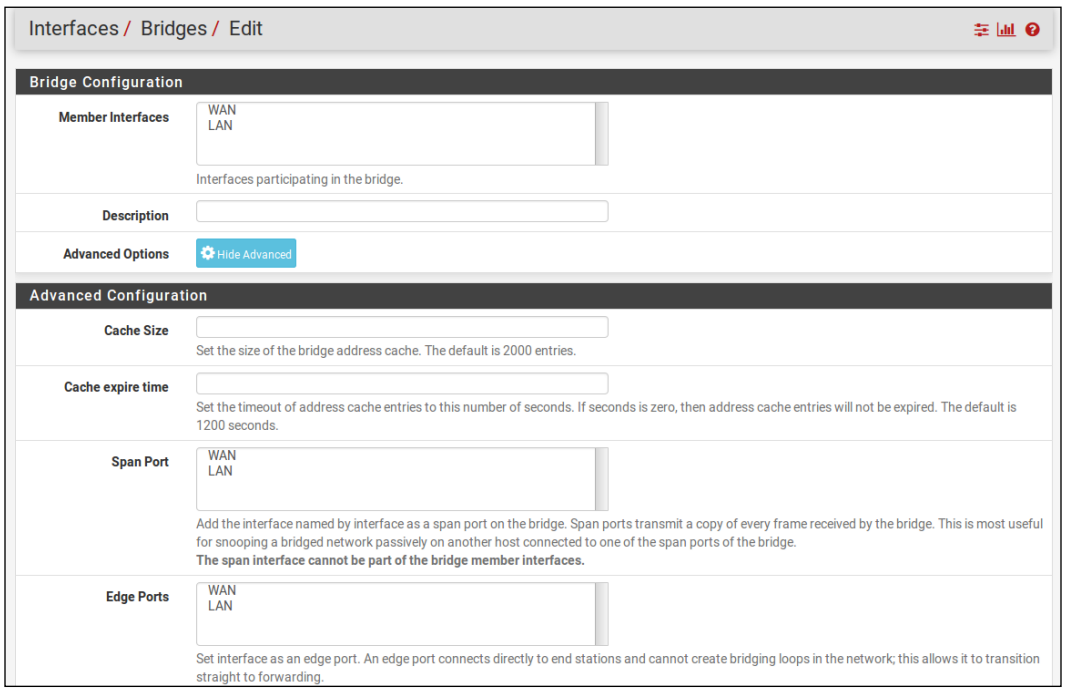
Bridging two internal interfaces in pfSense is fairly easy, but there are some issues that you need to address:

- One interface will have an IP address (the main interface) and one will have no IP address (the bridged interface)
- You need to make sure that the DHCP server is running only on the main interface and not on the one being bridged
- In order to allow DHCP traffic on the interface, you need to create a firewall rule on the bridged interface

Bridging interfaces

To bridge interfaces in pfSense, navigate to **Interfaces | (assign)** and click on the **Bridges** tab. On this tab a table displaying all configured bridges will be present. To add a new bridge, click on the **Add** button below the table and to the right.

On the **Bridge** configuration page, you must select at least two interfaces in the **Member Interfaces** listbox. These are the interfaces that will be bridged. You may also enter a brief non-parsed description in the **Description** edit box.



The Bridges configuration page, showing some advanced settings.

Setting up a bridge can be as simple as selecting the interfaces, but clicking on the **Show Advanced** button reveals a number of advanced options, many of them pertaining to spanning trees. The **Cache size** edit box allows you to set the size of the bridge address cache. The default size is **2000** entries. The **Cache expire time** edit box allows you to set the timeout (in seconds) of address cache entries. The address cache entries will not be expired if this field is set to zero. The default expire time is **1200** seconds.

The next setting is the **Span Port** listbox. If an interface is set as a span port, then that interface will transmit a copy of each frame received by the bridge. This can be useful for monitoring network traffic. Note that the span interface cannot be one of the bridge members.

Next is the **Edge Ports** listbox. An edge port is a port that is only connected to one bridge. As such, it cannot create bridging loops in the network, and thus can transition straight to the forwarding state. The **Auto Edge Ports** listbox will cause the selected ports to automatically detect the edge status, which is the default for bridge interfaces.

The **PTP Ports** listbox sets the selected interfaces as point-to-point links, which is necessary if the interface is to make a straight transition to forwarding. The **Auto PTP Ports** listbox allows you to select interfaces for which pfSense will automatically detect the point-to-point status by checking the **full duplex link** status. This is the default for bridged interfaces.

The **Sticky Ports** listbox allows you to mark an interface as sticky, which causes dynamically learned address entries from the interface to be treated as static once they enter the cache. These entries are never aged out of the cache or replaced, even if the learned address is seen on a different interface. Finally, the **Private Ports** listbox allows you to mark selected interfaces as private interfaces; these interfaces will not forward traffic to any other interface that is also private.

If you are going to use a spanning tree, you have to choose which STP to use. pfSense currently supports two protocols:

- **STP**: As described earlier, the original STP creates a spanning tree within a network of layer 2 bridges and disables links that are not part of the spanning tree, leaving a single path between any two nodes on the tree. This protocol was eventually standardized by the IEEE as 802.1D. STP is a relatively simple protocol, but it can take close to a minute for it to respond to a topology change.

- **Rapid Spanning Tree Protocol (RSTP)**: Standardized by the IEEE as 802.1w, RSTP reduces the convergence time for responding to a topology change to a matter of seconds, but at the price of some added complexity. STP has three bridge port roles – root, designated, and disabled – and RSTP adds two (alternate, which provides an alternate path to the root bridge, and backup, which is a backup or redundant path to a segment) for a total of five bridge port roles. This, and the fact that the number of switch port states is reduced to three (discarding, learning, and forwarding), helps decrease the convergence time.

You can set the STP options by scrolling down to the **RSTP/STP** section. Right above this section is the **Enable RSTP/STP** checkbox, which you must check to enable these protocols. Next is the **Protocol** drop-down box, where you can select the protocol. The **STP Interfaces** listbox allows you to select the interfaces on which STP/RSTP is enabled. The **Valid time** field allows you to specify how long a spanning tree configuration will be valid, while in the **Forward time** field you can specify a delay for forwarding packets when RSTP or STP is enabled. The defaults for **Valid time** and **Forward time** are **20** seconds and **30** seconds respectively. The **Hello Time** field allows you to set the time between broadcasting STP configuration messages (when STP mode is invoked). The **Priority** field is where you can enter the bridge priority, and the **Hold count** field represents the number of packets that will be sent before rate limiting is invoked.

The final series of edit boxes sets the spanning tree priority for each of the interfaces. You can set them to anything from 0 to 240 (in increments of 16); the default is **128**. You can also set the path cost for each interface. By default, the path cost is calculated from the link speed. However, you can manually set it to anything from 1 to 200000000. Set it to 0 to change it back to the default behavior. When you are done making changes, click on the **Save** button and, from the main **Bridges** page, click on **Apply Changes**.

If you haven't done so already, you should disable DNS on the bridged interface. You can do this by navigating to **Services** | **DHCP Server** (or **DHCPv6 Server/RA**), clicking on the tab for the bridged interface, making sure the **Enable** checkbox is unchecked, and clicking on the **Save** button. This will ensure that DHCP continues to function properly.

You also need to create a firewall rule on the bridged interface to allow DHCP traffic. To do that, navigate to **Firewall | Rules**, click on the tab of the bridged interface, and click the **Add** button. Normally, the **Source** field is set to a network or IP address. DHCP is a special case, because a client does not yet have an IP address. Thus, you must set the **Source** to `0.0.0.0` (choose **Single host or alias** in the **Source** drop-down box). Set the source port to `68`. In the **Destination** field, set the destination to `255.255.255.255` and set the destination port to `67`. In the **Protocol** drop-down box, select **UDP**. Make sure the **Action** drop-down box is set to **Allow**, click on the **Save** button, then click on **Apply Changes** on the main **Firewall** page. Make sure the new rule is at the top of the list of rules for the interface. Once this rule has been added, clients in the bridged segment should be able to receive DHCP leases.

Special issues

Bridged interfaces behave somewhat differently from non-bridged interfaces, and for that reason you may find there are some things that cannot be done with bridges. In other cases, you may have to make modifications in order to get a pfSense feature to work with bridging.

A captive portal requires an IP on each interface on which it is active; this IP address is used to serve the portal contents. But bridged interfaces do not have an IP address. Therefore, captive portals do not work with bridging.

Another situation where bridged interfaces can be problematic is with multi-WAN setups. This is because the nodes on the bridged interfaces often have a different gateway than pfSense, and the router that is the default gateway for these nodes is the only device that can direct traffic from these nodes. However, multi-WAN can still work on a pfSense firewall in the following situations:

- Nodes on the bridged interfaces have pfSense as their default firewall
- Multi-WAN is being used only on non-bridged interfaces

CARP also does not work well with bridging, and we can illustrate why it doesn't work well with a diagram. A standard CARP setup with two firewalls, one master and one backup, will have both firewalls connected to the switch for each internal interface (for example, **LAN** and **OPT1**). This is acceptable, as there is still only one path to each of the switches for a node. The two network segments are essentially merged into a single larger network when they are bridged. A loop is formed when two paths are created between the switches for each interface. For example, in a CARP setup without looping, a node on **LAN** has one path to a node on **OPT1** – through the master firewall. If the interfaces are bridged, however, there will be two paths to **OPT1** – the bridge on the master firewall and the bridge on the backup firewall.

If the interface switch is a managed switch, we can handle it better by implementing STP or RSTP on the managed switch. Unmanaged switches, however, have no way of preventing looping, and looping can essentially crash a network.

There is another way of using bridged interfaces with CARP, although it is somewhat inelegant. It entails the following steps:

1. Configure your master and backup firewalls as you would with any CARP deployment, taking care to ensure the interface assignments are identical on all firewalls. This should carry over to the bridged interfaces; the bridges should be copied so they are also identical.
2. If you are using managed switches, use STP/RSTP to ensure the port connecting the switch to the master firewall has priority over the port connecting the switch to the backup firewall. When you are done configuring the ports, confirm that the master firewall's port is forwarding traffic and the backup firewall's port is blocking traffic.
3. Another possible method is to use a script to ensure that a bridge on the firewall is up only if the firewall is designated as **MASTER**. This can be done by running the `ifconfig` command on the `carp0` interface, and checking the content of the command's output using a command such as `grep`. Once you have installed the script, you can run the script automatically using the cron daemon. You will likely want to run the script fairly often – for example, every 60 seconds – to ensure that, when there is a failover, it is as smooth as possible.
4. Yet another possible method is to use `devd` to catch when the actual CARP state transition happens. You can edit `/etc/devd.conf` on the master and backup firewalls so that the bridge (or bridges) is/are brought up and down whenever a CARP state transition is detected.

It is beyond the scope of this chapter to describe these procedures in detail. If you require to implement this solution on your network, you can find these methods described in a post at the official pfSense forum at `http://forum.pfsense.org/index.php/topic,4984.0.html`.

Bridging example

To provide an example of bridging, we'll use pfSense to bridge two interfaces – **LAN** and **OPT1**. We will also assume that there are downstream routers and, to prevent looping, we will run RSTP on the bridged interfaces. In this case, **LAN1** will be the main interface and **OPT1** will be the bridged interface. Assume that the LAN interface has an IP address of `172.16.1.1` and a subnet of `172.16.0.0`, and that the DHCP server is running on LAN.

To begin, we navigate to **Services** | **DHCP Server** and disable **DHCP** on **OPT1**. To do this, we uncheck the **Enable** checkbox, and click on the **Save** button. Now we can create our bridge. To do so, we navigate to **Interfaces** | **(assign)** and click on the **Bridges** tab. We click on the **Add** button on that page to add a new bridge.

Since we are bridging **LAN** and **OPT1**, we select these two interfaces in the **Member Interfaces** listbox. We also enter a brief description in the **Description** edit box (for example `LAN to OPT1 bridge`). If all we wanted to do is create a simple bridge, we would be done with configuration, but we want to run RSTP on the bridged interfaces, so we click on the **Show Advanced** button and scroll down the page. We check the **Enable RSTP** checkbox, and then in the **RSTP/STP** section we leave the protocol in the **Protocol** dropdown set to **RSTP**. In the **STP interfaces** listbox, we select **LAN** and **OPT1**. Assume also that, in spanning tree calculations, we want the LAN port to be favored over **OPT1**, so we scroll down and set **LAN Path cost** to `1` and **OPT1** to `1000`. Once we are done setting these values, we click on the **Save** button and then click on **Apply Changes** on the main **Bridges** page.

We have now configured the bridge, but we still must create a firewall rule on the **OPT1** interface to allow for DHCP traffic. Thus, we navigate to **Firewall** | **Rules** and click on the **OPT1** tab, then click on the **Add** button. On the **Rules** configuration page, we set **Protocol** to **UDP**. In the **Source** drop-down box, we select **Single host or alias** and type `0.0.0.0` in the corresponding edit box. We click on the **Display Advanced** button, and in the **Source** port range edit box, we enter `68`. For **Destination**, we also select **Single host or alias** and type `255.255.255.255` in the corresponding edit box. In the **Destination port range** edit box, we enter `67`. We enter a brief description (for example, `Allow DHCP traffic`), click on the **Save** button, and then click on the **Apply Changes** button on the main firewall rules page.

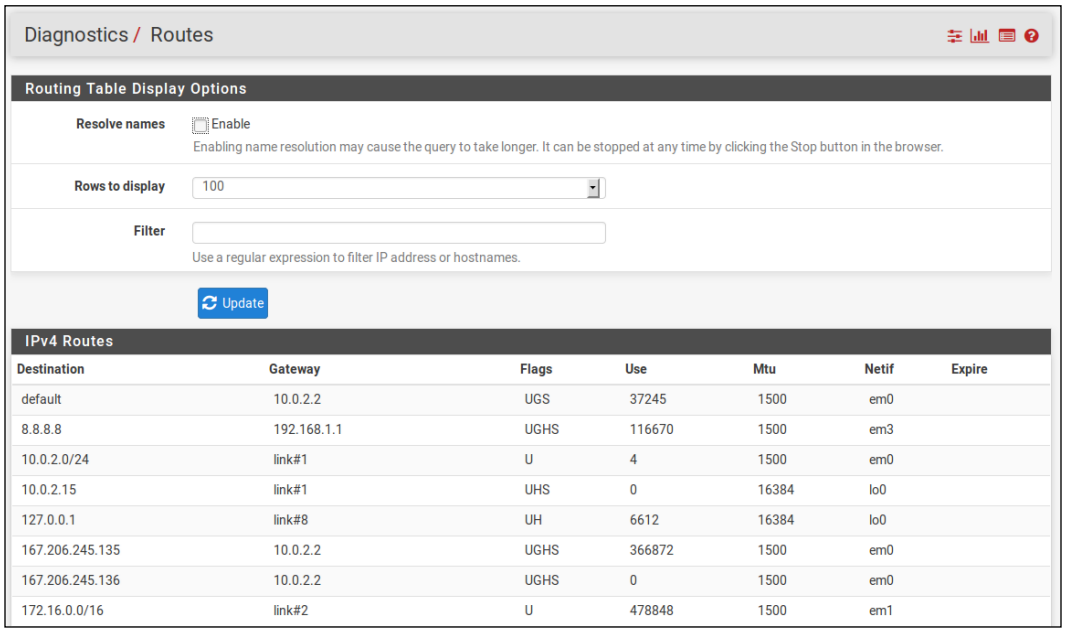
When we have confirmed that the newly created rule is at the top of the list of rules for the **OPT1** interface, our configuration is complete. Clients connecting to **OPT1** should now be able to receive an address on the `172.16.0.0` subnet from the DHCP server on LAN.

Troubleshooting routing and bridging

Once you have learned the fundamentals of routing and bridging and begin to implement them in your network, it is almost inevitable that you will encounter a situation where you need to employ your troubleshooting skills. In this section, we will consider how to troubleshoot both routing and bridging.

The pfSense routing table, which can be found by navigating to **Diagnostics | Routes**, is a good starting point for learning about which routes exist, how they are configured, and the number of times a route has been used. The table is divided into two sections, one for IPv4 routes and the other for IPv6 routes. Each entry in the table has several columns: **Destination** is the route's destination, **Gateway** is the gateway through which the route travels, **Use** is the number of times the route has been used, **Mtu** is the maximum transmission unit, **Netif** is the gateway's interface, and **Expire** tells us if the route has expired (which may be the case for a temporary route such as an ICMP redirect). There is also a column called **Flags** which informs us of the flags that are set for this route. The netstat man page provides a complete listing of the flags and what they mean, but some of the more common ones are:

- **U = RTF_UP**: Route is usable
- **G = RTF_GATEWAY**: Destination requires forwarding by an intermediary
- **H = RTF_HOST**: Host entry
- **S = RTF_STATIC**: Manually added entry



The pfSense routing table.

Since routing encompasses both static routing and dynamic routing, we will first consider static routing. Let's consider a simple example, using the network we considered in the section on static routes. As you might recall, we had a **DMZ** network with a subnet of `192.168.2.0` that was connected to the **LAN** network. Assume we also have an **OPT1** network directly connected to pfSense with a subnet of `192.168.3.0`. Thus, the **LAN** and **OPT1** networks are known to pfSense, while the **DMZ** network is only known to pfSense via a static route (the **DMZ** router's IP address of `192.168.1.2` is configured as a gateway). A node on the **DMZ** network with an IP address of `192.168.2.10` is unable to establish a session with a node on **OPT1** with an IP address of `192.168.3.10`.

First, we should consider obvious potential issues, such as an interface that is in shutdown mode, or a misconfigured interface. In this case, we begin at `192.168.2.10`. The router's WAN IP address is `192.168.1.2`, and the LAN-side IP address (not to be confused with the LAN network) is `192.168.2.1`. Therefore, the default gateway on `192.168.2.10` should be `192.168.2.1`. If it is not configured as such, we need to change it.

Now we need to confirm connectivity with the router, and we can do that by pinging `192.168.2.1` from `192.168.2.10`. If the ping fails, then the problem is likely a local issue, and the router is either malfunctioning or misconfigured. If we can ping the router, however, we can begin to look elsewhere.

You could use the `traceroute` command (or `tracert` in Windows) to trace the route to `192.168.3.10`, which might be the better solution in a more complex networking scenario, but since our network is fairly simple pinging the LAN address (`192.168.1.1`) will tell us a good deal. If the ping is unsuccessful, there are several possibilities:

- The LAN interface is down or is misconfigured
- The static route to the DMZ is misconfigured, and therefore pfSense doesn't know where to send the ping replies, or is sending them to the wrong address

One possible way of eliminating the first of these as a possibility is to try to ping `192.168.1.2` from pfSense, which we can do from the web GUI by navigating to **Diagnostics | Ping**. If we can ping the router in this manner, then we have proven that the LAN interface is up-and-running and that there is a path to the **DMZ** router from pfSense. If we can ping `192.168.1.2` from pfSense but not `192.168.2.1` or `192.168.2.10`, however, then there is a good possibility that the static route to the **DMZ** network is misconfigured.

If the pfSense firewall is reachable from `192.168.2.10`, however, then we may need to consider problems with the **OPT1** interface. If we can ping `192.168.3.10` from pfSense, then **OPT1** is up and running and there is connectivity with the node that `192.168.2.10` is trying to reach. If not, then we have isolated the problem to the **OPT1** network.

But what if pfSense can be pinged from `192.168.2.10`, and pfSense can ping `192.168.3.10`? If so, we have proven both nodes have connectivity with pfSense, and that the static route to the **DMZ** network is configured correctly. Keep in mind, however, that this is inter-network traffic, and therefore firewall rules apply. We navigate to **Firewall** | **Rules**, and click on the **LAN** tab, since DMZ traffic is coming in through the LAN interface. It is here that we discover the problem: the *Allow LAN to any* rule only allows traffic to pass if its source is the LAN subnet. Since **DMZ** traffic doesn't match this requirement, the rule doesn't apply and traffic to **OPT1** is not allowed to pass. We need to either modify this rule to allow traffic from the **LAN** interface to anywhere else to pass regardless of its source, or create another rule to allow traffic from the **DMZ** network (`192.168.2.0`) to pass.

Your network topology may be more complex than this, but the same basic troubleshooting techniques apply. Try to employ a divide and conquer approach; keep in mind that `ping` and `traceroute` are our friends and, if you are using Cisco switches, you have other command-line tools at your disposal, such as:

- `showip route`: This command shows, at the very least, the next hop, as well as other information such as the route metric, total delay, and reliability.
- `showip interface brief`: This command can be used to display a summary of the status information for each router interface.
- `showcdp neighbors`: This command can be used to display information about neighboring devices discovered during the **Cisco Discovery Process** (**CDP**). Adding detail to the command will cause it to display such information as network address, protocols, hold time, and the software version.

As our networks get more complex, static routing tends to prove inadequate and we opt for more elegant solutions, such as dynamic routing. But dynamic routing brings with it a whole set of issues that we have to consider. Keep in mind, however, that, just as with static routes, we have to consider the obvious issues such as an incorrect gateway setting, or a port being down. Another common issue is that often there is connectivity between routers, but one or more routers (or more likely, specific ports on the router) are not configured to use the routing protocol being used by the rest of the network.

Another potential issue is that, as your networks grow, your routers may require more CPU and RAM in order to hold routing tables and calculate dynamic routes. This can be avoided by choosing the right hardware for your network, and upgrading equipment as needed.

More likely, however, you may encounter a looping issue. This may be the case even if you are running STP or RSTP. A misconfigured or malfunctioning switch could still bring your network to its knees. You should make sure all devices are running the same version of STP (either legacy STP or RSTP, but not both). Once you have confirmed this, you can begin to look into other problems. If a switch recently went down, and you are having problems, perhaps the interval for calculating a new spanning tree is too long. It is also possible that there is an issue with convergence – the switch is not recognized as being down by all routers, hence the delay in incorporating this information into the spanning tree.

Another possibility is an incompatibility between versions of the routing protocol being used. For example, RIP v2 is backwards-compatible with RIP v1, but not all subsequent versions of routing protocols may be backwards-compatible with older versions. If you are running different versions of the same protocol, check your documentation to ensure they are compatible.

Bridging interfaces can cause a number of problems that require troubleshooting. There are several common problems with bridges:

- The bridge may not be forwarding traffic, or may only be forwarding traffic intermittently
- The opposite may occur – the bridge causes a storm of duplicate traffic, flooding the network
- After adding the bridge, the network seems unstable, and it might even cause pfSense to freeze

If the bridge is not forwarding traffic, then it's possible the bridge has not been created properly, or it was created but one or both interfaces is disabled. Since firewall rules still apply to traffic between interfaces in a bridge, there is the possibility that the firewall rules are blocking traffic, so you need to consult the firewall rules for interfaces participating in the bridge.

If the bridge is forwarding traffic intermittently, then there are several possibilities. One is that STP is running on the bridge, and there are so many network topology changes that the spanning tree has to be constantly recalculated. Another possible reason is that there are equipment outages. The bridge forwarding delay adds at least 15 seconds to even the briefest of outages.

If there is a storm of traffic, then the cause is almost certainly a loop. One of the ways of solving this problem is to manually determine where the loops are and break them. The preferable way, however, would be to run STP or RSTP, but running these protocols can sometimes create pitfalls, as outlined previously when discussing troubleshooting for static routes.

If the network is unstable and/or pfSense freezes, it is possible this happened because you are using one of the bridged interfaces for remote administration. There is also a possibility that it happened because users are relying on the bridged interfaces for essential network services, such as file sharing. Or it could be that it is a hardware issue with one or more of the bridged interfaces.

Bridging network interfaces usually is not a good idea, especially if there is a more elegant and straightforward solution available. But by employing some common-sense troubleshooting techniques, you should be able to get your bridged interfaces to work.

Summary

In this chapter, we introduced some basic concepts about bridging and routing. We noted that, while bridging and routing are conceptually quite different, they are often employed for similar purposes. As we later discovered, they create similar issues; for example, looping is an issue with both bridges and static/dynamic routes. We covered both static and dynamic routing, and introduced several packages that can be added to pfSense to add dynamic routing capabilities. We also covered bridging, discussed some cases where bridging issues can break functionality within pfSense, and also covered troubleshooting for routing and bridging.

We covered three packages in this chapter, but we have barely scratched the surface in considering the extent to which a stock pfSense installation can be enhanced through the addition of third-party packages. Fortunately, the next chapter deals exclusively with packages, and reading it should provide you with a good overview of what packages are currently available and how they can make your life easier.

9
Extending pfSense with Packages

We have already demonstrated how packages can be used to extend the functionality of pfSense in previous chapters. For example, we used the OpenVPN Client Export Utility to make OpenVPN client configuration easier. We also showed how routed packages can be used to make dynamic routing available with pfSense. These packages, however, only represent a fraction of what is available.

We can divide the packages available for pfSense into several categories:

- **Utilities**: These are packages that often do little more than provide the same functionality available with many stock Linux installations, but are nonetheless useful because they help provide solutions to unusual problems. For example, in the previous chapter we outlined a solution for eliminating loops in a CARP configuration with bridges that required the use of the `cron` utility. NoJ:\JUNK\New folder of them are just Linux command-line utilities, but most perform simple functions. For example, `Service_Watchdog` monitors pfSense for stopped services and restarts them. Packages such as `arping`, `cron`, and `sudo` fall into this category.
- **Network monitoring**: There are several utilities whose main purpose is simply to gather information on network usage. For example, you can use these utilities to find out who is on Facebook all day or who is using up 90% of your bandwidth downloading torrents. `darkstat`, `RRD_Summary`, and `softflowdare` are among the packages that fall into this category.

- **Intrusion detection and prevention**: These are network security utilities that monitor network activities and detect malicious (or potentially malicious) activities. Some of them merely notify the network admins of such activity, while some are capable of taking steps to prevent the malicious party from carrying out their attacks – for example, by blocking their IP address(es). Packages such as `nmap`, `snort`, and `suricata` fall into this category.
- **Proxies**: These are packages that provide the ability to cache web pages as well as block certain sites. Some of them have spam-filtering capabilities as well. pfBlocker, squid, and SquidGuard fall into this category.
- **Miscellaneous**: This category covers everything that does not fall into one of these categories, such as freeradius2 (an implementation of the RADIUS protocol), HAproxy (which provides additional load-balancing capabilities), and LADVD (for sending and receiving link layer advertisements).

It is impossible to do justice to all the packages available for pfSense within a single chapter, but we will cover the most important packages. The outline of this chapter is as follows:

- Basic considerations
- Installing packages
- Popular packages
- Other packages

Basic considerations

For the most part, you can begin installing and configuring pfSense packages without worrying too much about the effects they will have on your pfSense system. Nonetheless, some caution is called for when installing packages on mission-critical systems. First, having some basic knowledge of the technologies underlying the packages you want to install is helpful. For example, it would be ill-advised to install routed (the Routing Information Protocol daemon) without having some basic knowledge of how dynamic protocols work in general and how RIPv1 and RIPv2 work.

Beyond that, you should be mindful of the fact that installing additional packages may consume additional resources. Simple packages such as `arping` and `cron` can be installed on virtually any pfSense system without much consideration, but they are the exception to the rule. Installing and configuring a proxy server requires additional disk space to store cached web pages. Many packages require additional CPU resources. Any dynamic routing protocol requires CPU resources to calculate routes, as do many intrusion detection systems. If you had not foreseen installing such packages when you initially came up with the specifications for your pfSense box, you may have to adjust these specifications accordingly.

Installing and using packages without consideration of resource utilization can result in the following:

- CPU resources being taxed heavily, bringing pfSense to a crawl
- Disk space being completely used up, so that the DHCP server stops functioning, and no more DHCP leases are assigned
- pfSense cannot update, because there is insufficient disk space
- In some cases, insufficient disk space/CPU resources can render pfSense unusable, requiring a complete reinstallation of pfSense

All of these are outcomes we want to avoid in a production environment, so obviously some caution is justified when installing and configuring packages.

Furthermore, you should take into consideration the way packages interact with existing pfSense functionality and other packages. For example, some packages are installed in the same location as other packages and thus cannot co-exist with each other (OpenBGPD and Quagga OSPF come to mind). If you already have firewall rules in place upon which you rely, be aware that installing a proxy can affect outcomes, and traffic that was assumed to be blocked may no longer be blocked, as we will see when we cover squid later in this chapter.

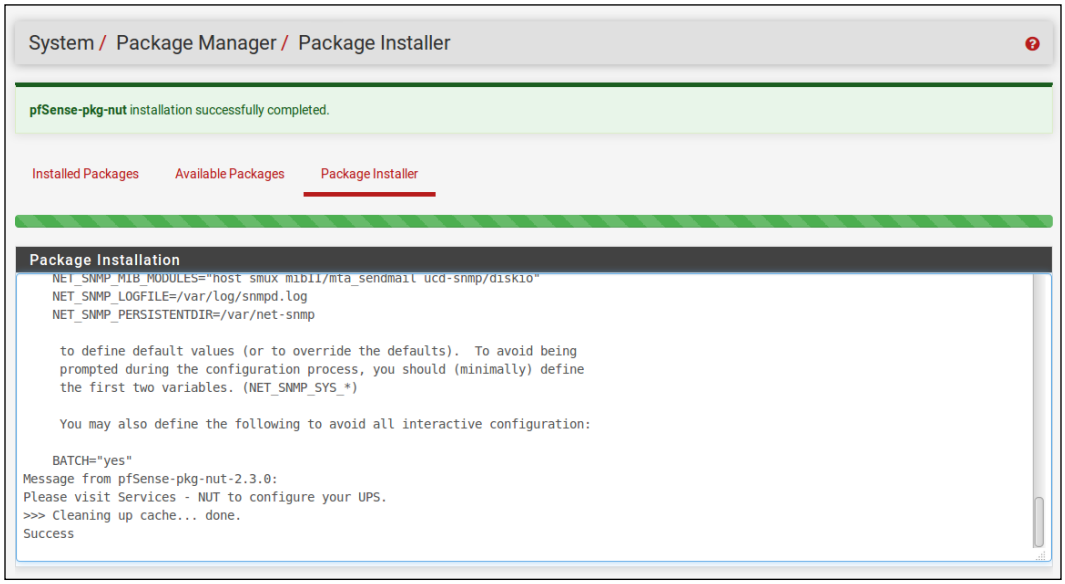
Installing packages

To install a package using the pfSense web GUI, navigate to **System** | **Package Manager** and click on the **Available Packages** tab. This tab contains a table listing all available packages. There is also a search box at the top of the page, so if you know at least part of the name and/or description of the package for which you are looking, you can type it into the search box. The adjacent drop-down box allows you to search the name, description, or both.

Each entry in the packages table has three columns: **Name**, **Version**, and **Description**:

- **Name**: The name of the package. This column also links to the package's official website, if one exists.
- **Version**: The current version of the package. This column links to the GitHub repository for the project, if available.
- **Description**: A brief description of the package, along with any notes and warnings. There is also a section in this column called **Package Dependencies**, which lists any dependencies the package has (each package is its own dependency, so there is at least one item listed for each package). Each dependency listed provides a link to the `www.freshports.org` entry for the package, which provides more information about it.

To install a particular package, find the package's listing in the table and click on the **Install** button to the right of its description. Once you do, you will be presented with a new page with a **Confirm** button. Click this button to confirm installation, and the package will install. Most packages should take no more than a few minutes to install.



Package installation within the GUI.

You can also install packages at the command line. To do so, type in the following at the command prompt:

```
pfSsh.php playback installpkg "some package"
```

This should result in the following command line output:

```
Starting the pfSense developer shell…


Installing package "some package" … Done.
```

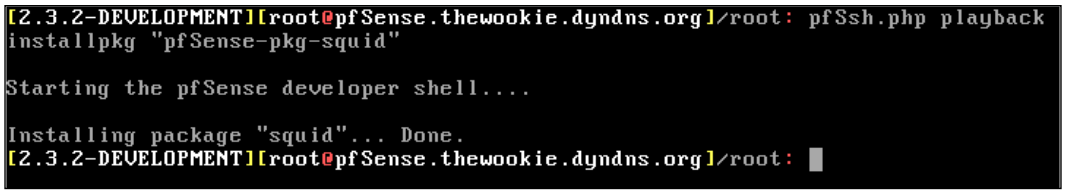
Thus it does not provide as much feedback about the status of package installation as you would get from installing packages within the web GUI, but it gets the job done, and you could easily write a script to install several packages at the same time to automate the process. To uninstall a package at the command line, type the following:

```
pfSsh.php playback uninstallpkg "some package"
```

And to list available packages, type the following:

```
pfSsh.php playback listpkg
```

The following screenshot shows the installation of Squid at the command prompt:



Installing Squid at the command prompt.

Once you have installed a package, it should appear on the **Installed Packages** tab of Package Manager. Each package's entry looks similar to its entry on the **Available Packages** tab, with a few significant differences:

- The **Name** column has an icon to the left of the name. A check mark icon indicates that the package is up-to-date, while circular arrows indicate that the package can be updated (in this case, clicking on the circular arrows icon updates the package).
- The **Actions** column has several options. Clicking on the trash can icon uninstalls the package; clicking on the arrows icon reinstalls the package, and clicking on the lowercase **i** icon (when available) redirects you to the package's website for more information.

Popular packages

It should be noted that with the release of pfSense 2.3, many packages have been dropped and others have been deprecated. The complete list of removed packages can be found at the official pfSense site at `http://doc.pfsense.org/index.php/2.3_Removed_Packages`. Some of the more significant packages to be either dropped or deprecated include the following:

- `HAVP antivirus`: No longer maintained; antivirus support can be found in Squid
- `ntop`: Deprecated in favor of `ntopng`
- `olsrd`: No longer maintained
- `Sarg`: Deprecated in favor of `lightsquid`
- `spamd`: No longer maintained
- `Zabbix-2 agent`, `Zabbix-2 proxy`: Deprecated in favor of Zabbix LTS

That said, the packages in this section not only still exist, but are among the most popular pfSense packages available.

Squid

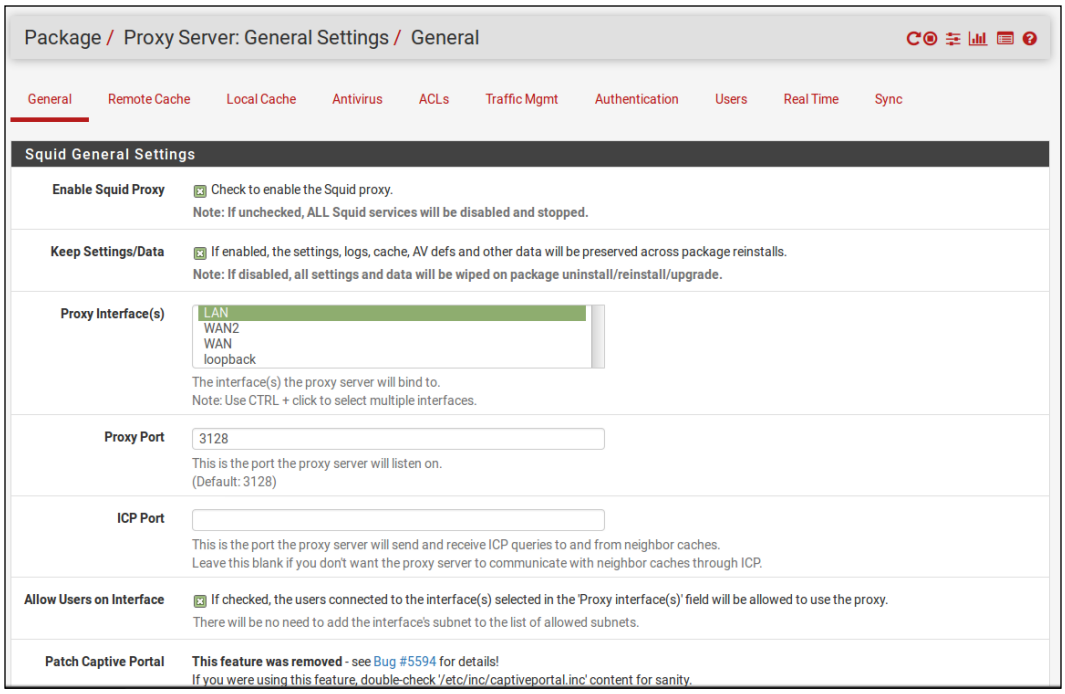
Squid is a caching and forwarding web proxy that was originally designed to run as a daemon on Unix-like systems (Linux, FreeBSD, and so on). Version 1.0.0 was released in July 1996, and as of today, Squid is capable of running on over a dozen different Unix variants. It is also capable of being used as a client-side cache (allowing the client to cache web pages or other content), and as a reverse proxy. If it is being used as a reverse proxy, it is used server-side to cache pages from one or more web servers.

Proxy servers were quite commonplace in the days when dialup Internet access was common. The reason for this is obvious. If you have at best a 56 kbps Internet connection, then it is faster to retrieve a local copy of a web page than it would be to acquire the remote copy of the page. As broadband Internet connections have become more commonplace, proxy servers have become less commonplace. If you have a fast enough Internet connection, using a proxy server might actually take longer than it would take to retrieve the page directly. The reason for this is obvious if you consider what happens when you request a web page through a proxy. First, you make a request to the proxy. Next, the proxy must check to see if there is a newer version of the web page available. If there is a newer version, it must retrieve the page, cache it, and send it to the client. If not, it will send a copy of the cached page.

If the page has been updated, then it is pretty obvious that the time required to retrieve the page is longer, since we end up eventually requesting the page from a remote web server, which we would have done if we had lacked a proxy, but now we have added another step to the process. But even if the page has not been updated, there is some overhead associated with checking to see if the page has been updated. Thus in many cases, using a web proxy is slower than directly accessing websites.

However, there are some situations where using a web proxy can be advantageous. Let's assume that 25 users on your network simultaneously request a web page (imagine a classroom-type situation, or perhaps one in which users are simultaneously reading online documentation for a product). If there is no proxy, then 25 separate requests for the same web page are consuming your bandwidth. If however, you have a web proxy and a cached local copy; the page can be sent to your network users at LAN speed instead of Internet speed, and without consuming any of your Internet bandwidth.

To begin Squid configuration, once it is installed navigate to **Services | Squid Proxy Server**. There are 10 separate tabs on this page, but the default tab is **General**. From this tab, you should be able to get Squid up-and-running. The **Enable Squid Proxy** checkbox controls whether the Squid proxy is active; checking it activates Squid. The **Keep Settings/Data** checkbox, if checked, preserves settings and data across package reinstalls. The **Proxy Interfaces** listbox allows you to select to which interfaces the proxy server will bind. The **Proxy Port** edit box allows you to specify on which port the proxy server will listen; the default is `3128`. The **ICP Port** edit box allows you to specify the port on which the proxy server will send and receive ICP queries to and from neighbor caches. By default such queries are not allowed. The **Allow Users on Interface** checkbox, if checked, will allow users connected to interfaces selected in the **Proxy Interfaces** listbox to use the proxy. The **Resolve DNS IPv4 First** checkbox enables forcing DNS IPv4 lookup first.



Squid's General tab.

Starting with version 1.1.9, Squid supports using ICMP **round trip time** (**RTT**) measurements to select the best location to forward a cache miss. Checking the **Disable ICMP** checkbox, however, disables the Squid ICMP pingerhelper, forcing Squid to rely on ICP reply times in determining where to forward cache misses. Finally, the **Use Alternate DNS Servers for the Proxy Server** edit box allows you to specify DNS servers other than the servers configured in the pfSense DNS forwarder/resolver.

If you check the **Transparent HTTP Proxy** checkbox, pfSense will forward all requests that have port `80` as their destination to the Squid proxy server without any additional configuration being necessary. In the **Transparent Proxy Interface(s)** listbox, you can choose the interfaces on which Squid will transparently intercept requests. The **Bypass Proxy for Private Address Destination** checkbox, if checked, will cause Squid to not forward traffic to private address space (`10.x.x.x`, `172.16.x.x` to `172.31.x.x` and `192.168.x.x`) addresses. The **Bypass Proxy for These Source Addresses** edit box allows you to specify IPs, networks, hostnames or aliases for which the proxy server will not be invoked if they are the source; instead, these hosts will be able to pass directly through the firewall. **The Bypass Proxy for These Destination IPs** edit box allows you to specify IPs, networks hostnames or aliases to which the proxy server will not be invoked if they are the destination.

The next section is **SSL Man In the Middle Filtering**. The **HTTPS/SSL Interception** checkbox, if checked, will enable SSL filtering. If this option is not enabled, then port `443` traffic will not be filtered by Squid even if Squid is being run in transparent mode. The **SSL Intercept Interface** listbox allows you to select the interfaces on which Squid will intercept SSL requests. The **SSL Proxy port** edit box allows you to specify the port on which the proxy will listen to intercept SSL. The **CA** drop-down box allows you to select a **Certificate Authority** (**CA**) to use when SSL interception is enabled. You should install the CA certificate as a trusted root CA on each computer on which you want to filter SSL to avoid an SSL error on each connection. The **SSL Certificate Daemon Children** edit box allows you to specify the number of SSL certificate daemon children to start. You may need to increase this if Squid is going to be used in busy environments. The **Remote Cert Checks** listbox allows you to select which remote SSL certificate checks to perform on SSL traffic. Finally, the **Certificate Adapt** listbox allows you to pass SSL certificate information on to users in order to allow the end user to make an informed decision on whether to trust a server certificate.

The **Enable Access Logging** checkbox, if checked, will enable the access log. This, of course, will use up even more disk space, so you should not enable this unless you have enough disk space. The **Log Store Directory** edit box allows you to specify where the logs will be stored. The **Rotate Logs** edit box allows you to choose how many days of log files will be kept. By default, rotation is disabled. The **Log Pages Denied By SquidGuard** checkbox, if checked, will make it possible for pages denied by Squid to be included in the logs.

The next section of the page is called **Headers Handling, Language and Other Customizations**. This section includes such options as setting the hostname and e-mail address to display on error pages, and the ability to suppress the Squid version string in HTTP headers and HTML error pages (this can be useful if you don't want end users to know which Squid version is being used). By pressing the **Show Advanced** button, we can see a number of advanced options. The **Integrations** listbox allows you to add Squid options added from packages such as SquidGuard. The **Custom ACLS (Before Auth)** listbox allows you to put custom options that will be added to the configuration before Squid processes the authentication **access control list** (**ACLs**) lines. Any options placed in the **Custom ACLS (After Auth)** line will be executed after the ACLs lines.

There are several other tabs with options. The **Remote Cache** tab allows you to specify remote Squid proxy servers from which web pages can be forwarded, which can help reduce network latency and incorporate redundancy into the network. Clicking on the **Add** button allows you to add configuration information about a remote server. Remote caches can be configured hierarchically. The three options for cache hierarchy are as follows:

- **Parent**: This is typically a more distant cache, such as your ISP's cache.
- **Sibling**: Closer caches are usually configured as siblings. You can have more than one sibling, and Squid will query them simultaneously.
- **Multicast**: You can cut down on network traffic by setting up a multicast address for a cache.

Note that the difference between a parent and a sibling is, to some extent, academic. When Squid queries more than one cache, it does not query each cache in sequence, but instead sends all ICP queries at the same time. Squid will get the page from the fastest-responding cache. The designation of a cache as a parent is significant because Squid will go to a parent cache when there is no response from a sibling cache; when there is no response from parent caches, by default Squid will attempt to go directly to the origin server.

Multicast can be used to increase the efficiency of cache requests. Unlike unicast (one-to-one communication) and broadcast (one-to-everyone on the subnet), multicast packets are one-to-many, and unlike broadcast packets, they can traverse network segments. This can be helpful in a scenario where multiple caches are being used. For example, if your cache hierarchy has four caches, to find out if a web page is cached a host would normally have to query each of the four caches, which consumes bandwidth. If you configure a multicast address, however, the host can just send one packet to the multicast address. Once the packet reaches the local subnet, each cache can pick up the packet and reply. This cuts down considerably on traffic between networks.

There are also several options for determining which cache is selected:

- **Default**: The first peer to respond to an ICP query is used as the source.
- **Round-robin**: This is a simple load balancing method. Squid maintains a counter for each cache. The cache with the lowest counter is used (and its counter is incremented).
- **Weighted-round-robin**: Parent caches are used in round-robin fashion, with each cache having its own counter, but caches with lower RTTs are given greater weight.
- **CARP**: Not to be confused with Common Address Redundancy Protocol, this **CARP** refers to **Cache Array Routing Protocol**. This method entails taking the URL requested and feeding it into a hash function that generates large numbers. These numbers all fit in a certain range, and by dividing the range by however many caches we have, we can send the request to one of the caches based on this hash value.
- **Userhash**: Similar to CARP, but the hashing is done based on the client `proxy_auth` or `ident` username.
- **Sourcehash**: The hash function takes as input the client source IP.
- **Multicast-siblings**: If the peer is the multicast type, you can use this option.

Also of interest on this page is the **ICP Settings** section. In the **ICP Port** edit box, you can specify a port to connect to the upstream proxy with the ICP protocol. The default value is **7**, which disables ICP communication. In the **ICP Options** drop-down box, you can select an ICP mode for the cache being configured:

- **no-query**: Do not allow ICP queries from this cache to the remote cache
- **multicast-responder**: The peer being configured is a member of a multicast group

- **closest-only**: For `ICP_IP_MISS` replies (the cache did not have the page requested), we'll only forward `CLOSEST_PARENT_MISSes` (parent with lowest RTT) and never `FIRST_PARENT_MISSes` (fastest weighted RTT)
- **background-ping**: Only send ICP queries to this neighbor infrequently

The **Local Cache** tab, as the name implies, controls settings for the Squid cache on the local firewall. The **Cache Replacement Policy** drop-down box allows you to select from amongst several cache replacement policy options:

- **LRU**: **Least Recently Used**; this algorithm discards the least recently used items first.
- **Heap GDSF**: **Greedy Dual Size Frequency**; this algorithm keeps smaller popular objects in the cache at the expense of larger popular objects.
- **Heap LFUDA**: **Least Frequently Used with Dynamic Aging**; this algorithm keeps popular objects in the cache regardless of their size. Thus, a large popular object may keep smaller objects out of the cache.
- **Heap LRU**: **Least Recently Used** algorithm implemented with a heap.

There are also several options on this page for controlling the hard disk cache size, as well as the cache location and the threshold at which cache replacement occurs (the point at which the cache replacement policy is invoked to evict certain items from the cache). You can also select the hard disk cache system, and you can force a wiping of the cache on this page if necessary.

The **Antivirus** tab allows you to use Squid in conjunction with **Clam Antivirus** (**ClamAV**). Clam AV is a free and open source antivirus program licensed under the GNU GPL. The **Enable** checkbox, if checked, enables ClamAV. The **Client Forward Options** drop-down box allows you to choose what client information to forward to ClamAV. The **Enable Manual Configuration** drop-down box allows you to select manual configuration mode, which causes ClamAV to ignore any options set on this tab; instead, it uses the configuration settings from the configuration files (`squidclamav.conf`, `c-icap.conf`, `c-icap.magic`, `freshclam.conf`, and `clamd.conf`). These configuration files can be edited from this page by scrolling down and clicking on the **Show Advanced** button.

The **Redirect URL** edit box allows you to specify a URL to send users to when a virus is found. If no URL is specified here, the default Squid/pfSense web GUI error URL is used. Checking the **Google Safe Browsing** checkbox enables Google Safe Browsing. The Google Safe Browsing database includes information about harmful websites, such as websites that may be phishing sites or sources of malware. It should be noted that this option consumes a significant amount of RAM. The **Exclude Audio/Video Streams** checkbox, if checked, will disable antivirus scanning of streamed video and audio.

The **ClamAV Database Update** drop-down box allows you to select the database update interval. If you are using Google Safe Browsing, the interval should be set to one hour. You can also click on the **Update AV** button to update the database now. You can also schedule updates with the cron daemon. The **Regional ClamAV Database Update Mirror** drop-down box allows you to select a regional database mirror. Finally, the **Optional ClamAV Database Update Servers** edit box allows you to specify additional ClamAV databases (separated by semicolons).

The **ACLs** tab is where you can configure the **access control lists** (**ACLs**) for Squid. The **Allowed Subnets** listbox is where you can enter subnets that are allowed to use the proxy. The interfaces specified on the **General** tab in the **Proxy Interfaces** listbox do not have to have their subnets added. However, if you want to add subnets other than the subnets of the interfaces selected in **Proxy Interfaces**, you can add them here.

The **Unrestricted IPs** listbox allows you to add unrestricted IP addresses and/or networks. These entries will not be subject to the access control directives specified on the **ACLs** tab. The **Banned Hosts Addresses** listbox allows you to enter IP addresses and/or networks that will not be allowed to use the proxy. The **Whitelist** listbox allows you to enter domains that will be accessible to users, while the **Blacklist** listbox allows you to enter domains that will be blocked for proxy users. The **Block User Agents** edit box allows you to enter user agents that will be blocked for proxy users. This field is useful if you want to prevent users on your network from using certain types of software (for example, torrent clients). The **Block MIME Types (Reply Only)** listbox allows you to enter MIME types that will be blocked for users who use the proxy. This is useful for blocking JavaScript, among other types.

The next section on the page is **Squid Allowed Ports**. The **ACL Safe Ports** edit box allows you to enter ports on which traffic will be allowed to pass, in addition to the default list of ports (the default ports are **21**, **70**, **80**, **210**, **280**, **443**, **488**, **563**, **591**, **631**, **777**, **901**, and **1025-65535**). The **ACL SSL Ports** edit box allows you to specify ports on which SSL connections will be allowed, in addition to the default list (**443** and **563**).

The **Traffic Mgmt** tab allows you to have some degree of control over your users' bandwidth consumption. The **Maximum Download Size** and **Maximum Upload Size** edit boxes allow you to set the maximum total download and upload sizes (in kilobytes) respectively. Of particular interest is the last section of the page: **Squid Transfer Quick Abort Settings**. By default, Squid continues downloading aborted requests that are almost done downloading. This may be undesirable in some cases (for example, slow links). Users may repeatedly request and abort downloads, thus tying up file descriptors and bandwidth. The parameters in this section allow you to control under what circumstances a transfer continues or is aborted. Thus we get the **Finish transfer if less than x KB remaining**, **Abort transfer if more than x KB remaining**, and **Finish transfer if more than x % finished** edit boxes.

By default, proxy users are not required to provide authentication, but if you want to require authentication, you can do so on the **Authentication** tab. The **Authentication Method** drop-down box allows you to select what form of authentication takes place. The default is **None**, but **Local** is supported (authentication through Squid), as well as **LDAP**, **RADIUS**, **Captive Portal**, and **NT Domain**. You can also specify subnets that will not be asked for authentication to access the proxy in the **Subnets That Don't Need Authentication** listbox.

If you selected **Local** as the **Authentication Method** on the **Authentication** tab, you will have to enter users via the **Users** tab. Click on the **Add** button to add a user. There are fields for **Username**, and **Password**, and a **Description** field where you can enter a brief non-parsed description.

The **Real Time** tab allows you to view information about Squid as it is running. You can view the access logs here, the cache logs, SquidGuard logs, and ClamAV logs. You can also filter the logs using the options in the **Filtering** section. You can specify the number of lines that will be displayed, and you can also filter the results by typing a regular expression into the **String filter** edit box.

The **Sync** tab allows you to do an XMLRPC sync of the Squid proxy to another firewall. There are three options in the **Enable Sync** drop-down box:

- **Do not sync this package configuration**: This is the default; no sync is performed
- **Sync to configured system backup server**: Sync to the CARP backup firewall (or firewalls)
- **Sync to host(s) defined below**: Allows you to specify the hosts to which Squid will sync

The **Sync Timeout** dropdown allows you to choose the XMLRPC timeout (the default is **250** seconds). The **Replication Targets** subsection allows you to specify the IP address and/or hostname and port of hosts to which Squid will sync. You can also specify a **Replication Protocol** (either HTTP or HTTPS), as well as an **Admin Password**. Click on the **Add** button to add a host. You also need to check the **Enable** checkbox to enable replication.

Issues with Squid

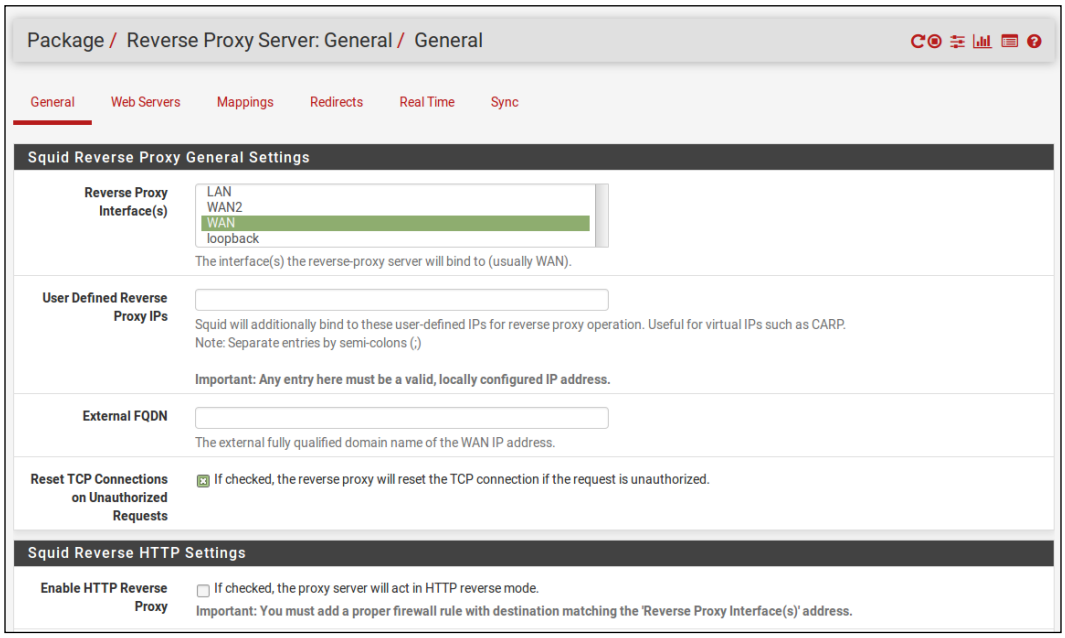
Although Squid is an extremely popular and useful package, there are some issues you should consider. First, Squid ACLs take precedence over any rules defined on the interfaces to which Squid binds. For example, assume that we have a rule for LAN to block access to a certain website. We subsequently install Squid and configure it to bind to LAN without configuring any of the ACLs (including the blacklist). Access to the site is not blocked by Squid. Once Squid is enabled, access to the blocked website will be possible, even though there is a firewall rule blocking the site.

The solution, of course, is to navigate to **Services | Squid Proxy Server**, then click on the **ACL** tab, and add the website to the **Blacklist** listbox. The **Black** listbox also accepts regular expressions, so if you want to specify a wildcard, you could do that as well. Since Squid makes it easier to block multiple websites, this should not be a problem. But if all you want to do is block a few websites, you might find that using firewall rules is the better solution, as it doesn't require the overhead of running a proxy server. You could even block multiple websites using aliases, and block them on multiple interfaces using floating rules.

Squid as a reverse proxy server

As mentioned earlier, Squid can also be used as a reverse proxy server. In this situation, Squid is caching content for one or more web servers, reducing the load on the servers. You can configure the reverse proxy server by navigating to **Services | Squid Reverse Proxy**. There are several tabs, but the default tab is **General**.

The first setting is the **Reverse Proxy Interfaces** listbox, which allows you to select one or more interfaces to which the reverse proxy will bind. Since the reverse proxy will be serving content to remote users, you probably want to bind it to **WAN** (or possibly to multiple WAN-type interfaces). In the **User Defined Reverse Proxy IPs**, you can specify user-defined IPs to which Squid will bind. You also need to specify the external fully qualified domain name of the WAN IP address in the **External FQDN** edit box. You can use Squid as a reverse proxy for both HTTP traffic and HTTPS traffic, but you have to enable them separately; there are two separate checkboxes on the page: **Enable HTTP Reverse Proxy** and **Enable HTTPS Reverse Proxy**. You can also specify different HTTP and HTTPS ports from the defaults of `80` and `443`.



Squid Reverse Proxy Server General Settings.

You will need to specify at least one web server for use with the reverse proxy; you can do that by clicking on the **Web Servers** tab and clicking on the **Add** button. The configuration page requires you to enter a name to identify the web server on Squid (**Peer Alias**), the IP address of the server (**Peer IP**), the port (**Peer Port**), and the protocol (**Peer Protocol**). You may also enter a brief description in the **Peer Description** edit box. You need to check the **Enable This Peer** checkbox to allow the peer to be available for reverse proxy configuration.

If you have several web servers for the same website, you can use the **Mappings** tab to organize them into a single group. To do so, click on **Mappings** and then click on the **Add** button. You will have to enter an identifier for Squid (**Group Name**). Then you will have to select one or more already defined peers in the **Peers** listbox. The **URI (Uniform Resource Identifier)** edit box is where you specify the regular expression that will match this group. For example, if you type `*.mydomain.com`, Squid will direct traffic for `www.mydomain.com`, `subdomain.mydomain.com`, and `old.mydomain.com` to the peers specified in the **Peers** listbox. You can also enter a brief description in the **Group Description** edit box.

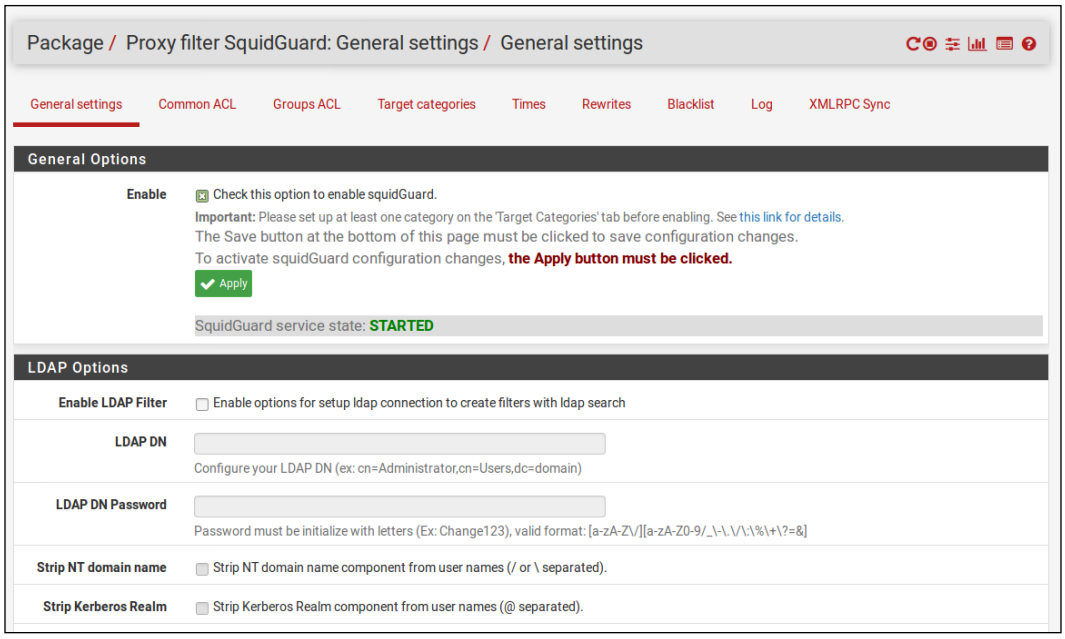
If you need to redirect one or more domains to a different URL, you can do so at the **Redirects** tab. To do so, click on the **Redirects** tab and then click on the **Add** button, which will bring you to the redirect configuration page. You need to specify a Squid identifier for the redirect (**Redirect Name**), the protocol on which to redirect (**Redirect Protocol** - you can select HTTP, HTTPS, or both). In the **Blocked Domains** edit box, you enter the domains to be redirected. To add more than one domain, type the domain in the edit box, click on the **Add** button, and repeat the process for as many domains as you need to redirect. You can use the **Path Regex** edit box if you don't want to redirect all traffic to the domain(s) but want to redirect a path or paths. As the name implies, the box will accept any regular expression. Enter `^/$` here to match the domain only. You must also enter the URL to which traffic will be redirected in the **URL to Redirect To** edit box. You may also enter a brief description in the **Redirect Description** edit box.

The **Real Time** and **Sync** tabs are similar to the **Real Time** and **Sync** tabs on the **Squid Proxy Server** page; therefore, we will not go into detail on them here. Suffice it to say that the **Real Time** tab displays real-time data from the Squid reverse proxy logs, and the **Sync** tab allows you to perform an XMLRPC sync of your reverse proxy server to either a CARP backup firewall/firewalls or to an arbitrarily defined list of hosts.

SquidGuard

If all you want is a high-speed URL filter and redirector, you might consider installing SquidGuard instead of Squid. With SquidGuard, you can use your own custom blacklist, or use a third-party blacklist. SquidGuard also allows for scheduling, so you can block/unblock sites during certain hours.

To configure SquidGuard, once it has been installed, navigate to **Services | SquidGuard Proxy Filter**. The default tab is **General settings**. Checking the **Enable** checkbox enables SquidGuard. There is also an **Apply** button; to activate configuration changes, you must click this button.



The SquidGuard General settings page with SquidGuard started.

If you are running **Lightweight Directory Access Protocol** (**LDAP**) on your network, you can use **LDAP search** to create filters. You can enable this by checking the **Enable LDAP Filter** checkbox. You must specify your LDAP **Distinguished Name** (**DN**) in the **LDAP DN** field, and a password in the **LDAP DN Password** field. You can also choose the **LDAP version** (either Version 2 or 3). There are also a number of logging settings in the **Logging options** section.

The **Clean Advertising** checkbox, if checked, will display a blank GIF image instead of the default block page if an image if blocked. In the **Blacklist** options section, you can specify a proxy in the **Blacklist proxy** edit box, and you can specify the path to the blacklist in the **Blacklist URL** edit box. The blacklist should be tarred and gzipped (`blacklist.tar.gz`). You must check the **Blacklist** checkbox to enable blacklists.

The **Blacklist** tab is where you can specify the blacklist. In order for this setting to work, you must have already enabled blacklists on the **General settings** tab. Type the FTP or HTTP path to the blacklist archive into the edit box, and then click on the **Download** button. The **Restore Default** button can be used to revert to the default blacklist.

The **Common ACL** tab is where you configure access control lists. The **Target Rules** edit box is where you enter rules which govern SquidGuard's behavior. Click on the plus icon next to **Target Rules List** and select every rule you want to allow or block. You can also add a message to **Proxy Denied Error Field**; this message will be displayed if the proxy blocks access to a resource. The **Use SafeSearch engine** checkbox, if checked, enables the protected mode of search engines such as Google, Yahoo and Bing to limit access to mature content. The **Log** checkbox can be checked to enable logging for the ACL.

The **Groups ACL** tab allows you to define different ACLs for different users. To create a new rule, click on the **Add** button on this tab. The **Disabled** checkbox, if checked, disables the ACL rule. You must enter a name in the **Name** edit box. In the **Order** drop-down box, you can choose a new position for the ACL (ACLs are evaluated on a first-match source basis). In the **Client** listbox, you can enter the client's IP address, network, or domain. You can also enter the username bounded by single quotes to match a specific username. You may also enter an LDAP search term here, provided that the LDAP filter was enabled on the **General settings** tab. In the **time** drop-down box, you can select a time, provided that you have defined at least one time on the **Times** tab. In the **Target Rules** subsection, click on the **Target rules List** and set each category to either **allow** or **deny**.

The **Do not allow IP-Addresses in URL** checkbox, if checked, prevents users from bypassing the ACL by using the IP address of the site instead of the FQDN. The **Redirect mode** drop-down box allows you to select what happens when a user tries to access a blocked site. There are several options; you can redirect them to an error page (you can enter a brief error message in the listbox below), or you can enter an external URL for an error page. **Ext url** move will cause the end user to be moved to the site specified in the listbox. The **Groups ACL** tab, like the **Common ACL** tab, has a **SafeSearch** option.

The **Target categories** tab allows you to define lists of sites to filter. To create a target category, click on this tab and click on the **Add** button. You can enter **Domain List**, a **URL List**, and you can also enter regular expressions in the **Regular Expression** listbox. You can also select a **Redirect mode** for a target category.

The **Times** tab allows you to define different time ranges. Once defined, they can be used on the **Group ACL** tab to select when an ACL is invoked. You can define time ranges that recur weekly, every day of the week, during a specific date range, or that are only invoked on a specific date.

The **Rewrites** tab allows you to define which URLs will be redirected to other URLs. You can then use the rewrite rules defined on this tab on both the **Common ACL** tab and the **Groups ACL** tab. To create a rewrite rule, click on the **Rewrite** tab and click on the **Add** button. You must enter a name for the rule and, in the **Rewrite rules** subsection, define the behavior of the rule:

- **Target URL regular expression**: This field contains the original URL the user wants to visit. This field may also contain a regular expression.
- **Replace to URL**: This field contains the replacement URL, the URL the user will see instead of the original one.
- **Opt.**: This drop-down box controls the options for the rule. **no case** means the rule will be case-insensitive; in other words, if the target URL is `www.myexample.com`, it will also apply to `WWW.MyExample.Com`. redirect means the user will be redirected to the replacement URL, and **no case +** redirect means that the rule will be case-insensitive and the user will be redirected to the replacement URL.

You can add multiple rules to a single rewrite rules ACL by clicking on the **Add** button. The **Log** checkbox, if checked, enables logging for this ACL entry. Finally, you can enter a brief description in the **Description** field.

The **Log** and **XMLRPC Sync** tabs are similar to the **Log** and **XMLRPC Sync** tabs in Squid and therefore we will not cover them in detail here. It is worth mentioning that the **Log** tab not only allows you to view the log file, but also allows you to view the proxy config and filter config files (although it does not allow you to edit them). The **XMLRPC Sync** tab allows you to synchronize your SquidGuard settings either to a CARP failover group or to an arbitrarily defined host.

LightSquid

LightSquid is a web-based Squid proxy traffic analyzer. You can utilize it to analyze access logs as well as to generate user and group reports. It is a lightweight set of tools that uses Perl (no database is required) and thus requires little in the way of additional resources.

To use LightSquid, a few prerequisites are required. Obviously, Squid must be installed in order for LightSquid to work. You also must enable **Access Logging** in the Squid package, or LightSquid won't have any data to use. If Squid is not set up as a transparent proxy, you must include the loopback interface as one of the configured interfaces in the Interfaces listbox on the **General** tab.

In the **Web Service Settings** section, you can set the **Lightsquid Web Port** (the default port is `7445`), and you can also check the **Lightsquid Web SSL** checkbox to use SSL for Lightsquid access. You can enter a username and password, and there are two links in this section: one to open the main Lightsquid page, and another to open sqstat, which provides real-time information about Squid users.

The **Report Template Settings** section contains a number of options for formatting reports. You can select the language in the **Language** drop-down box (there are 10 different languages supported). The **Report Template** drop-down box allows you to choose from one of four templates, and the **Bar Color** drop-down box allows you to select the bar color.

The **Reporting Settings and Scheduler** section allows you to configure different report options. The **IP Resolve Method** dropdown allows you to select which method or methods should be attempted to resolve IPs to hostnames. The default is **DNS**, which does a DNS lookup on the IPs, but there are other options, including using **Squid AUTHNAME** or **NetBIOS name**, alternatively, you can choose to not resolve IP addresses at all.

The **Skip URL(s)** listbox allows you to omit some sites from statistics by adding their URLs to the listbox. The **Refresh Scheduler** drop-down box allows you to specify a data refresh interval for LightSquid. If you need more up-to-date statistics, however, you can click on the **Refresh** button, which will reparse that day's entries in Squid's `access.log` file. The **Refresh Full** button reparses all entries in Squid's access logs, including the rotated ones.

pfBlockerNG

pfBlockerNG, the *next generation* of pfBlocker, is a relatively new package that blocks countries and IP ranges. It was designed to combine the features of Countryblock and IPblocklist. pfBlocker is a good package to have if you are running an e-mail server, as it allows you to quickly block the top countries from which spam originates. In addition, you do not even need to come up with your own block lists, as there are several free block lists available on the Web.

Once you have installed pfBlockerNG, you need to run **geoipupdate** in order to update the GeoIP2 databases, which provide information about users, including country and approximate location. To do so, type in the following at the console or at **Diagnostics | Command Prompt**:

```
/usr/local/bin/geoipupdate.sh
```

To begin pfBlockerNG configuration, navigate to **Firewall | pfBlockerNG**. There are several tabs, but the default tab is the **General** tab. The first setting is the **Enable pfBlockerNG** checkbox, which, if checked, enables pfBlockerNG. The **Keep Settings** checkbox, if checked, will maintain pfBlockerNG's settings across a reinstall or upgrade (if this option is not checked, these settings will be erased). The **CRON settings** drop-down boxes allow you to select the interval at with the **MaxMind** interface is updated.

The **Global Logging** checkbox, if checked, enables the logging of firewall rules. You can check **Disable Maxmind Updates** to disable the download of the monthly country database update. You can also set the maximum daily download failure threshold in the **Download Failure Threshold** drop-down box. Finally, you can set the number of lines in the log files in the **Logfile Size** drop-down box.

The **Inbound Firewall Rules** listbox allows you to select the interfaces to which the inbound rules apply. You probably want to select **WAN** here. The adjacent drop-down box allows you to select what action to take when inbound rules are applied. You probably want to keep this set to **Block**. The **Outbound Firewall Rules** listbox allows you to select one or more interfaces on which outbound traffic will be blocked. If you want to do this (in order to prevent the users on your network from connecting to IP addresses that are on the block lists), you should select **LAN** here and possibly also select additional internal interfaces. The corresponding drop-down box allows you to select what action to take when outbound rules are applied. The default value of **Reject** is probably what you want here; this will tell the users on your network what is happening when they try to connect to forbidden sites.

The **OpenVPN Interface** checkbox, if checked, will add auto-rules for OpenVPN. The **Floating Rules** checkbox enables you to ensure that auto-rules are generated in the **Floating Rules** tab. This is helpful if you want to ensure the auto-rules are in a single place. The **Rule Order** drop-down box allows you to select in what order the rules are placed; by default, pfBlocker rules take precedence over all other rules.

The **Update** tab allows you to configure some of the update settings for pfBlockerNG. The **Update Settings** section includes a **Status** subsection, which informs you of the next time cron will update the pfBlocker database. There is also a section called **Force Options** if you wish to force an update. There are three options for forcing updates: **Update**, which just updates at the current time; **Cron**, which does an update but does it as a cron job; and **Reload**, which just reloads the rules. If you choose **Reload**, you can choose to reload **All**, just the IP ranges (**IP**), or the blacklist(s) (**DNSBL**). As you update, any log activity will be reported in the **Log** section.

The **Country** tab allows you to quickly block any of the top countries from which spam originates. There are two top 20 spammer country lists: one for IPv4 and another for IPv6. You can select countries by pressing *Ctrl* (one country) or *Shift* (multiple countries) and clicking on countries. The **List Action** drop-down box allows you to select what happens to traffic from the selected countries. The options are: **Disabled**, **Deny**, **Permit**, **Match**, and **Alias**. The **Deny**, **Permit** and **Match** options have three options each. You can deny/permit/match inbound connections, outbound connections, or both. You can choose **Alias** if you want to create an alias for traffic that matches this rule.

There are two additional sections on this page: **Advanced Inbound Firewall Rule Settings** and **Advanced Outbound Firewall Rule Settings**. These sections allow you to configure options similar to the options available for other firewall rules. For example, the **Custom Protocol** drop-down box will cause this rule to only match if the traffic matches the protocol set here. The **Custom DST Port** and **Custom Destination** fields require that you use aliases, not actual ports and IP addresses.

If you want to select specific countries, click on the appropriate continent tab in pfBlockerNG (**Africa**, **Asia**, **Europe**, **North America**, **Oceania**, or **South America**) and select the countries in the listboxes at the top of the page. You can also whitelist a country by selecting one of the **Permit** options in the **List Action** drop-down box. The options on these pages are identical to the options on the main **Country** tab. The **Proxy and Satellite** tab allows you to match traffic to and from proxies and/or satellite providers.

You can also add your own IP lists by; specifying a URL for a public block list that will then be automatically downloaded and then periodically update it. To enable this feature, click on the **DNSBL** tab. The main tab in this section will enable you to configure DNSBL list retrieval. Clicking on the **Enable DNSBL** checkbox enables DNS block lists. You can also enter a virtual IP in the **DNSBL Virtual IP** field. You can also enter a listening port and SSL listening port on this page. You can also select the interface you want DNSBL to listen on (the default is **LAN**; whichever interface is chosen, it should be a local interface). You can also check the **DNSBL Firewall Rule** checkbox to create a floating firewall rule that will allow traffic from interfaces selected in the accompanying listbox to access **DNSBL virtual IP**.

The **Alexa Whitelist** section allows you use Alexa's top 1 million sites list. To do so, check the **Enable Alexa** checkbox. You can also select a subset of this list to whitelist by selecting an option in the **number of AlexaTop Domains to Whitelist** drop-down box; the options range from 1,000 to all 1 million. In the **Alexa TLD Inclusion** listbox, you can select **top-level domains** (**TLDs**) to whitelist (the defaults are `.com`, `.net`, `.org`, `.ca`, `.co`, and `.io`). In the **Custom Domain Suppression** section, you can enter URLs to whitelist.

The **DNSBL Feeds** tab is where you actually add and configure blacklists. You can do so by clicking on this tab and then clicking on the **Add** button. You need to enter **DNS GROUP Name** for each entry and you can also enter a **Description**. In the **DNSBL** subsection, you can select a **Format** (**Auto** or **rsync**) and a **State** (**ON**, **OFF**, **HOLD**, or **FLEX**). You must also specify **Source**, which can be either a URL or a local file. In the **Header/Label** field, you must enter a unique identifier. You can add more than one blacklist by clicking on the **Add** button and adding another entry.

There is a **List Action** drop-down box where you can select what action to take on the blacklisted items. The **Update Frequency** drop-down box allows you to select how often list files will be downloaded. In the **Weekly (Day of the Week)** drop-down box, you can select the day of the week to update, which is only required if you choose **Weekly** in **Update Frequency**. The **Enable Alexa Whitelist** checkbox, if checked, will result in pfBlocker whitelisting sites that were otherwise blocked if they appear in Alexa. You can also add a custom domain name block list in the **Custom Block List** section.

The **DNSBL EasyList** tab allows you to add one or more EasyList feeds to your pfBlocker NG setup. EasyList feeds provide lists of ad servers and trackers that you can block at the firewall level. You can choose two different EasyList feeds:

- **EasyList w/o Elements**: EasyList without element hiding. The practice of element hiding hides sections of a page that previously contained advertising.
- **EasyPrivacy**: An optional filter list that removes all forms of tracking.

You can also select different categories to block, such as **EASYLIST Adservers**, **EASYLIST Adult Adservers**, and **EASYLIST trackers**. You can choose an update frequency for the list, and you can also filter this list through Alexa to enable certain sites that show up on Alexa's list of top sites.

The **IPv4** and **IPv6** tabs allow you to add lists of IP addresses or ranges of IP addresses to filter. You can do this by clicking on either the **IPv4** or **IPv6** tab and clicking on the **Add** button. Each entry must be given a name, which is specified in the **Alias Name** field. Your list can either be accessible via a URL or locally.

The **Reputation** tab allows you to enable pfBlocker to search for repeat offenders in each IP range. If there are enough offenders in a subnet, then the entire subnet will be blocked rather than just the individual IP addresses. For the purposes of this algorithm, subnets are always `/24` ranges. The **Enable Max** checkbox, if checked, enables the search for repeat offenders. The **[Max] Setting** drop-down box allows you to select the maximum number of repeat offenders that will be allowed in a single IP range. The default is **5**, but you can allow up to 50 repeat offenders in a subnet.

pMax and **dMax** allow you to perform further analysis on repeat offenders. **pMax** will look for repeat offenders in subnets but will not use the country exclusions, whereas **dMax** will look for repeat offenders, but will apply country exclusions. In the **Country Code Settings** section, you can ignore repeat offenders in selected countries.

The **Alerts** tab enables you to view alerts, as well as control how many alerts are displayed. Under **Alert Settings**, you can control the number of **Deny**, **DNSBL**, **Permit**, and **Match** entries shown (the defaults are **25**, **5**, **5**, and **5**). Under **Alert Filter**, you can filter the results based on such criteria as date, source and destination IP address, source and destination port, and protocol.

The **Logs** and **Sync** tabs are similar to the **Logs** and **Sync** tabs in Squid and SquidGuard. The **Logs** tab allows you to view the logs, and the **Sync** tab allows you to perform an XMLRPC sync with a CARP backup node, or to a specified host.

Installation of the pfBlockerNG package results in the pfBlockerNG widget appearing on the pfSense dashboard. This widget provides you with a summary of pfBlockerNG activity. The table provides information about each alias, the number of sites blocked by the alias (**Count**), the number of packets blocked by the alias (**Packets**), and the last update time of the alias (**Updated**).

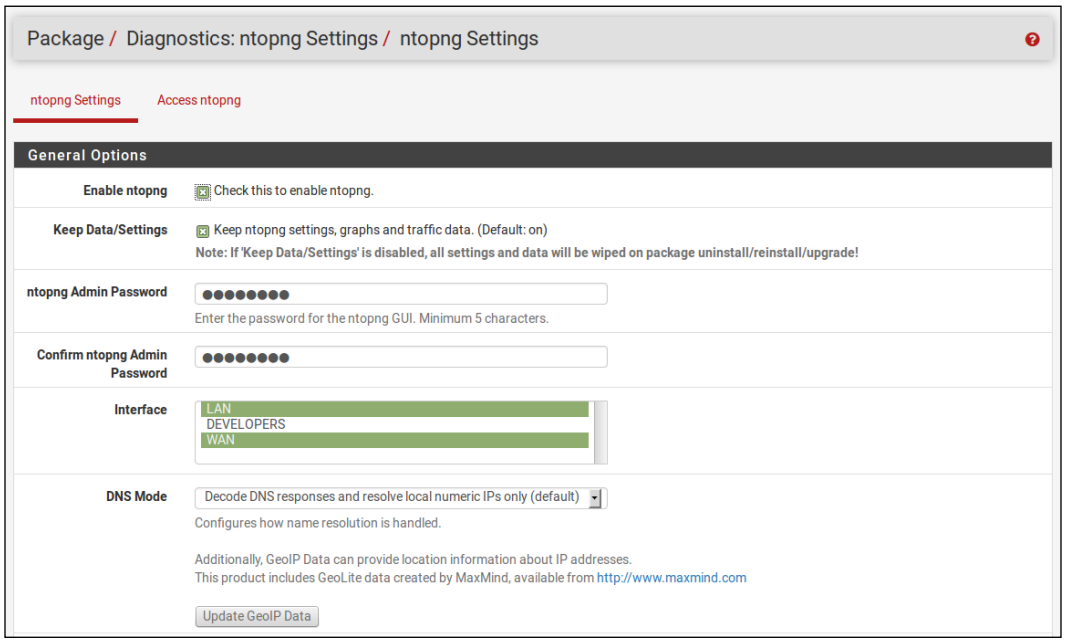
ntopng

ntopng is computer software for monitoring network traffic. It is designed to be the successor to ntop (**ntopng** = **ntop Next Generation**). There are versions of ntop for virtually every Unix platform, Windows, and Mac OS X. It can monitor network traffic, and does the following:

- It allows you to sort traffic by many criteria (for example, IP address, port, and protocol)
- It allows you to identify top talkers and listeners
- It provides flow reports
- It stores persistent traffic statistics
- It allows you to geolocate hosts and display reports based on host location

It can do all this and more with a simple web frontend and is not very resource-intensive; its CPU/memory footprint is small. The `ntopng` package has been recently removed from the pfSense package list because it will not compile. According to the documentation for pfSense 2.3, however, `ntopng` will return soon to the package list.

To configure ntopng, navigate to **Diagnostics | ntopng Settings**. The **Enable ntopng** checkbox must be checked in order for ntopng to work. The **Keep Data/Settings** checkbox, if checked, will result in settings, graphs, and traffic data being retained across package reinstalls and upgrades (if not checked, the settings will be wiped under these circumstances). You can enter an admin password on this page as well.



The ntopng Settings page.

The **Interface** listbox allows you to select the interfaces on which ntop will collect information. The **DNS Mode** drop-down box allows you to select how name resolution is handled. The default is **Decode DNS responses and resolve local numeric IPs only**, but you can choose to resolve all IPs, no IPs, and you can also choose not to decode DNS responses. You can also get data from GeoIP for location information about IP addresses; to update this data, click on the **Update GeoIP Data** button.

The **Local Networks** drop-down box determines how local networks are defined by ntopng. You can select **Consider all RFC1918 networks local**, so that all IPs within local addresses spaces will be considered local, **Consider selected interface networks local**, or **Consider only LAN interface local**. The **Historical Data Storage** checkbox, if checked, enables historical data storage, but this consumes a great deal of disk space. The **Delete (Historical) Data** button allows us to delete this data. Finally, checking the **Disable Alerts** checkbox disables all alerts generated by ntopng.

Once you have enabled and configured ntopng, you can click on the **Access ntopng** tab. Clicking on this tab simply redirects you to port `3000` of your pfSense firewall, which allows you to access the ntopng web GUI.

The **Active Flows** page displays information about current sessions. The information presented includes the application (if known), level four protocol (TCP or UDP), the client IP address, the server IP address, and the duration of the connection. The **Breakdown** column graphically shows how much of the traffic for the session is on the client side and how much is on the server side. Finally, the **Bytes** column informs you how much data has been transferred during the session.

The **Top Flow Talkers** page displays both the local and remote IP addresses that generate the most traffic on your network. There is also a graph that displays which application layer protocols are used the most.

The **Local Hosts Matrix** field displays which local hosts connect to each other, and how much traffic is generated. Finally, the hosts page provides a breakdown of each local interface: its IP address, MAC address, as well as the total traffic sent and traffic received by the interface.

Nmap

Nmap, short for **network map**, is a program that is used to discover hosts and services on a computer network. Hence, it creates a map of the network. It is often used for network security audits, but it is also useful for routine administrative tasks. When you run nmap, you receive a list of scanned targets as an output. The output depends upon which options are used, but you will always get a list of *interesting ports*, what services are running on those ports, and the state of the port (open, filtered, closed, or unfiltered). These states can be defined as follows:

- **Open**: If a port is listed as open, then an application is listening on this port; in other words, it is waiting for connections.
- **Filtered**: The port is blocked by a firewall. As a result, it could be open or closed, but Nmap cannot tell which is the case.

- **Closed**: No applications are listening on the port.
- Unfiltered: The port responds to Nmap's probes, but Nmap cannot tell if the port is open or closed.

To begin using Nmap, navigate to **Diagnostics | NMap**. Enter the IP address or hostname you want to scan in the **IP or Hostname** edit box. In the **Interface** drop-down box, select the source interface. The **Scan Method** drop-down box is where you select the manner in which the port scan is done. The options are as follows:

- **SYN**: As you probably know, establishing a TCP connection involves a three-way handshake, which is initiated with a `SYN` packet being sent by the client. The server responds with an acknowledgment that the `SYN` packet was received (`SYN-ACK`), and the client responds with an acknowledgment to which the server need not respond. With this method, Nmap initially sends a `SYN` packet. If it receives a `SYN/ACK` response (or a `SYN` packet), then the port is marked as open. If Nmap receives an `RST` (reset) response, the port is marked as closed. If there is no response, the port is marked as filtered.
- **TCP connect()**: This method involves issuing a TCP `connect()` command through the Berkeley Sockets API (this is the API used by FreeBSD). This method is slower and more likely to be logged than a SYN scan.
- **Ping**: This method involves sending ping requests to scanned ports.
- **UDP**: With this method, Nmap sends a UDP packet to every scanned port. In some cases, a protocol-specific payload is also sent. This potentially increases the response rate in cases where a port is commonly associated with a specific protocol. The remote host will either respond with a UDP packet or not. If a response is received, the port will be marked as open. If there is no response, the port will be marked as **Open | Filtered**.
- If an `ICMP port unreachable` error is received, the port is marked as closed, but other ICMP unreachable errors result in the port being marked as filtered. One problem with UDP scanning is that it tends to take much longer than TCP scanning; open UDP ports rarely respond (keep in mind UDP is a stateless protocol); therefore, if Nmap doesn't get a response after a timeout period, it will resend a UDP packet just to make sure the packet wasn't lost in transmission. If the port is closed or filtered and an ICMP error is returned, this reply should be returned relatively quickly, but some operating systems limit the number of ICMP replies within a time period. Still, it is good practice to include a UDP scan in your security audit.
- **ARP**: This is the preferred method for scanning local hosts. Sending an **ARP** (**Address Resolution Protocol**) request to a local host is, in most cases, faster and more reliable than doing an IP-based scan, so unless there are other reasons for not using ARP, you should use this on local networks.

There are also several checkboxes corresponding to different Nmap command-line options:

- **-P0**: Do not attempt to ping hosts before scanning – Sometimes, networks do not allow ICMP echo requests/responses through their firewall. If you are scanning such a network, you may want to skip this step even though it is part of the Nmap network discovery process.
- **-sV**: Attempt to identify service versions – With this option, if a TCP or UDP port is discovered, Nmap version detection will communicate with those ports, and try to determine what is running. It will try to determine the service protocol (for example, FTP, SSH, HTTP, and so on), the application name (for example, Apache), the version number, and sometimes other miscellaneous details.
- **-O**: Enable Operating System detection – This activates remote host identification via TCP/IP fingerprinting (it looks at the network stack and compares it with a database of known OS fingerprints to try and determine the OS of the host).

It should be noted that the options on the **Nmap** page represent only a fraction of the options available for Nmap. They may be enough for your purposes, but it may be beneficial to read the Nmap documentation and, if there is an Nmap option that cannot be invoked from this page, run Nmap from the command line, either by dropping to the shell from the console, via SSH, or by navigating to **Diagnostics** | **Command Prompt**.

Complete Nmap documentation can be found at the official Nmap site `http://nmap.org`. A simple web search will also find numerous articles and tutorials on using Nmap.

Other packages

There are also quite a few packages that, while not as popular as the packages mentioned in the previous section, are nonetheless useful and should not be overlooked. We will cover some of them here.

Snort

Snort is an open source network intrusion prevention system and intrusion detection system. Among its features, it can do real-time traffic analysis and packet logging. It can be run in three different modes:

- **Packet sniffing mode**: In this mode, Snort simply intercepts traffic on your network in a manner similar to how a program like Wireshark would.
- **Packet logging mode**: This mode is useful for network traffic debugging. Packets are logged to a disk.
- **Network intrusion prevention mode**: In this mode, Snort monitors network traffic, and analyses it against a user-defined rule set. The program can perform a specific action based on the rule that has been matched.

Snort provides its own rules that you can use for intrusion detection. You can pay for a subscription or you can obtain the community rules for free. Even if you don't pay for a subscription, if you create an account on `Snort.org` you can download the registered user rule packages.

It is beyond the scope of this chapter to provide a comprehensive guide to Snort. In fact, the official Snort manual is 266 pages. It can be found at `https://s3.amazonaws.com/snort-org-site/production/document_files/files/000/000/100/original/snort_manual.pdf`.

Once you have installed Snort, you can begin configuration by navigating to **Services** | **Snort** and clicking on the **Global Settings** tab. Note that you can enable the download of the rules simply by checking a checkbox. The **Enable Snort VRT** checkbox, if checked, downloads the free registered user or paid subscriber rules, while checking the **Enable Snort GPLv2** checkbox enables downloading of the community rules (which, as mentioned, are free of charge).You can also enable the download of **Emerging Threats** (**ET**) rules. The **Enable ET Open** checkbox, if checked, enables downloading of the open source version of ET rules, while checking **Enable ET Pro** enables the downloading of ET Pro rules, which requires signing up for an ET Pro account.

If you are using Snort, you may want to use the Open AppID plugin. This plugin enables Snort to detect, monitor, and manage application usage. If so, you will have to download the Sourcefire Open AppID detectors, and checking the **Enable OpenAppID** checkbox makes this possible. Open AppID was introduced in February 2014, and there are already more than 1,500 applications that can be detected by this plugin.

The **Rules Update Settings** section allows you to control when rules are updated. In order to enable auto-updates, you must choose an option other than **NEVER** in the **Update Interval** drop-down box. You may also specify a start time for updates in the **Update Start Time** edit box. In this section, there is also an option to hide deprecated rules categories in the GUI and remove them from the configuration (the **Hide Deprecated Rules Categories** checkbox).

The **General Settings** section contains a few more options. The **Remove Blocked Hosts Interval** drop-down box allows you to select the amount of time hosts will be blocked. The **Remove Blocked Hosts Interval** checkbox, if checked, will clear all blocked hosts added by Snort when the package is removed. If you check the **Keep Snort Settings after Deinstall** checkbox, Snort settings will be retained after package removal. Finally, the **Startup/Shutdown Logging** checkbox, if checked, will output detailed messages to the system log when Snort is starting and stopping.

Once you have configured these options, you can click on the **Updates** tab and see what rules have been enabled in your configuration. There is also an **Update Your Rule Set** section that has two buttons. **Update Rules** automatically checks and applies any new posted updates for enabled rules packages. The **Force Update** button, if clicked, will zero out the MD5 hashes, thus forcing a download of the entire rules packages. You can also view the log file on this page by clicking on **View Log page**, or clear the log by clicking on **Clear Log**.

Level seven traffic shaping was part of pfSense's traffic shaper but, according to the official pfSense site, it has been broken since version 2.2.x, and, as a result it has been removed from version 2.3. An alternative is to use Snort, which is capable of identifying application-layer protocols and therefore can identify such traffic.

Snort is configurable on a per-interface basis; you can configure interfaces by clicking on the **Snort Interfaces** tab. There, you can click on the **Add** tab to add a new interface. Once you choose an interface to inspect traffic on (in the **Interface** dropdown), you can choose whether to automatically block hosts that generate a Snort alert (the **Block Offenders** checkbox). You can also choose the pattern matcher algorithm in the **Search Method** drop-down box. The default algorithm is Aho-Corasick Binary NFA (**AC-BNFA**), but there are a number of other options, some of which require more resources than others.

The **Split ANY-ANY** checkbox, if checked, enables the splitting of an **ANY-ANY** port group. An *ANY-ANY* rule is a rule which will match any address and any port. For example:

```
alerttcp any any ->192.168.1.0/24 53
```

This will generate an alert when a host on any IP address and any port tries to connect to port `53` of any host on the `192.168.1.0` subnet. The default behavior of Snort is to add an *ANY-ANY* port rule to every non-ANY-ANY port group. This way, only one evaluation needs to be done per packet. But suspending this behavior (not putting an *ANY-ANY* rule into every other port group) can significantly reduce the memory footprint, at the cost of requiring two group evaluations per packet.

The **Choose the Networks Snort Should Inspect and Whitelist** section allows you to choose **Home Net** and an **External Net** that will be whitelisted. You can also specify a suppression or filtering list in the **Alert Suppression and Filtering** drop-down box. Finally, you can specify additional parameters in the **Advanced Configuration Pass-Through** listbox.

The **Iface Categories** tab allows you to select the rulesets Snort will load at the startup for this interface. Any rulesets you have downloaded or created should be visible on this page. You can also enable automatic flowbit resolution on this tab (flowbits allow you to track the state of a flow during a TCP session; automatic flowbit resolution automatically converts old rules that do not use the **file-identify.rules** category to the new format).

The **Iface Rules** tab allows you to enable and disable individual rules. You can choose from decoder rules, pre-processor rules, and sensitive data rules. You can also enable and disable any custom rules you have defined. The **Iface Variables** tab allows you to define the values of certain predefined variables used in rules.

The **Iface Preprocs** tab controls a number of pre-processor configuration settings. Two important settings on this page are the **Enable Performance Stats** checkbox and the **Protect Customized Preprocessor Rules** checkbox. The **Enable Performance Stats** checkbox, if checked, will result in Snort automatically generating performance statistics for this interface. The **Protect Customized Preprocessor Rules** checkbox, if checked, will prevent customized pre-processor rules from being overwritten by automatic Snort VRT rule updates.

The **Iface Barnyard2** tab allows you to enable and configure Barnyard2 on the interface. Barnyard2 is a spooler for Snort's unified2 binary output files that allows for efficient writing of data to disk to be parsed by another process so that Snort doesn't miss network traffic. The **Enable Barnyard2** checkbox enables Barnyard2 on the interface, and there are other options on the page. The **Unified2 Log Limit** drop-down box allows you to choose a **Unified2 Log file size** limit. There is also an option on this page to enable logging of alerts to a MySQL database instance (in which case you will have to provide the database login credentials). You can also enable logging of alerts to a local or remote syslog receiver on this page.

The **Iface IP Rep** tab allows you to enable and configure the use of IP reputation lists on the interface. IP reputation, as described in the section on pfBlockerNG, will cause entire subnets to be blocked if there are enough alerts generated from IP addresses on the subnet. Checking the **Enable IP Reputation** checkbox enables the use of IP reputation lists, and the **Memory Cap** field allows you to set the maximum memory in megabytes supported for IP reputation lists. To add or upload IP reputation lists, click on the **IP Lists** tab on the main **Snort** menu.

The **Iface Logs** tab allows you to view log files for the interface. You can choose one of the log files in the **Log File to View** drop-down box. The **Log Contents** section will display the contents of the log file, if the selected log file exists.

The **Alerts** tab allows you to view alerts on a per-interface basis. The **Interface to Inspect** drop-down box allows you to select an interface, and the adjacent edit box allows you to determine how many lines appear. The **Auto-refresh view** checkbox will result in the page updating automatically as new alerts are generated. You can also download the alert log by clicking on the **Download** button and clear the log by clicking on the **Clear** button. The **Blocked** tab allows you to view hosts that have been blocked by Snort. You can choose the number of blocked hosts that appear on this page (the default is **500**), and there is a **Refresh** checkbox to auto-refresh the page's contents. You can also download the list of blocked hosts by clicking on the **Download** button.

The **Pass Lists** tab allows you to generate whitelists, which you can do by clicking on this tab and then clicking on the **Add** button. To make life easier, there are some sets of IP addresses that can be added to the list just by clicking on a checkbox: namely **firewall connected local networks**, **WAN gateways**, **WAN DNS servers**, **virtual IPs**, and **VPN addresses**. You can also add a configured alias to the list.

The **Suppress** tab allows you to define suppression lists in a similar manner; to do so, click on the tab and click on the **Add** button. After entering a name and description for the list, simply add the suppression rules into the appropriate listbox. The rules must follow Snort's format for such rules.

The **SID (Signature ID) Mgmt** tab has a single option. The **Enable Automatic SID State Management** checkbox enables automatic management of rule state and content using criteria specified in configuration files. If you enable this option, Snort will generate a series of configuration files that will appear in the **SID Management Configuration Files** section. You can add, upload, and download these configuration files from this section (the configuration files can be downloaded individually via the download icons in the table, or as a single gzip archive using the **Download** button). You can also add and delete configuration files within this section. You will need to specify the enable, disable, and modify SID files. None are selected by default; most likely, you will have to create or generate separate files for each of these and specify them in the corresponding drop-down boxes. The **SID State Order** drop-down box determines which file is executed first: the disable SID file or the enable SID file. Check the **Rebuild** button to rebuild the rules from the selected configuration files.

The **Log Mgmt** tab allows you to control a number of log settings. The **Remove Snort Logs on Package Uninstall** checkbox, if checked, will remove the Snort log files on uninstall. The **Auto Log Management** checkbox allows you to enable automatic unattended management of the Snort logs using the parameters specified in the **Log Directory Size Limit** section and the **Log Size and Retention Limits** section. The **Log Directory Size Limit** edit box imposes a hard limit on the combined log directory size, while the **Log Size and Retention Limits** edit box allows you to control the size of individual logs.

The **Sync** tab is essentially identical to the **Sync** tab in such applications as Squid. It allows you to sync Snort settings via XMLRPC. The sync target can either be part of a CARP failover group or any arbitrarily defined node. Moreover, you can select more than one replication target by entering the information in the **Replication Targets** subsection, entering the relevant information, clicking on the **Add** button, and repeating the process.

Suricata

Suricata is another network intrusion detection system/intrusion prevention system and network security monitoring package. It is highly scalable (since it is multi-threaded, it will automatically load-balance across multiple processors), it is highly effective in identifying protocols, and it can identify thousands of different file types.

One of the features of Suricata is that it is mostly compatible with Snort. If you click on the **Global Settings** tab in Suricata, you will notice that you can use both Snort VRT rules and ETOpen or ETPro rules, just as you can with Snort. Snort rules are compatible with Suricata save for a few exceptions, and Suricata also supports Barnyard2. The Suricata web GUI is similar to that of Snort (it can be viewed by navigating to **Services** | **Suricata** after installation).

There are, however, some features that Suricata has that Snort does not. If you add an interface, there are a number of configurable options that appear, such as the **Iface App Parsers** tab, where you can easily control the detection of both layer four protocols and layer seven protocols. There are also a number of flow and stream settings available (under the **Iface Flow/Stream** tab) that are not available in Snort. Thus, while Snort and Suricata are both good options for network intrusion detection/intrusion prevention systems, you should look at the advantages and disadvantages of each of these packages before deciding which to install.

HAProxy

HAProxy is a free, open source load balancer and proxy for TCP-and HTTP-based applications. It has the reputation of being fast and efficient, and it is used by a number of high-profile websites. The latest version includes such features as native SSL support, HTTP/1.1 compression, and support for dynamic ACLs.

To configure HAProxy, navigate to **Services** | **HAProxy**. The default tab is **Frontend**; if you are using HAProxy as a load balancer, then you probably want to configure the frontend and backend before you enable HAProxy. To add a frontend, click on the **Add** button. You must enter a name in the **Name** field and you also may enter a description in the **Description** field. You can set **Status** to either **Active** or **Disabled**.

The **External address** subsection is where you specify the IP address of the frontend, the IP address where clients will connect (the **Listen** address). Most likely, you want to set this to the WAN address, but you can set it to any interface on the firewall, or you can specify a custom address by selecting **any** in the drop-down box. You also need to specify the port. You can specify more than one port. For example, if you accept HTTP connections on both ports `80` and `8080`, you could specify `80` or `8080`; if you accept HTTPS connections, then you most likely want to check the **SSL Offloading** checkbox. You can specify additional parameters in the **Advanced** edit box. You can add more than one listen address; click on the down arrow to add another entry. You can also enter the maximum amount of connections the frontend will accept in the **Max connections** edit box, and you can specify the type of processing that will be done by HAProxy in the **Type** drop-down box.

In the next section, you can add access control lists, as well as the default backend. In the **Access Control list** subsection, you can specify the name of the ACL (**Name**) and what constitutes a match (**Expression**). In the **Actions** subsection, you can select the backend to use or perform other actions. You can also select a default backend in the **Default backend** drop-down box.

The next step is configuring one or more backends. To do so, click on the **Backend** tab, and then click on the **Add** button. You must enter a name for the backend pool, and then enter information on the backend servers. Click on the down arrow to add an entry into the **Server** list table. Enter a name in the **Name** field, the IP address in the **Address** field, and the port in the **Port** field. If the backend is using SSL, then the **SSL** checkbox should be checked. You can also enter a weight in the **Weight** edit box. This is a number between 0 and 256, with higher numbers receiving more weight. A server with a weight of 0 won't get any new traffic. The default value for this parameter is **1**.

The **Balance** subsection contains the load-balancing algorithm options. Selecting **None** allows writing your own custom balance settings into the advanced section. **Round robin** causes each server to be used in turn, according to its weight. **Static round robin** works similarly to round robin, except that it is static, so changing a server's weight on-the-fly will have no effect (although it likely has no effect even in standard **Round robin**, as the HAProxy package probably does not support changing weight on-the-fly). This option also has slightly less overhead than **Round robin**. The **Least Connections** option will result in the server with the lowest number of connections receiving the connection. The final two options use hashing algorithms. With the **Source** option, the source IP address is hashed and divided by the total weight of the running servers to determine which server receives the request. The **Uri** option, which is available for HTTP backends only, will hash either the part of the URI before the question mark or the whole URI (if the **Allow using whole URI** checkbox is checked) and divide this hash value by the total weight of the running servers.

You can also add ACLs on this page in the **Access control lists and actions** section. The **Name** field is where you enter the ACL filename. The **Expression** drop-down box is where you specify the condition to match (for example, **Host starts with:**). In the **Value** edit box, you specify the hostname or URL to match (this can also be a regular expression). You can check the **Not** checkbox to negate the condition specified in the expression/value combination: for example, checking the **Not** checkbox when the **Expression** is **Host starts with:** and the **Value** is `myexample.com` will result in there being a match whenever the host does not start with `myexample.com`. In the **Actions** table, you can specify an action to take when there is an ACL match. The **Action** drop-down box allows you to select an action and the **Condition acl names** edit box allows you to select an ACL filename.

Once you have configured the frontend and backend, you can click on the **Settings** tab and enable HAProxy by clicking on the checkbox at the top of the page. You can also set the maximum per-process number of concurrent connections in the **Maximum connections** edit box. It should also be noted that, unlike many of the other packages, which have a separate **Sync** tab for XMLRPC syncing, the CARP settings for HAProxy are controlled on the **Settings** tab. The **CARP monitor** drop-down box allows you to enable the CARP monitor and only run HAProxy on the master firewall, while the **HAProxy Sync** checkbox at the bottom of the **Settings** page allows you to enable syncing HAProxy to the backup CARP members. Unlike many of the other packages, there does not seem to be any way of performing an XMLRPC sync to an arbitrary host.

Summary

In this chapter, we took a look at some of the more significant packages available for pfSense. With the release of pfSense 2.3, many packages have been removed and many others have been deprecated, which has reduced the number of packages available. The packages that remain, however, can be quite useful in securing your network. The two categories covered most extensively were proxies and network intrusion prevention/detection systems, and these packages tend to be the ones that are used most extensively. If none of these packages meet your particular requirements, however, don't let this be a hindrance: browse the pfSense package list and see if you can find one suitable for your needs.

In the final chapter, we will cover a topic that is essential to creating and maintaining a computer network but is often overlooked: troubleshooting.

10
Troubleshooting pfSense

If you are implementing or maintaining a network, it is almost certain that, at some point, something will go wrong. This could be the result of human error (for example, a misconfiguration issue), hardware failure, or a software problem. In such circumstances, your troubleshooting skills will be put to the test. The aim of this chapter is to help you develop your troubleshooting skills.

The following topics will be covered in this chapter:

- Troubleshooting basics
- pfSense troubleshooting tools
- Troubleshooting scenarios

The first section will outline a procedure for troubleshooting networks in general before delving into pfSense troubleshooting. If you are already familiar with network troubleshooting, feel free to skip the section.

Troubleshooting basics

Implementing effective network troubleshooting involves a multi-step approach. These steps both provide a framework for troubleshooting and help reduce the amount of time spent resolving problems:

- **Identify the problem**: This seems obvious, but we often assume that we know the exact scope of the problem, when we might be better served gathering information, identifying symptoms, and, when applicable, questioning users. If there is more than one problem, we should recognize it as such so we can approach each problem individually. Sometimes end users are good sources of information. For example, you can ask a user how the system behaves during normal operation and compare it to how the system currently behaves. Recreate the problem, if possible, and try to isolate the location of the problem.
- **Formulate a theory of probable cause**: A single problem can have many causes, but if you have done your homework with information gathering and if you apply a modicum of common sense, you can eliminate many of these causes. Often the most obvious solution is the correct one, and looking at the easiest solution first is a reasonable approach. Keep in mind, however, that your initial theory may be incorrect and you may have to consider other theories.
- **Test the theory**: Once you have established a theory of probable cause, you should attempt to confirm the theory. If the theory can be confirmed, then you can move on to the next step. If not, you need to formulate another theory.
- **Establish a plan**: Once you think you have identified the cause, you need to establish a plan of action. This becomes more important when troubleshooting in enterprise-level environments. Implementing a solution may involve taking systems offline, and you have to determine when they will be taken offline and for how long. In many cases, your organization may have formal or informal procedures for taking the system offline. This often includes scheduling a time – often during non-working hours – when the work will be done. Nonetheless, once you have a plan in place, you should be able to implement a solution.
- **Implement the solution**: Once the corrective change has been made to your network, you still need to test the solution. You can't assume that the solution has worked without testing it, and often you need to be mindful that early results may be deceptive, and you may need to test it again to make sure the solution has worked.

- **Verify system functionality**: Sometimes a solution that fixes one problem creates another. This is why it is important to verify full system functionality before you decide the solution was successful. In fact, it might be best to assume that the changes you make will affect the network in one way or another and determine how it will affect it.
- **Document the problem and solution**: Documenting the solution involves keeping a record of all the steps taken while solving the problem. Documenting both failures and successes can save you time in the future, and in large organizations keeping a record of the person who implemented the solution can be helpful if someone in the organization has a question about it.

If the problem was initially reported by an end user, you might also consider providing feedback to the user. Such feedback might not only encourage users to report problems in the future, but you might be able to provide information as to how the problem could have been avoided in the first place.

One of the ways we can evaluate problems is to use the seven-layer OSI model and try to determine what layer or layers the problem is on:

- **Physical layer**: This covers such problems as damaged or dirty cabling, or terminations, high levels of signal attenuation, and insufficient cable bandwidth. It also covers such problems as wireless interference or access points malfunctioning.
- **Data link layer**: This covers such problems as MAC address misconfiguration and VLAN misconfiguration or sub-optimal VLAN performance. It also encompasses some protocol issues such as improper L2TP or OSPF configuration.
- **Network layer**: This covers such problems as damaged or defective networking devices, misconfigured devices, sub-optimal device configuration, authentication issues, and lack of sufficient network bandwidth.
- **Transport layer**: This covers issues with the TCP and UDP protocols.
- **Session/Presentation/Application layers**: This covers problems related to applications and application layer protocols (for example, FTP and SMTP).

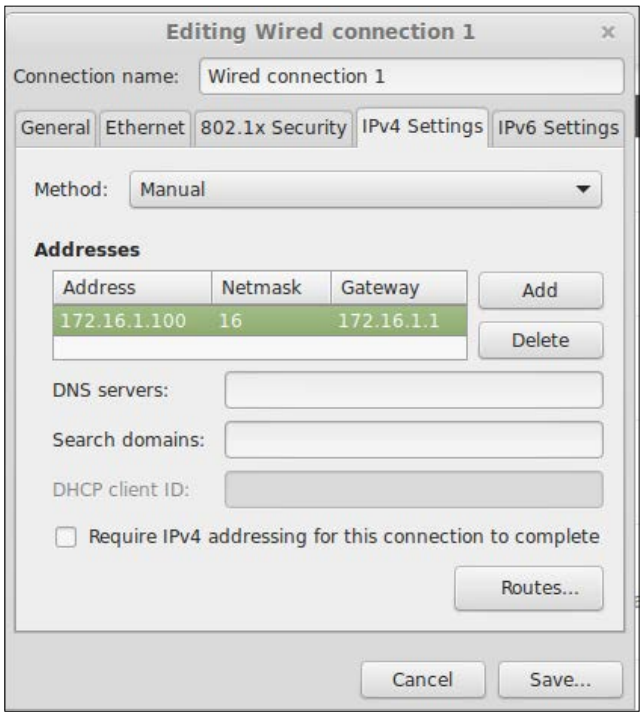
Common networking problems

There are also some issues that come up so often in the networking world that we would be remiss if we did not take note of them. You can consider the following problems as obvious possible causes that, in many scenarios, should be considered before other, less obvious possible causes are considered.

Wrong subnet mask or gateway

This one is very simple: if the subnet mask specified on the host does not match the subnet mask for the network, then communicating with the network will not be possible. Finding the subnet mask is usually quite easy. In recent versions of Windows, such information can be obtained by navigating to **Settings** | **Network Connections**, right clicking on the network adapter you are using, and selecting **Properties**. There should be a listbox displaying the installed protocols; scroll down to **Internet Protocol Version 6** or **Internet Protocol Version 4** depending on what version you are using, and click on the **Properties** button. This should show you what the subnet mask is.

In Linux, finding the subnet mask is just as easy. For example, in Ubuntu or Mint Linux, click on the networking icon in the tray on the right end of the taskbar (the icon should look like two interconnected cables if you have a wired connection or a series of arcs if you have a wireless connection). This should launch the **Network Connections** dialog box. Find your connection (for example, **Wired Connection 1**) and double-click on it. This will launch the **Editing** dialog box, where you can change settings for the connection. Click on either the **IPv4 Settings** or **IPv6 Settings** tab to find the subnet mask.



Setting the gateway in Mint Linux.

Correct configuration of the subnet mask should allow intra-network communications, but a missing or misconfigured gateway setting will prevent a host from communicating with other networks. You should confirm that the gateway is set correctly; since the gateway is often specified in the same place as the subnet mask, this should not be difficult to do.

Wrong DNS configuration

The **Domain Name System** (**DNS**) provides us with a means of translating hostnames into IP addresses. If a DNS server is not specified at all, then the host will not be able to take advantage of DNS services. If the correct DNS server is not specified (for example, if the primary server is incorrect), then DNS resolution can take longer than necessary, thus giving the impression that Internet access is slower than it actually is.

A good indicator that DNS configuration is incorrect is if you can ping a site when you specify the IP address, but the ping fails when you specify the hostname (and ping returns `unknown hostname` or a similar error). If this happens, you should definitely check the DNS configuration, first on the host and then on the firewall.

Duplicate IP addresses

All IP addresses on a network must be unique. This includes network cards, routers and access points. If a network device is on the LAN, then its IP address must be unique on the LAN. If it is connected to the Internet, then it must be unique on the Internet. Problems with duplicate IP addresses can range from receiving error messages informing you of the existence of duplicate IP addresses to not being able to connect to the network from the device with the duplicate address.

Obviously, the use of DHCP, in which assignment of IP addresses is managed by the DHCP server, and IPv6, which has a greater number of private addresses to assign, greatly cuts down on the possibility of duplicate IP addresses. Duplicate addresses are most likely to happen on IPv4 networks in which the IP addresses are statically assigned.

Network loops

As mentioned in *Chapter 8*, *Routing and Bridging*, there can only be a single path between two network devices. If there is more than one path, then the resultant looping can generate a broadcast storm that brings your network to its knees. It is especially a concern if you have bridged one or more interfaces on your network. One way to prevent looping is to manually configure network ports to ensure there is only one path to each device. The more likely scenario, however, is that you utilize a protocol such as **Spanning Tree Protocol** (**STP**), or its successor, **Rapid Spanning Tree Protocol** (**RSTP**).

Another situation where looping can occur is when the information in the routing table is incorrect, either through a manual misconfiguration or a failure in automatic route detection. Such errors are often easy to detect because, as with physical loops, they will quickly bog down a network.

Routing issues

In *Chapter 8*, *Routing and Bridging*, we described how to set up a static route in pfSense. Static routes can easily cause problems on a network, since a change in network topology can render a static route incorrect. Therefore, if you make changes to your network and you have static routes, you should consider how the changes impact these static routes and make changes to them accordingly.

Port configuration

By default, pfSense will block all ports on the WAN side of the router. Therefore, if a remote user tries to connect to a port on a local host, the user will be blocked from doing so. In order to connect to a port on a local host, there must be a port-forwarding rule forwarding the traffic to the host, and there must be a rule on the network to which the local host is connected permitting such traffic (in pfSense, NAT port forwarding has an option for auto-generating firewall rules that correspond to port forwarding rules, thus ensuring that both steps can be completed at the same time).

Black holes

Sometimes, network traffic is dropped without the source ever being informed that the traffic never reached its intended target. The error can only be detected by monitoring network traffic. Such a situation is referred to as a black hole.

One such scenario is when a host tries to connect to an IP address that was assigned to a host that is down or to an IP address that was never assigned to a host. Although TCP has mechanisms for communicating a failure to connect back to the original host, often the packets are just dropped. Moreover, if you are using a protocol such as UDP that is both connectionless and unreliable, then there is no means of communicating back to the original host that the IP address is dead.

Another common situation is with **Maximum Transmission Unit** (**MTU**) black holes. This happens when an MTU packet is larger than the maximum MTU size allowed on a network, and the **Don't Fragment** (**DF**) flag is set in the IP header. If this happens, any device whose MTU is smaller than the packet's size will drop the packet. The solution here is to make sure **Path MTU Discovery** (**PMTUD**) is running on all network devices. PMTUD solves this problem by sending back a **Fragmentation Needed** ICMP message back, thus causing the offending device to reduce its MTU size. Some network devices block ICMP messages for security reasons, however, and if this is the case on your network you could end up with black hole connections: the TCP three-way handshake will be completed, but when data is transferred, the connection will hang because of the MTU size mismatch.

One possible solution is to use the RFC 4821 version of PMTUD. This version uses TCP or another protocol to probe the patch with progressively larger packets. Another solution is to change the **maximum segment size** (**MSS**) of all TCP connections lower than the Ethernet default of **1500**.

Physical issues

You should also be aware that there are many issues related to cabling that can cause problems. The most common form of network cabling used in homes and offices is **unshielded twisted pair** (**UTP**), with fiber-optic cabling being the more expensive alternative. UTP cabling is susceptible to various forms of interference. One such form is crosstalk, when the signal from one cable bleeds into another cable. This often happens when two cables are run too close to each other. **Near end crosstalk** (**NEXT**) is when an outgoing data transmission leaks into an incoming transmission. **Far end crosstalk** (**FEXT**) is when a transmitting station at the other end of a transmission line leaks into the receiving line. One of the ways you can minimize crosstalk is to purchase high-quality UTP cable, in which the twisted pairs are twisted more tightly; the greater the number of twists, the less crosstalk.

EMI can also reduce signal strength. Computer monitors and fluorescent lighting both create an electromagnetic field, and can cause problems with UTP network cabling. **Radio frequency interference** (**RFI**) from objects such as cell phones can also be an issue. The solution to this problem is to run network cabling away from such devices.

The signal in a UTP cable is susceptible to attenuation if the cable is too long. Keep in mind that the maximum length for Cat 5 and Cat 6 UTP cabling is 100 meters. If there are intermittent network problems and you notice that the cables are too long, this may be the problem. If you can't shorten the cable run, then installing a repeater will solve this problem.

One way to avoid all these problems is to install fiber-optic cabling. Because fiber-based media uses light transmissions instead of electronic signals, the issues discussed in this section, such as crosstalk, EMI, and attenuation, become nonissues. Fiber-optic cabling is also a secure medium, as accessing the data signals requires physically tapping into the media, which is difficult to do.

Unfortunately, the high cost of fiber-opting cabling precludes a lot of organizations from implementing it in their networks. Moreover, fiber-optic media is incompatible with most electronic equipment, requiring you to purchase fiber-compatible network equipment. Thus, while fiber-optic cabling will continue to play a role in networking, particularly in serving as the media for the Internet, WANs, and **metropolitan area networks** (**MANs**), its impact on smaller networks will likely be limited for the foreseeable future.

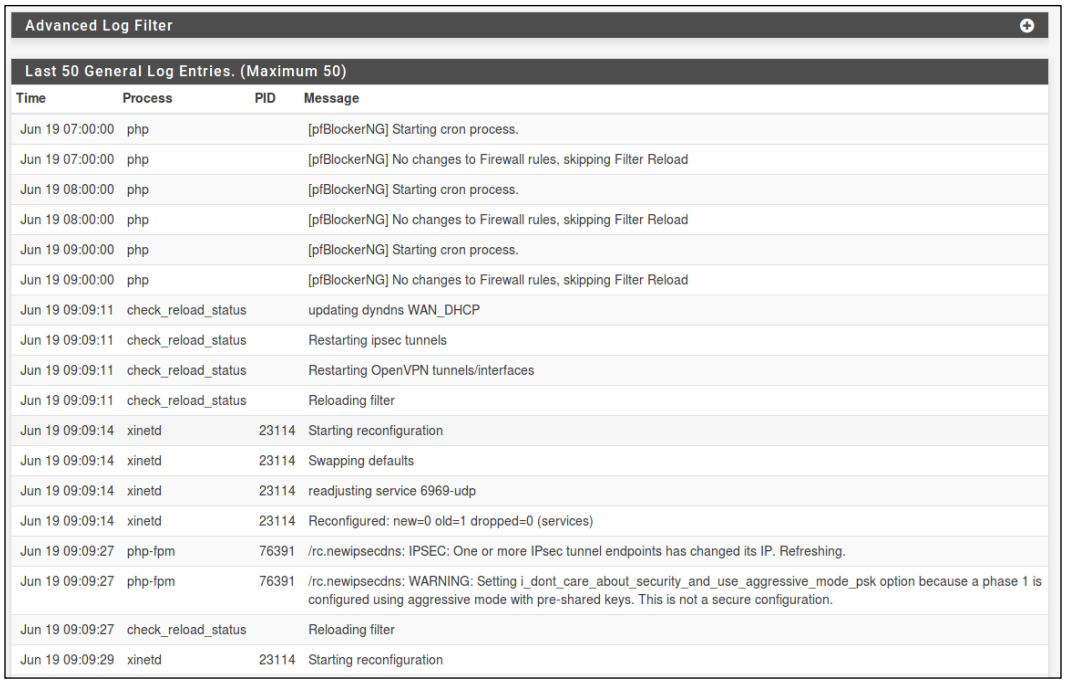
pfSense troubleshooting tools

pfSense provides a great deal of information and data related to the functioning of your network, and this information and data can be extremely helpful when troubleshooting network issues. One of the first places you'll probably want to start looking is in the logs, so we'll begin with that.

System logs

To access the system logs, navigate to **Status | System Logs**. There are several tabs in this section, but the default tab is **System**. Note that different subcategories (for example, **Firewall** and **DHCP**) have their own tabs where you can view log entries related to such activity, which simultaneously makes it easier to find log activity for a specific subcategory and also reduces clutter on the **System** tab. The **System** tab is itself divided into several subcategories: **General**, **Gateways**, **Routing**, **DNS Resolver**, and **Wireless**.

pfSense logs are stored in such a way as to not overflow the available disk space. The logs have a binary circular log file format; these log files are a fixed size and they store a maximum of 50 entries. If the limit is reached, older log entries are overwritten by newer ones. If you want to retain these logs, you can copy them to another server with syslog.



Advanced Log Filter

Last 50 General Log Entries. (Maximum 50)

Time	Process	PID	Message
Jun 19 07:00:00	php		[pfBlockerNG] Starting cron process.
Jun 19 07:00:00	php		[pfBlockerNG] No changes to Firewall rules, skipping Filter Reload
Jun 19 08:00:00	php		[pfBlockerNG] Starting cron process.
Jun 19 08:00:00	php		[pfBlockerNG] No changes to Firewall rules, skipping Filter Reload
Jun 19 09:00:00	php		[pfBlockerNG] Starting cron process.
Jun 19 09:00:00	php		[pfBlockerNG] No changes to Firewall rules, skipping Filter Reload
Jun 19 09:09:11	check_reload_status		updating dyndns WAN_DHCP
Jun 19 09:09:11	check_reload_status		Restarting ipsec tunnels
Jun 19 09:09:11	check_reload_status		Restarting OpenVPN tunnels/interfaces
Jun 19 09:09:11	check_reload_status		Reloading filter
Jun 19 09:09:14	xinetd	23114	Starting reconfiguration
Jun 19 09:09:14	xinetd	23114	Swapping defaults
Jun 19 09:09:14	xinetd	23114	readjusting service 6969-udp
Jun 19 09:09:14	xinetd	23114	Reconfigured: new=0 old=1 dropped=0 (services)
Jun 19 09:09:27	php-fpm	76391	/rc.newipsecdns: IPSEC: One or more IPsec tunnel endpoints has changed its IP. Refreshing.
Jun 19 09:09:27	php-fpm	76391	/rc.newipsecdns: WARNING: Setting i_dont_care_about_security_and_use_aggressive_mode_psk option because a phase 1 is configured using aggressive mode with pre-shared keys. This is not a secure configuration.
Jun 19 09:09:27	check_reload_status		Reloading filter
Jun 19 09:09:29	xinetd	23114	Starting reconfiguration

Displaying the system logs in pfSense.

As you can see in the sample log file displayed here, the **General** tab includes entries for several different services, including pfBlocker, VPN tunnels, and Dynamic DNS. The default log order is chronological, although you can show the log entries in reverse order by clicking on the **Settings** tab and checking the **Forward/Reverse Display** checkbox. Note that there is an **Advanced Log Filter** section at the top of the page (this section can be expanded by clicking on the plus icon on the right of the section heading). This section allows you to filter log entries by several criteria: by time, process, **process ID** (**PID**), the quantity of entries displayed (the default is **50**), and the message contained in the log entry. Each of these fields except for **Quantity** can contain a regular expression as well. To filter the logs, click on the **Apply Filter** button.

You can control many log settings by clicking on the **Settings** tab. We already mentioned the **Forward/Reverse Display** checkbox, which allows you to show the log entries in reverse order. The **GUI Log Entries** edit box allows you to control the number of log entries displayed in the GUI (but not the number of entries in the actual log files). The next option, the **Log file size (Bytes)** edit box, allows you to change the size of each log file. By default, each log file is approximately **500** KB. Since there are about 20 log files, the disk space used by log files by default is about **10** MB. If you want to retain more than 50 entries per log file, you can increase this number. Be aware, however, that increasing this value increases every log file size, so make sure you have enough disk space available. For example, if you specify 1,048,576 here (1 MB), the total amount of disk space used will be 20 MB, and each log will contain 100 entries.

The next subsection is **Log firewall default blocks**. The **Log packets matched from the default block rules in the ruleset** checkbox, if checked, will log packets that are blocked by the implicit default block rule. By default, all internetwork traffic is blocked; unless traffic is explicitly allowed elsewhere, if this option is set this blocked traffic will be logged. If the log packets matched from the default pass rules in the ruleset are checked, pfSense will log packets that are allowed by the implicit default pass rule. Since you generally don't want to log traffic that is allowed to pass, by default this option is not checked. The **Log packets blocked by 'Block Bogon Networks' rules** and the **Log packets blocked by 'Block Private Networks' rules** checkboxes, if checked, logs packets blocked by those rules.

If the **Web Server Log** checkbox is checked, errors from the web server process for the pfSense GUI or the captive portal will appear in the main system log. The **Raw Logs** checkbox, if checked, will show the logs without being interpreted by the log parser. The raw log file, though more difficult to read, can be helpful in troubleshooting as it provides detailed information that is left out in the parsed log output.

The next option is the **Where to show rule descriptions** drop-down box. This option allows you to show a description of the applied rule in the firewall log. The options are as follows:

- **Don't load descriptions**: This is the default option
- **Display as column**: The applied firewall rule will appear as an additional column
- **Display as second row**: The applied firewall rule will appear below the corresponding log entry

The **Local Logging** checkbox, if checked, will disable writing log files to the local disk. Clicking the **Reset Log Files** button will clear all local log files and reinitialize them as empty logs. This will also restart the DHCP daemon. If you have made any changes to settings on this page, you should click on the **Save** button before clearing the log files.

The next section is the **Remote Logging Options** section. Checking the **Enable Remote Logging** checkbox allows you to send log messages to a remote syslog server. If you check this option, a number of other options will appear. The **Source Address** drop-down box allows you to choose to which IP address the syslog daemon will bind. The choices include each interface on your pfSense system (which normally would include at least the WAN and LAN interfaces) and localhost. If one of these options is selected, then remote syslog servers must all be of that IP type (either **IPv4** or **IPv6**). In order to mix IPv4 and IPv6 syslog servers, select **Default (any)** to bind to all interfaces. Also, if an IP address cannot be located on the chosen interface, the daemon will bind to all addresses.

The **IP Protocol** drop-down box allows you to select the IP type of the address specified in the **Source Address** drop-down box. However, if an IP address of the type selected here is not found, the other type will be tried. The **Remote log servers** edit boxes allow you to specify the IP addresses and ports of up to three syslog servers. Finally, the **Remote Syslog Contents** checkboxes allow you to select what events are sent to the syslog server(s). Keep in mind that you must configure the syslog daemon on the remote server to accept syslog messages from pfSense. When you are done making changes, click on the **Save** button.

Dashboard

You can also gather a great deal of information from the pfSense dashboard, which you can access by navigating to **Status | Dashboard** (the dashboard is also the first page you see when you log into the web GUI). The dashboard contains a great deal of information about your pfSense system, such as the uptime, CPU usage, memory usage, as well as the version being run and whether an upgrade is available. The dashboard has been redesigned for version 2.3; you can choose the number of columns in the display under **General Setup**. If you resize the width of your web browser, the dashboard will resize to a single column, thus ensuring that you do not have to scroll left and right. There is also an **Interfaces** widget which displays the interfaces, their speed, and their IP addresses. You can add widgets to the page by clicking on the plus sign on the right side of the title bar. There are widgets for gateways, traffic graphs, CARP status, load balancer status, and many packages have their own widgets. The dashboard updates every few seconds, so you don't have to hit the **Reload** button.

Interfaces

You can view information about the status of interfaces by navigating to **Status | Interfaces**. Information about all interfaces is available here, including the following:

- The device name of the interface (for example, **fxp0**, **em1**, and so on)
- Interface status (**up** or **down**)
- The MAC address of the interface
- IP address, subnet mask, and gateway (for WAN-type interfaces)
- The number of packets that have passed (in and out), and that have been blocked (in and out)
- The number of errors and collisions

If an interface has been configured to receive its IP address via DHCP (this is likely true for all WAN-type interfaces on your system), you can renew the DHCP lease via this page.

Services

Most system and package services display their status on the **Services** page, which can be viewed by navigating to **Status | Services**. On this page, you will find a table that lists the name of the service (**Service**), a brief description (**Description**), and whether the service is running or stopped (**Status**). There is also an **Actions** column. By clicking on the appropriate icon for a service, you can either start a stopped service or restart/stop a running service. Normally it is not necessary to control services in such a way, but you may need to do so in a troubleshooting scenario.

There are three additional icons that appear in some, but not all, entries in the **Services** table:

- **Related settings**: This is the icon that looks like three sliders. This links to the settings page for the service.
- **Related status**: This icon looks like a bar graph. Many of the services listed have their own page on the **Status** menu; if they do, it is linked to here.
- **Related log entries**: This icon looks like a logbook page. If the service has its own tab in **Status | Logs**, it will be linked to here.

Monitoring

By navigating to **System | Monitoring**, you can view another useful set of data relating to the real-time operation of your pfSense system. There are two sections on this page: a graph (**Interactive Graph**) and a summary of the information in the graph (**Data Summary**). There are several pieces of information available on this page, and they relate to the percentage of CPU usage attributable to different processes:

- **User util.**: User-related processes
- **Nice util.**: Nice (low-priority) processes
- **System util.**: Non-nice system processes
- **Interrupt**: System interrupts

There is also a column representing the grand total of processes. Each entry includes the minimum, maximum, and average percentage of CPU usage for each category.

Traffic graphs

You can view traffic graphs for each interface by navigating to **Status | Traffic Graph**. You can select the interface for which a graph is generated in the **Interface** drop-down box. Information displayed in the table adjacent to the graph is sorted in descending order based on either bandwidth in or bandwidth out, depending on what is selected in the **Sort by** drop-down box. The **Filter** drop-down box allows you to display either only local traffic or only remote traffic in the table (the default selection is **All**). The **Display** drop-down box allows you to select what is displayed in the **Host Name or IP** column: the IP address, the hostname, a description, or the **Fully Qualified Domain Name** (**FQDN**).

Firewall states

Sometimes when troubleshooting, it is helpful to view information about the firewall states. These states can be viewed several different ways from within the pfSense web GUI and the console.

States

One way to view the states table is to navigate to **Diagnostics | States**. This table provides information about each state table entry, including the interface, protocol, the direction of the traffic, the socket status, and the number of packets and bytes exchanged. By using the options in the **State Filter** section, you can filter the state table entries by interface or by a regular expression. By clicking on the **Reset States** tab, you can also clear the state table, if necessary.

States summary

If you just need an overview of state information rather than information about each individual entry, you can navigate to **Diagnostics** | **States Summary**. Here you will find sections in which states are organized by source IP, by destination IP, the total per IP, and by IP pair. This page is useful for seeing if an IP address has an unusual number of states.

pfTop

pfTop is available in both the web GUI (by navigating to **Diagnostics** | **pfTop**), and at the console (it is 9 on the console menu). pfTop provides a live view of the state table and the total amount of bandwidth utilized by each state. If you are using pfTop from the console, type `q` to quit; this will return you to the console menu.

```
pfTop: Up State 1-22/113, View: default, Order: none, Cache: 10000      01:39:09
1404                                                                          P
R    D SRC                    DEST                  STATE   AGE   EXP  PKTS BYTES
udp   O ::1[27947]            ::1[9364]              2:2  92359    54  8393  401K
udp   I ::1[27947]            ::1[9364]              2:2  92359    54  8393  401K
udp   O ::1[48209]            ::1[42864]             2:2  2073m    54 10952  521K
udp   I ::1[48209]            ::1[42864]             2:2  2073m    54 10952  521K
udp   O ::1[52063]            ::1[34528]             2:2  2072m    54 10951  521K
udp   I ::1[52063]            ::1[34528]             2:2  2072m    54 10951  521K
udp   O ::1[59438]            ::1[48690]             2:2  2066m    54 10930  520K
udp   I ::1[59438]            ::1[48690]             2:2  2066m    54 10930  520K
udp   O ::1[35274]            ::1[3070]              2:2  2066m    54 10929  520K
udp   I ::1[35274]            ::1[3070]              2:2  2066m    54 10929  520K
udp   O ::1[25677]            ::1[6184]              2:2  2065m    54 10927  520K
udp   I ::1[25677]            ::1[6184]              2:2  2065m    54 10927  520K
udp   O ::1[47219]            ::1[16977]             2:2  2065m    54 10926  520K
udp   I ::1[47219]            ::1[16977]             2:2  2065m    54 10926  520K
udp   O ::1[5982]             ::1[63669]             2:2  2062m    54 10918  519K
udp   I ::1[5982]             ::1[63669]             2:2  2062m    54 10918  519K
udp   O ::1[59055]            ::1[20342]             2:2  2062m    54 10916  519K
udp   I ::1[59055]            ::1[20342]             2:2  2062m    54 10916  519K
udp   O ::1[6847]             ::1[29159]             2:2  2061m    54 10914  519K
udp   I ::1[6847]             ::1[29159]             2:2  2061m    54 10914  519K
udp   O ::1[36976]            ::1[35431]             2:2  2061m    54 10913  519K
udp   I ::1[36976]            ::1[35431]             2:2  2061m    54 10913  519K
```

Running pfTop at the console.

Most of the column headings in pfTop are self-explanatory. For example, the default view provides the following column headings: **PR**, **D**, **SRC**, **DEST**, **STATE**, **AGE**, **EXP**, **PKTS**, **BYTES**.

PR stands for protocol; **D** stands for direction (in or out); **SRC** and **DEST** stand for source and destination, respectively. **AGE** indicates how long it has been since the entry was created; **EXP** indicates when the entry expires; **PKTS** indicates the number of packets that have been handled by the rule, and **BYTES** indicates the number of bytes.

STATE indicates the state of the connection in the format `client:server`. Since the states will not fit into an 80-column table, pfTop uses integers, such as 1:0. The numbers signify the following:

Number	State
0	TCP_CLOSED
1	TCP_LISTEN
2	TCP_SYN_SENT
3	TCP_SYN_RECEIVED
4	TCP_ESTABLISHED
5	TCP_CLOSE_WAIT
6	TCP_FIN_WAIT_1
7	TCP_CLOSING
8	TCP_LAST_ACK
9	TCP_FIN_WAIT_2
10	TCP_TIME_WAIT

Thus an entry of `1:0` indicates that the state on the client side is `TCP_LISTEN`, and the state on the server side is `TCP_CLOSED`.

One of the advantages of using pfSense within the web GUI is that it is very easy to change the output to suit your needs. The **View** drop-down menu allows you to choose how pfTop displays its output. There are several options, including:

- **label**: The **LABEL** column represents the rule that is being invoked, and how many packets, bytes, and states are accounted for by the rule
- **long**: Displays the protocol, source, destination, gateway, state, and age of each entry
- **queue**: If the traffic shaper is configured, it will display results organized by queue
- **rules**: This option will display each rule being invoked in the rightmost column, and the number of states associated with each rule

There is also a **Sort by** drop-down box, which allows you to sort output in descending order by several categories (for example, **Bytes**, **Age**, **Destination Address**, **Source Address**, and others). The **Maximum # of States** drop-down box allows you to control the number of states that appear on the page.

If you run pfTop from the console, it will be running in interactive mode, which means that pfTop will read commands from the terminal and act upon them accordingly; characters will be processed as soon as they are typed, and the display will be updated immediately after the characters are processed.

Refer to the pfTop man page for a full listing of commands available in interactive mode, as well as pfTop command-line options.

tcpdump

Often the most effective way of troubleshooting a networking problem is through packet capturing, also known as packet sniffing. One way of capturing packets is to use the command-line tool **tcpdump**, which is part of the default pfSense installation. Tcpdump is a command-line utility used to capture and analyze packets; details can either be displayed on the screen or saved to a file. It uses the `libpcap` library for packet capturing.

The results of packet capture will differ depending on which interface's traffic you capture. As a result, you should give some consideration as to which interface's traffic you choose to capture, and in some cases, you may want to capture traffic from several interfaces at the same time. In order to use `tcpdump`, you will have to use the underlying device names of the interfaces. If you don't remember what they are, you can navigate to **Interfaces** | **(assign)** within the web GUI. The console menu also lists each interface and has a separate column for the device name. Another way of retrieving a list of interface names is to issue to following command from the console shell:

```
tcpdump -D
```

Then, to run tcpdump on a single interface, type the following:

```
tcpdump -iinterface_name
```

where `interface_name` is the device name (for example, `fxp0`, `em1`, and so on). Alternatively, you can run tcpdump without any command-line options to capture packets from all interfaces.

If you run tcpdump, you may notice that the hostname of the source and destination is displayed. By default, tcpdump does a DNS lookup on IP addresses. As a result, tcpdump can generate a considerable amount of DNS traffic.

By default, tcpdump runs continuously until you press *Ctrl* + *C*, but you can limit the number of packets captured with the –c option. For example:

```
tcpdump -c 10
```

This will cause tcpdump to capture `10` packets and then stop running. The default maximum capture size for each packet is 64 K, but in many cases you may only want to see what's in the header. You can use the `-s` parameter to limit the amount of each packet captured; for example:

```
tcpdump -s 96
```

This will only capture the first `96` bytes of each packet.

Tcpdump allows you to save packet capture files in `pcap` format for later analysis. This is useful, especially if you want to load the files onto another computer running Wireshark or some other graphical network protocol analyzer. To save the output to a file, use the `-w` option, like this:

```
tcpdump -w filename
```

Be aware that, when you are using this option, the frames will not be displayed on the screen, as they otherwise would be.

By default, tcpdump puts your network interface into promiscuous mode, which shows every frame on the wire, not just frames being sent to its MAC address. In modern networks, this should not be much of a problem, as most networks employ switches, and the interface generally will only receive traffic it should receive. If you have hubs on your network, however, running tcpdump in promiscuous mode can result in you capturing a great deal of traffic that may not be of interest to you. By using the `-p` option, which runs tcpdump in non-promiscuous mode, you can improve the signal-to-noise ratio and focus on traffic destined for the interface on which you are capturing packets.

You can control the verbosity of tcpdump's output with the `-v` flag. This flag only controls the output on the screen and not the contents of tcpdump output saved to a file (assuming that output is being saved). In addition to `-v`, you may also choose `-vv` or `-vvv`, which provide additional verbosity for screen output. If you invoked the `-w` option to write to a file along with one of the verbosity options, then tcpdump will report the number of packets captured at 10-second intervals.

The `-e` option causes tcpdump to display the MAC addresses of the source and destination of the packet as well as 802.1Q VLAN tag information.

You may notice that tcpdump displays packet sequence numbers. You may also notice that when displaying multiple packets from the same source/destination, the first packet in a series of packets has large sequence numbers, but all subsequent packets have smaller numbers. This is because tcpdump switches to relative sequence numbers in order to save display space. To see only actual sequence numbers, use the `-S` flag.

If you want a simple frontend for tcpdump, you can use the tcpdump page in the web GUI instead. To do so, navigate to **Diagnostics** | **Packet Capture**. Once there, use the **Interface** drop-down box to select the interface whose packets will be captured (note that there does not seem to be an option to capture all interfaces on this page). Checking the **Promiscuous** checkbox enables promiscuous mode. The **Address Family** drop-down box allows you to select IPv4 packets, IPv6 packets, or both. The **Protocol** drop-down box has several options: you can capture any packets (**Any**), or the following: **ICMP**, **Exclude ICMP**, **ICMPv6**, **Exclude ICMPv6**, **TCP**, **Exclude TCP**, **UDP**, **Exclude UDP**, **ARP**, **Exclude ARP**, **CARP**, **Exclude CARP**, **pfsync**, **Exclude pfsync**, **ESP**, and **Exclude ESP**.

The **Host Address** edit box allows you to specify a source or destination IP address or subnet (in CIDR notation). Tcpdump will look for the address specified in either field. You can negate the IP address by preceding the value with `!`, in which case tcpdump will match everything except the IP address. Multiple IP addresses or CIDR subnets may be specified here; comma-separated values (,) perform a Boolean AND, while separating addresses with a pipe (`|`) performs a Boolean OR. If this field is left blank, then all packets on the specified interface that meet the other criteria specified will be captured, regardless of the source or destination IP address.

If you specify a port in the **Port** edit box, tcpdump will look for the port in either field. If you leave this field blank, tcpdump will not filter by port. The **Packet Length** edit box lets you specify the number of bytes of each packet that will be captured. The default value is **0**, which will cause the entire frame to be captured. The **Count** edit box allows you to specify the number of packets tcpdump will grab. The default value is **100**; specifying 0 will result in tcpdump continuously capturing packets.

The **Level of detail** drop-down box controls the amount of detail that will be displayed after you hit **Stop** when packets have been captured. The options are **Normal**, **Medium**, **High**, and **Full**. This option does not affect the level of detail in the packet capture file if you choose to download it when the packet capture completes.

The **Reverse DNS Lookup** checkbox, if checked, will result in tcpdump performing a reverse DNS lookup on all IP addresses. As noted when discussing the command-line options for tcpdump, doing a reverse DNS lookup generates considerable DNS traffic and also creates delays, and therefore is not generally recommended. When you are done selecting options on this page, click on the **Start** button.

Once you click on **Start**, you should see a **Packet capture is running** message across the bottom of the page, and the **Start** button should become a **Stop** button. Once you click on the **Stop** button, a **Packets Captured** listbox will appear at the bottom of the page with information about the packets captured. You can change the level of detail by changing the value in the **Level of Detail** edit box and clicking on **View Capture** to update the display. Finally, you can save the packet capture by clicking on the **Download Capture** button; this will save the capture as a `.cap` file, which can be opened by many network protocol analyzers such as Wireshark.

tcpflow

tcpflow, like tcpdump, allows you to view the text contents of network packets in real time. Whereas tcpdump is more suited to capturing packets as well as protocol information, tcpflow is better suited for viewing the actual data flow between two hosts. One significant difference between tcpflow and tcpdump is that, while tcpdump displays output to the console by default, tcpflow writes the output to a file by default. In order to display tcpflow's output on the console, you can use the `-c` option.

Much of the syntax of tcpflow is similar to that of tcpdump. For example:

```
tcpflow -i fxp0 -c host 172.16.1.2 and port 80
```

This would capture packets on the `fxp0` interface with either a source or destination of `172.16.1.2` port `80`. Here are some of the options available for tcpflow:

Option	Description	tcpdump equivalent
`-bmax_bytes`	Capture no more than `max_bytes` per flow	`-c`
`-c`	Console print	NA (default)
`-ddebug_level`	Debug level	
`-iiface`	Capture packets from interface `iface`	`-i`
`-p`	Do not put the interface in promiscuous mode	`-p`
`-r file`	Read packets from file, when file was created using tcpdump's `-w` option	`-r`

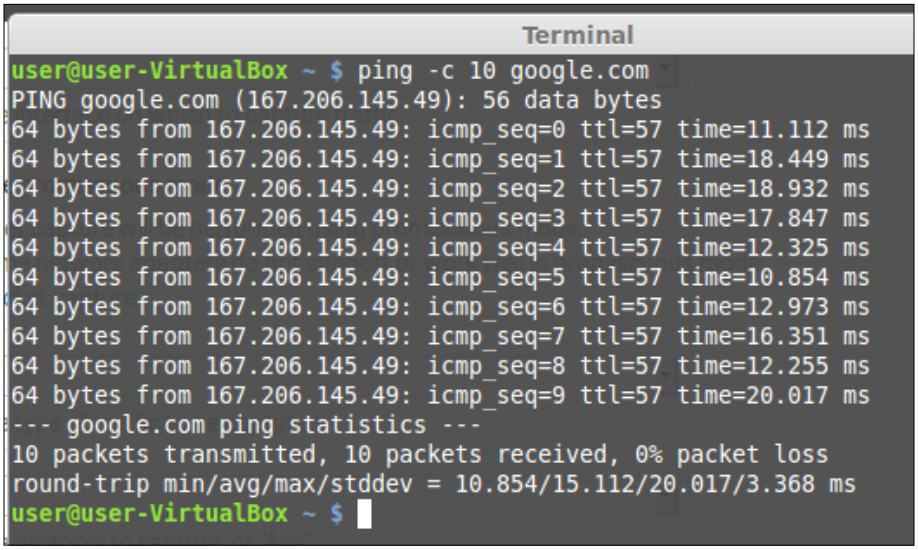
Option	Description	tcpdump equivalent
`-s`	Convert all non-printable characters to the "." character before displaying or saving output	NA
`-v`	Verbose operation (equivalent to `-d` 10)	`-v`

ping, traceroute, and netstat

`ping`, `traceroute`, and `netstat` are old command-line utilities used to test the reachability of hosts, provide routing information, and information about network connections. Often they are the first tools used by network technicians when testing networks. They can prove invaluable when troubleshooting networks. Both `ping` and `traceroute` are accessible from pfSense's web GUI, although they are more commonly used from the console.

ping

The purpose of ping is to measure the **round-trip time** (**RTT**) for messages sent from a source host to a destination host that are then echoed back to the source. It uses **Internet Control Message Protocol** (**ICMP**), sending ICMP Echo Request packets to the destination host and waiting for an ICMP Echo Reply. The following displays typical ping output under Linux:



The first item reported is the size of the packet received. The default size is 56 bytes, but an ICMP `ECHO_REQUEST` packet contains an additional 8 bytes as an ICMP header followed by an arbitrary amount of data. Thus, the size reported is 64 bytes. Next is the destination IP address. By default, ping displays the IP address to which the hostname resolves rather than the hostname.

The `icmp_seq` field reveals the ordering of the ICMP packets. ping reports on each packet as it is received, and the packets are not necessarily received in the same order as they are sent, although when the networks are functioning properly, they usually are. **ttl** stands for **time to live**. The **TTL** field is reduced by one by every router en route to its destination. If the **TTL** field reaches zero before the packet arrives, then an ICMP error is sent back (**ICMP Time Exceeded**). As you may have guessed, the default start value used by ping in Linux is 64. Finally, the last field is the RTT of each packet, which is a good measure of the latency of a connection.

Once the results for each packet are reported, ping reports aggregate statistics for the ping session. The number of packets transmitted and received is reported, as well as the percentage of packet loss. On the final line, we see: the minimum RTT, the average RTT, the maximum RTT, and the standard deviation.

One caveat that should be made concerning ping is that many firewalls block ICMP traffic, rendering the ping utility useless with hosts behind restrictive firewalls. In fact, pfSense blocks such traffic by default, so if you want to ping your hosts from the other side of the firewall, you will have to explicitly allow such traffic. Even so, you may have occasion to ping a network you don't control that blocks ICMP traffic. In such cases, you may be better off utilizing a utility that relies on TCP or UDP for sending packets, since such protocols are much less likely to be blocked by most firewalls. One such utility is tcpping, and it has a similar syntax to ping. If you are pinging to local hosts, you can use arping, which uses the **Address Resolution Protocol** (**ARP**) request method to resolve IP addresses.

To install tcpping, you must first install tcptraceroute and then `tcpping`, which is a script that utilizes tcptraceroute. You can install tcptraceroute from the repositories. If you are using Debian/Ubuntu/Mint Linux, type the following at the console:

```
sudo apt-get install tcptraceroute
```

For CentOS/Red Hat Enterprise Level, the command is:

```
sudo yum install tcptraceroute
```

Then you have to install tcpping, which can be done with the `wget` command:

```
$ cd /usr/bin
$ sudowget http://www.vdberg.org/~richard/tcpping
```

You'll also want to set permissions for tcpping, which you can do with `chmod`:

```
$ sudochmod 755 tcpping
```

To see the command line options for tcpping, type the following at the console:

```
tcpping --help
```

This caveat aside, the ping utility is useful in a number of different troubleshooting scenarios:

- ping can help us determine if there is network connectivity between two hosts.
- ping can help us determine if there is an unacceptable rate of packet loss. We may have connectivity between two hosts, but if the packet loss rate is consistently high, network performance will undoubtedly suffer.
- ping is a good tool for measuring latency between two hosts.

As an example of the last of these scenarios, you might consider pinging a well-known host (for example, `google.com`) and measuring the latency in a number of different scenarios: for example, on a broadband connection, on a DSL connection, on a mobile connection, through a VPN, and so on.

You may have noticed that, when we invoked the `ping` command under Linux, we used one flag: the `-c` flag, which limits the number of packets sent. Without the `-c` flag, `ping` would have sent packets continuously until we pressed *Ctrl* + *C* at the console. This is just one of many flags and options available for ping. The following table covers some of the more commonly used ping options:

Option	Description	Windows equivalent
`-c count`	Stop after receiving count `ECHO_RESPONSE` packets	`-n count`
`-D`	Set the DF bit	`-f`
`-f`	Flood ping; output packets as fast as they come back (use with caution)	NA
`-i wait`	Wait seconds before sending each packet	NA
`-mttl`	Set the ttl for each packet.	`-I ttl`
`-S source_ addr`	Use `source_addr` as the source address in outgoing packets; useful for forcing the IP address to be something other than the IP address on which the `ping` packet is sent out (only works if the IP address is one of the host's IP addresses)	`-S source_addr`
`-spacketsize`	Specify the number of data bytes to be sent (the default is 56)	`-lpacketsize`
`-t timeout`	Specify a timeout, in seconds, before ping exits regardless of how many packets have been received	NA
`-v`	Verbose output; ICMP packets other than `ECHO_RESPONSE` packets are also displayed	NA

Be aware that this is not an exhaustive list of ping options; consult the ping man page for a complete.

If you are running ping from the Windows command prompt, the output is similar, with some exceptions:

- By default, ping sends four packets instead of sending all the packets. To send packets continuously, use the `-t` option. To send an arbitrary number of packets, use the `-n` count option.
- The default packet size is 32 bytes.
- The summary does not show the standard deviation.

Other than that, the behavior of ping under Windows is similar to its behavior under Linux, although it seems to have fewer command-line options. The preceding table lists some of the Windows ping flag equivalents.

You can also invoke ping from within the pfSense web GUI. To do so, navigate to **Diagnostics | Ping**. In the **Hostname** edit box, specify the hostname or IP address to ping. You can specify the protocol in the **IP Protocol** drop-down box (**IPv4** or **IPv6**). In the **Source Address** drop-down box, you can set a source address for the ping. Finally, in the **Maximum number of pings** edit box, you can set the maximum number of pings (the default is 3). When you are done configuring the ping settings, click on the **Ping** button.

traceroute

`traceroute` (or `tracert`, as it is known under Windows) is a network diagnostic tool for IP networks. Its purpose is twofold: to display the path of packets, and the transit delays along each step (known as a hop). The RTT of each hop is recorded, and the sum of the mean times in each hop is a measure of the total time taken to establish the connection. By default, `traceroute` outputs the results of each hop, as well as the final results. `traceroute` sends three packets, and it proceeds unless all three are lost more than twice. In this case, the connection is considered lost and the route/path cannot be evaluated.

```
C:\>tracert google.com

Tracing route to google.com [167.206.252.99]
over a maximum of 30 hops:

  1    <1 ms    <1 ms     1 ms  pfSense.localdomain [192.168.2.1]
  2    16 ms    22 ms    18 ms  pfSense.localdomain [192.168.2.1]
  3     9 ms     8 ms     9 ms  67.59.248.125
  4    11 ms    10 ms    11 ms  ool-4353f894.dyn.optonline.net [67.83.248.148]
  5    14 ms     9 ms    24 ms  65.19.119.159
  6     8 ms    12 ms     9 ms  167.206.252.99

Trace complete.

C:\>
```

Using traceroute at the Windows command prompt.

`traceroute` is available at the Windows command prompt (as `tracert`), but it is not part of most default Linux installations. Instead, it is available from the repositories, both as a standalone package (`traceroute`) and as part of the inetutils utilities (`inetutils-traceroute`). The output of `traceroute` is relatively simple. The first column displays the hop count. The final column displays the IP address and hostname (if available) of the host/router. The middle three columns display the RTT of each of the three packets sent.

The only required parameter is the hostname or IP address of the destination host. There are, however, many other options available, as shown in the following table:

Option	Description
`-e`	Firewall evasion mode; uses fixed destination ports for UDP, UDP-lite, TCP, and SCTP probes
`-ffirst_ttl`	Set the ttl for the first outgoing packet
`-F`	Set the DF bit
`-d`	Enable socket-level debugging
`-I`	Use ICMP ECHO instead of UDP datagrams
`-M first_ttl`	Set the ttl value used in outgoing probe packets
`-P proto`	Set the protocol (`proto`) used in outgoing probe packets; the currently supported values are UDP, UDP-Lite, TCP, SCTP, GRE, and ICMP
`-ssrc_addr`	Use `src_addr` as the IP address in outgoing probe packets to force the source address to something other than the IP address of the interface the probe packet is sent on (only works if the IP address is the address of one of the interfaces on the host)
`-S`	Print a summary of how many probes were not answered at each hop
`-v`	Verbose output (all received ICMP packets shown)
`-w`	Set the time to wait for a response to a probe (default is 5 seconds)

I omitted the **Windows Equivalent** column on this table, since few of the options available for `traceroute` under Linux exist for the Windows version. If you need to use another protocol, you can use the `-P` option; there is also a utility called **tcptraceroute** (available for Linux), which sends TCP probe packets.

You can also invoke `traceroute` from the web GUI. To do so, navigate to **Diagnostics | Traceroute**. Type in the hostname or IP address in the **Hostname** edit box. You can select the protocol (**IPv4** or **IPv6**) in the **IP Protocol** drop-down box. You can select the source address for the trace in the **Source Address** drop-down box. In the **Maximum number of hops** drop-down box, you can set the maximum number of network hops to trace (the maximum number is 20; the default is 18). You can enable DNS lookup by checking the **Reverse Address Lookup** checkbox. Finally, you can change the protocol used by `traceroute` from UDP to ICMP by checking the **Use ICMP** checkbox. When you are done configuring settings, click on the **Traceroute** button.

netstat

netstat is a network utility that displays a variety of statistics for network connections on a system. It displays incoming and outgoing connections, routing tables, and a number of other network statistics. Under Linux, it is considered deprecated, and you are advised to use `dss` instead (part of the `iproute2` package), although `netstat` may still work, depending on which distribution you are using.

netstat, without any command-line arguments, will display a list of active sockets for each network protocol. If you invoke netstat under Linux, it will also display a list of active Unix domain sockets. There are several columns of output. **Proto** stands for protocol, with a 6 denoting use of IPv6. **Recv-Q** tells you how many packets have not yet been copied from the socket buffer by the application. **Send-Q** tells you how many packets have been sent, but for which an `ACK` packet has not yet been received. **Local Address** indicates the IP address/hostname and port of the local end of the connection, while **Foreign Address** indicates the IP address/hostname and port of the remote end of the connection. Finally, **State** indicates the state of the socket. This column may be left blank, since there are no states in **RAW** and usually no states used in UDP.

For active Unix domain sockets, there are several columns not present under active Internet connections. **RefCnt** stands for reference count, which is the number of attached processes connected via this socket. The **Flags** column contains a number of flags that are used on both connected and unconnected sockets, such as `SO_ACCEPTON` (displayed as **ACC**), `SO_WAITDATA` (**W**) and `SO_NOSPACE` (**N**). The **Type** column indicates the type of socket access. **DGRAM** indicates that the socket is in datagram (connectionless) mode, while **STREAM** indicates that the socket is a stream (connection) socket. **RAW** indicates a raw socket. The **State** column will contain one of several different states: **FREE** indicates that the socket is not allocated; **LISTENING** indicates that the socket is listening for a connection request. **CONNECTING** indicates the socket is about to establish a connection, while **CONNECTED** indicates the socket is already connected. Finally, **DISCONNECTING** indicates the socket is disconnecting. The **I-Node** and the **Path** columns show the inode and path of the file object representing the process attached to the socket.

As with `ping` and `traceroute`, there are many command-line options; here are some of the more useful ones:

Option	Description	Windows equivalent
`-faddress_family`	Limit the display to a specific `address_family` (for example, inet, inet6, unix)	NA

Option	Description	Windows equivalent
`-p protocol`	Limit the display to a specific protocol (tcp, udp, icmp, and so on)	`-p protocol`
`-r`	Display the content of routing tables	`-r`
`-rs`	Display routing statistics	NA
`-n`	Do not resolve addresses and ports; instead show addresses and ports as numbers	`-n`
`-W`	Avoid truncating addresses even if this causes some fields to overflow	NA

Troubleshooting scenarios

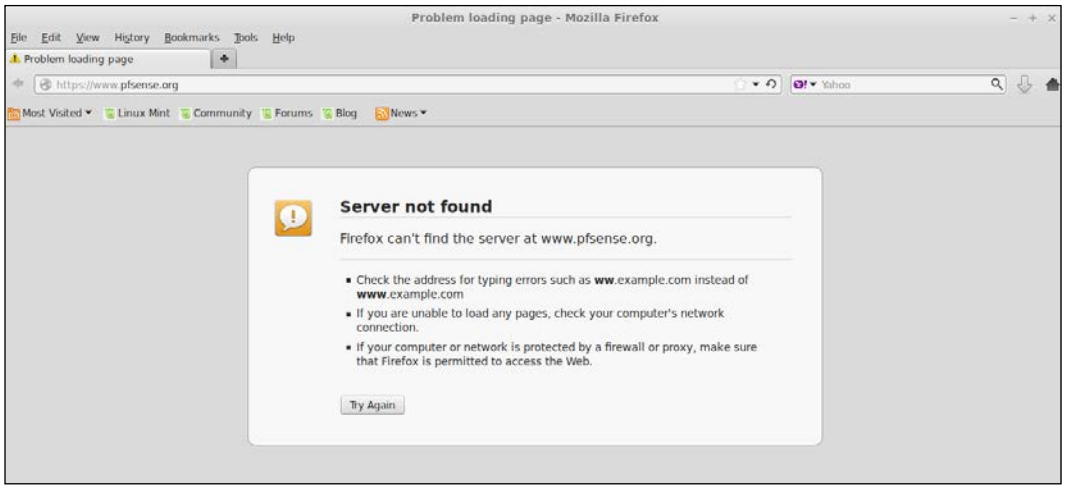
It is beyond the scope of this chapter to cover network troubleshooting scenarios in depth, but it may prove enlightening to make mention of problems that are likely to occur if you are a network administrator, and what the cause might be. Most of these problems have multiple potential causes, so you will likely have to gather some information before you can make conjectures about the root cause.

User cannot connect to a website

This is probably the most common end user problem, if not the most common one: a user reports that they cannot access a particular website, and they are consistently getting the same error message. Without knowing more information about the problem, you cannot tell which of many causes may be operative:

- User error
- A computer configuration issue
- A network connection issue
- An issue with the router or modem providing Internet access
- An issue with the Internet or the specific website

Obviously, if the problem is with the Internet or the website, then it is beyond your control. The other issues, however, are more likely to be within your sphere of control, even if the problem requires escalation to another tier within your support team.



A familiar "Server not found" error message.

Going back to the approach we outlined for troubleshooting in the first section, we would we well-served to spend some time identifying the problem and gathering information. For example, we might question the user and ask them what the error message was. If they cannot remember, ask them if they can recreate the problem. For example, they might try to access the site again and receive a **Server Not Found** error page, like the one shown here.

This error message can be the result of several different causes. The web server to which the user is trying to connect may be down; the user's Internet connection may be broken, or DNS resolution may have failed. Another possible cause is that the user may be using a proxy, and the proxy may be misconfigured. Narrowing down the cause of the problem involves a process of elimination, and it might prove useful to begin with the most wide-ranging problems first.

One possible cause is that the user's Internet connection is broken, so we will begin with that. Most organizations have shared Internet connections; the end user's system connects to a router, which in turn connects to an ISP. If you are supporting a pfSense deployment, the router is likely connected to a modem or perhaps to a leased telephone line. There are several problems that could arise:

- There may be a problem with the router's connection to the ISP or the ISP's connection to the Internet. In this case, the problem is beyond your control, and there isn't much you can do about it, other than to report the problem to your ISP.
- There may be a problem with the network. There could be a broken network cable or a misconfigured switch or router. The number of users affected by such a problem depends on which component has malfunctioned. For example, a broken cable between the user's computer and a switch will only affect that user, while a broken switch will likely affect more users.
- The user's computer may be the source of the problem. There may be a problem with the network card, the networking software, or the computer's network configuration. If so, the problem will affect only one computer.

In this scenario, a malfunctioning router is unlikely to be the source of the problem. If the router were malfunctioning, you would probably have multiple users reporting the same problem. Still, it should be easy to check to see if there is a router problem, and you should do so in order to eliminate the router as a potential problem. The simplest way of testing the router is to try to access an Internet site using a separate computer that shares the same Internet connection. This will narrow down the source of the problem, and we can begin to focus on the user, their computer, the way they access the site, or the computer's connection to the switch or router.

If, however, you are unable to access the Internet via another computer, then the problem could be in one or more areas. It could be that a component that both you and the user used to access the Internet is broken. It could be a switch, cable, or another component; it could even be the router. It could also be the connection between your router and the ISP. If the problem is the connection between your router and ISP, then very likely it is beyond your control. Even if the modem is malfunctioning, unless you have a spare modem that can be configured for use with your ISP, then you will probably be waiting on your ISP for support. If the problem is with hardware or software within the ISP's network, then you almost definitely will be relying on the ISP for support. If the problem is with equipment that is part of your network, then you should continue the process of narrowing down the cause.

If you are accessing the Web through a proxy such as Squid, then this could also be the source of the problem. If you suspect that it is, you could temporarily disable the proxy and see if it resolves your problem. If you can access the Internet after disabling the proxy, then it is probably at least one of the causes of your problem. If not, then it is likely not the cause.

If you have narrowed down the source of the problem to either the user or the user's computer, then you should continue the process of tracing it back to the source. You can do this by asking the user to access a different website. If the user can connect to other Internet websites, then the network, the router, and Internet connection are all functioning correctly. In this case, the problem is likely either a website that is down or an error made by the user.

If not, then you should ask the user to open another network client application and use it to try to connect to the Internet. Any application that connects directly to an Internet site will do: for example, an e-mail client or an FTP client. If the user can connect to the Internet using another client application, then the problem is likely in the browser software on their computer. But if the user cannot connect to the Internet at all, you will have to determine what element of the computer's Internet access is at fault.

One possibility is that the user's computer's DNS configuration is wrong. Hosts rely on DNS servers to resolve hostnames to IP addresses, and if the user's computer is not configured with one or more valid DNS servers, then name resolution will fail. As mentioned earlier in this chapter, one way to detect DNS problems is to ping an IP address rather than a hostname. If you can ping a site by entering the IP address, but the ping fails when you enter the hostname, then you can be reasonably certain you have a DNS issue. In this case, you will want to have the user check his computer's DNS settings. In most cases, the user's computer can acquire DNS server addresses from an upstream router, so resolving the issue may be as simple as having the user click on **Obtain DNS server address automatically** (in recent versions of Windows) or the functional equivalent in their operating system.

If the DNS configuration is not at fault, there could be another configuration issue. If an incorrect gateway is specified, then the user will only be able to access the local subnet. You may consider having the user ping a host on the same network, and then ping a host on another network (that the user normally would be able to access) and see what the results are. If the user can access the local network but not another network, then there is a good chance there is a network configuration issue. If even a ping to a local host fails, however, then the problem may lie in the computer hardware.

If you suspect that the network card may be at fault, have the user ping the loopback address (`127.x.x.x`). If this fails, then there is a good chance the network card drivers may need to be reinstalled, or the network card itself may be broken. If the user can ping the loopback address, however, then it is likely that the network card is functioning, and you might consider checking the cabling between the user's computer and the hub instead.

Once you have identified the problem, you will then have to formulate a plan of action. In a situation like this, anyone affected by the problem will likely want to have the issue resolved as soon as possible, so you can likely begin working on fixing the problem right away; however, if implementing the solution is likely to affect a number of users, then it is probably a good idea to inform them, and to follow whatever procedures your organization may have for performing such maintenance. As always, you will want to verify system functionality and document what you have done.

As you can tell by our brief discussion of this scenario, a simple problem can have many potential causes. Nevertheless, by employing some of the troubleshooting steps we discussed in the first section, such as identifying the problem, gathering information, formulating theories, and testing them, we can work toward eliminating many of these possibilities and zero in on the real cause of the problem.

VLAN configuration problem

I would like to conclude this section by providing a concrete example of a network problem and how it was resolved. I installed a TP-Link TL-SG108E switch on my network, and had planned to set up two VLANs using this switch. I had given some consideration as to how the VLANs would be configured, and I settled on the following:

- Each VLAN would be assigned three ports (the TL-SG108E is an eight-port switch; thus, six ports would be assigned to VLANs, leaving two ports to act as trunk ports)
- One VLAN (**DEVELOPERS**) would be assigned the network `192.168.10.x`; the other VLAN would be assigned the VLAN `192.168.20.x`
- The **DEVELOPERS** VLAN would be assigned a VLAN ID of `10`; the **ENGINEERING** VLAN would be assigned a VLAN of `20` (thus, the VLAN IDs would match the third octet of the network)

Since I wanted to set up 802.1q VLANs, I started the TP-Link Easy Smart Configuration Utility and selected **VLAN** from the sidebar menu, and then I selected the **802.1q** menu. I set up `1` as the default VLAN, and tagged ports `3` to `5` with a VLAN ID of `10` and tagged ports `6` to `8` with a VLAN ID of `20`. After clicking on the **Apply** button, I continued configuration in pfSense. After creating the two VLANs, I set up interfaces for each of them, and enabled the DHCP server on both interfaces. The switch was connected to the parent interface of the VLANs.

If everything had worked as expected, connecting a computer to one of the VLAN ports should have resulted in outgoing traffic from the port being tagged with a VLAN ID. pfSense should have then assigned a DHCP lease for the VLAN whose VLAN ID matches the ID of the packets. Unfortunately, DHCP assignment never took place, and the computer connected to the VLAN port could not access the network.

I checked the DHCP and VLAN settings under pfSense, but could find nothing wrong, so I returned to the switch configuration utility. There was a separate page for PVID configuration. **PVID** (**Port VLAN ID**) is the default VLAN ID of the port. I set ports `3-5` to have a default VLAN ID of `10` and ports `6-8` to have a default VLAN ID of `20`, leaving ports `1` and `2` having a default VLAN ID of **1**. After clicking on the **Apply** button, I disabled and re-enabled the Ethernet connection on the computer being used to test the VLANs. Still, there was no DHCP assignment and no network connectivity.

I checked the configuration settings again and could not find anything obviously wrong, but I noticed that the **Port Based VLAN** option only allows you to set the VLAN ID between 1 and 8. Since I saw no other obvious solution, I tried setting the VLAN IDs to lower numbers. The DEVELOPERS VLAN ID was set to `2` and the ENGINEERING VLAN to `3`.

When I disabled and re-enabled the connection on the computer connected to the switch, the computer was assigned a DHCP lease and I was able to access other networks. Thus, setting the VLAN IDs to lower numbers seemed to solve the problem, but I still was unsure whether setting up PVIDs was necessary or not. Therefore, I set the PVIDs back to `1` for all the ports and tested connectivity again. This time, the same problem recurred (no DHCP assignment or network connectivity).

Thus, it was apparent that, in order for 802.1q VLAN tagging to work with this switch, both PVIDs had to be configured and the VLAN IDs had to be set to a number between 1 and 8. Once I confirmed that setting the VLAN IDs to higher numbers did not work, I verified system functionality and documented the results.

What conclusions can we draw from the approach I employed here? I probably should have spent more time gathering information; because I was configuring this switch for the first time, I assumed that it was a switch configuration issue, an assumption that turned out to be correct. Nonetheless, the tried and true method of formulating a theory of probable cause, testing the theory, and then repeating the process until a solution is found served me well. Also, it's important to remember that finding the solution isn't the end of the process; you still have to implement the solution, verify system functionality, and document the results.

Summary

In this chapter, we covered some troubleshooting fundamentals, including some basic steps you can employ in any troubleshooting scenario. We also covered some common networking problems and some troubleshooting tools you can use. Finally, we considered some real-world troubleshooting scenarios.

Needless to say, this chapter barely scratches the surface of network troubleshooting, and if you want to learn more about it, there are copious amounts of material available, both in book form and online. Of course, there is no substitute for practical experience, and there is a great deal you can learn from building and maintaining networks. Acquiring troubleshooting skills is something that will aid you not just in mastering pfSense, but in understanding networking in general.

Index

Symbol

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

Q

R

S

T

U

V

W

X