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CCNA 200-301

Volume 2

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4. ACL IV
5. ACL V
6. ACL VI
7. ACL Analysis I
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9. Named ACL II
10. Named ACL III
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13. Extended ACL II Configuration Scenario

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CCNA
200-301
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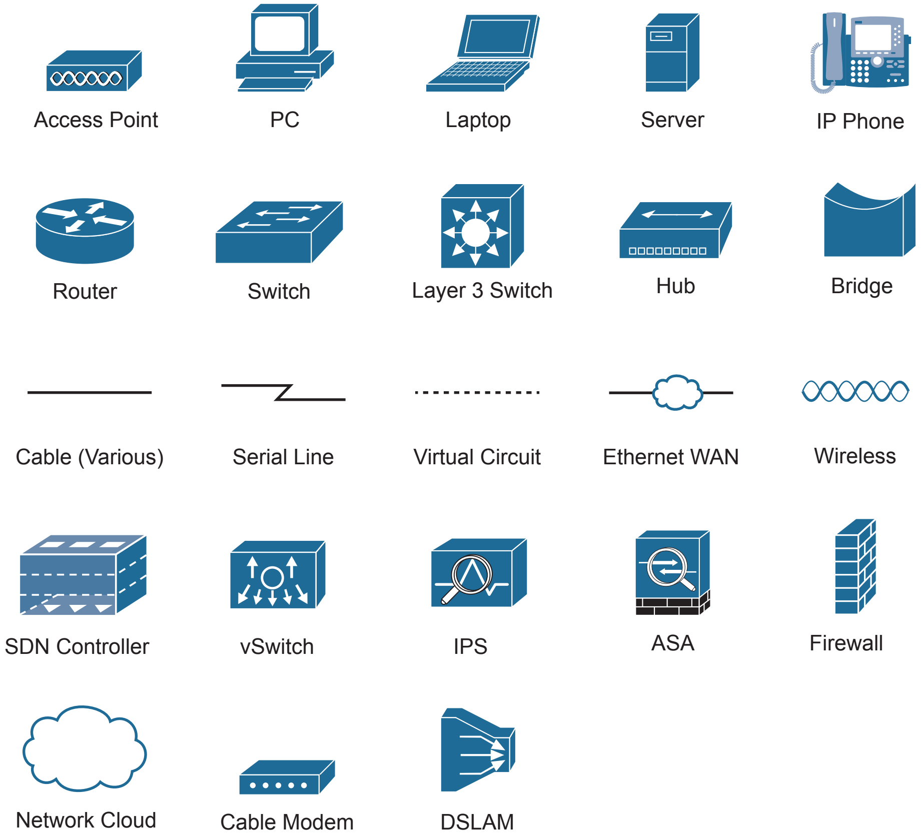
Contents at a Glance

Icons Used in This Book



Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italic* indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

CHAPTER 5

Securing Network Devices

This chapter covers the following exam topics:

1.0 Network Fundamentals

1.1 Explain the Role of Network Components

1.1.c Next-generation Firewalls and IPS

4.0 IP Services

4.8 Configure network devices for remote access using SSH

5.0 Security Fundamentals

5.3 Configure device access control using local passwords

All devices in the network—endpoints, servers, and infrastructure devices like routers and switches—include some methods for the devices to legitimately communicate using the network. To protect those devices, the security plan will include a wide variety of tools and mitigation techniques, with the chapters in Part II of this book discussing a large variety of those tools and techniques.

This chapter focuses on two particular security needs in an enterprise network. First, access to the CLI of the network devices needs to be protected. The network engineering team needs to be able to access the devices remotely, so the devices need to allow remote SSH (and possibly Telnet) access. The first half of this chapter discusses how to configure passwords to keep them safe and how to filter login attempts at the devices themselves.

The second half of the chapter turns to two different security functions most often implemented with purpose-built appliances: firewalls and IPSs. These devices together monitor traffic in transit to determine if the traffic is legitimate or if it might be part of some exploit. If considered to be part of an exploit, or if contrary to the rules defined by the devices, they can discard the messages, stopping any attack before it gets started.

"Do I Know This Already?" Quiz

Take the quiz (either here or use the PTP software) if you want to use the score to help you decide how much time to spend on this chapter. The letter answers are listed at the bottom of the page following the quiz. Appendix C, found both at the end of the book as well as on the companion website, includes both the answers and explanations. You can also find both answers and explanations in the PTP testing software.

Table 5-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
Securing IOS Passwords	1–4
Firewalls and Intrusion Prevention Systems	5, 6

5. A next-generation firewall sits at the edge of a company's connection to the Internet. It has been configured to prevent Telnet clients residing in the Internet from accessing Telnet servers inside the company. Which of the following might a next-generation firewall use that a traditional firewall would not?

- **a.** Match message destination well-known port 23
- **b.** Match message application data
- **c.** Match message IP protocol 23
- **d.** Match message source TCP ports greater than 49152

6. Which actions show a behavior typically supported by a Cisco next-generation IPS (NGIPS) beyond the capabilities of a traditional IPS? (Choose two answers)

- **a.** Gather and use host-based information for context
- **b.** Comparisons between messages and a database of exploit signatures
- **c.** Logging events for later review by the security team
- **d.** Filter URIs using reputation scores

Foundation Topics

Securing IOS Passwords

The ultimate way to protect passwords in Cisco IOS devices is to not store passwords in IOS devices. That is, for any functions that can use an external authentication, authorization, and accounting (AAA) server, use it. However, it is common to store some passwords in a router or switch configuration, and this first section of the chapter discusses some of the ways to protect those passwords.

As a brief review, Figure 5-1 summarizes some typical login security configuration on a router or switch. On the lower left, you see Telnet support configured, with the use of a password only (no username required). On the right, the configuration adds support for login with both username and password, supporting both Telnet and SSH users. The upper left shows the one command required to define an enable password in a secure manner.

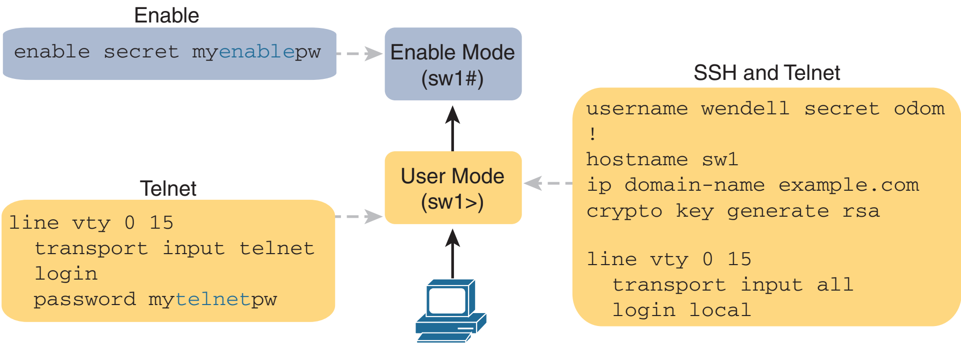


Figure 5-1 *Sample Login Security Configuration*

NOTE The configuration on the far right of the figure supports both SSH and Telnet, but consider allowing SSH only by instead using the **transport input ssh** command. The Telnet protocol sends all data unencrypted, so any attacker who copies the message with a Telnet login will have a copy of the password.

The rest of this first section discusses how to make these passwords secure. In particular, this section looks at ways to avoid keeping clear-text passwords in the configuration and storing the passwords in ways that make it difficult for attackers to learn the password.

Encrypting Older IOS Passwords with service password-encryption

Some older-style IOS passwords create a security exposure because the passwords exist in the configuration file as clear text. These clear-text passwords might be seen in printed versions of the configuration files, in a backup copy of the configuration file stored on a server, or as displayed on a network engineer's display.

Cisco attempted to solve this clear-text problem by adding a command to encrypt those passwords: the **service password-encryption** global configuration command. This command encrypts passwords that are normally held as clear text, specifically the passwords for these commands:

Key Topic

`password` *`password`* (console or vty mode)

`username` *`name`* **`password`** *`password`* (global)

`enable password` *`password`* (global)

To see how it works, Example 5-1 shows how the **service password-encryption** command encrypts the clear-text console password. The example uses the **show running-config | section line con 0** command both before and after the encryption; this command lists only the section of the configuration about the console.

Example 5-1 *Encryption and the* **service password-encryption** *Command*

```
Switch3# show running-config | section line con 0
line con 0
 password cisco
 login

Switch3# configure terminal
Enter configuration commands, one per line.   End with CNTL/Z.
Switch3(config)# service password-encryption
Switch3(config)# ^Z

Switch3# show running-config | section line con 0
line con 0
 password 7 070C285F4D06
 login
```

A close examination of the before and after **show running-config** command output reveals both the obvious effect and a new concept. The encryption process now hides the original clear-text password. Also, IOS needs a way to signal that the value in the **password** command lists an encrypted password rather than the clear text. IOS adds the encryption or encoding type of "7" to the command, which specifically refers to passwords encrypted with the **service password-encryption** command. (IOS considers the clear-text passwords to be type 0; some commands list the 0, and some do not.)

While the **service password-encryption** global command encrypts passwords, the **no service password-encryption** global command does not immediately decrypt the passwords back to their clear-text state. Instead, the process works as shown in Figure 5-2. Basically, after you enter the **no service password-encryption** command, the passwords remain encrypted until you change a password.

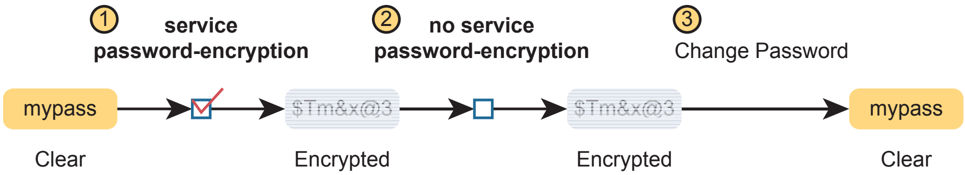


Figure 5-2 *Encryption Is Immediate; Decryption Awaits Next Password Change*

Unfortunately, the **service password-encryption** command does not protect the passwords very well. Armed with the encrypted value, you can search the Internet and find sites with tools to decrypt these passwords. In fact, you can take the encrypted password from this example, plug it into one of these sites, and it decrypts to "cisco." So, the **service password-encryption** command will slow down the curious, but it will not stop a knowledgeable attacker.

Encoding the Enable Passwords with Hashes

In the earliest days of IOS, Cisco used the **enable password** *password* global command to define the password that users had to use to reach enable mode (after using the **enable** EXEC command). However, as just noted, the **enable password** *password* command stored the password as clear text, and the **service password-encryption** command encrypted the password in a way that was easily decrypted.

Cisco solved the problem of only weak ways to store the password of the **enable password** *password* global command by making a more secure replacement: the **enable secret** *password* global command. However, both these commands exist in IOS even today. The next few pages look at these two commands from a couple of angles, including interactions between these two commands, why the **enable secret** command is more secure, along with a note about some advancements in how IOS secures the **enable secret** password.

Interactions Between Enable Password and Enable Secret

First, for real life: use the **enable secret** *password* global command, and ignore the **enable password** *password* global command. That has been true for around 20 years.

However, to be complete, Cisco has never removed the much weaker **enable password** command from IOS. So, on a single switch (or router), you can configure one or the other,

---

Answers to the "Do I Know This Already?" quiz:

1 B **2** A **3** B **4** A **5** B **6** A, D both, or neither. What, then, does the switch expect us to type as the password to reach enable mode? It boils down to these rules:

Key Topic

Both commands configured: Users must use the password in the **enable secret** *password* command (and ignore the **enable password** *password* command).

Only one command configured: Use the password in that one command.

Neither command configured (default): Console users move directly to enable mode without a password prompt; Telnet and SSH users are rejected with no option to supply an enable password.

Making the Enable Secret Truly Secret with a Hash

The Cisco **enable secret** command protects the password value by never even storing the clear-text password in the configuration. However, that one sentence may cause you a bit of confusion: If the router or switch does not remember the clear-text password, how can the switch know that the user typed the right password after using the **enable** command? This section works through a few basics to show you how and appreciate why the password's value is secret.

5

First, by default, IOS uses a hash function called Message Digest 5 (MD5) to store an alternative value in the configuration, rather than the clear-text password. Think of MD5 as a rather complex mathematical formula. In addition, this formula is chosen so that even if you know the exact result of the formula—that is, the result after feeding the clear-text password through the formula as input—it is computationally difficult to compute the original clear-text password. Figure 5-3 shows the main ideas:

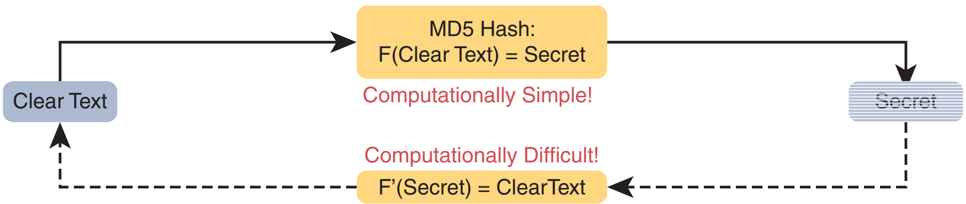


Figure 5-3 *One-Way Nature of MD5 Hash to Create Secret*

NOTE "Computationally difficult" is almost a code phrase, meaning that the designers of the function hope that no one is willing to take the time to compute the original clear text.

So, if the original clear-text password cannot be re-created, how can a switch or router use it to compare to the clear-text password typed by the user? The answer depends on another fact about these security hashes like MD5: each clear-text input results in a unique result from the math formula.

The **enable secret fred** command generates an MD5 hash. If a user types **fred** when trying to enter enable mode, IOS will run MD5 against that value and get the same MD5 hash as is listed in the **enable secret** command, so IOS allows the user to access enable mode. If the user typed any other value besides **fred**, IOS would compute a different MD5 hash than the value stored with the **enable secret** command, and IOS would reject that user's attempt to reach enable mode.

Knowing that fact, the switch can make a comparison when a user types a password after using the **enable** EXEC command as follows:

Key Topic

Step 1. IOS computes the MD5 hash of the password in the **enable secret** command and stores the hash of the password in the configuration.

Step 2. When the user types the **enable** command to reach enable mode, a password that needs to be checked against that configuration command, IOS hashes the clear-text password as typed by the user.

Step 3. IOS compares the two hashed values: if they are the same, the user-typed password must be the same as the configured password.

As a result, IOS can store the hash of the password but never store the clear-text password; however, it can still determine whether the user typed the same password.

Switches and routers already use the logic described here, but you can see the evidence by looking at the switch configuration. Example 5-2 shows the creation of the **enable secret** command, with a few related details. This example shows the stored (hashed) value as revealed in the **show running-configuration** command output. That output also shows that IOS changed the **enable secret fred** command to list the encryption type 5 (which means the listed password is actually an MD5 hash of the clear-text password). The gobbledygook long text string is the hash, preventing others from reading the password.

Example 5-2 *Cisco IOS Encoding Password "cisco" as Type 5 (MD5)*

```
Switch3(config)# enable secret fred
Switch3(config)# ^Z
Switch3# show running-config | include enable secret

enable secret 5 $1$ZGMA$e8cmvkz4UjiJhVp7.maLE1

Switch3# configure terminal
Enter configuration commands, one per line.   End with CNTL/Z.
Switch3(config)# no enable secret
Switch3(config)# ^Z
```

The end of the example also shows an important side point about deleting the **enable secret** password: after you are in enable mode, you can delete the enable secret password using the **no enable secret** command, without even having to enter the password value. You can also overwrite the old password by just repeating the **enable secret** command. But you cannot view the original clear-text password.

NOTE Example 5-2 shows another shortcut illustrating how to work through long **show** command output, this time using the pipe to the **include** command. The **| include enable secret** part of the command processes the output from **show running-config** to include only the lines with the case-sensitive text "enable secret."

Improved Hashes for Cisco's Enable Secret

The use of any hash function to encode passwords relies on several key features of the particular hash function. In particular, every possible input value must result in a single hashed value, so that when users type a password, only one password value matches each hashed value. Also, the hash algorithm must result in computationally difficult math (in other words, a pain in the neck) to compute the clear-text password based on the hashed value to discourage attackers.

The MD5 hash algorithm has been around 30 years. Over those years, computers have gotten much faster, and researchers have found creative ways to attack the MD5 algorithm, making MD5 less challenging to crack. That is, someone who saw your running configuration would have an easier time re-creating your clear-text secret passwords than in the early years of MD5.

These facts are not meant to say that MD5 is bad, but like many cryptographic functions before MD5, progress has been made, and new functions were needed. To provide more recent options that would create a much greater challenge to attackers, Cisco added two additional hashes in the 2010s, as noted in Figure 5-4.

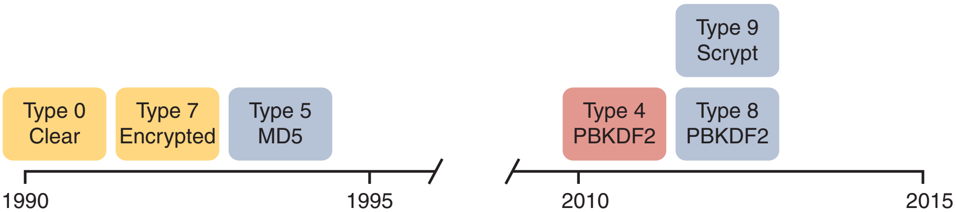


Figure 5-4 *Timeline of Encryptions/Hashes of Cisco IOS Passwords*

IOS now supports two alternative algorithm types in the more recent router and switch IOS images. Both use an SHA-256 hash instead of MD5, but with two newer options, each of which has some differences in the particulars of how each algorithm uses SHA-256. Table 5-2 shows the configuration of all three algorithm types on the **enable secret** command.

Table 5-2 Commands and Encoding Types for the **enable secret** Command

Command	Type	Algorithm
enable [algorithm-type md5] secret *password*	5	MD5
enable algorithm-type sha256 secret *password*	8	SHA-256
enable algorithm-type scrypt secret *password*	9	SHA-256

Example 5-3 shows the **enable secret** command being changed from MD5 to the scrypt algorithm. Of note, the example shows that only one **enable secret** command should exist between those three commands in Table 5-2. Basically, if you configure another **enable secret** command with a different algorithm type, that command replaces any existing **enable secret** command.

Example 5-3 *Cisco IOS Encoding Password "mypass1" as Type 9 (SHA-256)*

```
R1# show running-config | include enable
enable secret 5 $1$ZSYj$725dBZmLUJ0nx8gFPTtTv0
R1# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)# enable algorithm-type scrypt secret mypass1
R1(config)# ^Z
```

```
R1#
R1# show running-config | include enable
enable secret 9 $9$II/EeKiRW91uxE$fwYuOE5EHoii16AWv2wSywkLJ/KNeGj8uK/24B0TVU6
R1#
```

Following the process shown in the example, the first command confirms that the current **enable secret** command uses encoding type 5, meaning it uses MD5. Second, the user configures the password using algorithm type scrypt. The last command confirms that only one **enable secret** command exists in the configuration, now with encoding type 9.

Encoding the Passwords for Local Usernames

Cisco added the **enable secret** command back in the 1990s to overcome the problems with the **enable password** command. The **username password** and **username secret** commands have a similar history. Originally, IOS supported the **username** *user* **password** *password* command—a command that had those same issues of being a clear-text password or a poorly encrypted value (with the **service password-encryption** feature). Many years later, Cisco added the **username** *user* **secret** *password* global command, which encoded the password as an MD5 hash, with Cisco adding support for the newer SHA-256 hashes later.

Today, the **username secret** command is preferred over the **username password** command; however, IOS does not use the same logic for the **username** command as it does for allowing both the **enable secret** plus **enable password** commands to exist in the same configuration. IOS allows

Key Topic

- Only one **username** command for a given username—either a **username** *name* **password** *password* command or a **username** *name* **secret** *password* command
- A mix of commands (**username password** and **username secret**) in the same router or switch (for different usernames)

You should use the **username secret** command instead of the **username password** command when possible. However, note that some IOS features require that the router knows a clear-text password via the **username** command (for instance, when performing some common authentication methods for serial links called PAP and CHAP). In those cases, you still need to use the **username password** command.

As mentioned, the more recent IOS versions on both switches and routers use the additional encoding options beyond MD5, just as supported with the **enable secret** command. Table 5-3 shows the syntax of those three options in the **username** command, with the MD5 option shown as an option because it is the default used with the **username secret** command.

Table 5-3 Commands and Encoding Types for the **username secret** Command

Command	Type	Algorithm
username *name* [**algorithm-type md5**] **secret** *password*	5	MD5
username *name* **algorithm-type sha256 secret** *password*	8	SHA-256
username *name* **algorithm-type scrypt secret** *password*	9	SHA-256

Controlling Password Attacks with ACLs

Attackers can repeatedly try to log in to your network devices to gain access, but IOS has a feature that uses ACLs to prevent the attacker from even seeing a password prompt. When an external user connects to a router or switch using Telnet or SSH, IOS uses a vty line to represent that user connection. IOS can apply an ACL to the vty lines, filtering the addresses that can telnet or SSH into the router or switch. If filtered, the user never sees a login prompt.

For example, imagine that all the network engineering staff's devices connect into subnet 10.1.1.0/24. The security policy states that only the network engineering staff should be allowed to telnet or SSH into any of the Cisco routers in a network. In such a case, the configuration shown in Example 5-4 could be used on each router to deny access from IP addresses not in that subnet.

Example 5-4 *vty Access Control Using the* **access-class** *Command*

```
line vty 0 4
 login
 password cisco
 access-class 3 in
!
! Next command is a global command that matches IPv4 packets with
! a source address that begins with 10.1.1.
 access-list 3 permit 10.1.1.0 0.0.0.255
```

The **access-class** command refers to the matching logic in **access-list 3**. The keyword **in** refers to Telnet and SSH connections into this router—in other words, people telnetting into this router. As configured, ACL 3 checks the source IP address of packets for incoming Telnet connections.

IOS also supports using ACLs to filter outbound Telnet and SSH connections. For example, consider a user who first uses Telnet or SSH to connect to the CLI and now sits in user or enable mode. With an outbound vty filter, IOS will apply ACL logic if the user tries the **telnet** or **ssh** commands to connect *out of the local device* to another device.

To configure an outbound VTY ACL, use the **access-class** *acl* **out** command in VTY configuration mode. Once configured, the router filters any attempts made by current vty users to use the **telnet** and **ssh** commands to initiate new connections to other devices.

Of the two options—to protect inbound and outbound connections—protecting inbound connections is by far the more important and more common. However, to be complete, outbound VTY ACLs have a surprisingly odd feature in how they use the ACL. When the **out** keyword is used, the standard IP ACL listed in the **access-class** command actually looks at the *destination IP address*, and not the source. That is, it filters based on the device to which the **telnet** or **ssh** command is trying to connect.

Firewalls and Intrusion Prevention Systems

The next topic examines the roles of a couple of different kinds of networking devices: firewalls and intrusion prevention systems (IPSs). Both devices work to secure networks but with slightly different goals and approaches.

This second major section of the chapter takes a look at each. This section first discusses the core traditional features of both firewalls and IPSs. The section closes with a description of the newer features in the current generation of these products, called next-generation products, which improves the functions of each.

Traditional Firewalls

Traditionally, a firewall sits in the forwarding path of all packets so that the firewall can then choose which packets to discard and which to allow through. By doing so, the firewall protects the network from different kinds of issues by allowing only the intended types of traffic to flow in and out of the network. In fact, in its most basic form, firewalls do the same kinds of work that routers do with ACLs, but firewalls can perform that packet-filtering function with many more options, as well as perform other security tasks.

Figure 5-5 shows a typical network design for a site that uses a physical firewall. The figure shows a firewall, like the Cisco Adaptive Security Appliance (ASA) firewall, connected to a Cisco router, which in turn connects to the Internet. All enterprise traffic going to or from the Internet would be sent through the firewall. The firewall would consider its rules and make a choice for each packet, whether the packet should be allowed through.

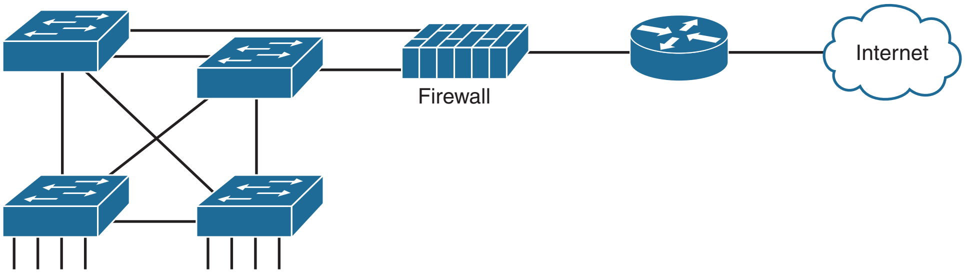


Figure 5-5 *Firewall as Positioned in the Packet Forwarding Path*

Although firewalls have some router-like features (such as packet forwarding and packet filtering), they provide much more advanced security features than a traditional router. For example, most firewalls can use the following kinds of logic to make the choice of whether to discard or allow a packet:

- Like router IP ACLs, match the source and destination IP addresses
- Like router IP ACLs, identify applications by matching their static well-known TCP and UDP ports
- Watch application-layer flows to know what additional TCP and UDP ports are used by a particular flow, and filter based on those ports
- Match the text in the URI of an HTTP request—that is, look at and compare the contents of what is often called the web address—and match patterns to decide whether to allow or deny the download of the web page identified by that URI
- Keep state information by storing information about each packet, and make decisions about filtering future packets based on the historical state information (called *stateful inspection*, or being a stateful firewall)

The stateful firewall feature provides the means to prevent a variety of attacks and is one of the more obvious differences between the ACL processing of a router versus security filtering by a firewall. Routers must spend as little time as possible processing each packet so that the packets experience little delay passing through the router. The router cannot take the time to gather information about a packet, and then for future packets, consider some saved state information about earlier packets when making a filtering decision. Because they focus on network security, firewalls do save some information about packets and can consider that information for future filtering decisions.

As an example of the benefits of using a stateful firewall, consider a simple denial of service (DoS) attack. An attacker can make this type of attack against a web server by using tools that create (or start to create) a large volume of TCP connections to the server. The firewall might allow TCP connections to that server normally, but imagine that the server might typically receive 10 new TCP connections per second under normal conditions and 100 per second at the busiest times. A DoS attack might attempt thousands or more TCP connections per second, driving up CPU and RAM use on the server and eventually overloading the server to the point that it cannot serve legitimate users.

A stateful firewall could be tracking the number of TCP connections per second—that is, recording state information based on earlier packets—including the number of TCP connection requests from each client IP address to each server address. The stateful firewall could notice a large number of TCP connections, check its state information, and then notice that the number of requests is very large from a small number of clients to that particular server, which is typical of some kinds of DoS attacks. The stateful firewall could then start filtering those packets, helping the web server survive the attack, whereas a stateless firewall or a router ACL would not have had the historical state information to realize that a DoS attack was occurring.

Security Zones

Firewalls not only filter packets, they also pay close attention to which host initiates communications. That concept is most obvious with TCP as the transport layer protocol, where the client initiates the TCP connection by sending a TCP segment that sets the SYN bit only (as seen in Figure 1-5 in Chapter 1, "Introduction to TCP/IP Transport and Applications").

Firewalls use logic that considers which host initiated a TCP connection by watching these initial TCP segments. To see the importance of who initiates the connections, think about a typical enterprise network with a connection to the Internet, as shown in Figure 5-6. The company has users inside the company who open web browsers, initiating connections to web servers across the Internet. However, by having a working Internet connection, that same company opens up the possibility that an attacker might try to create a TCP connection to the company's internal web servers used for payroll processing. Of course, the company does not want random Internet users or attackers to be able to connect to their payroll server.

Firewalls use the concept of *security zones* (also called a *zone* for short) when defining which hosts can initiate new connections. The firewall has rules, and those rules define which host can initiate connections from one zone to another zone. Also, by using zones, a firewall can place multiple interfaces into the same zone, in cases for which multiple interfaces should have the same security rules applied. Figure 5-7 depicts the idea with the inside part of the enterprise considered to be in a separate zone compared to the interfaces connected toward the Internet.

Key Topic

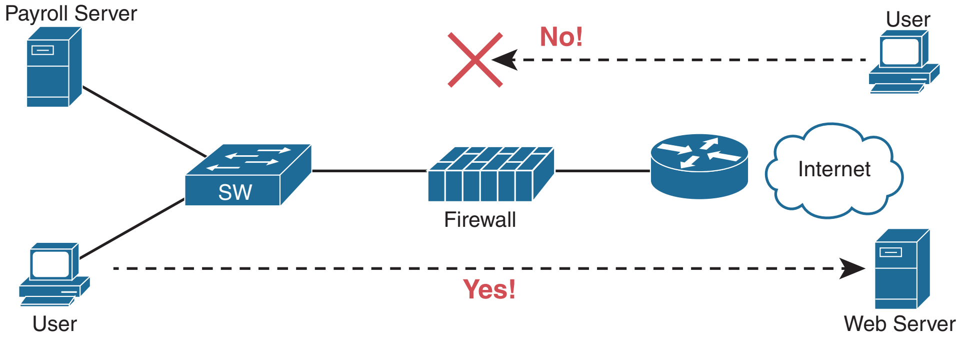


Figure 5-6 *Allowing Outbound Connections and Preventing Inbound Connections*

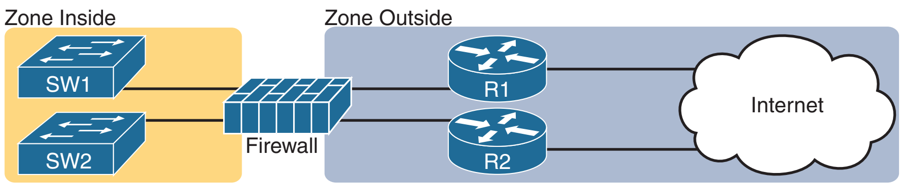


Figure 5-7 *Using Security Zones with Firewalls*

The most basic firewall rule when using two zones like Figure 5-7 reduces to this logic:

> Allow hosts from zone inside to initiate connections to hosts in zone outside, for a predefined set of safe well-known ports (like HTTP port 80, for instance).

Note that with this one simple rule, the correct traffic is allowed while filtering the unwanted traffic by default. Firewalls typically disallow all traffic unless a rule specifically allows the packet. So, with this simple rule to allow inside users to initiate connections to the outside zone, and that alone, the firewall also prevents outside users from initiating connections to inside hosts.

Most companies have an inside and outside zone, as well as a special zone called the *demilitarized zone (DMZ)*. Although the DMZ name comes from the real world, it has been used in IT for decades to refer to a firewall security zone used to place servers that need to be available for use by users in the public Internet. For example, Figure 5-8 shows a typical Internet edge design, with the addition of a couple of web servers in its DMZ connected through the firewall. The firewall then needs another rule that enables users in the zone outside—that is, users in the Internet—to initiate connections to those web servers in the DMZ. By separating those web servers into the DMZ, away from the rest of the enterprise, the enterprise can prevent Internet users from attempting to connect to the internal devices in the inside zone, preventing many types of attacks.

Key Topic

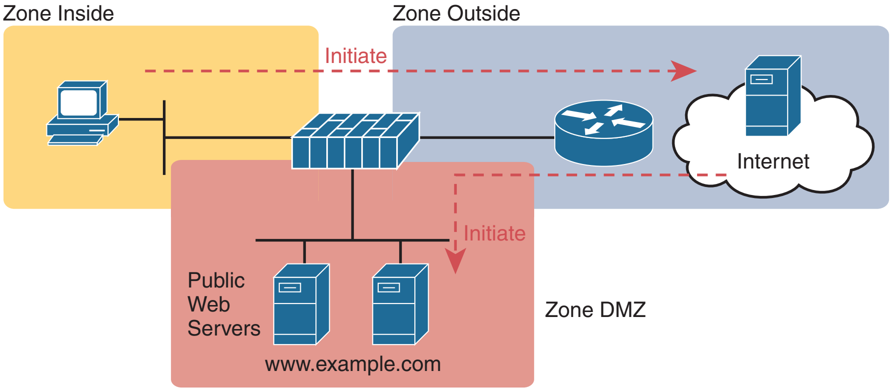


Figure 5-8 *Using a DMZ for Enterprise Servers That Need to Be Accessible from the Internet*

Intrusion Prevention Systems (IPS)

Traditionally, a firewall works with a set of user-configured rules about where packets should be allowed to flow in a network. The firewall needs to sit in the path of the packets so it can filter the packets, redirect them for collection and later analysis, or let them continue toward their destination.

A traditional intrusion prevention system (IPS) can sit in the path packets take through the network, and it can filter packets, but it makes its decisions with different logic. The IPS first downloads a database of exploit signatures. Each signature defines different header field values found in sequences of packets used by different exploits. Then the IPS can examine packets, compare them to the known exploit signatures, and notice when packets may be part of a known exploit. Once identified, the IPS can log the event, discard packets, or even redirect the packets to another security application for further examination.

A traditional IPS differs from firewalls in that instead of an engineer at the company defining rules for that company based on applications (by port number) and zones, the IPS applies the logic based on signatures supplied mostly by the IPS vendor. Those signatures look for these kinds of attacks:

- DoS
- DDoS
- Worms
- Viruses

To accomplish its mission, the IPS needs to download and keep updating its signature database. Security experts work to create the signatures. The IPS must then download the exploit signature database and keep downloading updates over time, as shown in Figure 5-9.

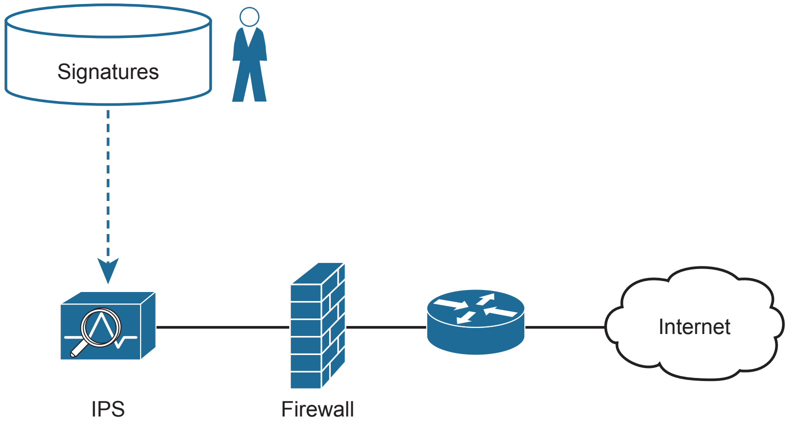


Figure 5-9 *IPS and Signature Database*

For example, think about what happens when an entirely new computer virus has been created. Host-based security products, like antivirus software, should be installed on the computers inside the company. These tools use a similar model as the IPS, keeping an updated database of virus signatures. The signatures might look for patterns in how a computer virus could be stored inside files on the computer, or in files sent to the computer via email or web browsers. But there will be some time lag between the day when the virus has been discovered (called zero-day attacks) and when researchers have developed a virus signature, changed their database, and allowed time for all the hosts to update their antivirus software. The hosts are at risk during this time lag.

The IPS provides a complimentary service to prevent viruses. Researchers will look for ways an IPS could recognize the same virus while in flight through the network with new IPS signatures—for instance, looking for packets with a particular port and a particular hex string in the application payload. Once developed, the IPS devices in the network need to be updated with the new signature database, protecting against that virus. Both the host-based and IPS-based protections play an important role, but the fact that one IPS protects sections of a network means that the IPS can sometimes more quickly react to new threats to protect hosts.

Cisco Next-Generation Firewalls

The CCNA 200-301 exam topics mention the terms *firewall* and *IPS* but prefaced with the term *next-generation*. Around the mid 2010s, Cisco and some of their competitors started using the term *next generation* when discussing their security products to emphasize some of the newer features. In short, a next-generation firewall (NGFW) and a next-generation IPS (NGIPS) are the now-current firewall and IPS products from Cisco.

However, the use of the term *next generation* goes far beyond just a marketing label: the term emphasizes some major shifts and improvements over the years. The security industry sees endless cycles of new attacks followed by new solutions, with some solutions requiring new product features or even new products. Some of the changes that have required new security features include the proliferation of mobile devices—devices that leave the enterprise, connect to the Internet, and return to the Enterprise—creating a whole new level of risk. Also, no single security function or appliance (firewall, IPS, antimalware) can hope to stop some threats, so the next-generation tools must be able to work better together to provide solutions. In short, the next-generation products have real useful features not found in their predecessor products.

As for Cisco products, for many years Cisco branded its firewalls as the Cisco Adaptive Security Appliance (ASA). Around 2013, Cisco acquired Sourcefire, a security product company. Many of the next-generation firewall (and IPS) features come from software acquired through that acquisition. As of 2019 (when this chapter was written), all of Cisco's currently sold firewalls have names that evoke memories of the Sourcefire acquisition, with most of the firewall product line being called Cisco Firepower firewalls (www.cisco.com/go/firewalls).

An NGFW still does the traditional functions of a firewall, of course, like stateful filtering by comparing fields in the IP, TCP, and UDP headers, and using security zones when defining firewall rules. To provide some insight into some of the newer next-generation features, consider the challenge of matching packets with ports:

1. Each IP-based application should use a well-known port.
2. Attackers know that firewalls will filter most well-known ports from sessions initiated from the outside zone to the inside zone (see Figure 5-8).
3. Attackers use port scanning to find any port that a company's firewall will allow through right now.
4. Attackers attempt to use a protocol of their choosing (for example, HTTP) but with the nonstandard port found through port scanning as a way to attempt to connect to hosts inside the enterprise.

The sequence lists a summary of some of the steps attackers need to take but does not list every single task. However, even to this depth, you can see how attackers can find a way to send packets past the corporate firewall.

The solution? A next-generation firewall that looks at the application layer data to identify the application instead of relying on the TCP and UDP port numbers used. Cisco performs their deep packet inspection using a feature called Application Visibility and Control (AVC). Cisco AVC can identify many applications based on the data sent (application layer headers plus application data structures far past the TCP and UDP headers). When used with a Cisco NGFW, instead of matching port numbers, the firewall matches the application, defeating attacks like the one just described.

The following list mentions a few of the features of an NGFW. Note that while *NGFW* is a useful term, the line between a traditional firewall and a next-generation firewall can be a bit blurry, as the terms describe products that have gone through repeated changes over long periods of time. This list does summarize a few of the key points, however:

Key Topic

- **Traditional firewall:** An NGFW performs traditional firewall features, like stateful firewall filtering, NAT/PAT, and VPN termination.
- **Application Visibility and Control (AVC):** This feature looks deep into the application layer data to identify the application. For instance, it can identify the application based on the data, rather than port number, to defend against attacks that use random port numbers.
- **Advanced Malware Protection:** NGFW platforms run multiple security services, not just as a platform to run a separate service, but for better integration of functions. A network-based antimalware function can run on the firewall itself, blocking file transfers that would install malware, and saving copies of files for later analysis.

- **URL Filtering:** This feature examines the URLs in each web request, categorizes the URLs, and either filters or rate limits the traffic based on rules. The Cisco Talos security group monitors and creates reputation scores for each domain known in the Internet, with URL filtering being able to use those scores in its decision to categorize, filter, or rate limit.
- **NGIPS:** The Cisco NGFW products can also run their NGIPS feature along with the firewall.

Note that for any of the services that benefit from being in the same path that packets traverse, like a firewall, it makes sense that over time those functions could migrate to run on the same product. So, when the design needs both a firewall and IPS at the same location in the network, these NGFW products can run the NGIPS feature as shown in the combined device in Figure 5-10.

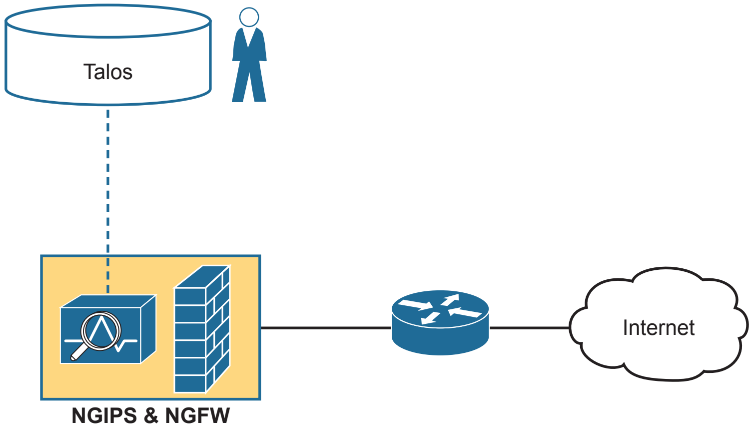


Figure 5-10 *Next-Generation Firewall with Next-Generation IPS Module*

Cisco Next-Generation IPS

The Cisco next-generation IPS (NGIPS) products have followed a similar path as the Cisco NGFW products. Cisco first added NGIPS features primarily through its Sourcefire acquisition, with the now-current (in 2019) Cisco IPS products also using the Firepower name. In fact, as a product line, the hardware NGFW and NGIPS products are the same products, with the ability to run both the NGFW and NGIPS.

As with the NGFW, the NGIPS adds features to a traditional IPS. For instance, one of the biggest issues with a traditional IPS comes with the volume of security events logged by the IPS. For instance:

1. An IPS compares the signature database, which lists all known exploits, to all messages.
2. It generates events, often far more than the security staff can read.
3. The staff must mentally filter events to find the proverbial needle in the haystack, possible only through hard work, vast experience, and a willingness to dig.

An NGIPS helps with this issue in a couple of ways. First, an NGIPS examines the context by gathering data from all the hosts and the users of those hosts. The NGIPS will know the OS, software revision levels, what apps are running, open ports, the transport protocols and port numbers in use, and so on. Armed with that data, the NGIPS can make much more intelligent choices about what events to log.

For instance, consider an NGIPS placed into a network to protect a campus LAN where end users connect, but no data center exists in that part of the network. Also, all PCs happen to be running Windows, and possibly the same version, by corporate policy. The signature database includes signatures for exploits of Linux hosts, Macs, Windows version nonexistent in that part of the network, and exploits that apply to server applications that are not running on those hosts. After gathering those facts, an NGIPS can suggest de-emphasizing checks for exploits that do not apply to those endpoints, spending more time and focus on events that could occur, greatly reducing the number of events logged.

The following list mentions a few of the Cisco NGIPS features:

Key Topic

- **Traditional IPS:** An NGIPS performs traditional IPS features, like using exploit signatures to compare packet flows, creating a log of events, and possibly discarding and/or redirecting packets.
- **Application Visibility and Control (AVC):** As with NGFWs, an NGIPS has the ability to look deep into the application layer data to identify the application.
- **Contextual Awareness:** NGFW platforms gather data from hosts—OS, software version/level, patches applied, applications running, open ports, applications currently sending data, and so on. Those facts inform the NGIPS as to the often more limited vulnerabilities in a portion of the network so that the NGIPS can focus on actual vulnerabilities while greatly reducing the number of logged events.
- **Reputation-Based Filtering:** The Cisco Talos security intelligence group researches security threats daily, building the data used by the Cisco security portfolio. Part of that data identifies known bad actors, based on IP address, domain, name, or even specific URL, with a reputation score for each. A Cisco NGIPS can perform reputation-based filtering, taking the scores into account.
- **Event Impact Level:** Security personnel need to assess the logged events, so an NGIPS provides an assessment based on impact levels, with characterizations as to the impact if an event is indeed some kind of attack.

If you want to learn a little more about these topics for your own interest, let me refer you to a couple of resources. First, check out articles and blog posts from the Cisco Talos Intelligence Group (www.talosintelligence.com). The Cisco Talos organization researches security issues around the globe across the entire spectrum of security products. Additionally, one Cisco Press book has some great information about both next-generation firewalls and IPSs, written at a level appropriate as a next step. If you want to read more, check out this book with the long name: *Integrated Security Technologies and Solutions, Volume I: Cisco Security Solutions for Advanced Threat Protection with Next Generation Firewall, Intrusion Prevention, AMP, and Content Security* (or just use its ISBN, 9781587147067), with one chapter each on NGFW and NGIPS.

Chapter Review

One key to doing well on the exams is to perform repetitive spaced review sessions. Review this chapter's material using either the tools in the book or interactive tools for the same material found on the book's companion website. Refer to the "Your Study Plan" element for more details. Table 5-4 outlines the key review elements and where you can find them. To better track your study progress, record when you completed these activities in the second column.

Table 5-4 Chapter Review Tracking

Review Element	Review Date(s)	Resource Used
Review key topics		Book, website
Review key terms		Book, website
Repeat DIKTA questions		Book, PTP
Do labs		Blog
Review command tables		Book

Review All the Key Topics

Key Topic

Table 5-5 Key Topics for Chapter 5

Key Topic Element	Description	Page Number
List	Commands whose passwords are encrypted by **service password-encryption**	89
List	Rules for when IOS uses the password set with the **enable password** versus **enable secret** commands	91
List	Logic by which IOS can use the **enable secret** hash when a user types a clear-text password to reach enable mode	92
List	Rule for combinations of the **username** command	94
Figure 5-6	Typical client filtering by firewall at Internet edge	98
Figure 5-8	Firewall security zones with DMZ	99
List	Features of next-generation firewalls	101
List	Features of next-generation IPSs	103

Key Terms You Should Know

enable secret, local username, MD5 hash, username secret, firewall, IPS, next-generation firewall (NGFW), next-generation IPS (NGIPS), Application Visibility and Control

Do Labs

The Sim Lite software is a version of Pearson's full simulator learning product with a subset of the labs, included free with this book. The Sim Lite with this book includes a couple of labs about various password-related topics. Also, check the author's blog site pages for configuration exercises (Config Labs) at https://blog.certskills.com/config-labs.

Command References

Tables 5-6 and 5-7 list configuration and verification commands used in this chapter. As an easy review exercise, cover the left column in a table, read the right column, and try to recall the command without looking. Then repeat the exercise, covering the right column, and try to recall what the command does.

Table 5-6 Chapter 5 Configuration Commands

Command	Mode/Purpose/Description
line console 0	Command that changes the context to console configuration mode.
line vty *1st-vty last-vty*	Command that changes the context to vty configuration mode for the range of vty lines listed in the command.
login	Console and vty configuration mode. Tells IOS to prompt for a password.
password *pass-value*	Console and vty configuration mode. Lists the password required if the **login** command is configured.
login local	Console and vty configuration mode. Tells IOS to prompt for a username and password, to be checked against locally configured **username** global configuration commands.
username *name* [**algorithm-type md5** | **sha256** | **scrypt**] **secret** *pass-value*	Global command. Defines one of possibly multiple usernames and associated passwords, stored as a hashed value (default MD5), with other hash options as well.
username *name* **password** *pass-value*	Global command. Defines a username and password, stored in clear text in the configuration by default.
crypto key generate rsa [**modulus 512** | **768** | **1024**]	Global command. Creates and stores (in a hidden location in flash memory) the keys required by SSH.
transport input {**telnet** | **ssh** | **all** | **none**}	vty line configuration mode. Defines whether Telnet and/or SSH access is allowed into this switch.
[**no**] **service password-encryption**	Global command that encrypts all clear-text passwords in the running-config. The **no** version of the command disables the encryption of passwords when the password is set.
enable password *pass-value*	Global command to create the enable password, stored as a clear text instead of a hashed value.
enable [**algorithm-type md5** | **sha256** | **scrypt**] **secret** *pass-value*	Global command to create the enable password, stored as a hashed value instead of clear text, with the hash defined by the algorithm type.
no enable secret **no enable password**	Global command to delete the **enable secret** or **enable password** commands, respectively.
access-class *number* | *name* **in**	A vty mode command that enables inbound ACL checks against Telnet and SSH clients connecting to the router.

Table 5-7 Chapter 5 EXEC Command Reference

Command	Purpose
show running-config | section vty	Lists the vty lines and subcommands from the configuration.
show running-config | section con	Lists the console and subcommands from the configuration.
show running-config | include enable	Lists all lines in the configuration with the word *enable*.