Red Hat Enterprise Linux 8

Securing networks

Configuring secured networks and network communication
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Abstract

This title assists administrators with securing networks, connected machines, and network communication against various attacks.
Table of Contents

MAKING OPEN SOURCE MORE INCLUSIVE ................................................................. 6

PROVIDING FEEDBACK ON RED HAT DOCUMENTATION ...................................... 7

CHAPTER 1. USING SECURE COMMUNICATIONS BETWEEN TWO SYSTEMS WITH OPENSSH .............. 8
  1.1. SSH AND OPENSSH .................................................................................. 8
  1.2. CONFIGURING AND STARTING AN OPENSSH SERVER ............................. 9
  1.3. SETTING AN OPENSSH SERVER FOR KEY-BASED AUTHENTICATION .......... 10
  1.4. GENERATING SSH KEY PAIRS .................................................................. 11
  1.5. USING SSH KEYS STORED ON A SMART CARD ...................................... 13
  1.6. MAKING OPENSSH MORE SECURE ....................................................... 14
  1.7. CONNECTING TO A REMOTE SERVER USING AN SSH JUMP HOST .......... 16
  1.8. CONNECTING TO REMOTE MACHINES WITH SSH KEYS USING SSH-AGENT .................................................. 17
  1.9. ADDITIONAL RESOURCES .................................................................... 18

CHAPTER 2. CONFIGURING SECURE COMMUNICATION WITH THE SSH SYSTEM ROLES .............. 20
  2.1. SSH SERVER SYSTEM ROLE VARIABLES .............................................. 20
  2.2. CONFIGURING OPENSSH SERVERS USING THE SSH SERVER SYSTEM ROLE .................................................. 22
  2.3. SSH CLIENT SYSTEM ROLE VARIABLES .............................................. 25
  2.4. CONFIGURING OPENSSH CLIENTS USING THE SSH CLIENT SYSTEM ROLE .......................................................................................................................... 27
  2.5. USING THE SSH SERVER SYSTEM ROLE FOR NON-EXCLUSIVE CONFIGURATION .................................................. 29

CHAPTER 3. PLANNING AND IMPLEMENTING TLS .......................................................... 31
  3.1. SSL AND TLS PROTOCOLS ...................................................................... 31
  3.2. SECURITY CONSIDERATIONS FOR TLS IN RHEL 8 ................................. 31
    3.2.1. Protocols ......................................................................................... 32
    3.2.2. Cipher suites .................................................................................. 32
    3.2.3. Public key length ........................................................................... 33
  3.3. HARDENING TLS CONFIGURATION IN APPLICATIONS ......................... 33
    3.3.1. Configuring the Apache HTTP server .............................................. 33
    3.3.2. Configuring the Nginx HTTP and proxy server .................... 34
    3.3.3. Configuring the Dovecot mail server ............................................. 34

CHAPTER 4. CONFIGURING A VPN WITH IPSEC ......................................................... 36
  4.1. LIBRESWAN AS AN IPSEC VPN IMPLEMENTATION ............................... 36
  4.2. AUTHENTICATION METHODS IN LIBRESWAN ..................................... 37
  4.3. INSTALLING LIBRESWAN ....................................................................... 38
  4.4. CREATING A HOST-TO-HOST VPN ....................................................... 39
  4.5. CONFIGURING A SITE-TO-SITE VPN .................................................... 40
  4.6. CONFIGURING A REMOTE ACCESS VPN ............................................. 41
  4.7. CONFIGURING A MESH VPN ............................................................... 42
  4.8. DEPLOYING A FIPS-COMPLIANT IPSEC VPN ...................................... 44
  4.9. PROTECTING THE IPSEC NSS DATABASE BY A PASSWORD .................... 46
  4.10. CONFIGURING AN IPSEC VPN TO USE TCP ..................................... 48
  4.11. CONFIGURING AUTOMATIC DETECTION AND USAGE OF ESP HARDWARE OFFLOAD TO ACCELERATE AN IPSEC CONNECTION .................................................. 49
  4.12. CONFIGURING ESP HARDWARE OFFLOAD ON A BOND TO ACCELERATE AN IPSEC CONNECTION .................................................. 50
  4.13. CONFIGURING IPSEC CONNECTIONS THAT OPT OUT OF THE SYSTEM-WIDE CRYPTO POLICIES .................................................. 51
  4.14. TROUBLESHOOTING IPSEC VPN CONFIGURATIONS ......................... 52
  4.15. ADDITIONAL RESOURCES .................................................................. 56

CHAPTER 5. CONFIGURING VPN CONNECTIONS WITH IPSEC BY USING THE VPN RHEL SYSTEM ROLE .................................................. 57
  5.1. CREATING A HOST-TO-HOST VPN WITH IPSEC USING THE VPN SYSTEM ROLE .................................................. 57
5.2. CREATING AN OPPORTUNISTIC MESH VPN CONNECTION WITH IPSEC BY USING THE VPN SYSTEM ROLE

5.3. ADDITIONAL RESOURCES

CHAPTER 6. USING MACSEC TO ENCRYPT LAYER-2 TRAFFIC IN THE SAME PHYSICAL NETWORK

6.1. CONFIGURING A MACSEC CONNECTION USING NMCLI

6.2. ADDITIONAL RESOURCES

CHAPTER 7. USING AND CONFIGURING FIREWALLD

7.1. GETTING STARTED WITH FIREWALLD
   7.1.1. When to use firewalld, nftables, or iptables
   7.1.2. Zones
   7.1.3. Predefined services
   7.1.4. Starting firewalld
   7.1.5. Stopping firewalld
   7.1.6. Verifying the permanent firewalld configuration

7.2. VIEWING THE CURRENT STATUS AND SETTINGS OF FIREWALLD
   7.2.1. Viewing the current status of firewalld
   7.2.2. Viewing allowed services using GUI
   7.2.3. Viewing firewalld settings using CLI

7.3. CONTROLLING NETWORK TRAFFIC USING FIREWALLD
   7.3.1. Disabling all traffic in case of emergency using CLI
   7.3.2. Controlling traffic with predefined services using CLI
   7.3.3. Controlling traffic with predefined services using GUI
   7.3.4. Adding new services
   7.3.5. Opening ports using GUI
   7.3.6. Controlling traffic with protocols using GUI
   7.3.7. Opening source ports using GUI

7.4. CONTROLLING PORTS USING CLI
   7.4.1. Opening a port
   7.4.2. Closing a port

7.5. CONFIGURING PORTS USING SYSTEM ROLES

7.6. WORKING WITH FIREWALLD ZONES
   7.6.1. Listing zones
   7.6.2. Modifying firewalld settings for a certain zone
   7.6.3. Changing the default zone
   7.6.4. Assigning a network interface to a zone
   7.6.5. Assigning a zone to a connection using nmcli
   7.6.6. Manually assigning a zone to a network connection in an ifcfg file
   7.6.7. Creating a new zone
   7.6.8. Zone configuration files
   7.6.9. Using zone targets to set default behavior for incoming traffic

7.7. USING ZONES TO MANAGE INCOMING TRAFFIC DEPENDING ON A SOURCE
   7.7.1. Adding a source
   7.7.2. Removing a source
   7.7.3. Adding a source port
   7.7.4. Removing a source port
   7.7.5. Using zones and sources to allow a service for only a specific domain

7.8. FILTERING FORWARDED TRAFFIC BETWEEN ZONES
   7.8.1. The relationship between policy objects and zones
   7.8.2. Using priorities to sort policies
   7.8.3. Using policy objects to filter traffic between locally hosted Containers and a network physically connected to the host
7.8.4. Setting the default target of policy objects
7.9. CONFIGURING NAT USING FIREWALLD
  7.9.1. The different NAT types: masquerading, source NAT, destination NAT, and redirect
  7.9.2. Configuring IP address masquerading
7.10. PORT FORWARDING
  7.10.1. Adding a port to redirect
  7.10.2. Redirecting TCP port 80 to port 88 on the same machine
  7.10.3. Removing a redirected port
  7.10.4. Removing TCP port 80 forwarded to port 88 on the same machine
7.11. MANAGING ICMP REQUESTS
  7.11.1. Listing and blocking ICMP requests
  7.11.2. Configuring the ICMP filter using GUI
7.12. SETTING AND CONTROLLING IP SETS USING FIREWALLD
  7.12.1. Configuring IP set options using CLI
7.13. PRIORITIZING RICH RULES
  7.13.1. How the priority parameter organizes rules into different chains
  7.13.2. Setting the priority of a rich rule
7.14. CONFIGURING FIREWALL LOCKDOWN
  7.14.2. Configuring lockdown allowlist options using CLI
  7.14.3. Configuring lockdown allowlist options using configuration files
7.15. ENABLING TRAFFIC FORWARDING BETWEEN DIFFERENT INTERFACES OR SOURCES WITHIN A FIREWALLD ZONE
  7.15.1. The difference between intra-zone forwarding and zones with the default target set to ACCEPT
  7.15.2. Using intra-zone forwarding to forward traffic between an Ethernet and Wi-Fi network
7.16. USING RHEL SYSTEM ROLES WITH ANSIBLE TO CONFIGURE FIREWALLD SETTINGS
  7.16.1. Introduction to the firewall RHEL System Role
  7.16.2. Forwarding incoming traffic from one local port to a different local port
  7.16.3. Configuring ports using System Roles
  7.16.4. Configuring a DMZ firewalld zone by using the firewalld RHEL System Role
7.17. ADDITIONAL RESOURCES
8.1. MIGRATING FROM IPTABLES TO NFTABLES
  8.1.1. When to use firewalld, nftables, or iptables
  8.1.2. Converting iptables and ip6tables rule sets to nftables
  8.1.3. Converting single iptables and ip6tables rules to nftables
  8.1.4. Comparison of common iptables and nftables commands
  8.1.5. Additional resources
8.2. WRITING AND EXECUTING NFTABLES SCRIPTS
  8.2.1. Supported nftables script formats
  8.2.2. Running nftables scripts
  8.2.3. Using comments in nftables scripts
  8.2.4. Using variables in an nftables script
  8.2.5. Including files in an nftables script
  8.2.6. Automatically loading nftables rules when the system boots
8.3. CREATING AND MANAGING NFTABLES TABLES, CHAINS, AND RULES
  8.3.1. Standard chain priority values and textual names
  8.3.2. Displaying the nftables rule set
  8.3.3. Creating an nftables table
  8.3.4. Creating an nftables chain
  8.3.5. Appending a rule to the end of an nftables chain
  8.3.6. Inserting a rule at the beginning of an nftables chain
8.4. ADDITIONAL RESOURCES

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CHAPTER 8. GETTING STARTED WITH NFTABLES

8.1. MIGRATING FROM IPTABLES TO NFTABLES
  8.1.1. When to use firewalld, nftables, or iptables
  8.1.2. Converting iptables and ip6tables rule sets to nftables
  8.1.3. Converting single iptables and ip6tables rules to nftables
  8.1.4. Comparison of common iptables and nftables commands
  8.1.5. Additional resources
8.2. WRITING AND EXECUTING NFTABLES SCRIPTS
  8.2.1. Supported nftables script formats
  8.2.2. Running nftables scripts
  8.2.3. Using comments in nftables scripts
  8.2.4. Using variables in an nftables script
  8.2.5. Including files in an nftables script
  8.2.6. Automatically loading nftables rules when the system boots
8.3. CREATING AND MANAGING NFTABLES TABLES, CHAINS, AND RULES
  8.3.1. Standard chain priority values and textual names
  8.3.2. Displaying the nftables rule set
  8.3.3. Creating an nftables table
  8.3.4. Creating an nftables chain
  8.3.5. Appending a rule to the end of an nftables chain
  8.3.6. Inserting a rule at the beginning of an nftables chain
8.4. ADDITIONAL RESOURCES
8.3.7. Inserting a rule at a specific position of an nftables chain
8.4. CONFIGURING NAT USING NFTABLES
  8.4.1. The different NAT types: masquerading, source NAT, destination NAT, and redirect
  8.4.2. Configuring masquerading using nftables
  8.4.3. Configuring source NAT using nftables
  8.4.4. Configuring destination NAT using nftables
  8.4.5. Configuring a redirect using nftables
8.5. USING SETS IN NFTABLES COMMANDS
  8.5.1. Using anonymous sets in nftables
  8.5.2. Using named sets in nftables
  8.5.3. Additional resources
8.6. USING VERDICT MAPS IN NFTABLES COMMANDS
  8.6.1. Using anonymous maps in nftables
  8.6.2. Using named maps in nftables
  8.6.3. Additional resources
8.7. CONFIGURING PORT FORWARDING USING NFTABLES
  8.7.1. Forwarding incoming packets to a different local port
  8.7.2. Forwarding incoming packets on a specific local port to a different host
8.8. USING NFTABLES TO LIMIT THE AMOUNT OF CONNECTIONS
  8.8.1. Limiting the number of connections using nftables
  8.8.2. Blocking IP addresses that attempt more than ten new incoming TCP connections within one minute
8.9. DEBUGGING NFTABLES RULES
  8.9.1. Creating a rule with a counter
  8.9.2. Adding a counter to an existing rule
  8.9.3. Monitoring packets that match an existing rule
8.10. BACKING UP AND RESTORING THE NFTABLES RULE SET
  8.10.1. Backing up the nftables rule set to a file
  8.10.2. Restoring the nftables rule set from a file
8.11. ADDITIONAL RESOURCES

CHAPTER 9. SECURING NETWORK SERVICES

9.1. SECURING THE RPCBIND SERVICE
9.2. SECURING THE RPC.MOUNTD SERVICE
9.3. SECURING THE NFS SERVICE
  9.3.1. Export options for securing an NFS server
  9.3.2. Mount options for securing an NFS client
  9.3.3. Securing NFS with firewall
9.4. SECURING THE FTP SERVICE
  9.4.1. Securing the FTP greeting banner
  9.4.2. Preventing anonymous access and uploads in FTP
  9.4.3. Securing user accounts for FTP
  9.4.4. Additional resources
9.5. SECURING HTTP SERVERS
  9.5.1. Security enhancements in httpd.conf
  9.5.2. Securing the Nginx server configuration
9.6. SECURING POSTGRESQL BY LIMITING ACCESS TO AUTHENTICATED LOCAL USERS
9.7. SECURING THE MEMCACHED SERVICE
  9.7.1. Hardening Memcached against DDoS
MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright’s message.
PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

We appreciate your input on our documentation. Please let us know how we could make it better.

- For simple comments on specific passages:
  1. Make sure you are viewing the documentation in the *Multi-page HTML* format. In addition, ensure you see the **Feedback** button in the upper right corner of the document.
  2. Use your mouse cursor to highlight the part of text that you want to comment on.
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- For submitting feedback via Bugzilla, create a new ticket:
  1. Go to the [Bugzilla](https://bugzilla.redhat.com) website.
  2. As the Component, use **Documentation**.
  3. Fill in the **Description** field with your suggestion for improvement. Include a link to the relevant part(s) of documentation.
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CHAPTER 1. USING SECURE COMMUNICATIONS BETWEEN TWO SYSTEMS WITH OPENSSH

SSH (Secure Shell) is a protocol which provides secure communications between two systems using a client-server architecture and allows users to log in to server host systems remotely. Unlike other remote communication protocols, such as FTP or Telnet, SSH encrypts the login session, which prevents intruders to collect unencrypted passwords from the connection.

Red Hat Enterprise Linux includes the basic OpenSSH packages: the general openssh package, the openssh-server package and the openssh-clients package. Note that the OpenSSH packages require the OpenSSL package openssl-libs, which installs several important cryptographic libraries that enable OpenSSH to provide encrypted communications.

1.1. SSH AND OPENSSH

SSH (Secure Shell) is a program for logging into a remote machine and executing commands on that machine. The SSH protocol provides secure encrypted communications between two untrusted hosts over an insecure network. You can also forward X11 connections and arbitrary TCP/IP ports over the secure channel.

The SSH protocol mitigates security threats, such as interception of communication between two systems and impersonation of a particular host, when you use it for remote shell login or file copying. This is because the SSH client and server use digital signatures to verify their identities. Additionally, all communication between the client and server systems is encrypted.

A host key authenticates hosts in the SSH protocol. Host keys are cryptographic keys that are generated automatically when OpenSSH is first installed, or when the host boots for the first time.

OpenSSH is an implementation of the SSH protocol supported by Linux, UNIX, and similar operating systems. It includes the core files necessary for both the OpenSSH client and server. The OpenSSH suite consists of the following user-space tools:

- ssh is a remote login program (SSH client).
- sshd is an OpenSSH SSH daemon.
- scp is a secure remote file copy program.
- sftp is a secure file transfer program.
- ssh-agent is an authentication agent for caching private keys.
- ssh-add adds private key identities to ssh-agent.
- ssh-keygen generates, manages, and converts authentication keys for ssh.
- ssh-copy-id is a script that adds local public keys to the authorized_keys file on a remote SSH server.
- ssh-keyscan gathers SSH public host keys.

Two versions of SSH currently exist: version 1, and the newer version 2. The OpenSSH suite in RHEL supports only SSH version 2. It has an enhanced key-exchange algorithm that is not vulnerable to exploits known in version 1.

OpenSSH, as one of core cryptographic subsystems of RHEL, uses system-wide crypto policies. This
ensures that weak cipher suites and cryptographic algorithms are disabled in the default configuration. To modify the policy, the administrator must either use the `update-crypto-policies` command to adjust the settings or manually opt out of the system-wide crypto policies.

The OpenSSH suite uses two sets of configuration files: one for client programs (that is, `ssh`, `scp`, and `sftp`), and another for the server (the `sshd` daemon).

System-wide SSH configuration information is stored in the `/etc/ssh/` directory. User-specific SSH configuration information is stored in `~/.ssh/` in the user’s home directory. For a detailed list of OpenSSH configuration files, see the `FILES` section in the `sshd(8)` man page.

**Additional resources**

- Man pages listed by using the `man -k ssh` command
- Using system-wide cryptographic policies

### 1.2. CONFIGURING AND STARTING AN OPENSSH SERVER

Use the following procedure for a basic configuration that might be required for your environment and for starting an OpenSSH server. Note that after the default RHEL installation, the `sshd` daemon is already started and server host keys are automatically created.

**Prerequisites**

- The `openssh-server` package is installed.

**Procedure**

1. Start the `sshd` daemon in the current session and set it to start automatically at boot time:

   ```
   # systemctl start sshd
   # systemctl enable sshd
   ```

2. To specify different addresses than the default `0.0.0.0` (IPv4) or `::` (IPv6) for the `ListenAddress` directive in the `/etc/ssh/sshd_config` configuration file and to use a slower dynamic network configuration, add the dependency on the `network-online.target` target unit to the `sshd.service` unit file. To achieve this, create the `/etc/systemd/system/sshd.service.d/local.conf` file with the following content:

   ```
   [Unit]
   Wants=network-online.target
   After=network-online.target
   ```

3. Review if OpenSSH server settings in the `/etc/ssh/sshd_config` configuration file meet the requirements of your scenario.

4. Optionally, change the welcome message that your OpenSSH server displays before a client authenticates by editing the `/etc/issue` file, for example:

   ```
   Welcome to ssh-server.example.com
   Warning: By accessing this server, you agree to the referenced terms and conditions.
   ```
Ensure that the **Banner** option is not commented out in `/etc/ssh/sshd_config` and its value contains `/etc/issue`:

```bash
# less /etc/ssh/sshd_config | grep Banner
Banner /etc/issue
```

Note that to change the message displayed after a successful login you have to edit the `/etc/motd` file on the server. See the `pam_motd` man page for more information.

5. Reload the **systemd** configuration and restart **sshd** to apply the changes:

```bash
# systemctl daemon-reload
# systemctl restart sshd
```

### Verification

1. Check that the **sshd** daemon is running:

```bash
# systemctl status sshd
```

```
● sshd.service - OpenSSH server daemon
   Loaded: loaded (/usr/lib/systemd/system/sshd.service; enabled; vendor preset: enabled)
   Active: active (running) since Mon 2019-11-18 14:59:58 CET; 6min ago
     Docs: man:sshd(8)
             man:sshd_config(5)
   Main PID: 1149 (sshd)
   Tasks: 1 (limit: 11491)
   Memory: 1.9M
   CGroup: /system.slice/sshd.service
          └─ 1149 /usr/sbin/sshd -D -oCiphers=aes128-ctr,aes256-ctr,aes128-cbc,aes256-cbc -oMACs=hmac-sha2-256,

Nov 18 14:59:58 ssh-server-example.com systemd[1]: Starting OpenSSH server daemon...
Nov 18 14:59:58 ssh-server-example.com sshd[1149]: Server listening on 0.0.0.0 port 22.
Nov 18 14:59:58 ssh-server-example.com sshd[1149]: Server listening on :: port 22.
Nov 18 14:59:58 ssh-server-example.com systemd[1]: Started OpenSSH server daemon.
```

2. Connect to the SSH server with an SSH client.

```bash
# ssh user@ssh-server-example.com
```

```
ECDSA key fingerprint is SHA256:dXbaS0RG/UzITTkU8GtXSz0S1++lPegSy31v3L/FAEc.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'ssh-server-example.com' (ECDSA) to the list of known hosts.
```

```
user@ssh-server-example.com's password:
```

Additional resources

- `sshd(8)` and `sshd_config(5)` man pages.

### 1.3. SETTING AN OPENSSH SERVER FOR KEY-BASED AUTHENTICATION
To improve system security, enforce key-based authentication by disabling password authentication on your OpenSSH server.

**Prerequisites**

- The `openssh-server` package is installed.
- The `sshd` daemon is running on the server.

**Procedure**

1. Open the `/etc/ssh/sshd_config` configuration in a text editor, for example:
   ```bash
   # vi /etc/ssh/sshd_config
   ``

2. Change the `PasswordAuthentication` option to `no`:
   ```bash
   PasswordAuthentication no
   ```

   On a system other than a new default installation, check that `PubkeyAuthentication no` has not been set and the `ChallengeResponseAuthentication` directive is set to `no`. If you are connected remotely, not using console or out-of-band access, test the key-based login process before disabling password authentication.

3. To use key-based authentication with NFS-mounted home directories, enable the `use_nfs_home_dirs` SELinux boolean:
   ```bash
   # setsebool -P use_nfs_home_dirs 1
   ``

4. Reload the `sshd` daemon to apply the changes:
   ```bash
   # systemctl reload sshd
   ```

**Additional resources**

- `sshd(8)`, `sshd_config(5)`, and `setsebool(8)` man pages.

### 1.4. GENERATING SSH KEY PAIRS

Use this procedure to generate an SSH key pair on a local system and to copy the generated public key to an OpenSSH server. If the server is configured accordingly, you can log in to the OpenSSH server without providing any password.

**IMPORTANT**

If you complete the following steps as `root`, only `root` is able to use the keys.

**Procedure**

1. To generate an ECDSA key pair for version 2 of the SSH protocol:
   ```bash
   $ ssh-keygen -t ecdsa
   Generating public/private ecdsa key pair.
   ```
Enter file in which to save the key (/home/joesec/.ssh/id_ecdsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/joesec/.ssh/id_ecdsa.
Your public key has been saved in /home/joesec/.ssh/id_ecdsa.pub.
The key fingerprint is:
SHA256:Q/x+qms4j7PCQ0qFd09iZEFHA+SqwBKRNaU72oZfaCl
joesec@localhost.example.com
The key's randomart image is:

```
+---[ECDSA 256]---+
|.. o oo..o=++     |
|.. oo..o         |
|....o+S .        |
|+=+. .o          |
|E.*+. . . .      |
|+=+. +.. o       |
|   oo*+o.        |
+----[SHA256]-----+
```

You can also generate an RSA key pair by using the `-t rsa` option with the `ssh-keygen` command or an Ed25519 key pair by entering the `ssh-keygen -t ed25519` command.

2. To copy the public key to a remote machine:

```
$ ssh-copy-id joesec@ssh-server-example.com
```

```
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter out any that are already installed
joesec@ssh-server-example.com's password:
...
Number of key(s) added: 1
```

Now try logging into the machine, with: "ssh 'joesec@ssh-server-example.com'" and check to make sure that only the key(s) you wanted were added.

If you do not use the `ssh-agent` program in your session, the previous command copies the most recently modified `~/.ssh/id*.pub` public key if it is not yet installed. To specify another public-key file or to prioritize keys in files over keys cached in memory by `ssh-agent`, use the `ssh-copy-id` command with the `-i` option.

**NOTE**

If you reinstall your system and want to keep previously generated key pairs, back up the `~/.ssh/` directory. After reinstalling, copy it back to your home directory. You can do this for all users on your system, including `root`.

**Verification**

1. Log in to the OpenSSH server without providing any password:

```
$ ssh joesec@ssh-server-example.com
Welcome message.
...
Last login: Mon Nov 18 18:28:42 2019 from ::1
```
Additional resources

- `ssh-keygen(1)` and `ssh-copy-id(1)` man pages.

1.5. USING SSH KEYS STORED ON A SMART CARD

Red Hat Enterprise Linux enables you to use RSA and ECDSA keys stored on a smart card on OpenSSH clients. Use this procedure to enable authentication using a smart card instead of using a password.

Prerequisites

- On the client side, the `opensc` package is installed and the `pcscd` service is running.

Procedure

1. List all keys provided by the OpenSC PKCS #11 module including their PKCS #11 URIs and save the output to the `keys.pub` file:

   ```
   $ ssh-keygen -D pkcs11: > keys.pub
   $ ssh-keygen -D pkcs11:
   ssh-rsa AAAAB3NzaC1yc2E...KKZMzcQZxx
   pkcs11:id=%02;object=SIGN%20pubkey;token=SSH%20key;manufacturer=piv_II?module-path=/usr/lib64/pkcs11/opensc-pkcs11.so
   ecdsa-sha2-nistp256 AAA...J0hkYnnsM=
   pkcs11:id=%01;object=PIV%20AUTH%20pubkey;token=SSH%20key;manufacturer=piv_II?
   module-path=/usr/lib64/pkcs11/opensc-pkcs11.so
   ```

2. To enable authentication using a smart card on a remote server (`example.com`), transfer the public key to the remote server. Use the `ssh-copy-id` command with `keys.pub` created in the previous step:

   ```
   $ ssh-copy-id -f -i keys.pub username@example.com
   ```

3. To connect to `example.com` using the ECDSA key from the output of the `ssh-keygen -D` command in step 1, you can use just a subset of the URI, which uniquely references your key, for example:

   ```
   $ ssh -i "pkcs11:id=%01?module-path=/usr/lib64/pkcs11/opensc-pkcs11.so" example.com
   Enter PIN for 'SSH key':
   [example.com]$ 
   ```

4. You can use the same URI string in the `~/.ssh/config` file to make the configuration permanent:

   ```
   $ cat ~/.ssh/config
   IdentityFile "pkcs11:id=%01?module-path=/usr/lib64/pkcs11/opensc-pkcs11.so"
   $ ssh example.com
   Enter PIN for 'SSH key':
   [example.com]$ 
   ```

Because OpenSSH uses the `p11-kit-proxy` wrapper and the OpenSC PKCS #11 module is registered to PKCS#11 Kit, you can simplify the previous commands:
$ ssh -i "pkcs11:id=%01" example.com
Enter PIN for ‘SSH key’:
[example.com] $

If you skip the id= part of a PKCS #11 URI, OpenSSH loads all keys that are available in the proxy module. This can reduce the amount of typing required:

$ ssh -i pkcs11: example.com
Enter PIN for ‘SSH key’:
[example.com] $

Additional resources

- Fedora 28: Better smart card support in OpenSSH
- p11-kit(8), opensc.conf(5), pcscd(8), ssh(1), and ssh-keygen(1) man pages

1.6. MAKING OPENSSH MORE SECURE

The following tips help you to increase security when using OpenSSH. Note that changes in the /etc/ssh/sshd_config OpenSSH configuration file require reloading the sshd daemon to take effect:

# systemctl reload sshd

IMPORTANT

The majority of security hardening configuration changes reduce compatibility with clients that do not support up-to-date algorithms or cipher suites.

Disabling insecure connection protocols

- To make SSH truly effective, prevent the use of insecure connection protocols that are replaced by the OpenSSH suite. Otherwise, a user’s password might be protected using SSH for one session only to be captured later when logging in using Telnet. For this reason, consider disabling insecure protocols, such as telnet, rsh, rlogin, and ftp.

Enabling key-based authentication and disabling password-based authentication

- Disabling passwords for authentication and allowing only key pairs reduces the attack surface and it also might save users’ time. On clients, generate key pairs using the ssh-keygen tool and use the ssh-copy-id utility to copy public keys from clients on the OpenSSH server. To disable password-based authentication on your OpenSSH server, edit /etc/ssh/sshd_config and change the PasswordAuthentication option to no:

    PasswordAuthentication no

Key types

- Although the ssh-keygen command generates a pair of RSA keys by default, you can instruct it to generate ECDSA or Ed25519 keys by using the -t option. The ECDSA (Elliptic Curve Digital Signature Algorithm) offers better performance than RSA at the equivalent symmetric key
strength. It also generates shorter keys. The Ed25519 public-key algorithm is an implementation of twisted Edwards curves that is more secure and also faster than RSA, DSA, and ECDSA. OpenSSH creates RSA, ECDSA, and Ed25519 server host keys automatically if they are missing. To configure the host key creation in RHEL, use the `sshd-keygen@.service` instantiated service. For example, to disable the automatic creation of the RSA key type:

```
# systemctl mask sshd-keygen@rsa.service
```

- To exclude particular key types for SSH connections, comment out the relevant lines in `/etc/ssh/sshd_config`, and reload the `sshd` service. For example, to allow only Ed25519 host keys:

```
# HostKey /etc/ssh/ssh_host_rsa_key
# HostKey /etc/ssh/ssh_host_ecdsa_key
HostKey /etc/ssh/ssh_host_ed25519_key
```

### Non-default port

- By default, the `sshd` daemon listens on TCP port 22. Changing the port reduces the exposure of the system to attacks based on automated network scanning and thus increase security through obscurity. You can specify the port using the `Port` directive in the `/etc/ssh/sshd_config` configuration file.

You also have to update the default SELinux policy to allow the use of a non-default port. To do so, use the `semanage` tool from the `policycoreutils-python-utils` package:

```
# semanage port -a -t ssh_port_t -p tcp port_number
```

Furthermore, update `firewalld` configuration:

```
# firewall-cmd --add-port port_number/tcp
# firewall-cmd --runtime-to-permanent
```

In the previous commands, replace `port_number` with the new port number specified using the `Port` directive.

### No root login

- If your particular use case does not require the possibility of logging in as the root user, you should consider setting the `PermitRootLogin` configuration directive to `no` in the `/etc/ssh/sshd_config` file. By disabling the possibility of logging in as the root user, the administrator can audit which users run what privileged commands after they log in as regular users and then gain root rights.

Alternatively, set `PermitRootLogin` to `prohibit-password`:

```
PermitRootLogin prohibit-password
```

This enforces the use of key-based authentication instead of the use of passwords for logging in as root and reduces risks by preventing brute-force attacks.

### Using the X Security extension

- The X server in Red Hat Enterprise Linux clients does not provide the X Security extension. Therefore, clients cannot request another security layer when connecting to untrusted SSH
servers with X11 forwarding. Most applications are not able to run with this extension enabled anyway.

By default, the ForwardX11Trusted option in the /etc/ssh/ssh_config.d/05-redhat.conf file is set to yes, and there is no difference between the ssh -X remote_machine (untrusted host) and ssh -Y remote_machine (trusted host) command.

If your scenario does not require the X11 forwarding feature at all, set the X11Forwarding directive in the /etc/ssh/sshd_config configuration file to no.

Restricting access to specific users, groups, or domains

- The AllowUsers and AllowGroups directives in the /etc/ssh/sshd_config configuration file server enable you to permit only certain users, domains, or groups to connect to your OpenSSH server. You can combine AllowUsers and AllowGroups to restrict access more precisely, for example:

  ```
  AllowUsers *@192.168.1.*, *@10.0.0.*, !@192.168.1.2
  AllowGroups example-group
  ```

  The previous configuration lines accept connections from all users from systems in 192.168.1.* and 10.0.0.* subnets except from the system with the 192.168.1.2 address. All users must be in the example-group group. The OpenSSH server denies all other connections.

  Note that using allowlists (directives starting with Allow) is more secure than using blocklists (options starting with Deny) because allowlists block also new unauthorized users or groups.

Changing system-wide cryptographic policies

- OpenSSH uses RHEL system-wide cryptographic policies, and the default system-wide cryptographic policy level offers secure settings for current threat models. To make your cryptographic settings more strict, change the current policy level:

  ```
  # update-crypto-policies --set FUTURE
  Setting system policy to FUTURE
  ```

- To opt-out of the system-wide crypto policies for your OpenSSH server, uncomment the line with the CRYPTO_POLICY= variable in the /etc/sysconfig/sshd file. After this change, values that you specify in the Ciphers, MACs, KexAlgorithms, and GSSAPIKexAlgorithms sections in the /etc/ssh/sshd_config file are not overridden. Note that this task requires deep expertise in configuring cryptographic options.

  - See Using system-wide cryptographic policies in the Security hardening title for more information.

Additional resources

- sshd_config(5), ssh-keygen(1), crypto-policies(7), and update-crypto-policies(8) man pages.

1.7. CONNECTING TO A REMOTE SERVER USING AN SSH JUMP HOST

Use this procedure for connecting your local system to a remote server through an intermediary server, also called jump host.

Prerequisites
A jump host accepts SSH connections from your local system.

A remote server accepts SSH connections only from the jump host.

**Procedure**

1. Define the jump host by editing the `~/.ssh/config` file on your local system, for example:
   ```
   Host jump-server1
   HostName jump1.example.com
   ```

   - The `Host` parameter defines a name or alias for the host you can use in `ssh` commands. The value can match the real host name, but can also be any string.

   - The `HostName` parameter sets the actual host name or IP address of the jump host.

2. Add the remote server jump configuration with the `ProxyJump` directive to `~/.ssh/config` file on your local system, for example:
   ```
   Host remote-server
   HostName remote1.example.com
   ProxyJump jump-server1
   ```

3. Use your local system to connect to the remote server through the jump server:
   ```
   $ ssh remote-server
   ```

   The previous command is equivalent to the `ssh -J jump-server1 remote-server` command if you omit the configuration steps 1 and 2.

   **NOTE**

   You can specify more jump servers and you can also skip adding host definitions to the configurations file when you provide their complete host names, for example:
   ```
   $ ssh -J jump1.example.com,jump2.example.com,jump3.example.com remote1.example.com
   ```

   Change the host name-only notation in the previous command if the user names or SSH ports on the jump servers differ from the names and ports on the remote server, for example:
   ```
   $ ssh -J johndoe@jump1.example.com:75,johndoe@jump2.example.com:75,johndoe@jump3.example.com:75 joesec@remote1.example.com:220
   ```

Additional resources

- `ssh_config(5)` and `ssh(1)` man pages.

1.8. CONNECTING TO REMOTE MACHINES WITH SSH KEYS USING SSH-AGENT
To avoid entering a passphrase each time you initiate an SSH connection, you can use the `ssh-agent` utility to cache the private SSH key. The private key and the passphrase remain secure.

**Prerequisites**
- You have a remote host with SSH daemon running and reachable through the network.
- You know the IP address or hostname and credentials to log in to the remote host.
- You have generated an SSH key pair with a passphrase and transferred the public key to the remote machine.

**Procedure**

1. Optional: Verify you can use the key to authenticate to the remote host:
   a. Connect to the remote host using SSH:
      ```bash
      $ ssh example.user1@198.51.100.1 hostname
      ```
   b. Enter the passphrase you set while creating the key to grant access to the private key.
      ```bash
      $ ssh example.user1@198.51.100.1 hostname host.example.com
      ```

2. Start the `ssh-agent`.
   ```bash
   $ eval $(ssh-agent)
   Agent pid 20062
   ```

3. Add the key to `ssh-agent`.
   ```bash
   $ ssh-add ~/.ssh/id_rsa
   Enter passphrase for ~/.ssh/id_rsa:
   Identity added: ~/.ssh/id_rsa (example.user0@198.51.100.1)
   ```

**Verification**
- Optional: Log in to the host machine using SSH.
  ```bash
  $ ssh example.user1@198.51.100.1
  Last login: Mon Sep 14 12:56:37 2020
  ```
  Note that you did not have to enter the passphrase.

**1.9. ADDITIONAL RESOURCES**
- `sshd(8), ssh(1), scp(1), sftp(1), ssh-keygen(1), ssh-copy-id(1), ssh_config(5), sshd_config(5), update-crypto-policies(8), and crypto-policies(7)` man pages.
- OpenSSH Home Page
• Configuring SELinux for applications and services with non-standard configurations

• Controlling network traffic using firewalld
CHAPTER 2. CONFIGURING SECURE COMMUNICATION WITH THE SSH SYSTEM ROLES

As an administrator, you can use the SSHD System Role to configure SSH servers and the SSH System Role to configure SSH clients consistently on any number of RHEL systems at the same time by using Red Hat Ansible Automation Platform.

2.1. SSH SERVER SYSTEM ROLE VARIABLES

In an SSH Server System Role playbook, you can define the parameters for the SSH configuration file according to your preferences and limitations.

If you do not configure these variables, the System Role produces an `sshd_config` file that matches the RHEL defaults.

In all cases, Booleans correctly render as `yes` and `no` in `sshd` configuration. You can define multi-line configuration items using lists. For example:

```
sshd_ListenAddress:
  - 0.0.0.0
  - '::'
```

renders as:

```
ListenAddress 0.0.0.0
ListenAddress ::
```

Variables for the SSH Server System Role

`sshd_enable`

If set to `False`, the role is completely disabled. Defaults to `True`.

`sshd_skip_defaults`

If set to `True`, the System Role does not apply default values. Instead, you specify the complete set of configuration defaults by using either the `sshd` dict, or `sshd_Key` variables. Defaults to `False`.

`sshd_manage_service`

If set to `False`, the service is not managed, which means it is not enabled on boot and does not start or reload. Defaults to `True` except when running inside a container or AIX, because the Ansible service module does not currently support `enabled` for AIX.

`sshd_allow_reload`

If set to `False`, `sshd` does not reload after a change of configuration. This can help with troubleshooting. To apply the changed configuration, reload `sshd` manually. Defaults to the same value as `sshd_manage_service` except on AIX, where `sshd_manage_service` defaults to `False` but `sshd_allow_reload` defaults to `True`.

`sshd_install_service`

If set to `True`, the role installs service files for the `sshd` service. This overrides files provided in the operating system. Do not set to `True` unless you are configuring a second instance and you also change the `sshd_service` variable. Defaults to `False`.

The role uses the files pointed by the following variables as templates:
sshd_service_template_service (default: templates/sshd.service.j2)
sshd_service_template_at_service (default: templates/sshd@.service.j2)
sshd_service_template_socket (default: templates/sshd.socket.j2)

**sshd_service**

This variable changes the `sshd` service name, which is useful for configuring a second `sshd` service instance.

**sshd**

A dict that contains configuration. For example:

```yaml
sshd:
  Compression: yes
  ListenAddress: - 0.0.0.0
```

**sshd_OptionName**

You can define options by using simple variables consisting of the `sshd_` prefix and the option name instead of a dict. The simple variables override values in the `sshd` dict. For example:

```yaml
sshd_Compression: no
```

**sshd_match and sshd_match_1 to sshd_match_9**

A list of dicts or just a dict for a Match section. Note that these variables do not override match blocks as defined in the `sshd` dict. All of the sources will be reflected in the resulting configuration file.

**Secondary variables for the SSH Server System Role**

You can use these variables to override the defaults that correspond to each supported platform.

**sshd_packages**

You can override the default list of installed packages using this variable.

**sshd_config_owner, sshd_config_group, and sshd_config_mode**

You can set the ownership and permissions for the openssh configuration file that this role produces using these variables.

**sshd_config_file**

The path where this role saves the openssh server configuration produced.

**sshd_config_namespace**

The default value of this variable is null, which means that the role defines the entire content of the configuration file including system defaults. Alternatively, you can use this variable to invoke this role from other roles or from multiple places in a single playbook on systems that do not support drop-in directory. The `sshd_skip_defaults` variable is ignored and no system defaults are used in this case. When this variable is set, the role places the configuration that you specify to configuration snippets in an existing configuration file under the given namespace. If your scenario requires applying the role several times, you need to select a different namespace for each application.
NOTE

Limitations of the openssh configuration file still apply. For example, only the first option specified in a configuration file is effective for most of the configuration options.

Technically, the role places snippets in "Match all" blocks, unless they contain other match blocks, to ensure they are applied regardless of the previous match blocks in the existing configuration file. This allows configuring any non-conflicting options from different roles invocations.

**sshd_binary**

The path to the sshd executable of openssh.

**sshd_service**

The name of the sshd service. By default, this variable contains the name of the sshd service that the target platform uses. You can also use it to set the name of the custom sshd service when the role uses the sshd_install_service variable.

**sshd_verify_hostkeys**

Defaults to auto. When set to auto, this lists all host keys that are present in the produced configuration file, and generates any paths that are not present. Additionally, permissions and file owners are set to default values. This is useful if the role is used in the deployment stage to make sure the service is able to start on the first attempt. To disable this check, set this variable to an empty list [].

**sshd_hostkey_owner, sshd_hostkey_group, sshd_hostkey_mode**

Use these variables to set the ownership and permissions for the host keys from sshd_verify_hostkeys.

**sshd_sysconfig**

On RHEL-based systems, this variable configures additional details of the sshd service. If set to true, this role manages also the /etc/sysconfig/sshd configuration file based on the following configuration. Defaults to false.

**sshd_sysconfig_override_crypto_policy**

In RHEL, when set to true, this variable overrides the system-wide crypto policy. Defaults to false.

**sshd_sysconfig_use_strong_rng**

On RHEL-based systems, this variable can force sshd to reseed the openssl random number generator with the number of bytes given as the argument. The default is 0, which disables this functionality. Do not turn this on if the system does not have a hardware random number generator.

### 2.2. CONFIGURING OPENSSH SERVERS USING THE SSH SERVER SYSTEM ROLE

You can use the SSH Server System Role to configure multiple SSH servers by running an Ansible playbook.

NOTE

You can use the SSH Server System Role with other System Roles that change SSH and SSHD configuration, for example the Identity Management RHEL System Roles. To prevent the configuration from being overwritten, make sure that the SSH Server role uses namespaces (RHEL 8 and earlier versions) or a drop-in directory (RHEL 9).
Prerequisites

- Access and permissions to one or more managed nodes, which are systems you want to configure with the SSHD System Role.

- Access and permissions to a control node, which is a system from which Red Hat Ansible Core configures other systems.

  On the control node:

  - The **ansible-core** and **rhel-system-roles** packages are installed.

**IMPORTANT**

RHEL 8.0–8.5 provided access to a separate Ansible repository that contains Ansible Engine 2.9 for automation based on Ansible. Ansible Engine contains command-line utilities such as **ansible**, **ansible-playbook**, connectors such as **docker** and **podman**, and many plugins and modules. For information on how to obtain and install Ansible Engine, see the [How to download and install Red Hat Ansible Engine](#) Knowledgebase article.

RHEL 8.6 and 9.0 have introduced Ansible Core (provided as the **ansible-core** package), which contains the Ansible command-line utilities, commands, and a small set of built-in Ansible plugins. RHEL provides this package through the AppStream repository, and it has a limited scope of support. For more information, see the [Scope of support for the Ansible Core package included in the RHEL 9 and RHEL 8.6 and later AppStream repositories](#) Knowledgebase article.

- An inventory file which lists the managed nodes.

Procedure

1. Copy the example playbook for the SSH Server System Role:

   ```
   # cp /usr/share/doc/rhel-system-roles/sshd/example-root-login-playbook.yml path/custom-playbook.yml
   ```

2. Open the copied playbook by using a text editor, for example:

   ```
   # vim path/custom-playbook.yml
   ```

    ```
    ---
    - hosts: all
      tasks:
        - name: Configure sshd to prevent root and password login except from particular subnet
          include_role:
            name: rhel-system-roles.sshd
          vars:
            sshd:
              # root login and password login is enabled only from a particular subnet
              PermitRootLogin: no
              PasswordAuthentication: no
              Match:
                - Condition: "Address 192.0.2.0/24"
                  PermitRootLogin: yes
                  PasswordAuthentication: yes
    ```
The playbook configures the managed node as an SSH server configured so that:

- password and root user login is disabled
- password and root user login is enabled only from the subnet 192.0.2.0/24

You can modify the variables according to your preferences. For more details, see SSH Server System Role variables.

3. Optional: Verify playbook syntax.

```
# ansible-playbook --syntax-check path/custom-playbook.yml
```

4. Run the playbook on your inventory file:

```
# ansible-playbook -i inventory_file path/custom-playbook.yml
...
PLAY RECAP
**********************************************************************
localhost : ok=12 changed=2 unreachable=0 failed=0
skipped=10 rescued=0 ignored=0
```

Verification

1. Log in to the SSH server:

```
$ ssh user1@10.1.1.1
```

Where:

- **user1** is a user on the SSH server.
- **10.1.1.1** is the IP address of the SSH server.

2. Check the contents of the sshd_config file on the SSH server:

```
$ vim /etc/ssh/sshd_config

# Ansible managed
HostKey /etc/ssh/ssh_host_rsa_key
HostKey /etc/ssh/ssh_host_ecdsa_key
HostKey /etc/ssh/ssh_host_ed25519_key
AcceptEnv LANG LC_CTYPE LC_NUMERIC LC_TIME LC_COLLATE LC_MONETARY
LC_MESSAGES
AcceptEnv LC_PAPER LC_NAME LC_ADDRESS LC_TELEPHONE LC_MEASUREMENT
AcceptEnv LC_IDENTIFICATION LC_ALL LANGUAGE
AcceptEnv XMODIFIERS
AuthorizedKeysFile .ssh/authorized_keys
ChallengeResponseAuthentication no
GSSAPIAuthentication yes
GSSAPICleanupCredentials no
PasswordAuthentication no
```
PermitRootLogin no
PrintMotd no
Subsystem sftp /usr/libexec/openssh/sftp-server
SyslogFacility AUTHPRIV
UsePAM yes
X11Forwarding yes
Match Address 192.0.2.0/24
PasswordAuthentication yes
PermitRootLogin yes

3. Check that you can connect to the server as root from the 192.0.2.0/24 subnet:
   a. Determine your IP address:

```
$ hostname -I
192.0.2.1
```

    If the IP address is within the 192.0.2.1 - 192.0.2.254 range, you can connect to the server.

   b. Connect to the server as root:

```
$ ssh root@10.1.1.1
```

Additional resources
- ansible-playbook(1) man page.

2.3. SSH CLIENT SYSTEM ROLE VARIABLES

In an SSH Client System Role playbook, you can define the parameters for the client SSH configuration file according to your preferences and limitations.

If you do not configure these variables, the System Role produces a global ssh_config file that matches the RHEL defaults.

In all cases, booleans correctly render as yes or no in ssh configuration. You can define multi-line configuration items using lists. For example:

```
LocalForward:
  - 22 localhost:2222
  - 403 localhost:4003
```

renders as:

```
LocalForward 22 localhost:2222
LocalForward 403 localhost:4003
```

**NOTE**

The configuration options are case sensitive.
Variables for the SSH Client System Role

ssh_user

You can define an existing user name for which the System Role modifies user-specific configuration. The user-specific configuration is saved in ~/.ssh/config of the given user. The default value is null, which modifies global configuration for all users.

ssh_skip_defaults

Defaults to auto. If set to auto, the System Role writes the system-wide configuration file /etc/ssh/ssh_config and keeps the RHEL defaults defined there. Creating a drop-in configuration file, for example by defining the ssh_drop_in_name variable, automatically disables the ssh_skip_defaults variable.

ssh_drop_in_name

Defines the name for the drop-in configuration file, which is placed in the system-wide drop-in directory. The name is used in the template /etc/ssh/ssh_config.d/{ssh_drop_in_name}.conf to reference the configuration file to be modified. If the system does not support drop-in directory, the default value is null. If the system supports drop-in directories, the default value is 00-ansible.

WARNING

If the system does not support drop-in directories, setting this option will make the play fail.

The suggested format is NN-name, where NN is a two-digit number used for ordering the configuration files and name is any descriptive name for the content or the owner of the file.

ssh

A dict that contains configuration options and their respective values.

ssh_OptionName

You can define options by using simple variables consisting of the ssh_prefix and the option name instead of a dict. The simple variables override values in the ssh dict.

ssh_additional_packages

This role automatically installs the openssh and openssh-clients packages, which are needed for the most common use cases. If you need to install additional packages, for example, openssh-keysign for host-based authentication, you can specify them in this variable.

ssh_config_file

The path to which the role saves the configuration file produced. Default value:

- If the system has a drop-in directory, the default value is defined by the template /etc/ssh/ssh_config.d/(ssh_drop_in_name).conf.
- If the system does not have a drop-in directory, the default value is /etc/ssh/ssh_config.
- If the ssh_user variable is defined, the default value is ~/.ssh/config.

ssh_config_owner, ssh_config_group, ssh_config_mode
I he owner, group and modes of the created configuration file. By default, the owner of the file is
\texttt{root:root}, and the mode is \texttt{0644}. If \texttt{ssh_user} is defined, the mode is \texttt{0600}, and the owner and group
are derived from the user name specified in the \texttt{ssh_user} variable.

2.4. CONFIGURING OPENSSH CLIENTS USING THE SSH CLIENT SYSTEM ROLE

You can use the SSH Client System Role to configure multiple SSH clients by running an Ansible playbook.

NOTE

You can use the SSH Client System Role with other system roles that change SSH and
SSHD configuration, for example the Identity Management RHEL System Roles. To
prevent the configuration from being overwritten, make sure that the SSH Client role
uses a drop-in directory (default from RHEL 8).

Prerequisites

- Access and permissions to one or more \textit{managed nodes}, which are systems you want to
  configure with the SSH Client System Role.

- Access and permissions to a \textit{control node}, which is a system from which Red Hat Ansible Core
  configures other systems.

On the control node:

- The \texttt{ansible-core} and \texttt{rhel-system-roles} packages are installed.

IMPORTANT

RHEL 8.0-8.5 provided access to a separate Ansible repository that contains Ansible
Engine 2.9 for automation based on Ansible. Ansible Engine contains command-line
utilities such as \texttt{ansible, ansible-playbook}, connectors such as \texttt{docker} and \texttt{podman}, and
many plugins and modules. For information on how to obtain and install Ansible Engine,
see the \texttt{How to download and install Red Hat Ansible Engine} Knowledgebase article.

RHEL 8.6 and 9.0 have introduced Ansible Core (provided as the \texttt{ansible-core} package),
which contains the Ansible command-line utilities, commands, and a small set of built-in
Ansible plugins. RHEL provides this package through the AppStream repository, and it
has a limited scope of support. For more information, see the \texttt{Scope of support for the
Ansible Core package included in the RHEL 9 and RHEL 8.6 and later AppStream
repositories} Knowledgebase article.

- An inventory file which lists the managed nodes.

Procedure

1. Create a new \texttt{playbook.yml} file with the following content:

```yaml
---
- hosts: all
tasks:
  - name: "Configure ssh clients"
    include_role:
```
name: rhel-system-roles.ssh
vars:
  ssh_user: root
ssh:
  Compression: true
  GSSAPIAuthentication: no
  ControlMaster: auto
  ControlPath: ~/.ssh/.cm%C
  Host:
    - Condition: example
      Hostname: example.com
      User: user1
  ssh_ForwardX11: no

This playbook configures the root user’s SSH client preferences on the managed nodes with the following configurations:

- Compression is enabled.
- ControlMaster multiplexing is set to auto.
- The example alias for connecting to the example.com host is user1.
- The example host alias is created, which represents a connection to the example.com host with user1 user name.
- X11 forwarding is disabled.

Optionally, you can modify these variables according to your preferences. For more details, see SSH System Role variables.

2. Optional: Verify playbook syntax.

```
# ansible-playbook --syntax-check path/custom-playbook.yml
```

3. Run the playbook on your inventory file:

```
# ansible-playbook -i inventory_file path/custom-playbook.yml
```

**Verification**

- Verify that the managed node has the correct configuration by opening the SSH configuration file in a text editor, for example:

```
# vi ~root/.ssh/config
```

After application of the example playbook shown above, the configuration file should have the following content:

```
# Ansible managed
Compression yes
ControlMaster auto
ControlPath ~/.ssh/.cm%C
ForwardX11 no
GSSAPIAuthentication no
```
2.5. USING THE SSH SERVER SYSTEM ROLE FOR NON-EXCLUSIVE CONFIGURATION

Normally, applying the SSH Server System Role overwrites the entire configuration. This may be problematic if you have previously adjusted the configuration, for example with a different System Role or playbook. To apply the SSH Server System Role for only selected configuration options while keeping other options in place, you can use the non-exclusive configuration.

In RHEL 8 and earlier, you can apply the non-exclusive configuration with a configuration snippet.

Prerequisites

- Access and permissions to one or more managed nodes, which are systems you want to configure with the SSH Server System Role.
- Access and permissions to a control node, which is a system from which Red Hat Ansible Core configures other systems.

On the control node:

- The ansible-core package is installed.
- An inventory file which lists the managed nodes.
- A playbook for a different RHEL System Role. For additional information, see Applying a role.

Procedure

1. Add a configuration snippet with the sshd_config_namespace variable to the playbook:

```yaml
---
- hosts: all
  tasks:
  - name: <Configure SSHD to accept some useful environment variables>
    include_role:
      name: rhel-system-roles.sshd
    vars:
      sshd_config_namespace: <my-application>
      sshd:
        # Environment variables to accept
        AcceptEnv:
        LANG
        LS_COLORS
        EDITOR
```

When you apply the playbook to the inventory, the role adds the following snippet, if not already present, to the /etc/ssh/sshd_config file.

```
# BEGIN sshd system role managed block: namespace <my-application>
Match all
```

29
Verification

- Optional: Verify playbook syntax.

```bash
# ansible-playbook --syntax-check playbook.yml -i inventory_file
```

Additional resources

- `ansible-playbook(1)` man page.
TLS (Transport Layer Security) is a cryptographic protocol used to secure network communications. When hardening system security settings by configuring preferred key-exchange protocols, authentication methods, and encryption algorithms, it is necessary to bear in mind that the broader the range of supported clients, the lower the resulting security. Conversely, strict security settings lead to limited compatibility with clients, which can result in some users being locked out of the system. Be sure to target the strictest available configuration and only relax it when it is required for compatibility reasons.

### 3.1. SSL AND TLS PROTOCOLS

The Secure Sockets Layer (SSL) protocol was originally developed by Netscape Corporation to provide a mechanism for secure communication over the Internet. Subsequently, the protocol was adopted by the Internet Engineering Task Force (IETF) and renamed to Transport Layer Security (TLS).

The TLS protocol sits between an application protocol layer and a reliable transport layer, such as TCP/IP. It is independent of the application protocol and can thus be layered underneath many different protocols, for example: HTTP, FTP, SMTP, and so on.

<table>
<thead>
<tr>
<th>Protocol version</th>
<th>Usage recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSL v2</td>
<td>Do not use. Has serious security vulnerabilities. Removed from the core crypto libraries since RHEL 7.</td>
</tr>
<tr>
<td>SSL v3</td>
<td>Do not use. Has serious security vulnerabilities. Removed from the core crypto libraries since RHEL 8.</td>
</tr>
<tr>
<td>TLS 1.0</td>
<td>Not recommended to use. Has known issues that cannot be mitigated in a way that guarantees interoperability, and does not support modern cipher suites. In RHEL 8, enabled only in the LEGACY system-wide cryptographic policy profile.</td>
</tr>
<tr>
<td>TLS 1.1</td>
<td>Use for interoperability purposes where needed. Does not support modern cipher suites. In RHEL 8, enabled only in the LEGACY policy.</td>
</tr>
<tr>
<td>TLS 1.2</td>
<td>Supports the modern AEAD cipher suites. This version is enabled in all system-wide crypto policies, but optional parts of this protocol contain vulnerabilities and TLS 1.2 also allows outdated algorithms.</td>
</tr>
<tr>
<td>TLS 1.3</td>
<td>Recommended version. TLS 1.3 removes known problematic options, provides additional privacy by encrypting more of the negotiation handshake and can be faster thanks usage of more efficient modern cryptographic algorithms. TLS 1.3 is also enabled in all system-wide crypto policies.</td>
</tr>
</tbody>
</table>

**Additional resources**


### 3.2. SECURITY CONSIDERATIONS FOR TLS IN RHEL 8

In RHEL 8, cryptography-related considerations are significantly simplified thanks to the system-wide...
crypto policies. The DEFAULT crypto policy allows only TLS 1.2 and 1.3. To allow your system to negotiate connections using the earlier versions of TLS, you need to either opt out from following crypto policies in an application or switch to the LEGACY policy with the update-crypto-policies command. See Using system-wide cryptographic policies for more information.

The default settings provided by libraries included in RHEL 8 are secure enough for most deployments. The TLS implementations use secure algorithms where possible while not preventing connections from or to legacy clients or servers. Apply hardened settings in environments with strict security requirements where legacy clients or servers that do not support secure algorithms or protocols are not expected or allowed to connect.

The most straightforward way to harden your TLS configuration is switching the system-wide cryptographic policy level to FUTURE using the update-crypto-policies --set FUTURE command.

**WARNING**

Algorithms disabled for the LEGACY cryptographic policy do not conform to Red Hat’s vision of RHEL 8 security, and their security properties are not reliable. Consider moving away from using these algorithms instead of re-enabling them. If you do decide to re-enable them, for example for interoperability with old hardware, treat them as insecure and apply extra protection measures, such as isolating their network interactions to separate network segments. Do not use them across public networks.

If you decide to not follow RHEL system-wide crypto policies or create custom cryptographic policies tailored to your setup, use the following recommendations for preferred protocols, cipher suites, and key lengths on your custom configuration:

### 3.2.1. Protocols

The latest version of TLS provides the best security mechanism. Unless you have a compelling reason to include support for older versions of TLS, allow your systems to negotiate connections using at least TLS version 1.2.

Note that even though RHEL 8 supports TLS version 1.3, not all features of this protocol are fully supported by RHEL 8 components. For example, the 0-RTT (Zero Round Trip Time) feature, which reduces connection latency, is not yet fully supported by the Apache web server.

### 3.2.2. Cipher suites

Modern, more secure cipher suites should be preferred to old, insecure ones. Always disable the use of eNULL and aNULL cipher suites, which do not offer any encryption or authentication at all. If at all possible, ciphers suites based on RC4 or HMAC-MD5, which have serious shortcomings, should also be disabled. The same applies to the so-called export cipher suites, which have been intentionally made weaker, and thus are easy to break.

While not immediately insecure, cipher suites that offer less than 128 bits of security should not be considered for their short useful life. Algorithms that use 128 bits of security or more can be expected to be unbreakable for at least several years, and are thus strongly recommended. Note that while 3DES ciphers advertise the use of 168 bits, they actually offer 112 bits of security.
Always prefer cipher suites that support (perfect) forward secrecy (PFS), which ensures the confidentiality of encrypted data even in case the server key is compromised. This rules out the fast RSA key exchange, but allows for the use of ECDHE and DHE. Of the two, ECDHE is the faster and therefore the preferred choice.

You should also prefer AEAD ciphers, such as AES-GCM, over CBC-mode ciphers as they are not vulnerable to padding oracle attacks. Additionally, in many cases, AES-GCM is faster than AES in CBC mode, especially when the hardware has cryptographic accelerators for AES.

Note also that when using the ECDHE key exchange with ECDSA certificates, the transaction is even faster than a pure RSA key exchange. To provide support for legacy clients, you can install two pairs of certificates and keys on a server: one with ECDSA keys (for new clients) and one with RSA keys (for legacy ones).

3.2.3. Public key length

When using RSA keys, always prefer key lengths of at least 3072 bits signed by at least SHA-256, which is sufficiently large for true 128 bits of security.

WARNING

The security of your system is only as strong as the weakest link in the chain. For example, a strong cipher alone does not guarantee good security. The keys and the certificates are just as important, as well as the hash functions and keys used by the Certification Authority (CA) to sign your keys.

Additional resources

- System-wide crypto policies in RHEL 8.
- update-crypto-policies(8) man page.

3.3. HARDENING TLS CONFIGURATION IN APPLICATIONS

In RHEL, system-wide crypto policies provide a convenient way to ensure that your applications using cryptographic libraries do not allow known insecure protocols, ciphers, or algorithms.

If you want to harden your TLS-related configuration with your customized cryptographic settings, you can use the cryptographic configuration options described in this section, and override the system-wide crypto policies just in the minimum required amount.

Regardless of the configuration you choose to use, always make sure to mandate that your server application enforces server-side cipher order, so that the cipher suite to be used is determined by the order you configure.

3.3.1. Configuring the Apache HTTP server

The Apache HTTP Server can use both OpenSSL and NSS libraries for its TLS needs. RHEL 8 provides the mod_ssl functionality through eponymous packages:
The `mod_ssl` package installs the `/etc/httpd/conf.d/ssl.conf` configuration file, which can be used to modify the TLS-related settings of the Apache HTTP Server.

Install the `httpd-manual` package to obtain complete documentation for the Apache HTTP Server, including TLS configuration. The directives available in the `/etc/httpd/conf.d/ssl.conf` configuration file are described in detail in the `/usr/share/httpd/manual/mod/mod_ssl.html` file. Examples of various settings are described in the `/usr/share/httpd/manual/ssl/ssl_howto.html` file.

When modifying the settings in the `/etc/httpd/conf.d/ssl.conf` configuration file, be sure to consider the following three directives at the minimum:

**SSLProtocol**
- Use this directive to specify the version of TLS or SSL you want to allow.

**SSLCipherSuite**
- Use this directive to specify your preferred cipher suite or disable the ones you want to disallow.

**SSLHonorCipherOrder**
- Uncomment and set this directive to `on` to ensure that the connecting clients adhere to the order of ciphers you specified.

For example, to use only the TLS 1.2 and 1.3 protocol:

```bash
SSLProtocol all -SSLv3 -TLSv1 -TLSv1.1
```

See the Configuring TLS encryption on an Apache HTTP Server chapter in the Deploying different types of servers document for more information.

### 3.3.2. Configuring the Nginx HTTP and proxy server

To enable TLS 1.3 support in Nginx, add the `TLSv1.3` value to the `ssl_protocols` option in the `server` section of the `/etc/nginx/nginx.conf` configuration file:

```bash
server {
    listen 443 ssl http2;
    listen [::]:443 ssl http2;
    ....
    ssl_protocols TLSv1.2 TLSv1.3;
    ssl_ciphers ....
}
```

See the Adding TLS encryption to an Nginx web server chapter in the Deploying different types of servers document for more information.

### 3.3.3. Configuring the Dovecot mail server

To configure your installation of the Dovecot mail server to use TLS, modify the `/etc/dovecot/conf.d/10-ssl.conf` configuration file. You can find an explanation of some of the basic configuration directives available in that file in the `/usr/share/doc/dovecot/wiki/SSL.DovecotConfiguration.txt` file, which is installed along with the standard installation of Dovecot.
When modifying the settings in the `/etc/dovecot/conf.d/10-ssl.conf` configuration file, be sure to consider the following three directives at the minimum:

**ssl_protocols**

Use this directive to specify the version of TLS or SSL you want to allow or disable.

**ssl_cipher_list**

Use this directive to specify your preferred cipher suites or disable the ones you want to disallow.

**ssl_prefer_server_ciphers**

Uncomment and set this directive to `yes` to ensure that the connecting clients adhere to the order of ciphers you specified.

For example, the following line in `/etc/dovecot/conf.d/10-ssl.conf` allows only TLS 1.1 and later:

```ini
ssl_protocols = !SSLv2 !SSLv3 !TLSv1
```

Additional resources

- Deploying different types of servers on RHEL 8
- `config(5)` and `ciphers(1)` man pages.
- Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS).
- Mozilla SSL Configuration Generator.
- SSL Server Test.
CHAPTER 4. CONFIGURING A VPN WITH IPSec

In RHEL 8, a virtual private network (VPN) can be configured using the IPSec protocol, which is supported by the Libreswan application.

4.1. LIBRESWAN AS AN IPSec VPN IMPLEMENTATION

In RHEL, a Virtual Private Network (VPN) can be configured using the IPsec protocol, which is supported by the Libreswan application. Libreswan is a continuation of the Openswan application, and many examples from the Openswan documentation are interchangeable with Libreswan.

The IPsec protocol for a VPN is configured using the Internet Key Exchange (IKE) protocol. The terms IPsec and IKE are used interchangeably. An IPsec VPN is also called an IKE VPN, IKEv2 VPN, XAUTH VPN, Cisco VPN or IKE/IPsec VPN. A variant of an IPsec VPN that also uses the Layer 2 Tunneling Protocol (L2TP) is usually called an L2TP/IPsec VPN, which requires the xl2tpd package provided by the optional repository.

Libreswan is an open-source, user-space IKE implementation. IKE v1 and v2 are implemented as a user-level daemon. The IKE protocol is also encrypted. The IPsec protocol is implemented by the Linux kernel, and Libreswan configures the kernel to add and remove VPN tunnel configurations.

The IKE protocol uses UDP port 500 and 4500. The IPsec protocol consists of two protocols:

- Encapsulated Security Payload (ESP), which has protocol number 50.
- Authenticated Header (AH), which has protocol number 51.

The AH protocol is not recommended for use. Users of AH are recommended to migrate to ESP with null encryption.

The IPsec protocol provides two modes of operation:

- Tunnel Mode (the default)
- Transport Mode.

You can configure the kernel with IPsec without IKE. This is called Manual Keying. You can also configure manual keying using the ip xfrm commands, however, this is strongly discouraged for security reasons.

Libreswan interfaces with the Linux kernel using netlink. Packet encryption and decryption happen in the Linux kernel.

Libreswan uses the Network Security Services (NSS) cryptographic library. Both Libreswan and NSS are certified for use with the Federal Information Processing Standard (FIPS) Publication 140-2.

IMPORTANT

IKE/IPsec VPNs, implemented by Libreswan and the Linux kernel, is the only VPN technology recommended for use in RHEL. Do not use any other VPN technology without understanding the risks of doing so.

In RHEL, Libreswan follows system-wide cryptographic policies by default. This ensures that Libreswan uses secure settings for current threat models including IKEv2 as a default protocol. See Using system-wide crypto policies for more information.

Libreswan does not use the terms “source” and “destination” or “server” and “client” because IKE/IPsec...
are peer to peer protocols. Instead, it uses the terms "left" and "right" to refer to end points (the hosts). This also allows you to use the same configuration on both end points in most cases. However, administrators usually choose to always use "left" for the local host and "right" for the remote host.

The **leftid** and **rightid** options serve as identification of the respective hosts in the authentication process. See the `ipsec.conf(5)` man page for more information.

### 4.2. AUTHENTICATION METHODS IN LIBRESWAN

Libreswan supports several authentication methods, each of which fits a different scenario.

#### Pre-Shared key (PSK)

*Pre-Shared Key* (PSK) is the simplest authentication method. For security reasons, do not use PSKs shorter than 64 random characters. In FIPS mode, PSKs must comply with a minimum-strength requirement depending on the integrity algorithm used. You can set PSK by using the `authby=secret` connection.

#### Raw RSA keys

*Raw RSA keys* are commonly used for static host-to-host or subnet-to-subnet IPsec configurations. Each host is manually configured with the public RSA keys of all other hosts, and Libreswan sets up an IPsec tunnel between each pair of hosts. This method does not scale well for large numbers of hosts.

You can generate a raw RSA key on a host using the `ipsec newhostkey` command. You can list generated keys by using the `ipsec showhostkey` command. The `leftrsasigkey=` line is required for connection configurations that use CKA ID keys. Use the `authby=rsasig` connection option for raw RSA keys.

#### X.509 certificates

*X.509 certificates* are commonly used for large-scale deployments with hosts that connect to a common IPsec gateway. A central *certificate authority* (CA) signs RSA certificates for hosts or users. This central CA is responsible for relaying trust, including the revocations of individual hosts or users.

For example, you can generate X.509 certificates using the `openssl` command and the NSS `certutil` command. Because Libreswan reads user certificates from the NSS database using the certificates' nickname in the `leftcert=` configuration option, provide a nickname when you create a certificate.

If you use a custom CA certificate, you must import it to the Network Security Services (NSS) database. You can import any certificate in the PKCS #12 format to the Libreswan NSS database by using the `ipsec import` command.

---

**WARNING**

Libreswan requires an Internet Key Exchange (IKE) peer ID as a subject alternative name (SAN) for every peer certificate as described in section 3.1 of RFC 4945. Disabling this check by changing the `require-id-on-certificated=` option can make the system vulnerable to man-in-the-middle attacks.

---

Use the `authby=rsasig` connection option for authentication based on X.509 certificates using RSA with SHA-1 and SHA-2. You can further limit it for ECDSA digital signatures using SHA-2 by setting
**authby**= to **ecdsa** and RSA Probabilistic Signature Scheme (RSASSA-PSS) digital signatures based authentication with SHA-2 through **authby=rsa-sha2**. The default value is **authby=rsasig,ecdsa**.

The certificates and the **authby**= signature methods should match. This increases interoperability and preserves authentication in one digital-signature system.

**NULL authentication**

**NULL authentication** is used to gain mesh encryption without authentication. It protects against passive attacks but not against active attacks. However, because IKEv2 allows asymmetric authentication methods, NULL authentication can also be used for internet-scale opportunistic IPsec. In this model, clients authenticate the server, but servers do not authenticate the client. This model is similar to secure websites using TLS. Use **authby=null** for NULL authentication.

**Protection against quantum computers**

In addition to the previously mentioned authentication methods, you can use the **Post-quantum Pre-shared Key** (PPK) method to protect against possible attacks by quantum computers. Individual clients or groups of clients can use their own PPK by specifying a PPK ID that corresponds to an out-of-band configured pre-shared key.

Using IKEv1 with pre-shared keys provides protection against quantum attackers. The redesign of IKEv2 does not offer this protection natively. Libreswan offers the use of **Post-quantum Pre-shared Key** (PPK) to protect IKEv2 connections against quantum attacks.

To enable optional PPK support, add **ppk=yes** to the connection definition. To require PPK, add **ppk=insist**. Then, each client can be given a PPK ID with a secret value that is communicated out-of-band (and preferably quantum safe). The PPK’s should be very strong in randomness and not based on dictionary words. The PPK ID and PPK data are stored in **ipsec.secrets**, for example:

```
@west @east : PPKS "user1" "thestringismeanttobearandomstr"
```

The **PPKS** option refers to static PPKs. This experimental function uses one-time-pad-based Dynamic PPKs. Upon each connection, a new part of the one-time pad is used as the PPK. When used, that part of the dynamic PPK inside the file is overwritten with zeros to prevent re-use. If there is no more one-time-pad material left, the connection fails. See the **ipsec.secrets(5)** man page for more information.

![WARNING]

The implementation of dynamic PPKs is provided as an unsupported Technology Preview. Use with caution.

### 4.3. INSTALLING LIBRESWAN

This procedure describes the steps for installing and starting the Libreswan IPsec/IKE VPN implementation.

**Prerequisites**

- The **AppStream** repository is enabled.
Procedure

1. Install the **libreswan** packages:
   ```
   # yum install libreswan
   ```

2. If you are re-installing Libreswan, remove its old database files and create a new database:
   ```
   # systemctl stop ipsec
   # rm /etc/ipsec.d/*db
   # ipsec initnss
   ```

3. Start the **ipsec** service, and enable the service to be started automatically on boot:
   ```
   # systemctl enable ipsec --now
   ```

4. Configure the firewall to allow 500 and 4500/UDP ports for the IKE, ESP, and AH protocols by adding the **ipsec** service:
   ```
   # firewall-cmd --add-service="ipsec"
   # firewall-cmd --runtime-to-permanent
   ```

### 4.4. CREATING A HOST-TO-HOST VPN

To configure Libreswan to create a host-to-host IPsec VPN between two hosts referred to as *left* and *right* using authentication by raw RSA keys, enter the following commands on both of the hosts:

**Prerequisites**

- Libreswan is installed and the **ipsec** service is started on each node.

**Procedure**

1. Generate a raw RSA key pair on each host:
   ```
   # ipsec newhostkey
   ```

2. The previous step returned the generated key's **ckaid**. Use that **ckaid** with the following command on *left*, for example:
   ```
   # ipsec showhostkey --left --ckaid 2d3ea57b61c9419dfd6cf43a1eb6cb306c0e857d
   ```
   The output of the previous command generated the **leftrsasigkey** line required for the configuration. Do the same on the second host (*right)*:
   ```
   # ipsec showhostkey --right --ckaid a9e1f6ce9ecd3608c24e8f701318383f41798f03
   ```

3. In the `/etc/ipsec.d/` directory, create a new **my_host-to-host.conf** file. Write the RSA host keys from the output of the **ipsec showhostkey** commands in the previous step to the new file. For example:
4. After importing keys, restart the **ipsec** service:

```
# systemctl restart ipsec
```

5. Load the connection:

```
# ipsec auto --add mytunnel
```

6. Establish the tunnel:

```
# ipsec auto --up mytunnel
```

7. To automatically start the tunnel when the **ipsec** service is started, add the following line to the connection definition:

```
auto=start
```

### 4.5. CONFIGURING A SITE-TO-SITE VPN

To create a site-to-site IPsec VPN, by joining two networks, an IPsec tunnel between the two hosts, is created. The hosts thus act as the end points, which are configured to permit traffic from one or more subnets to pass through. Therefore you can think of the host as gateways to the remote portion of the network.

The configuration of the site-to-site VPN only differs from the host-to-host VPN in that one or more networks or subnets must be specified in the configuration file.

**Prerequisites**

- A **host-to-host VPN** is already configured.

**Procedure**

1. Copy the file with the configuration of your host-to-host VPN to a new file, for example:

```
# cp /etc/ipsec.d/my_host-to-host.conf /etc/ipsec.d/my_site-to-site.conf
```

2. Add the subnet configuration to the file created in the previous step, for example:

```
conn mysubnet
  also=mytunnel
  leftsubnet=192.0.1.0/24
  rightsubnet=192.0.2.0/24
```
auto=start

conn mysubnet6
    also=mytunnel
    leftsubnet=2001:db8:0:1::/64
    rightsubnet=2001:db8:0:2::/64
    auto=start

# the following part of the configuration file is the same for both host-to-host and site-to-site connections:

conn mytunnel
    leftid=@west
    left=192.1.2.23
    leftrsa(sigkey=0sAQOrlo+hOafUZDlCQmXFrje/oZm [...] W2n417C/4urYHQkCvuIQ==
    rightid=@east
    right=192.1.2.45
    rightrsa(sigkey=0sAQO3fwC6nSSGgt64DWiYZzuHbc4 [...] D/v8t5YTQ==
    authby=rsasig

4.6. CONFIGURING A REMOTE ACCESS VPN

Road warriors are traveling users with mobile clients and a dynamically assigned IP address. The mobile clients authenticate using X.509 certificates.

The following example shows configuration for IKEv2, and it avoids using the IKEv1 XAUTH protocol.

On the server:

cconn roadwarriors
    ikev2=insist
    # support (roaming) MOBIKE clients (RFC 4555)
    mobike=yes
    fragmentation=yes
    left=1.2.3.4
    # if access to the LAN is given, enable this, otherwise use 0.0.0.0/0
    leftsubnet=10.10.0.0/16
    leftsubnet=0.0.0.0/0
    leftcert=gw.example.com
    leftid=%fromcert
    leftxauthserver=yes
    leftmodecfgserver=yes
    right=%any
    # trust our own Certificate Agency
    rightca=%same
    # pick an IP address pool to assign to remote users
    # 100.64.0.0/16 prevents RFC1918 clashes when remote users are behind NAT
    rightaddresspool=100.64.13.100-100.64.13.254
    # if you want remote clients to use some local DNS zones and servers
    modecfgdgs="1.2.3.4, 5.6.7.8"
    modecfgdomains="internal.company.com, corp"
    rightxauthserver=yes
    rightmodecfgserver=yes
    authby=rsasig
    # optionally, run the client X.509 ID through pam to allow or deny client
On the mobile client, the road warrior’s device, use a slight variation of the previous configuration:

```
conn to-vpn-server
  ikev2=insist
  # pick up our dynamic IP
  left=%defaultroute
  leftsubnet=0.0.0.0/0
  leftcert=myname.example.com
  leftid=%fromcert
  leftmodecfgclient=yes
  # right can also be a DNS hostname
  right=1.2.3.4
  # if access to the remote LAN is required, enable this, otherwise use 0.0.0.0/0
  rightsubnet=10.10.0.0/16
  rightsubnet=0.0.0.0/0
  fragmentation=yes
  # trust our own Certificate Agency
  rightca=%same
  authby=rsasig
  # allow narrowing to the server’s suggested assigned IP and remote subnet
  narrowing=yes
  # support (roaming) MOBIKE clients (RFC 4555)
  mobike=yes
  # initiate connection
  auto=start
```

4.7. CONFIGURING A MESH VPN

A mesh VPN network, which is also known as an any-to-any VPN, is a network where all nodes communicate using IPsec. The configuration allows for exceptions for nodes that cannot use IPsec. The mesh VPN network can be configured in two ways:

- To require IPsec.
- To prefer IPsec but allow a fallback to clear-text communication.

Authentication between the nodes can be based on X.509 certificates or on DNS Security Extensions (DNSSEC).

The following procedure uses X.509 certificates. These certificates can be generated using any kind of Certificate Authority (CA) management system, such as the Dogtag Certificate System. Dogtag assumes that the certificates for each node are available in the PKCS #12 format (.p12 files), which contain the private key, the node certificate, and the Root CA certificate used to validate other nodes’ X.509 certificates.

Each node has an identical configuration with the exception of its X.509 certificate. This allows for adding new nodes without reconfiguring any of the existing nodes in the network. The PKCS #12 files
require a "friendly name", for which we use the name "node" so that the configuration files referencing the friendly name can be identical for all nodes.

Prerequisites

- Libreswan is installed, and the ipsec service is started on each node.

Procedure

1. On each node, import PKCS #12 files. This step requires the password used to generate the PKCS #12 files:

   ```
   # ipsec import nodeXXX.p12
   ```

2. Create the following three connection definitions for the IPsec required (private), IPsec optional (private-or-clear), and No IPsec (clear) profiles:

   ```
   # cat /etc/ipsec.d/mesh.conf
   conn clear
   auto=ondemand
   type=passthrough
   authby=never
   left=%defaultroute
   right=%group

   conn private
   auto=ondemand
   type=transport
   authby=rsasig
   failureshunt=drop
   negotiationshunt=drop
   # left
   left=%defaultroute
   leftcert=nodeXXXX
   leftid=%fromcert
       leftrsasigkey=%cert
   # right
   rightrsasigkey=%cert
   rightid=%fromcert
   right=%opportunisticgroup

   conn private-or-clear
   auto=ondemand
   type=transport
   authby=rsasig
   failureshunt=passthrough
   negotiationshunt=passthrough
   # left
   left=%defaultroute
   leftcert=nodeXXXX
   leftid=%fromcert
       leftrsasigkey=%cert
   # right
   ```

CHAPTER 4. CONFIGURING A VPN WITH IPSEC
3. Add the IP address of the network in the proper category. For example, if all nodes reside in the 10.15.0.0/16 network, and all nodes should mandate IPsec encryption:

```
# echo "10.15.0.0/16" >> /etc/ipsec.d/policies/private
```

4. To allow certain nodes, for example, 10.15.34.0/24, to work with and without IPsec, add those nodes to the private-or-clear group using:

```
# echo "10.15.34.0/24" >> /etc/ipsec.d/policies/private-or-clear
```

5. To define a host, for example, 10.15.1.2, that is not capable of IPsec into the clear group, use:

```
# echo "10.15.1.2/32" >> /etc/ipsec.d/policies/clear
```

The files in the `/etc/ipsec.d/policies` directory can be created from a template for each new node, or can be provisioned using Puppet or Ansible.

Note that every node has the same list of exceptions or different traffic flow expectations. Two nodes, therefore, might not be able to communicate because one requires IPsec and the other cannot use IPsec.

6. Restart the node to add it to the configured mesh:

```
# systemctl restart ipsec
```

7. Once you finish with the addition of nodes, a `ping` command is sufficient to open an IPsec tunnel. To see which tunnels a node has opened:

```
# ipsec trafficstatus
```

### 4.8. DEPLOYING A FIPS-COMPLIANT IPSEC VPN

Use this procedure to deploy a FIPS-compliant IPsec VPN solution based on Libreswan. The following steps also enable you to identify which cryptographic algorithms are available and which are disabled for Libreswan in FIPS mode.

**Prerequisites**

- The **AppStream** repository is enabled.

**Procedure**

1. Install the **libreswan** packages:

```
# yum install libreswan
```

2. If you are re-installing Libreswan, remove its old NSS database:
3. Start the **ipsec** service, and enable the service to be started automatically on boot:

```
# systemctl enable ipsec --now
```

4. Configure the firewall to allow 500 and 4500/UDP ports for the IKE, ESP, and AH protocols by adding the **ipsec** service:

```
# firewall-cmd --add-service="ipsec"
# firewall-cmd --runtime-to-permanent
```

5. Switch the system to FIPS mode:

```
# fips-mode-setup --enable
```

6. Restart your system to allow the kernel to switch to FIPS mode:

```
# reboot
```

**Verification**

1. To confirm Libreswan is running in FIPS mode:

```
# ipsec whack --fipsstatus
000 FIPS mode enabled
```

2. Alternatively, check entries for the **ipsec** unit in the **systemd** journal:

```
$ journalctl -u ipsec
...
Jan 22 11:26:50 localhost.localdomain pluto[3076]: FIPS Product: YES
Jan 22 11:26:50 localhost.localdomain pluto[3076]: FIPS Kernel: YES
Jan 22 11:26:50 localhost.localdomain pluto[3076]: FIPS Mode: YES
```

3. To see the available algorithms in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | head -11
FIPS Product: YES
FIPS Kernel: YES
FIPS Mode: YES
NSS DB directory: sql:/etc/ipsec.d
Initializing NSS
Opening NSS database "sql:/etc/ipsec.d" read-only
NSS initialized
NSS crypto library initialized
FIPS HMAC integrity support [enabled]
FIPS mode enabled for pluto daemon
NSS library is running in FIPS mode
FIPS HMAC integrity verification self-test passed
```
4. To query disabled algorithms in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | grep disabled
Encryption algorithm CAMELLIA_CTR disabled; not FIPS compliant
Encryption algorithm CAMELLIA_CBC disabled; not FIPS compliant
Encryption algorithm SERPENT_CBC disabled; not FIPS compliant
Encryption algorithm TWOFISH_CBC disabled; not FIPS compliant
Encryption algorithm TWOFISH_SSH disabled; not FIPS compliant
Encryption algorithm NULL disabled; not FIPS compliant
Encryption algorithm CHACHA20_POLY1305 disabled; not FIPS compliant
Hash algorithm MD5 disabled; not FIPS compliant
PRF algorithm HMAC_MD5 disabled; not FIPS compliant
PRF algorithm AES_XCBC disabled; not FIPS compliant
Integrity algorithm HMAC_MD5_96 disabled; not FIPS compliant
Integrity algorithm HMAC_SHA2_256_TRUNCBUG disabled; not FIPS compliant
Integrity algorithm AES_XCBC_96 disabled; not FIPS compliant
DH algorithm MODP1024 disabled; not FIPS compliant
DH algorithm MODP1536 disabled; not FIPS compliant
DH algorithm DH31 disabled; not FIPS compliant
```

5. To list all allowed algorithms and ciphers in FIPS mode:

```
# ipsec pluto --selftest 2>&1 | grep ESP | grep FIPS | sed "s/^.*FIPS//"
{256,192,*128}  aes_ccm, aes_ccm_c
{256,192,*128}  aes_ccm_b
{256,192,*128}  aes_ccm_a
[*192]  3des
{256,192,*128}  aes_gcm, aes_gcm_c
{256,192,*128}  aes_gcm_b
{256,192,*128}  aes_gcm_a
{256,192,*128}  aesctr
{256,192,*128}  aes
{256,192,*128}  aes_gmac
sha, sha1, sha1_96, hmac_sha1
sha512, sha2_512, sha2_512_256, hmac_sha2_512
sha384, sha2_384, sha2_384_192, hmac_sha2_384
sha2, sha256, sha2_256, sha2_256_128, hmac_sha2_256
aes_cmac
null
null, dh0
dh14
dh15
dh16
dh17
dh18
ecp_256, ecp256
ecp_384, ecp384
ecp_521, ecp521
```

Additional resources

- Using system-wide cryptographic policies.

4.9. PROTECTING THE IPSEC NSS DATABASE BY A PASSWORD
By default, the IPsec service creates its Network Security Services (NSS) database with an empty password during the first start. Add password protection by using the following steps.

**NOTE**

In the previous releases of RHEL up to version 6.6, you had to protect the IPsec NSS database with a password to meet the FIPS 140-2 requirements because the NSS cryptographic libraries were certified for the FIPS 140-2 Level 2 standard. In RHEL 8, NIST certified NSS to Level 1 of this standard, and this status does not require password protection for the database.

**Prerequisites**

- The `/etc/ipsec.d/` directory contains NSS database files.

**Procedure**

1. Enable password protection for the NSS database for Libreswan:

   ```
   # certutil -N -d sql:/etc/ipsec.d
   Enter Password or Pin for "NSS Certificate DB":
   Enter a password which will be used to encrypt your keys.
   The password should be at least 8 characters long,
   and should contain at least one non-alphabetic character.

   Enter new password:
   ```

2. Create the `/etc/ipsec.d/nsspassword` file containing the password you have set in the previous step, for example:

   ```
   # cat /etc/ipsec.d/nsspassword
   NSS Certificate DB:MyStrongPasswordHere
   ```

   Note that the `nsspassword` file use the following syntax:

   ```
   token_1_name:the_password
   token_2_name:the_password
   ```

   The default NSS software token is **NSS Certificate DB**. If your system is running in FIPS mode, the name of the token is **NSS FIPS 140-2 Certificate DB**.

3. Depending on your scenario, either start or restart the `ipsec` service after you finish the `nsspassword` file:

   ```
   # systemctl restart ipsec
   ```

**Verification**

1. Check that the `ipsec` service is running after you have added a non-empty password to its NSS database:

   ```
   # systemctl status ipsec
   • ipsec.service - Internet Key Exchange (IKE) Protocol Daemon for IPsec
   ```
2. Optionally, check that the Journal log contains entries confirming a successful initialization:

```
# journalctl -u ipsec
...
pluto[23001]: NSS DB directory: sql:/etc/ipsec.d
pluto[23001]: Initializing NSS
pluto[23001]: Opening NSS database "sql:/etc/ipsec.d" read-only
pluto[23001]: NSS Password from file "/etc/ipsec.d/nsspassword" for token "NSS Certificate DB" with length 20 passed to NSS
pluto[23001]: NSS crypto library initialized
...
```

Additional resources

- certutil(1) man page.
- Government Standards Knowledgebase article.

### 4.10. CONFIGURING AN IPSEC VPN TO USE TCP

Libreswan supports TCP encapsulation of IKE and IPsec packets as described in RFC 8229. With this feature, you can establish IPsec VPNs on networks that prevent traffic transmitted via UDP and Encapsulating Security Payload (ESP). You can configure VPN servers and clients to use TCP either as a fallback or as the main VPN transport protocol. Because TCP encapsulation has bigger performance costs, use TCP as the main VPN protocol only if UDP is permanently blocked in your scenario.

#### Prerequisites

- A remote-access VPN is already configured.

#### Procedure

1. Add the following option to the `/etc/ipsec.conf` file in the `config setup` section:

   ```
   listen-tcp=yes
   ```

2. To use TCP encapsulation as a fallback option when the first attempt over UDP fails, add the following two options to the client’s connection definition:

   ```
   enable-tcp=fallback
tcp-remoteport=4500
   ```

   Alternatively, if you know that UDP is permanently blocked, use the following options in the client’s connection configuration:

   ```
   enable-tcp=yes
tcp-remoteport=4500
   ```

Additional resources
4.11. CONFIGURING AUTOMATIC DETECTION AND USAGE OF ESP HARDWARE OFFLOAD TO ACCELERATE AN IPSEC CONNECTION

Offloading Encapsulating Security Payload (ESP) to the hardware accelerates IPsec connections over Ethernet. By default, Libreswan detects if hardware supports this feature and, as a result, enables ESP hardware offload. This procedure describes how to enable the automatic detection in case that the feature was disabled or explicitly enabled.

Prerequisites

- The network card supports ESP hardware offload.
- The network driver supports ESP hardware offload.
- The IPsec connection is configured and works.

Procedure

1. Edit the Libreswan configuration file in the /etc/ipsec.d/ directory of the connection that should use automatic detection of ESP hardware offload support.

2. Ensure the nic-offload parameter is not set in the connection’s settings.

3. If you removed nic-offload, restart the ipsec service:

   ```
   # systemctl restart ipsec
   ```

Verification

If the network card supports ESP hardware offload support, following these steps to verify the result:

1. Display the tx_ipsec and rx_ipsec counters of the Ethernet device the IPsec connection uses:

   ```
   # ethtool -S enp1s0 | grep "_ipsec"
   tx_ipsec: 10
   rx_ipsec: 10
   ```

2. Send traffic through the IPsec tunnel. For example, ping a remote IP address:

   ```
   # ping -c 5 remote_ip_address
   ```

3. Display the tx_ipsec and rx_ipsec counters of the Ethernet device again:

   ```
   # ethtool -S enp1s0 | grep "_ipsec"
   tx_ipsec: 15
   rx_ipsec: 15
   ```

   If the counter values have increased, ESP hardware offload works.

Additional resources

- Configuring a VPN with IPsec
4.12. CONFIGURING ESP HARDWARE OFFLOAD ON A BOND TO ACCELERATE AN IPSEC CONNECTION

Offloading Encapsulating Security Payload (ESP) to the hardware accelerates IPsec connections. If you use a network bond for fail-over reasons, the requirements and the procedure to configure ESP hardware offload are different from those using a regular Ethernet device. For example, in this scenario, you enable the offload support on the bond, and the kernel applies the settings to the ports of the bond.

Prerequisites

- All network cards in the bond support ESP hardware offload.
- The network driver supports ESP hardware offload on a bond device. In RHEL, only the ixgbe driver supports this feature.
- The bond is configured and works.
- The bond uses the active-backup mode. The bonding driver does not support any other modes for this feature.
- The IPsec connection is configured and works.

Procedure

1. Enable ESP hardware offload support on the network bond:

   ```bash
   # nmcli connection modify bond0 ethtool.feature-esp-hw-offload on
   ```

   This command enables ESP hardware offload support on the bond0 connection.

2. Reactivate the bond0 connection:

   ```bash
   # nmcli connection up bond0
   ```

3. Edit the Libreswan configuration file in the `/etc/ipsec.d/` directory of the connection that should use ESP hardware offload, and append the `nic-offload=yes` statement to the connection entry:

   ```
   conn example
   ...
   nic-offload=yes
   ```

4. Restart the ipsec service:

   ```bash
   # systemctl restart ipsec
   ```

Verification

1. Display the active port of the bond:

   ```bash
   # grep "Currently Active Slave" /proc/net/bonding/bond0
   Currently Active Slave: enp1s0
   ```

2. Display the `tx_ipsec` and `rx_ipsec` counters of the active port:
ethtool -S enp1s0 | egrep "_ipsec"
  tx_ipsec: 10
  rx_ipsec: 10

3. Send traffic through the IPsec tunnel. For example, ping a remote IP address:

  # ping -c 5 remote_ip_address

4. Display the tx_ipsec and rx_ipsec counters of the active port again:

  # ethtool -S enp1s0 | egrep "_ipsec"
  tx_ipsec: 15
  rx_ipsec: 15

If the counter values have increased, ESP hardware offload works.

Additional resources

- Configuring network bonding
- Configuring a VPN with IPsec
- Configuring a VPN with IPsec chapter in the Securing networks document.

4.13. CONFIGURING IPSEC CONNECTIONS THAT OPT OUT OF THE SYSTEM-WIDE CRYPTO POLICIES

Overriding system-wide crypto-policies for a connection

The RHEL system-wide cryptographic policies create a special connection called %default. This connection contains the default values for the ikev2, esp, and ike options. However, you can override the default values by specifying the mentioned option in the connection configuration file.

For example, the following configuration allows connections that use IKEv1 with AES and SHA-1 or SHA-2, and IPsec (ESP) with either AES-GCM or AES-CBC:

    conn MyExample
    ...
    ikev2=never
    ike=aes-sha2,aes-sha1;modp2048
    esp=aes_gcm,aes-sha2,aes-sha1
    ...

Note that AES-GCM is available for IPsec (ESP) and for IKEv2, but not for IKEv1.

Disabling system-wide crypto policies for all connections

To disable system-wide crypto policies for all IPsec connections, comment out the following line in the /etc/ipsec.conf file:

    include /etc/crypto-policies/back-ends/libreswan.config

Then add the ikev2=never option to your connection configuration file.
4.14. TROUBLESHOOTING IPSEC VPN CONFIGURATIONS

Problems related to IPsec VPN configurations most commonly occur due to several main reasons. If you are encountering such problems, you can check if the cause of the problem corresponds to any of the following scenarios, and apply the corresponding solution.

Basic connection troubleshooting

Most problems with VPN connections occur in new deployments, where administrators configured endpoints with mismatched configuration options. Also, a working configuration can suddenly stop working, often due to newly introduced incompatible values. This could be the result of an administrator changing the configuration. Alternatively, an administrator may have installed a firmware update or a package update with different default values for certain options, such as encryption algorithms.

To confirm that an IPsec VPN connection is established:

```
# ipsec trafficstatus
006 #8: "vpn.example.com"[1] 192.0.2.1, type=ESP, add_time=1595296930, inBytes=5999, outBytes=3231, id='@vpn.example.com', lease=100.64.13.5/32
```

If the output is empty or does not show an entry with the connection name, the tunnel is broken.

To check that the problem is in the connection:

1. Reload the `vpn.example.com` connection:

   ```
   # ipsec auto --add vpn.example.com
   002 added connection description "vpn.example.com"
   ```

2. Next, initiate the VPN connection:

   ```
   # ipsec auto --up vpn.example.com
   ```

Firewall-related problems

The most common problem is that a firewall on one of the IPsec endpoints or on a router between the endpoints is dropping all Internet Key Exchange (IKE) packets.

- For IKEv2, an output similar to the following example indicates a problem with a firewall:

```
# ipsec auto --up vpn.example.com
181 "vpn.example.com"[1] 192.0.2.2 #15: initiating IKEv2 IKE SA
181 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: sent v2I1, expected v2R1
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 0.5 seconds for response
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 1 seconds for response
010 "vpn.example.com"[1] 192.0.2.2 #15: STATE_PARENT_I1: retransmission; will wait 2 seconds for
...
For IKEv1, the output of the initiating command looks like:

```bash
# ipsec auto --up vpn.example.com
002 "vpn.example.com" #9: initiating Main Mode
102 "vpn.example.com" #9: STATE_MAIN_I1: sent MI1, expecting MR1
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 0.5 seconds for response
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 1 seconds for response
010 "vpn.example.com" #9: STATE_MAIN_I1: retransmission; will wait 2 seconds for response
...```

Because the IKE protocol, which is used to set up IPsec, is encrypted, you can troubleshoot only a limited subset of problems using the `tcpdump` tool. If a firewall is dropping IKE or IPsec packets, you can try to find the cause using the `tcpdump` utility. However, `tcpdump` cannot diagnose other problems with IPsec VPN connections.

- To capture the negotiation of the VPN and all encrypted data on the `eth0` interface:

```bash
# tcpdump -i eth0 -n -n esp or udp port 500 or udp port 4500 or tcp port 4500
```

### Mismatched algorithms, protocols, and policies

VPN connections require that the endpoints have matching IKE algorithms, IPsec algorithms, and IP address ranges. If a mismatch occurs, the connection fails. If you identify a mismatch by using one of the following methods, fix it by aligning algorithms, protocols, or policies.

- If the remote endpoint is not running IKE/IPsec, you can see an ICMP packet indicating it. For example:

```bash
# ipsec auto --up vpn.example.com
...
000 "vpn.example.com"[1] 192.0.2.2 #16: ERROR: asynchronous network error report on wlp2s0 (192.0.2.2:500), complainant 198.51.100.1: Connection refused [errno 111, origin ICMP type 3 code 3 (not authenticated)]
...
```

- Example of mismatched IKE algorithms:

```bash
# ipsec auto --up vpn.example.com
...
003 "vpn.example.com"[1] 193.110.157.148 #3: dropping unexpected IKE_SA_INIT message containing NO_PROPOSAL_CHOSEN notification; message payloads: N; missing payloads: SA,KE,Ni
```

- Example of mismatched IPsec algorithms:

```bash
# ipsec auto --up vpn.example.com
...
182 "vpn.example.com"[1] 193.110.157.148 #5: STATE_PARENT_I2: sent v2I2, expected v2R2 {auth=IKEv2 cipher=AES_GCM_16_256 integ=n/a prf=HMAC_SHA2_256 group=MODP2048}
002 "vpn.example.com"[1] 193.110.157.148 #6: IKE_AUTH response contained the error notification NO_PROPOSAL_CHOSEN
```
A mismatched IKE version could also result in the remote endpoint dropping the request without a response. This looks identical to a firewall dropping all IKE packets.

- Example of mismatched IP address ranges for IKEv2 (called Traffic Selectors - TS):

```bash
# ipsec auto --up vpn.example.com
... 1v2 "vpn.example.com" #1: STATE_PARENT_I2: sent v2I2, expected v2R2 {auth=IKEv2 cipher=AES_GCM_16_256 integ=n/a prf=HMAC_SHA2_512 group=MODP2048}
002 "vpn.example.com" #2: IKE_AUTH response contained the error notification TS_UNACCEPTABLE
```

- Example of mismatched IP address ranges for IKEv1:

```bash
# ipsec auto --up vpn.example.com
... 031 "vpn.example.com" #2: STATE_QUICK_I1: 60 second timeout exceeded after 0 retransmits. No acceptable response to our first Quick Mode message: perhaps peer likes no proposal
```

- When using PreSharedKeys (PSK) in IKEv1, if both sides do not put in the same PSK, the entire IKE message becomes unreadable:

```bash
# ipsec auto --up vpn.example.com
... 003 "vpn.example.com" #1: received Hash Payload does not match computed value 223 "vpn.example.com" #1: sending notification INVALID_HASH_INFORMATION to 192.0.2.23:500
```

- In IKEv2, the mismatched-PSK error results in an AUTHENTICATION_FAILED message:

```bash
# ipsec auto --up vpn.example.com
... 002 "vpn.example.com" #1: IKE SA authentication request rejected by peer: AUTHENTICATION_FAILED
```

**Maximum transmission unit**

Other than firewalls blocking IKE or IPsec packets, the most common cause of networking problems relates to an increased packet size of encrypted packets. Network hardware fragments packets larger than the maximum transmission unit (MTU), for example, 1500 bytes. Often, the fragments are lost and the packets fail to re-assemble. This leads to intermittent failures, when a ping test, which uses small-sized packets, works but other traffic fails. In this case, you can establish an SSH session but the terminal freezes as soon as you use it, for example, by entering the 'ls -al /usr' command on the remote host.

To work around the problem, reduce MTU size by adding the `mtu=1400` option to the tunnel configuration file.

Alternatively, for TCP connections, enable an iptables rule that changes the MSS value:

```bash
# iptables -I FORWARD -p tcp --tcp-flags SYN,RST SYN -j TCPMSS --clamp-mss-to-pmtu
```

If the previous command does not solve the problem in your scenario, directly specify a lower size in the `set-mss` parameter:
Network address translation (NAT)

When an IPsec host also serves as a NAT router, it could accidentally remap packets. The following example configuration demonstrates the problem:

```plaintext
conn myvpn
  left=172.16.0.1
  leftsubnet=10.0.2.0/24
  right=172.16.0.2
  rightsubnet=192.168.0.0/16
...
```

The system with address 172.16.0.1 have a NAT rule:

```plaintext
iptables -t nat -I POSTROUTING -o eth0 -j MASQUERADE
```

If the system on address 10.0.2.33 sends a packet to 192.168.0.1, then the router translates the source 10.0.2.33 to 172.16.0.1 before it applies the IPsec encryption.

Then, the packet with the source address 10.0.2.33 no longer matches the `conn myvpn` configuration, and IPsec does not encrypt this packet.

To solve this problem, insert rules that exclude NAT for target IPsec subnet ranges on the router, in this example:

```plaintext
iptables -t nat -I POSTROUTING -s 10.0.2.0/24 -d 192.168.0.0/16 -j RETURN
```

Kernel IPsec subsystem bugs

The kernel IPsec subsystem might fail, for example, when a bug causes a desynchronizing of the IKE user space and the IPsec kernel. To check for such problems:

```bash
$ cat /proc/net/xfrm_stat
XfrmInError       0
XfrmInBufferError 0
...
```

Any non-zero value in the output of the previous command indicates a problem. If you encounter this problem, open a new support case, and attach the output of the previous command along with the corresponding IKE logs.

Libreswan logs

Libreswan logs using the syslog protocol by default. You can use the `journalctl` command to find log entries related to IPsec. Because the corresponding entries to the log are sent by the pluto IKE daemon, search for the “pluto” keyword, for example:

```bash
$ journalctl -b | grep pluto
```

To show a live log for the ipsec service:

```bash
$ journalctl -f -u ipsec
```
If the default level of logging does not reveal your configuration problem, enable debug logs by adding the `plutodebug=all` option to the `config setup` section in the `/etc/ipsec.conf` file.

Note that debug logging produces a lot of entries, and it is possible that either the `journald` or `syslogd` service rate-limits the `syslog` messages. To ensure you have complete logs, redirect the logging to a file. Edit the `/etc/ipsec.conf`, and add the `logfile=/var/log/pluto.log` in the `config setup` section.

Additional resources

- Troubleshooting problems using log files.
- `tcpdump(8)` and `ipsec.conf(5)` man pages.
- Using and configuring firewalld

4.15. ADDITIONAL RESOURCES

- `ipsec(8)`, `ipsec.conf(5)`, `ipsec.secrets(5)`, `ipsec_auto(8)`, and `ipsec_rsasigkey(8)` man pages.
- `/usr/share/doc/libreswan-version/` directory.
- The website of the upstream project.
- The Libreswan Project Wiki.
- All Libreswan man pages.
- NIST Special Publication 800-77: Guide to IPsec VPNs.
CHAPTER 5. CONFIGURING VPN CONNECTIONS WITH IPSEC BY USING THE VPN RHEL SYSTEM ROLE

With the VPN System Role, you can configure VPN connections on RHEL systems by using Red Hat Ansible Automation Platform. You can use it to set up host-to-host, network-to-network, VPN Remote Access Server, and mesh configurations.

For host-to-host connections, the role sets up a VPN tunnel between each pair of hosts in the list of `vpn_connections` using the default parameters, including generating keys as needed. Alternatively, you can configure it to create an opportunistic mesh configuration between all hosts listed. The role assumes that the names of the hosts under `hosts` are the same as the names of the hosts used in the Ansible inventory, and that you can use those names to configure the tunnels.

**NOTE**

The VPN RHEL System Role currently supports only Libreswan, which is an IPsec implementation, as the VPN provider.

5.1. CREATING A HOST-TO-HOST VPN WITH IPSEC USING THE VPN SYSTEM ROLE

You can use the VPN System Role to configure host-to-host connections by running an Ansible playbook on the control node, which will configure all the managed nodes listed in an inventory file.

**Prerequisites**

- Access and permissions to one or more *managed nodes*, which are systems you want to configure with the VPN System Role.
- Access and permissions to a *control node*, which is a system from which Red Hat Ansible Core configures other systems.

On the control node:

- The `ansible-core` and `rhel-system-roles` packages are installed.

**IMPORTANT**

RHEL 8.0–8.5 provided access to a separate Ansible repository that contains Ansible Engine 2.9 for automation based on Ansible. Ansible Engine contains command-line utilities such as `ansible`, `ansible-playbook`, connectors such as `docker` and `podman`, and many plugins and modules. For information on how to obtain and install Ansible Engine, see the *How to download and install Red Hat Ansible Engine* Knowledgebase article.

RHEL 8.6 and 9.0 have introduced Ansible Core (provided as the `ansible-core` package), which contains the Ansible command-line utilities, commands, and a small set of built-in Ansible plugins. RHEL provides this package through the AppStream repository, and it has a limited scope of support. For more information, see the *Scope of support for the Ansible Core package included in the RHEL 9 and RHEL 8.6 and later AppStream repositories* Knowledgebase article.

- An inventory file which lists the managed nodes.

**Procedure**
1. Create a new `playbook.yml` file with the following content:

```yaml
- name: Host to host VPN
  hosts: managed_node1, managed_node2
  roles:
  - rhel-system-roles.vpn
  vars:
    vpn_connections:
      - hosts:
          managed_node1:
          managed_node2:
```

This playbook configures the connection `managed_node1-to-managed_node2` using pre-shared key authentication with keys auto-generated by the system role.

2. Optional: Configure connections from managed hosts to external hosts that are not listed in the inventory file by adding the following section to the `vpn_connections` list of hosts:

```yaml
vpn_connections:
  - hosts:
      managed_node1:
      managed_node2:
      external_node:
        hostname: 192.0.2.2
```

This configures two additional connections: `managed_node1-to-external_node` and `managed_node2-to-external_node`.

**NOTE**

The connections are configured only on the managed nodes and not on the external node.

1. Optional: You can specify multiple VPN connections for the managed nodes by using additional sections within `vpn_connections`, for example a control plane and a data plane:

```yaml
- name: Multiple VPN
  hosts: managed_node1, managed_node2
  roles:
  - rhel-system-roles.vpn
  vars:
    vpn_connections:
      - name: control_plane_vpn
        hosts:
          managed_node1:
            hostname: 192.0.2.0 # IP for the control plane
          managed_node2:
            hostname: 192.0.2.1
      - name: data_plane_vpn
        hosts:
          managed_node1:
            hostname: 10.0.0.1 # IP for the data plane
          managed_node2:
            hostname: 10.0.0.2
```
2. Optional: You can modify the variables according to your preferences. For more details, see the 

3. Optional: Verify playbook syntax.

   # ansible-playbook --syntax-check /path/to/file/playbook.yml -i /path/to/file/inventory_file

4. Run the playbook on your inventory file:

   # ansible-playbook -i /path/to/file/inventory_file /path/to/file/playbook.yml

Verification

1. On the managed nodes, confirm that the connection is successfully loaded:

   # ipsec status | grep connection.name

   Replace connection.name with the name of the connection from this node, for example managed_node1-to-managed_node2.

   **NOTE**

   By default, the role generates a descriptive name for each connection it creates from the perspective of each system. For example, when creating a connection between managed_node1 and managed_node2, the descriptive name of this connection on managed_node1 is managed_node1-to-managed_node2 but on managed_node2 the connection is named managed_node2-to-managed_node1.

2. On the managed nodes, confirm that the connection is successfully started:

   # ipsec trafficstatus | grep connection.name

3. Optional: If a connection did not successfully load, manually add the connection by entering the following command. This will provide more specific information indicating why the connection failed to establish:

   # ipsec auto --add connection.name

   **NOTE**

   Any errors that may have occurred during the process of loading and starting the connection are reported in the logs, which can be found in /var/log/pluto.log. Because these logs are hard to parse, try to manually add the connection to obtain log messages from the standard output instead.

5.2. CREATING AN OPPORTUNISTIC MESH VPN CONNECTION WITH IPSEC BY USING THE VPN RHEL SYSTEM ROLE

You can use the VPN System Role to configure an opportunistic mesh VPN connection that uses certificates for authentication by running an Ansible playbook on the control node, which will configure all the managed nodes listed in an inventory file.
Authentication with certificates is configured by defining the **auth_method: cert** parameter in the playbook. The VPN System Role assumes that the IPsec Network Security Services (NSS) crypto library, which is defined in the **/etc/ipsec.d** directory, contains the necessary certificates. By default, the node name is used as the certificate nickname. In this example, this is **managed_node1**. You can define different certificate names by using the **cert_name** attribute in your inventory.

In the following example procedure, the control node, which is the system from which you will run the Ansible playbook, shares the same classless inter-domain routing (CIDR) number as both of the managed nodes (192.0.2.0/24) and has the IP address 192.0.2.7. Therefore, the control node falls under the private policy which is automatically created for CIDR 192.0.2.0/24.

To prevent SSH connection loss during the play, a clear policy for the control node is included in the list of policies. Note that there is also an item in the policies list where the CIDR is equal to default. This is because this playbook overrides the rule from the default policy to make it private instead of private-or-clear.

**Prerequisites**

- Access and permissions to one or more *managed nodes*, which are systems you want to configure with the VPN System Role.
  - On all the managed nodes, the NSS database in the **/etc/ipsec.d** directory contains all the certificates necessary for peer authentication. By default, the node name is used as the certificate nickname.

- Access and permissions to a *control node*, which is a system from which Red Hat Ansible Core configures other systems.
  
  **On the control node:**
  
  - The **ansible-core** and **rhel-system-roles** packages are installed.

**IMPORTANT**

RHEL 8.0–8.5 provided access to a separate Ansible repository that contains Ansible Engine 2.9 for automation based on Ansible. Ansible Engine contains command-line utilities such as **ansible**, **ansible-playbook**, connectors such as **docker** and **podman**, and many plugins and modules. For information on how to obtain and install Ansible Engine, see the How to download and install Red Hat Ansible Engine Knowledgebase article.

RHEL 8.6 and 9.0 have introduced Ansible Core (provided as the **ansible-core** package), which contains the Ansible command-line utilities, commands, and a small set of built-in Ansible plugins. RHEL provides this package through the AppStream repository, and it has a limited scope of support. For more information, see the Scope of support for the Ansible Core package included in the RHEL 9 and RHEL 8.6 and later AppStream repositories Knowledgebase article.

- An inventory file which lists the managed nodes.

**Procedure**

1. Create a new **playbook.yml** file with the following content:

   ```yaml
   - name: Mesh VPN
     hosts: managed_node1, managed_node2, managed_node3
     roles:
   ```
2. Optional: You can modify the variables according to your preferences. For more details, see the  

3. Optional: Verify playbook syntax.

    # ansible-playbook --syntax-check playbook.yml

4. Run the playbook on your inventory file:

    # ansible-playbook -i inventory_file /path/to/file/playbook.yml

5.3. ADDITIONAL RESOURCES

- For details about the parameters used in the VPN System Role and additional information about  
the role, see the /usr/share/doc/rhel-system-roles/vpn/README.md file.

- For details about the ansible-playbook command, see the ansible-playbook(1) man page.
CHAPTER 6. USING MACSEC TO ENCRYPT LAYER-2 TRAFFIC IN THE SAME PHYSICAL NETWORK

You can use MACsec to secure the communication between two devices (point-to-point). For example, your branch office is connected over a Metro-Ethernet connection with the central office, you can configure MACsec on the two hosts that connect the offices to increase the security.

Media Access Control security (MACsec) is a layer 2 protocol that secures different traffic types over the Ethernet links including:

- dynamic host configuration protocol (DHCP)
- address resolution protocol (ARP)
- Internet Protocol version 4 / 6 (IPv4 / IPv6) and
- any traffic over IP such as TCP or UDP

MACsec encrypts and authenticates all traffic in LANs, by default with the GCM-AES-128 algorithm, and uses a pre-shared key to establish the connection between the participant hosts. If you want to change the pre-shared key, you need to update the NM configuration on all hosts in the network that uses MACsec.

A MACsec connection uses an Ethernet device, such as an Ethernet network card, VLAN, or tunnel device, as parent. You can either set an IP configuration only on the MACsec device to communicate with other hosts only using the encrypted connection, or you can also set an IP configuration on the parent device. In the latter case, you can use the parent device to communicate with other hosts using an unencrypted connection and the MACsec device for encrypted connections.

MACsec does not require any special hardware. For example, you can use any switch, except if you want to encrypt traffic only between a host and a switch. In this scenario, the switch must also support MACsec.

In other words, there are 2 common methods to configure MACsec;

- host to host and
- host to switch then switch to other host(s)

IMPORTANT
You can use MACsec only between hosts that are in the same (physical or virtual) LAN.

6.1. CONFIGURING A MACSEC CONNECTION USING NMCLI

You can configure Ethernet interfaces to use MACsec using the `nmcli` utility. This procedure describes how to create a MACsec connection between two hosts that are connected over Ethernet.

Procedure

1. On the first host on which you configure MACsec:
   - Create the connectivity association key (CAK) and connectivity-association key name (CKN) for the pre-shared key:
a. Create a 16-byte hexadecimal CAK:

```
# dd if=/dev/urandom count=16 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
50b71a8ef0bd571ea76de6d6c98c03a
```

b. Create a 32-byte hexadecimal CKN:

```
# dd if=/dev/urandom count=32 bs=1 2> /dev/null | hexdump -e '1/2 "%04x"'
f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
```

2. On both hosts you want to connect over a MACsec connection:

3. Create the MACsec connection:

```
# nmcli connection add type macsec con-name macsec0 ifname macsec0
connection.autoconnect yes macsec.parent enp1s0 macsec.mode psk macsec.mka-cak 50b71a8ef0bd571ea76de6d6c98c03a macsec.mka-ckn f2b4297d39da7330910a74abc0449feb45b5c0b9fc23df1430e1898fcf1c4550
```

Use the CAK and CKN generated in the previous step in the `macsec.mka-cak` and `macsec.mka-ckn` parameters. The values must be the same on every host in the MACsec-protected network.

4. Configure the IP settings on the MACsec connection.

   a. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, and DNS server to the `macsec0` connection, enter:

```
# nmcli connection modify macsec0 ipv4.method manual ipv4.addresses '192.0.2.1/24' ipv4.gateway '192.0.2.254' ipv4.dns '192.0.2.253'
```

   b. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, and DNS server to the `macsec0` connection, enter:

```
```

5. Activate the connection:

```
# nmcli connection up macsec0
```

Verification steps

1. Verify that the traffic is encrypted:

```
# tcpdump -nn -i enp1s0
```

2. Optional: Display the unencrypted traffic:

```
# tcpdump -nn -i macsec0
```

3. Display MACsec statistics:
# ip macsec show

4. Display individual counters for each type of protection: integrity-only (encrypt off) and encryption (encrypt on)

# ip -s macsec show

6.2. ADDITIONAL RESOURCES

- MACsec: a different solution to encrypt network traffic blog.
A firewall is a way to protect machines from any unwanted traffic from outside. It enables users to control incoming network traffic on host machines by defining a set of firewall rules. These rules are used to sort the incoming traffic and either block it or allow through.

**firewalld** is a firewall service daemon that provides a dynamic customizable host-based firewall with a D-Bus interface. Being dynamic, it enables creating, changing, and deleting the rules without the necessity to restart the firewall daemon each time the rules are changed.

**firewalld** uses the concepts of zones and services, that simplify the traffic management. Zones are predefined sets of rules. Network interfaces and sources can be assigned to a zone. The traffic allowed depends on the network your computer is connected to and the security level this network is assigned. Firewall services are predefined rules that cover all necessary settings to allow incoming traffic for a specific service and they apply within a zone.

Services use one or more ports or addresses for network communication. Firewalls filter communication based on ports. To allow network traffic for a service, its ports must be open. **firewalld** blocks all traffic on ports that are not explicitly set as open. Some zones, such as trusted, allow all traffic by default.

Note that **firewalld** with **nftables** backend does not support passing custom **nftables** rules to **firewalld**, using the **--direct** option.

### 7.1. GETTING STARTED WITH **FIREWALLD**

This section provides information about **firewalld**.

#### 7.1.1. When to use **firewalld**, **nftables**, or **iptables**

The following is a brief overview in which scenario you should use one of the following utilities:

- **firewalld**: Use the **firewalld** utility for simple firewall use cases. The utility is easy to use and covers the typical use cases for these scenarios.

- **nftables**: Use the **nftables** utility to set up complex and performance critical firewalls, such as for a whole network.

- **iptables**: The **iptables** utility on Red Hat Enterprise Linux uses the **nf_tables** kernel API instead of the *legacy* back end. The **nf_tables** API provides backward compatibility so that scripts that use **iptables** commands still work on Red Hat Enterprise Linux. For new firewall scripts, Red Hat recommends to use **nftables**.

**IMPORTANT**

To avoid that the different firewall services influence each other, run only one of them on a RHEL host, and disable the other services.

#### 7.1.2. Zones

**firewalld** can be used to separate networks into different zones according to the level of trust that the user has decided to place on the interfaces and traffic within that network. A connection can only be part of one zone, but a zone can be used for many network connections.

**NetworkManager** notifies **firewalld** of the zone of an interface. You can assign zones to interfaces with:
- NetworkManager
- `firewall-config` tool
- `firewall-cmd` command-line tool
- The RHEL web console

The latter three can only edit the appropriate NetworkManager configuration files. If you change the zone of the interface using the web console, `firewall-cmd` or `firewall-config`, the request is forwarded to NetworkManager and is not handled by firewalld.

The predefined zones are stored in the `/usr/lib/firewalld/zones/` directory and can be instantly applied to any available network interface. These files are copied to the `/etc/firewalld/zones/` directory only after they are modified. The default settings of the predefined zones are as follows:

**block**
Any incoming network connections are rejected with an icmp-host-prohibited message for IPv4 and icmp6-adm-prohibited for IPv6. Only network connections initiated from within the system are possible.

**dmz**
For computers in your demilitarized zone that are publicly-accessible with limited access to your internal network. Only selected incoming connections are accepted.

**drop**
Any incoming network packets are dropped without any notification. Only outgoing network connections are possible.

**external**
For use on external networks with masquerading enabled, especially for routers. You do not trust the other computers on the network to not harm your computer. Only selected incoming connections are accepted.

**home**
For use at home when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

**internal**
For use on internal networks when you mostly trust the other computers on the network. Only selected incoming connections are accepted.

**public**
For use in public areas where you do not trust other computers on the network. Only selected incoming connections are accepted.

**trusted**
All network connections are accepted.

**work**
For use at work where you mostly trust the other computers on the network. Only selected incoming connections are accepted.

One of these zones is set as the *default* zone. When interface connections are added to NetworkManager, they are assigned to the default zone. On installation, the default zone in firewalld is set to be the public zone. The default zone can be changed.
NOTE
The network zone names should be self-explanatory and to allow users to quickly make a reasonable decision. To avoid any security problems, review the default zone configuration and disable any unnecessary services according to your needs and risk assessments.

Additional resources
- The `firewalld.zone(5)` man page.

7.1.3. Predefined services
A service can be a list of local ports, protocols, source ports, and destinations, as well as a list of firewall helper modules automatically loaded if a service is enabled. Using services saves users time because they can achieve several tasks, such as opening ports, defining protocols, enabling packet forwarding and more, in a single step, rather than setting up everything one after another.

Service configuration options and generic file information are described in the `firewalld.service(5)` man page. The services are specified by means of individual XML configuration files, which are named in the following format: `service-name.xml`. Protocol names are preferred over service or application names in `firewalld`.

Services can be added and removed using the graphical `firewall-config` tool, `firewall-cmd`, and `firewall-offline-cmd`.

Alternatively, you can edit the XML files in the `/etc/firewalld/services/` directory. If a service is not added or changed by the user, then no corresponding XML file is found in `/etc/firewalld/services/`. The files in the `/usr/lib/firewalld/services/` directory can be used as templates if you want to add or change a service.

Additional resources
- The `firewalld.service(5)` man page

7.1.4. Starting firewalld

Procedure
1. To start `firewalld`, enter the following command as `root`:

   ```
   # systemctl unmask firewalld
   # systemctl start firewalld
   ```

2. To ensure `firewalld` starts automatically at system start, enter the following command as `root`:

   ```
   # systemctl enable firewalld
   ```

7.1.5. Stopping firewalld

Procedure
1. To stop `firewalld`, enter the following command as `root`:
2. To prevent `firewalld` from starting automatically at system start:

```bash
# systemctl disable firewalld
```

3. To make sure `firewalld` is not started by accessing the `firewalld D-Bus` interface and also if other services require `firewalld`:

```bash
# systemctl mask firewalld
```

### 7.1.6. Verifying the permanent `firewalld` configuration

In certain situations, for example after manually editing `firewalld` configuration files, administrators want to verify that the changes are correct. This section describes how to verify the permanent configuration of the `firewalld` service.

**Prerequisites**

- The `firewalld` service is running.

**Procedure**

1. Verify the permanent configuration of the `firewalld` service:

```bash
# firewall-cmd --check-config
```

   If the permanent configuration is valid, the command returns `success`. In other cases, the command returns an error with further details, such as the following:

```bash
# firewall-cmd --check-config
Error: INVALID_PROTOCOL: 'public.xml': 'tcpx' not from {'tcp'|'udp'|'sctp'|'dccp'}
```

### 7.2. VIEWING THE CURRENT STATUS AND SETTINGS OF `FIREWALLD`

This section covers information about viewing current status, allowed services, and current settings of `firewalld`.

#### 7.2.1. Viewing the current status of `firewall`

The firewall service, `firewall`, is installed on the system by default. Use the `firewall` CLI interface to check that the service is running.

**Procedure**

1. To see the status of the service:

```bash
# firewall-cmd --state
```

2. For more information about the service status, use the `systemctl status` sub-command:
### 7.2.2. Viewing allowed services using GUI

To view the list of services using the graphical `firewall-config` tool, press the **Super** key to enter the Activities Overview, type `firewall`, and press **Enter**. The `firewall-config` tool appears. You can now view the list of services under the **Services** tab.

You can start the graphical firewall configuration tool using the command-line.

**Prerequisites**

- You installed the `firewall-config` package.

**Procedure**

- To start the graphical firewall configuration tool using the command-line:

  ```
  $ firewall-config
  ```

  The **Firewall Configuration** window opens. Note that this command can be run as a normal user, but you are prompted for an administrator password occasionally.

### 7.2.3. Viewing firewalld settings using CLI

With the CLI client, it is possible to get different views of the current firewall settings. The **--list-all** option shows a complete overview of the `firewalld` settings.

`firewalld` uses zones to manage the traffic. If a zone is not specified by the **--zone** option, the command is effective in the default zone assigned to the active network interface and connection.

**Procedure**

- To list all the relevant information for the default zone:

  ```
  # firewall-cmd --list-all
  public
    target: default
    icmp-block-inversion: no
    interfaces:
    sources:
    services: ssh dhcpv6-client
    ports:
    protocols:
    masquerade: no
    forward-ports:
  ```
source-ports:
icmp-blocks:
rich rules:

- To specify the zone for which to display the settings, add the `--zone=zone-name` argument to the `firewall-cmd --list-all` command, for example:

```
# firewall-cmd --list-all --zone=home
home
  target: default
  icmp-block-inversion: no
  interfaces:
  sources:
  services: ssh mdns samba-client dhcpv6-client ...
```

- To see the settings for particular information, such as services or ports, use a specific option. See the `firewalld` manual pages or get a list of the options using the command help:

```
# firewall-cmd --help
```

- To see which services are allowed in the current zone:

```
# firewall-cmd --list-services
ssh dhcppv6-client
```

**NOTE**

Listing the settings for a certain subpart using the CLI tool can sometimes be difficult to interpret. For example, you allow the SSH service and firewalld opens the necessary port (22) for the service. Later, if you list the allowed services, the list shows the SSH service, but if you list open ports, it does not show any. Therefore, it is recommended to use the `--list-all` option to make sure you receive a complete information.

### 7.3. CONTROLLING NETWORK TRAFFIC USING FIREWALLD

This section covers information about controlling network traffic using firewalld.

#### 7.3.1. Disabling all traffic in case of emergency using CLI

In an emergency situation, such as a system attack, it is possible to disable all network traffic and cut off the attacker.

**Procedure**

1. To immediately disable networking traffic, switch panic mode on:

```
# firewall-cmd --panic-on
```
Enabling panic mode stops all networking traffic. For this reason, it should be used only when you have the physical access to the machine or if you are logged in using a serial console.

2. Switching off panic mode reverts the firewall to its permanent settings. To switch panic mode off, enter:

```
# firewall-cmd --panic-off
```

**Verification**

- To see whether panic mode is switched on or off, use:

```
# firewall-cmd --query-panic
```

### 7.3.2. Controlling traffic with predefined services using CLI

The most straightforward method to control traffic is to add a predefined service to `firewalld`. This opens all necessary ports and modifies other settings according to the service definition file.

**Procedure**

1. Check that the service is not already allowed:

```
# firewall-cmd --list-services
```

```
ssh dhcpv6-client
```

2. List all predefined services:

```
# firewall-cmd --get-services
```

```
RH-Satellite-6 amanda-client amanda-k5-client bacula bacula-client bitcoin bitcoin-rpc bitcoin-testnet bitcoin-testnet-rpc ceph ceph-mon cfengine condor-collector ctdb dhcp dhcpv6 dhcpv6-client dns docker-registry ...
```

[trimmed for clarity]

3. Add the service to the allowed services:

```
# firewall-cmd --add-service=<service-name>
```

4. Make the new settings persistent:

```
# firewall-cmd --runtime-to-permanent
```

### 7.3.3. Controlling traffic with predefined services using GUI

This procedure describes how to control the network traffic with predefined services using graphical user interface.

**Prerequisites**
You installed the `firewall-config` package

**Procedure**

1. To enable or disable a predefined or custom service:
   a. Start the `firewall-config` tool and select the network zone whose services are to be configured.
   b. Select the **Zones** tab and then the **Services** tab below.
   c. Select the check box for each type of service you want to trust or clear the check box to block a service in the selected zone.

2. To edit a service:
   a. Start the `firewall-config` tool.
   b. Select **Permanent** from the menu labeled **Configuration**. Additional icons and menu buttons appear at the bottom of the **Services** window.
   c. Select the service you want to configure.

The **Ports**, **Protocols**, and **Source Port** tabs enable adding, changing, and removing of ports, protocols, and source port for the selected service. The modules tab is for configuring Netfilter helper modules. The **Destination** tab enables limiting traffic to a particular destination address and Internet Protocol (IPv4 or IPv6).

**NOTE**

It is not possible to alter service settings in the **Runtime** mode.

### 7.3.4. Adding new services

Services can be added and removed using the graphical `firewall-config` tool, `firewall-cmd`, and `firewall-offline-cmd`. Alternatively, you can edit the XML files in `/etc/firewalld/services/`. If a service is not added or changed by the user, then no corresponding XML file are found in `/etc/firewalld/services/`. The files `/usr/lib/firewalld/services/` can be used as templates if you want to add or change a service.

**NOTE**

Service names must be alphanumeric and can, additionally, include only _ (underscore) and - (dash) characters.

**Procedure**

To add a new service in a terminal, use `firewall-cmd`, or `firewall-offline-cmd` in case of not active `firewalld`.

1. Enter the following command to add a new and empty service:

   ```
   $ firewall-cmd --new-service=service-name --permanent
   ```

2. To add a new service using a local file, use the following command:
$ firewall-cmd --new-service-from-file=service-name.xml --permanent

You can change the service name with the additional --name=service-name option.

3. As soon as service settings are changed, an updated copy of the service is placed into /etc/firewalld/services/.
   As root, you can enter the following command to copy a service manually:

   # cp /usr/lib/firewalld/services/service-name.xml /etc/firewalld/services/service-name.xml

firewalld loads files from /usr/lib/firewalld/services in the first place. If files are placed in /etc/firewalld/services and they are valid, then these will override the matching files from /usr/lib/firewalld/services. The overridden files in /usr/lib/firewalld/services are used as soon as the matching files in /etc/firewalld/services have been removed or if firewalld has been asked to load the defaults of the services. This applies to the permanent environment only. A reload is needed to get these fallbacks also in the runtime environment.

7.3.5. Opening ports using GUI

To permit traffic through the firewall to a certain port, you can open the port in the GUI.

Prerequisites

- You installed the firewall-config package

Procedure

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the Ports tab and click the Add button on the right-hand side. The Port and Protocol window opens.

3. Enter the port number or range of ports to permit.

4. Select tcp or udp from the list.

7.3.6. Controlling traffic with protocols using GUI

To permit traffic through the firewall using a certain protocol, you can use the GUI.

Prerequisites

- You installed the firewall-config package

Procedure

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the Protocols tab and click the Add button on the right-hand side. The Protocol window opens.

3. Either select a protocol from the list or select the Other Protocol check box and enter the protocol in the field.
7.3.7. Opening source ports using GUI

To permit traffic through the firewall from a certain port, you can use the GUI.

**Prerequisites**

- You installed the `firewall-config` package

**Procedure**

1. Start the firewall-config tool and select the network zone whose settings you want to change.

2. Select the **Source Port** tab and click the **Add** button on the right-hand side. The **Source Port** window opens.

3. Enter the port number or range of ports to permit. Select **tcp** or **udp** from the list.

7.4. CONTROLLING PORTS USING CLI

Ports are logical devices that enable an operating system to receive and distinguish network traffic and forward it accordingly to system services. These are usually represented by a daemon that listens on the port, that is it waits for any traffic coming to this port.

Normally, system services listen on standard ports that are reserved for them. The **httpd** daemon, for example, listens on port 80. However, system administrators by default configure daemons to listen on different ports to enhance security or for other reasons.

**7.4.1. Opening a port**

Through open ports, the system is accessible from the outside, which represents a security risk. Generally, keep ports closed and only open them if they are required for certain services.

**Procedure**

To get a list of open ports in the current zone:

1. List all allowed ports:

   ```bash
   # firewall-cmd --list-ports
   ```

2. Add a port to the allowed ports to open it for incoming traffic:

   ```bash
   # firewall-cmd --add-port=port-number/port-type
   ```

   The port types are either **tcp**, **udp**, **sctp**, or **dccp**. The type must match the type of network communication.

3. Make the new settings persistent:

   ```bash
   # firewall-cmd --runtime-to-permanent
   ```

   The port types are either **tcp**, **udp**, **sctp**, or **dccp**. The type must match the type of network communication.
7.4.2. Closing a port

When an open port is no longer needed, close that port in `firewalld`. It is highly recommended to close all unnecessary ports as soon as they are not used because leaving a port open represents a security risk.

**Procedure**

To close a port, remove it from the list of allowed ports:

1. List all allowed ports:
   ```bash
   # firewall-cmd --list-ports
   ```

   **WARNING**
   
   This command will only give you a list of ports that have been opened as 
   ports. You will not be able to see any open ports that have been opened as 
   a service. Therefore, you should consider using the `--list-all` option instead 
   of `--list-ports`.

2. Remove the port from the allowed ports to close it for the incoming traffic:
   ```bash
   # firewall-cmd --remove-port=port-number/port-type
   ```

3. Make the new settings persistent:
   ```bash
   # firewall-cmd --runtime-to-permanent
   ```

7.5. CONFIGURING PORTS USING SYSTEM ROLES

You can use the Red Hat Enterprise Linux (RHEL) `firewalld` System Role to open or close ports in the local firewall for incoming traffic and make the new configuration persist across reboots. The example describes how to configure the default zone to permit incoming traffic for the HTTPS service.

Run this procedure on the Ansible control node.

**Prerequisites**

- Access and permissions to one or more managed nodes, which are systems you want to configure with the `firewalld` System Role.
- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.
- The `ansible` and `rhel-system-roles` packages are installed on the control node.
- If you use a different remote user than `root` when you run the playbook, this user has appropriate `sudo` permissions on the managed node.
- The host uses NetworkManager to configure the network.
Procedure

1. If the host on which you want to execute the instructions in the playbook is not yet inventoried, add the IP or name of this host to the `/etc/ansible/hosts` Ansible inventory file:

   ```
   node.example.com
   ```

2. Create the `~/adding-and-removing-ports.yml` playbook with the following content:

   ```yaml
   ---
   - name: Allow incoming HTTPS traffic to the local host
     hosts: node.example.com
     become: true

     tasks:
     - include_role:
       name: linux-system-roles.firewall

     vars:
       firewall:
       - port: 443/tcp
         service: http
         state: enabled
         runtime: true
         permanent: true
   ```

   The `permanent: true` option makes the new settings persistent across reboots.

3. Run the playbook:

   - To connect as `root` user to the managed host, enter:
     ```
     # ansible-playbook -u root ~/adding-and-removing-ports.yml
     ```
   - To connect as a user to the managed host, enter:
     ```
     # ansible-playbook -u user_name --ask-become-pass ~/adding-and-removing-ports.yml
     ```

   The `--ask-become-pass` option makes sure that the `ansible-playbook` command prompts for the `sudo` password of the user defined in the `-u user_name` option.

   If you do not specify the `-u user_name` option, `ansible-playbook` connects to the managed host as the user that is currently logged in to the control node.

Verification

1. Connect to the managed node:

   ```
   $ ssh user_name@node.example.com
   ```

2. Verify that the `443/tcp` port associated with the `HTTPS` service is open:
7.6. WORKING WITH FIREWALLD ZONES

Zones represent a concept to manage incoming traffic more transparently. The zones are connected to networking interfaces or assigned a range of source addresses. You manage firewall rules for each zone independently, which enables you to define complex firewall settings and apply them to the traffic.

7.6.1. Listing zones

This procedure describes how to list zones using the command line.

Procedure

1. To see which zones are available on your system:

   ```
   # firewall-cmd --get-zones
   ```

   The `firewall-cmd --get-zones` command displays all zones that are available on the system, but it does not show any details for particular zones.

2. To see detailed information for all zones:

   ```
   # firewall-cmd --list-all-zones
   ```

3. To see detailed information for a specific zone:

   ```
   # firewall-cmd --zone=zone-name --list-all
   ```

7.6.2. Modifying firewalld settings for a certain zone

The Controlling traffic with predefined services using cli and Controlling ports using cli explain how to add services or modify ports in the scope of the current working zone. Sometimes, it is required to set up rules in a different zone.

Procedure

- To work in a different zone, use the `--zone=zone-name` option. For example, to allow the SSH service in the zone public:

  ```
  # firewall-cmd --add-service=ssh --zone=public
  ```
System administrators assign a zone to a networking interface in its configuration files. If an interface is not assigned to a specific zone, it is assigned to the default zone. After each restart of the `firewalld` service, `firewalld` loads the settings for the default zone and makes it active.

Procedure
To set up the default zone:

1. Display the current default zone:
   ```
   # firewall-cmd --get-default-zone
   ```
2. Set the new default zone:
   ```
   # firewall-cmd --set-default-zone zone-name
   ```

   **NOTE**
   Following this procedure, the setting is a permanent setting, even without the `--permanent` option.

7.6.4. Assigning a network interface to a zone
It is possible to define different sets of rules for different zones and then change the settings quickly by changing the zone for the interface that is being used. With multiple interfaces, a specific zone can be set for each of them to distinguish traffic that is coming through them.

Procedure
To assign the zone to a specific interface:

1. List the active zones and the interfaces assigned to them:
   ```
   # firewall-cmd --get-active-zones
   ```
2. Assign the interface to a different zone:
   ```
   # firewall-cmd --zone=zone_name --change-interface=interface_name --permanent
   ```

7.6.5. Assigning a zone to a connection using `nmcli`
This procedure describes how to add a `firewalld` zone to a `NetworkManager` connection using the `nmcli` utility.

Procedure
1. Assign the zone to the `NetworkManager` connection profile:
   ```
   # nmcli connection modify profile connection.zone zone_name
   ```
2. Activate the connection:
   ```
   # nmcli connection up profile
   ```
7.6.6. Manually assigning a zone to a network connection in an ifcfg file

When the connection is managed by NetworkManager, it must be aware of a zone that it uses. For every network connection, a zone can be specified, which provides the flexibility of various firewall settings according to the location of the computer with portable devices. Thus, zones and settings can be specified for different locations, such as company or home.

Procedure

- To set a zone for a connection, edit the `/etc/sysconfig/network-scripts/ifcfg-connection_name` file and add a line that assigns a zone to this connection:
  ```
  ZONE=zone_name
  ```

7.6.7. Creating a new zone

To use custom zones, create a new zone and use it just like a predefined zone. New zones require the `--permanent` option, otherwise the command does not work.

Procedure

1. Create a new zone:
   ```
   # firewall-cmd --permanent --new-zone=zone-name
   ```

2. Check if the new zone is added to your permanent settings:
   ```
   # firewall-cmd --get-zones
   ```

3. Make the new settings persistent:
   ```
   # firewall-cmd --runtime-to-permanent
   ```

7.6.8. Zone configuration files

Zones can also be created using a zone configuration file. This approach can be helpful when you need to create a new zone, but want to reuse the settings from a different zone and only alter them a little.

A firewalld zone configuration file contains the information for a zone. These are the zone description, services, ports, protocols, icmp-blocks, masquerade, forward-ports and rich language rules in an XML file format. The file name has to be `zone-name.xml` where the length of `zone-name` is currently limited to 17 chars. The zone configuration files are located in the `/usr/lib/firewalld/zones/` and `/etc/firewalld/zones/` directories.

The following example shows a configuration that allows one service (SSH) and one port range, for both the TCP and UDP protocols:

```xml
<?xml version="1.0" encoding="utf-8"?>
<zone>
  <short>My Zone</short>
  <description>Here you can describe the characteristic features of the zone.</description>
  <service name="ssh"/>
```
To change settings for that zone, add or remove sections to add ports, forward ports, services, and so on.

Additional resources

- firewalld.zone manual page

### 7.6.9. Using zone targets to set default behavior for incoming traffic

For every zone, you can set a default behavior that handles incoming traffic that is not further specified. Such behavior is defined by setting the target of the zone. There are four options:

- **ACCEPT**: Accepts all incoming packets except those disallowed by specific rules.
- **REJECT**: Rejects all incoming packets except those allowed by specific rules. When `firewalld` rejects packets, the source machine is informed about the rejection.
- **DROP**: Drops all incoming packets except those allowed by specific rules. When `firewalld` drops packets, the source machine is not informed about the packet drop.
- **default**: Similar behavior as for **REJECT**, but with special meanings in certain scenarios. For details, see the Options to Adapt and Query Zones and Policies section in the `firewall-cmd(1)` man page.

**Procedure**

To set a target for a zone:

1. List the information for the specific zone to see the default target:

   ```
   # firewall-cmd --zone=zone-name --list-all
   ```

2. Set a new target in the zone:

   ```
   # firewall-cmd --permanent --zone=zone-name --set-target=<default|ACCEPT|REJECT|DROP>
   ```

Additional resources

- `firewall-cmd(1)` man page

### 7.7. USING ZONES TO MANAGE INCOMING TRAFFIC DEPENDING ON A SOURCE

You can use zones to manage incoming traffic based on its source. That enables you to sort incoming traffic and route it through different zones to allow or disallow services that can be reached by that traffic.
If you add a source to a zone, the zone becomes active and any incoming traffic from that source will be directed through it. You can specify different settings for each zone, which is applied to the traffic from the given sources accordingly. You can use more zones even if you only have one network interface.

### 7.7.1. Adding a source

To route incoming traffic into a specific zone, add the source to that zone. The source can be an IP address or an IP mask in the classless inter-domain routing (CIDR) notation.

**NOTE**

In case you add multiple zones with an overlapping network range, they are ordered alphanumerically by zone name and only the first one is considered.

- To set the source in the current zone:
  
  ```
  # firewall-cmd --add-source=<source>
  ```

- To set the source IP address for a specific zone:
  
  ```
  # firewall-cmd --zone=zone-name --add-source=<source>
  ```

The following procedure allows all incoming traffic from `192.168.2.15` in the trusted zone:

**Procedure**

1. List all available zones:
   
   ```
   # firewall-cmd --get-zones
   ```

2. Add the source IP to the trusted zone in the permanent mode:
   
   ```
   # firewall-cmd --zone=trusted --add-source=192.168.2.15
   ```

3. Make the new settings persistent:
   
   ```
   # firewall-cmd --runtime-to-permanent
   ```

### 7.7.2. Removing a source

Removing a source from the zone cuts off the traffic coming from it.

**Procedure**

1. List allowed sources for the required zone:
   
   ```
   # firewall-cmd --zone=zone-name --list-sources
   ```

2. Remove the source from the zone permanently:
   
   ```
   # firewall-cmd --zone=zone-name --remove-source=<source>
   ```
3. Make the new settings persistent:

```
# firewall-cmd --runtime-to-permanent
```

### 7.7.3. Adding a source port

To enable sorting the traffic based on a port of origin, specify a source port using the `--add-source-port` option. You can also combine this with the `--add-source` option to limit the traffic to a certain IP address or IP range.

**Procedure**

- To add a source port:

```
# firewall-cmd --zone=zone-name --add-source-port=<port-name>/<tcp|udp|sctp|dccp>
```

### 7.7.4. Removing a source port

By removing a source port you disable sorting the traffic based on a port of origin.

**Procedure**

- To remove a source port:

```
# firewall-cmd --zone=zone-name --remove-source-port=<port-name>/<tcp|udp|sctp|dccp>
```

### 7.7.5. Using zones and sources to allow a service for only a specific domain

To allow traffic from a specific network to use a service on a machine, use zones and source. The following procedure allows only HTTP traffic from the `192.0.2.0/24` network while any other traffic is blocked.

**WARNING**

When you configure this scenario, use a zone that has the `default` target. Using a zone that has the target set to `ACCEPT` is a security risk, because for traffic from `192.0.2.0/24`, all network connections would be accepted.

**Procedure**

1. List all available zones:

```
# firewall-cmd --get-zones
```

```
block dmz drop external home internal public trusted work
```

2. Add the IP range to the `internal` zone to route the traffic originating from the source through the zone:
3. Add the http service to the internal zone:

```
# firewall-cmd --zone=internal --add-service=http
```

4. Make the new settings persistent:

```
# firewall-cmd --runtime-to-permanent
```

Verification

- Check that the internal zone is active and that the service is allowed in it:

```
# firewall-cmd --zone=internal --list-all
internal (active)
    target: default
    icmp-block-inversion: no
    interfaces:
    sources: 192.0.2.0/24
    services: cockpit dhcpv6-client mdns samba-client ssh http ...
```

Additional resources

- `firewalld.zones(5)` man page

### 7.8. FILTERING FORWARDED TRAFFIC BETWEEN ZONES

With a policy object, users can group different identities that require similar permissions in the policy. You can apply policies depending on the direction of the traffic.

The policy objects feature provides forward and output filtering in firewalld. The following describes the usage of firewalld to filter traffic between different zones to allow access to locally hosted VMs to connect the host.

#### 7.8.1. The relationship between policy objects and zones

Policy objects allow the user to attach firewalld’s primitives’ such as services, ports, and rich rules to the policy. You can apply the policy objects to traffic that passes between zones in a stateful and unidirectional manner.

```
# firewall-cmd --permanent --new-policy myOutputPolicy
# firewall-cmd --permanent --policy myOutputPolicy --add-ingress-zone HOST
# firewall-cmd --permanent --policy myOutputPolicy --add-egress-zone ANY
```

HOST and ANY are the symbolic zones used in the ingress and egress zone lists.

- The HOST symbolic zone allows policies for the traffic originating from or has a destination to the host running firewalld.
- The **ANY** symbolic zone applies policy to all the current and future zones. **ANY** symbolic zone acts as a wildcard for all zones.

### 7.8.2. Using priorities to sort policies

Multiple policies can apply to the same set of traffic, therefore, priorities should be used to create an order of precedence for the policies that may be applied.

To set a priority to sort the policies:

```bash
# firewall-cmd --permanent --policy mypolicy --set-priority -500
```

In the above example, -500 is a lower priority value but has higher precedence. Thus, -500 will execute before -100. Higher priority values have precedence over lower values.

The following rules apply to policy priorities:

- Policies with negative priorities apply before rules in zones.
- Policies with positive priorities apply after rules in zones.
- Priority 0 is reserved and hence is unusable.

### 7.8.3. Using policy objects to filter traffic between locally hosted Containers and a network physically connected to the host

The policy objects feature allows users to filter their container and virtual machine traffic.

**Procedure**

1. Create a new policy.

```bash
# firewall-cmd --permanent --new-policy podmanToHost
```

2. Block all traffic.

```bash
# firewall-cmd --permanent --policy podmanToHost --set-target REJECT
# firewall-cmd --permanent --policy podmanToHost --add-service dhcp
# firewall-cmd --permanent --policy podmanToHost --add-service dns
```

**NOTE**

Red Hat recommends that you block all traffic to the host by default and then selectively open the services you need for the host.

3. Define the ingress zone to use with the policy.

```bash
# firewall-cmd --permanent --policy podmanToHost --add-ingress-zone podman
```

4. Define the egress zone to use with the policy.
# firewall-cmd --permanent --policy podmanToHost --add-egress-zone ANY

Verification

- Verify information about the policy.

  # firewall-cmd --info-policy podmanToHost

### 7.8.4. Setting the default target of policy objects

You can specify --set-target options for policies. The following targets are available:

- **ACCEPT** - accepts the packet
- **DROP** - drops the unwanted packets
- **REJECT** - rejects unwanted packets with an ICMP reply
- **CONTINUE (default)** - packets will be subject to rules in following policies and zones.

  # firewall-cmd --permanent --policy mypolicy --set-target CONTINUE

Verification

- Verify information about the policy

  # firewall-cmd --info-policy mypolicy

### 7.9. CONFIGURING NAT USING FIREWALLD

With **firewalld**, you can configure the following network address translation (NAT) types:

- Masquerading
- Source NAT (SNAT)
- Destination NAT (DNAT)
- Redirect

#### 7.9.1. The different NAT types: masquerading, source NAT, destination NAT, and redirect

These are the different network address translation (NAT) types:

**Masquerading and source NAT (SNAT)**

Use one of these NAT types to change the source IP address of packets. For example, Internet Service Providers do not route private IP ranges, such as **10.0.0.0/8**. If you use private IP ranges in your network and users should be able to reach servers on the Internet, map the source IP address of packets from these ranges to a public IP address.

Both masquerading and SNAT are very similar. The differences are:
Masquerading automatically uses the IP address of the outgoing interface. Therefore, use masquerading if the outgoing interface uses a dynamic IP address.

SNAT sets the source IP address of packets to a specified IP and does not dynamically look up the IP of the outgoing interface. Therefore, SNAT is faster than masquerading. Use SNAT if the outgoing interface uses a fixed IP address.

Destination NAT (DNAT)

Use this NAT type to rewrite the destination address and port of incoming packets. For example, if your web server uses an IP address from a private IP range and is, therefore, not directly accessible from the Internet, you can set a DNAT rule on the router to redirect incoming traffic to this server.

Redirect

This type is a special case of DNAT that redirects packets to the local machine depending on the chain hook. For example, if a service runs on a different port than its standard port, you can redirect incoming traffic from the standard port to this specific port.

7.9.2. Configuring IP address masquerading

The following procedure describes how to enable IP masquerading on your system. IP masquerading hides individual machines behind a gateway when accessing the Internet.

Procedure

1. To check if IP masquerading is enabled (for example, for the external zone), enter the following command as root:

```
# firewall-cmd --zone=external --query-masquerade
```

The command prints yes with exit status 0 if enabled. It prints no with exit status 1 otherwise. If zone is omitted, the default zone will be used.

2. To enable IP masquerading, enter the following command as root:

```
# firewall-cmd --zone=external --add-masquerade
```

3. To make this setting persistent, pass the --permanent option to the command.

4. To disable IP masquerading, enter the following command as root:

```
# firewall-cmd --zone=external --remove-masquerade
```

To make this setting permanent, pass the --permanent option to the command.

7.10. PORT FORWARDING

Redirecting ports using this method only works for IPv4–based traffic. For IPv6 redirecting setup, you must use rich rules.

To redirect to an external system, it is necessary to enable masquerading. For more information, see Configuring IP address masquerading.
NOTE
You cannot access a service through a redirected port from the host on which you have configured local forwarding.

7.10.1. Adding a port to redirect
Using `firewalld`, you can set up port redirection so that any incoming traffic that reaches a certain port on your system is delivered to another internal port of your choice or to an external port on another machine.

Prerequisites
- Before you redirect traffic from one port to another port, or another address, you have to know three things: which port the packets arrive at, what protocol is used, and where you want to redirect them.

Procedure
1. To redirect a port to another port:
   ```
   # firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp|sctp|dccp:toport=port-number
   ```
2. To redirect a port to another port at a different IP address:
   a. Add the port to be forwarded:
      ```
      # firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp:toport=port-number:toaddr=IP
      ```
   b. Enable masquerade:
      ```
      # firewall-cmd --add-masquerade
      ```

7.10.2. Redirecting TCP port 80 to port 88 on the same machine
Follow the steps to redirect the TCP port 80 to port 88.

Procedure
1. Redirect the port 80 to port 88 for TCP traffic:
   ```
   # firewall-cmd --add-forward-port=port=80:proto=tcp:toport=88
   ```
2. Make the new settings persistent:
   ```
   # firewall-cmd --runtime-to-permanent
   ```
3. Check that the port is redirected:
   ```
   # firewall-cmd --list-all
   ```
### 7.10.3. Removing a redirected port

This procedure describes how to remove the redirected port.

**Procedure**

1. To remove a redirected port:

   ```
   # firewall-cmd --remove-forward-port=port=port-number:proto=<tcp|udp>:toport=port-number:toaddr=<IP>
   ```

2. To remove a forwarded port redirected to a different address:
   a. Remove the forwarded port:

      ```
      # firewall-cmd --remove-forward-port=port=port-number:proto=<tcp|udp>:toport=port-number:toaddr=<IP>
      ```
   b. Disable masquerade:

      ```
      # firewall-cmd --remove-masquerade
      ```

### 7.10.4. Removing TCP port 80 forwarded to port 88 on the same machine

This procedure describes how to remove the port redirection.

**Procedure**

1. List redirected ports:

   ```
   ~]# firewall-cmd --list-forward-ports
   port=80:proto=tcp:toport=88:toaddr=
   ```

2. Remove the redirected port from the firewall:

   ```
   ~]# firewall-cmd --remove-forward-port=port=80:proto=tcp:toport=88:toaddr=
   ```

3. Make the new settings persistent:

   ```
   ~]# firewall-cmd --runtime-to-permanent
   ```

### 7.11. MANAGING ICMP REQUESTS

The Internet Control Message Protocol (ICMP) is a supporting protocol that is used by various network devices to send error messages and operational information indicating a connection problem, for example, that a requested service is not available. ICMP differs from transport protocols such as TCP and UDP because it is not used to exchange data between systems.

Unfortunately, it is possible to use the ICMP messages, especially echo-request and echo-reply, to reveal information about your network and misuse such information for various kinds of fraudulent activities. Therefore, firewalld enables blocking the ICMP requests to protect your network information.
7.11.1. Listing and blocking ICMP requests

Listing ICMP requests

The ICMP requests are described in individual XML files that are located in the /usr/lib/firewalld/icmptypes/ directory. You can read these files to see a description of the request. The firewall-cmd command controls the ICMP requests manipulation.

- To list all available ICMP types:
  ```
  # firewall-cmd --get-icmptypes
  ```

- The ICMP request can be used by IPv4, IPv6, or by both protocols. To see for which protocol the ICMP request has used:
  ```
  # firewall-cmd --info-icmptype=<icmptype>
  ```

- The status of an ICMP request shows yes if the request is currently blocked or no if it is not. To see if an ICMP request is currently blocked:
  ```
  # firewall-cmd --query-icmp-block=<icmptype>
  ```

Blocking or unblocking ICMP requests

When your server blocks ICMP requests, it does not provide the information that it normally would. However, that does not mean that no information is given at all. The clients receive information that the particular ICMP request is being blocked (rejected). Blocking the ICMP requests should be considered carefully, because it can cause communication problems, especially with IPv6 traffic.

- To see if an ICMP request is currently blocked:
  ```
  # firewall-cmd --query-icmp-block=<icmptype>
  ```

- To block an ICMP request:
  ```
  # firewall-cmd --add-icmp-block=<icmptype>
  ```

- To remove the block for an ICMP request:
  ```
  # firewall-cmd --remove-icmp-block=<icmptype>
  ```

Blocking ICMP requests without providing any information at all

Normally, if you block ICMP requests, clients know that you are blocking it. So, a potential attacker who is sniffing for live IP addresses is still able to see that your IP address is online. To hide this information completely, you have to drop all ICMP requests.

- To block and drop all ICMP requests:
  ```
  # firewall-cmd --permanent --set-target=DROP
  ```

Now, all traffic, including ICMP requests, is dropped, except traffic which you have explicitly allowed.
To block and drop certain ICMP requests and allow others:

1. Set the target of your zone to **DROP**:
   
   ```
   # firewall-cmd --permanent --set-target=DROP
   ```

2. Add the ICMP block inversion to block all ICMP requests at once:
   
   ```
   # firewall-cmd --add-icmp-block-inversion
   ```

3. Add the ICMP block for those ICMP requests that you want to allow:
   
   ```
   # firewall-cmd --add-icmp-block=<icmptype>
   ```

4. Make the new settings persistent:
   
   ```
   # firewall-cmd --runtime-to-permanent
   ```

The **block inversion** inverts the setting of the ICMP requests blocks, so all requests, that were not previously blocked, are blocked because of the target of your zone changes to **DROP**. The requests that were blocked are not blocked. This means that if you want to unblock a request, you must use the blocking command.

To revert the block inversion to a fully permissive setting:

1. Set the target of your zone to **default** or **ACCEPT**:
   
   ```
   # firewall-cmd --permanent --set-target=default
   ```

2. Remove all added blocks for ICMP requests:
   
   ```
   # firewall-cmd --remove-icmp-block=<icmptype>
   ```

3. Remove the ICMP block inversion:
   
   ```
   # firewall-cmd --remove-icmp-block-inversion
   ```

4. Make the new settings persistent:
   
   ```
   # firewall-cmd --runtime-to-permanent
   ```

### 7.11.2. Configuring the ICMP filter using GUI

- To enable or disable an ICMP filter, start the `firewall-config` tool and select the network zone whose messages are to be filtered. Select the **ICMP Filter** tab and select the check box for each type of ICMP message you want to filter. Clear the check box to disable a filter. This setting is per direction and the default allows everything.

- To enable inverting the **ICMP Filter**, click the **Invert Filter** check box on the right. Only marked ICMP types are now accepted, all other are rejected. In a zone using the DROP target, they are dropped.
7.12. SETTING AND CONTROLLING IP SETS USING FIREWALLD

To see the list of IP set types supported by `firewalld`, enter the following command as root.

```bash
# firewall-cmd --get-ipset-types
```

```
hash:net, net hash:net, port hash:net, port, net
```

7.12.1. Configuring IP set options using CLI

IP sets can be used in `firewalld` zones as sources and also as sources in rich rules. In Red Hat Enterprise Linux, the preferred method is to use the IP sets created with `firewalld` in a direct rule.

- To list the IP sets known to `firewalld` in the permanent environment, use the following command as `root`:
  ```bash
  # firewall-cmd --permanent --get-ipsets
  ```
  ```bash
  test
  ```

- To add a new IP set, use the following command using the permanent environment as `root`:
  ```bash
  # firewall-cmd --permanent --new-ipset=test --type=hash:net
  success
  ```

The previous command creates a new IP set with the name `test` and the `hash:net` type for IPv4.

- To create an IP set for use with IPv6, add the `--option=family/inet6` option. To make the new setting effective in the runtime environment, reload `firewalld`.

- List the new IP set with the following command as `root`:
  ```bash
  # firewall-cmd --permanent --get-ipsets
  test
  ```

- To get more information about the IP set, use the following command as `root`:
  ```bash
  # firewall-cmd --permanent --info-ipset=test
  test
type: hash:net
options:
entries:
```

Note that the IP set does not have any entries at the moment.

- To add an entry to the `test` IP set, use the following command as `root`:
  ```bash
  # firewall-cmd --permanent --ipset=test --add-entry=192.168.0.1
  success
  ```

The previous command adds the IP address 192.168.0.1 to the IP set.

- To get the list of current entries in the IP set, use the following command as `root`:
  ```bash
  # firewall-cmd --permanent --ipset=test --get-entries
  192.168.0.1
  ```
Generate a file containing a list of IP addresses, for example:

```bash
# cat > iplist.txt <<EOL
192.168.0.2
192.168.0.3
192.168.1.0/24
192.168.2.254
EOL
```

The file with the list of IP addresses for an IP set should contain an entry per line. Lines starting with a hash, a semi-colon, or empty lines are ignored.

To add the addresses from the `iplist.txt` file, use the following command as `root`:

```bash
# firewall-cmd --permanent --ipset=test --add-entries-from-file=iplist.txt
success
```

To see the extended entries list of the IP set, use the following command as `root`:

```bash
# firewall-cmd --permanent --ipset=test --get-entries
192.168.0.1
192.168.0.2
192.168.0.3
192.168.1.0/24
192.168.2.254
```

To remove the addresses from the IP set and to check the updated entries list, use the following commands as `root`:

```bash
# firewall-cmd --permanent --ipset=test --remove-entries-from-file=iplist.txt
success
# firewall-cmd --permanent --ipset=test --get-entries
192.168.0.1
```

You can add the IP set as a source to a zone to handle all traffic coming in from any of the addresses listed in the IP set with a zone. For example, to add the `test` IP set as a source to the `drop` zone to drop all packets coming from all entries listed in the `test` IP set, use the following command as `root`:

```bash
# firewall-cmd --permanent --zone=drop --add-source=ipset:test
success
```

The `ipset:` prefix in the source shows `firewalld` that the source is an IP set and not an IP address or an address range.

Only the creation and removal of IP sets is limited to the permanent environment, all other IP set options can be used also in the runtime environment without the `--permanent` option.
7.13. PRIORITIZING RICH RULES

By default, rich rules are organized based on their rule action. For example, *deny* rules have precedence over *allow* rules. The *priority* parameter in rich rules provides administrators fine-grained control over rich rules and their execution order.

7.13.1. How the priority parameter organizes rules into different chains

You can set the *priority* parameter in a rich rule to any number between -32768 and 32767, and lower values have higher precedence.

The *firewalld* service organizes rules based on their priority value into different chains:

- Priority lower than 0: the rule is redirected into a chain with the *_pre* suffix.
- Priority higher than 0: the rule is redirected into a chain with the *_post* suffix.
- Priority equals 0: based on the action, the rule is redirected into a chain with the *_log*, *_deny*, or *_allow* the action.

Inside these sub-chains, *firewalld* sorts the rules based on their priority value.

7.13.2. Setting the priority of a rich rule

The procedure describes an example of how to create a rich rule that uses the *priority* parameter to log all traffic that is not allowed or denied by other rules. You can use this rule to flag unexpected traffic.

**Procedure**

1. Add a rich rule with a very low precedence to log all traffic that has not been matched by other rules:

   ```bash
   # firewall-cmd --add-rich-rule='rule priority=32767 log prefix="UNEXPECTED: " limit value="5/m"
   ```

   The command additionally limits the number of log entries to 5 per minute.

2. Optionally, display the *nftables* rule that the command in the previous step created:

   ```bash
   # nft list chain inet firewalld filter_IN_public_post
   table inet firewalld {
   ```
7.14. CONFIGURING FIREWALL LOCKDOWN

Local applications or services are able to change the firewall configuration if they are running as root (for example, libvirt). With this feature, the administrator can lock the firewall configuration so that either no applications or only applications that are added to the lockdown allow list are able to request firewall changes. The lockdown settings default to disabled. If enabled, the user can be sure that there are no unwanted configuration changes made to the firewall by local applications or services.


This procedure describes how to enable or disable lockdown using the command line.

- To query whether lockdown is enabled, use the following command as root:
  
  ```
  # firewall-cmd --query-lockdown
  ```

  The command prints **yes** with exit status **0** if lockdown is enabled. It prints **no** with exit status **1** otherwise.

- To enable lockdown, enter the following command as root:
  
  ```
  # firewall-cmd --lockdown-on
  ```

- To disable lockdown, use the following command as root:
  
  ```
  # firewall-cmd --lockdown-off
  ```

7.14.2. Configuring lockdown allowlist options using CLI

The lockdown allowlist can contain commands, security contexts, users and user IDs. If a command entry on the allowlist ends with an asterisk "*", then all command lines starting with that command will match. If the "*" is not there then the absolute command including arguments must match.

- The context is the security (SELinux) context of a running application or service. To get the context of a running application use the following command:
  
  ```
  $ ps -e --context
  ```

  That command returns all running applications. Pipe the output through the **grep** tool to get the application of interest. For example:

  ```
  $ ps -e --context | grep example_program
  ```

- To list all command lines that are in the allowlist, enter the following command as root:
  
  ```
  # firewall-cmd --list-lockdown-whitelist-commands
  ```
To add a command `command` to the allowlist, enter the following command as `root`:

```
# firewall-cmd --add-lockdown-whitelist-command="/usr/bin/python3 -Es /usr/bin/command"
```

To remove a command `command` from the allowlist, enter the following command as `root`:

```
# firewall-cmd --remove-lockdown-whitelist-command="/usr/bin/python3 -Es /usr/bin/command"
```

To query whether the command `command` is in the allowlist, enter the following command as `root`:

```
# firewall-cmd --query-lockdown-whitelist-command="/usr/bin/python3 -Es /usr/bin/command"
```

The command prints `yes` with exit status 0 if true. It prints `no` with exit status 1 otherwise.

To list all security contexts that are in the allowlist, enter the following command as `root`:

```
# firewall-cmd --list-lockdown-whitelist-contexts
```

To add a context `context` to the allowlist, enter the following command as `root`:

```
# firewall-cmd --add-lockdown-whitelist-context=context
```

To remove a context `context` from the allowlist, enter the following command as `root`:

```
# firewall-cmd --remove-lockdown-whitelist-context=context
```

To query whether the context `context` is in the allowlist, enter the following command as `root`:

```
# firewall-cmd --query-lockdown-whitelist-context=context
```

Prints `yes` with exit status 0, if true, prints `no` with exit status 1 otherwise.

To list all user IDs that are in the allowlist, enter the following command as `root`:

```
# firewall-cmd --list-lockdown-whitelist-uids
```

To add a user ID `uid` to the allowlist, enter the following command as `root`:

```
# firewall-cmd --add-lockdown-whitelist-uid=uid
```

To remove a user ID `uid` from the allowlist, enter the following command as `root`:

```
# firewall-cmd --remove-lockdown-whitelist-uid=uid
```

To query whether the user ID `uid` is in the allowlist, enter the following command:

```
$ firewall-cmd --query-lockdown-whitelist-uid=uid
```

Prints `yes` with exit status 0, if true, prints `no` with exit status 1 otherwise.
To list all user names that are in the allowlist, enter the following command as root:

```bash
# firewall-cmd --list-lockdown-whitelist-users
```

To add a user name `user` to the allowlist, enter the following command as root:

```bash
# firewall-cmd --add-lockdown-whitelist-user=user
```

To remove a user name `user` from the allowlist, enter the following command as root:

```bash
# firewall-cmd --remove-lockdown-whitelist-user=user
```

To query whether the user name `user` is in the allowlist, enter the following command:

```bash
$ firewall-cmd --query-lockdown-whitelist-user=user
```

Prints `yes` with exit status 0, if true, prints `no` with exit status 1 otherwise.

### 7.14.3. Configuring lockdown allowlist options using configuration files

The default allowlist configuration file contains the `NetworkManager` context and the default context of `libvirt`. The user ID 0 is also on the list.

> The allowlist configuration files are stored in the `/etc/firewalld/` directory.

```xml
<?xml version="1.0" encoding="utf-8"?>
<whitelist>
  <selinux context="system_u:system_r:NetworkManager_t:s0"/>
  <selinux context="system_u:system_r:virtd_t:s0-s0:c0.c1023"/>
  <user id="0"/>
</whitelist>
```

Following is an example allowlist configuration file enabling all commands for the `firewall-cmd` utility, for a user called `user` whose user ID is 815:

```xml
<?xml version="1.0" encoding="utf-8"?>
<whitelist>
  <command name="/usr/libexec/platform-python -s /bin/firewall-cmd"/>
  <selinux context="system_u:system_r:NetworkManager_t:s0"/>
  <user id="815"/>
  <user name="user"/>
</whitelist>
```

This example shows both `user id` and `user name`, but only one option is required. Python is the interpreter and is prepended to the command line. You can also use a specific command, for example:

```
/usr/bin/python3 /bin/firewall-cmd --lockdown-on
```

In that example, only the `--lockdown-on` command is allowed.

In Red Hat Enterprise Linux, all utilities are placed in the `/usr/bin/` directory and the `/bin/` directory is sym-linked to the `/usr/bin/` directory. In other words, although the path for `firewall-cmd` when entered as `root` might resolve to `/bin/firewall-cmd`, `/usr/bin/firewall-cmd` can now be used. All new scripts
should use the new location. But be aware that if scripts that run as root are written to use the
/bin/firewall-cmd path, then that command path must be added in the allowlist in addition to the
/usr/bin/firewall-cmd path traditionally used only for non-root users.

The * at the end of the name attribute of a command means that all commands that start with this string
match. If the * is not there then the absolute command including arguments must match.

7.15. ENABLING TRAFFIC FORWARDING BETWEEN DIFFERENT INTERFACES OR SOURCES WITHIN A FIREWALLD ZONE

Intra-zone forwarding is a firewalld feature that enables traffic forwarding between interfaces or
sources within a firewalld zone.

7.15.1. The difference between intra-zone forwarding and zones with the default
target set to ACCEPT

When intra-zone forwarding is enabled, the traffic within a single firewalld zone can flow from one
interface or source to another interface or source. The zone specifies the trust level of interfaces and
sources. If the trust level is the same, communication between interfaces or sources is possible.

Note that, if you enable intra-zone forwarding in the default zone of firewalld, it applies only to the
interfaces and sources added to the current default zone.

The trusted zone of firewalld uses a default target set to ACCEPT. This zone accepts all forwarded
traffic, and intra-zone forwarding is not applicable for it.

As for other default target values, forwarded traffic is dropped by default, which applies to all standard
zones except the trusted zone.

7.15.2. Using intra-zone forwarding to forward traffic between an Ethernet and Wi-Fi network

You can use intra-zone forwarding to forward traffic between interfaces and sources within the same
firewalld zone. For example, use this feature to forward traffic between an Ethernet network connected
to enp1s0 and a Wi-Fi network connected to wlp0s20.

Procedure

1. Enable packet forwarding in the kernel:

```
# echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
# sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
```

2. Ensure that interfaces between which you want to enable intra-zone forwarding are not
assigned to a zone different than the internal zone:

```
# firewall-cmd --get-active-zones
```

3. If the interface is currently assigned to a zone other than internal, reassign it:

```
# firewall-cmd --zone=internal --change-interface=interface_name --permanent
```
4. Add the `enp1s0` and `wlp0s20` interfaces to the `internal` zone:

   ```sh
   # firewall-cmd --zone=internal --add-interface=enp1s0 --add-interface=wlp0s20
   ```

5. Enable intra-zone forwarding:

   ```sh
   # firewall-cmd --zone=internal --add-forward
   ```

### Verification

The following verification steps require that the `nmap-ncat` package is installed on both hosts.

1. Log in to a host that is in the same network as the `enp1s0` interface of the host you enabled zone forwarding on.

2. Start an echo service with `ncat` to test connectivity:

   ```sh
   # ncat -e /usr/bin/cat -l 12345
   ```

3. Log in to a host that is in the same network as the `wlp0s20` interface.

4. Connect to the echo server running on the host that is in the same network as the `enp1s0`:

   ```sh
   # ncat <other host> 12345
   ```

5. Type something and press `Enter`, and verify the text is sent back.

### Additional resources

- `firewalld.zones(5)` man page

### 7.16. USING RHEL SYSTEM ROLES WITH ANSIBLE TO CONFIGURE FIREWALLD SETTINGS

You can use the Ansible firewall System Role to configure settings of the `firewalld` service on multiple clients at once. This solution:

- Provides an interface with efficient input settings.
- Keeps all intended `firewalld` parameters in one place.

After you run the `firewall` role on the control node, the System Role applies the `firewalld` parameters to the managed node immediately and makes them persistent across reboots.

**IMPORTANT**

Note that RHEL System Roles delivered over RHEL channels are available to RHEL customers as an RPM package in the default AppStream repository. RHEL System Roles are also available as a collection to customers with Ansible subscriptions over Ansible Automation Hub.

### 7.16.1. Introduction to the firewall RHEL System Role
RHEL System Roles is a set of contents for the Ansible automation utility. This content together with the Ansible automation utility provides a consistent configuration interface to remotely manage multiple systems.

The `rhel-system-roles.firewall` role from the RHEL System Roles was introduced for automated configurations of the `firewalld` service. The `rhel-system-roles` package contains this system role, and also the reference documentation.

To apply the `firewalld` parameters on one or more systems in an automated fashion, use the `firewall` System Role variable in a playbook. A playbook is a list of one or more plays that is written in the text-based YAML format.

You can use an inventory file to define a set of systems that you want Ansible to configure.

With the `firewall` role you can configure many different `firewalld` parameters, for example:

- Zones.
- The services for which packets should be allowed.
- Granting, rejection, or dropping of traffic access to ports.
- Forwarding of ports or port ranges for a zone.

Additional resources

- `README.md` and `README.html` files in the `/usr/share/doc/rhel-system-roles/firewall/` directory
- Working with playbooks
- How to build your inventory

### 7.16.2. Forwarding incoming traffic from one local port to a different local port

With the `rhel-system-roles.firewall` role you can remotely configure `firewalld` parameters with persisting effect on multiple managed hosts.

**Prerequisites**

- Entitled by your RHEL subscription, you installed the `ansible-core` and `rhel-system-roles` packages on the control node.
- An inventory of managed hosts is present on the control machine and Ansible is able to connect to them.
- You have permission to run Ansible playbooks on the managed hosts.
- If you use a different remote user than `root` when you run the playbook, this user has appropriate `sudo` permissions on the managed host.
- The inventory file lists the hosts on which the playbook should perform the actions. The playbook in this procedure runs on hosts in the group `testinservers`. 
IMPORTANT

RHEL 8.0 - 8.5 provided access to a separate Ansible repository that contains Ansible Engine 2.9 for automation based on Ansible. Ansible Engine contains command-line utilities such as `ansible`, `ansible-playbook`; connectors such as `docker` and `podman`; and the entire world of plugins and modules. For information on how to obtain and install Ansible Engine, refer to How do I Download and Install Red Hat Ansible Engine?.

RHEL 8.6 and later has introduced Ansible Core (provided as `ansible-core` RPM), which contains the Ansible command-line utilities, commands, and a small set of built-in Ansible plugins. The AppStream repository provides `ansible-core`, which has a limited scope of support. You can learn more by reviewing Scope of support for the ansible-core package included in the RHEL 9 AppStream.

Procedure

1. Create the `~/port_forwarding.yml` file and add the following content:

   ```yaml
   ---
   - name: Forward incoming traffic on port 8080 to 443
     hosts: testingservers

     tasks:
     - include_role:
       name: rhel-system-roles.firewall

     vars:
       firewall:
       - { forward_port: 8080/tcp;443;, state: enabled, runtime: true, permanent: true }
   ```

   This file represents a playbook and usually contains an ordered list of tasks, also called plays, that are run against specific managed hosts selected from your inventory file. In this case, the playbook will run against the `testingservers` group of managed hosts.

   The hosts key in the play specifies the hosts against which the play is run. You can provide the value or values for this key as individual names of managed hosts or as groups of hosts as defined in the inventory file.

   The tasks section has the include_role key, which specifies what system role is going to configure the parameters and values mentioned in the vars section.

   The vars section contains a role variable called firewall. This variable is a list of dictionary values and specifies parameters that will be applied to firewalld on managed hosts. The example role will forward the traffic coming to port 8080 to port 443. The settings will come to effect immediately and will also persist across reboots.

2. Optionally, verify that the syntax in the playbook is correct:

   ```bash
   # ansible-playbook --syntax-check ~/port_forwarding.yml
   playbook: port_forwarding.yml
   ```

   This example shows the successful verification of a playbook.

3. Execute the playbook:
# ansible-playbook ~/port_forwarding.yml

**Verification**

- On the managed host:
  - Restart the host to verify if the firewalld settings are still in place after a reboot:
    
    ```
    # reboot
    ```
  - Display the firewalld settings:
    
    ```
    # firewall-cmd --list-forward-ports
    ```

**Additional resources**

- Getting started with RHEL System Roles
- README.html and README.md files in the /usr/share/doc/rhel-system-roles/firewall/ directory
- Build Your Inventory
- Configuring Ansible
- Working With Playbooks
- Using Variables
- Roles

### 7.16.3. Configuring ports using System Roles

You can use the Red Hat Enterprise Linux (RHEL) firewalld System Role to open or close ports in the local firewall for incoming traffic and make the new configuration persist across reboots. The example describes how to configure the default zone to permit incoming traffic for the HTTPS service.

Run this procedure on the Ansible control node.

**Prerequisites**

- Access and permissions to one or more managed nodes, which are systems you want to configure with the firewalld System Role.
- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.
- The ansible and rhel-system-roles packages are installed on the control node.
- If you use a different remote user than root when you run the playbook, this user has appropriate sudo permissions on the managed node.
- The host uses NetworkManager to configure the network.
Procedure

1. If the host on which you want to execute the instructions in the playbook is not yet inventoried, add the IP or name of this host to the `/etc/ansible/hosts` Ansible inventory file:

```bash
node.example.com
```

2. Create the `~/adding-and-removing-ports.yml` playbook with the following content:

```yaml
---
- name: Allow incoming HTTPS traffic to the local host
  hosts: node.example.com
  become: true
  tasks:
    - include_role:
        name: linux-system-roles.firewall
        vars:
          firewall:
            - port: 443/tcp
            service: http
            state: enabled
            runtime: true
            permanent: true
```

The `permanent: true` option makes the new settings persistent across reboots.

3. Run the playbook:

   - To connect as `root` user to the managed host, enter:

     ```bash
     # ansible-playbook -u root ~/adding-and-removing-ports.yml
     ```

   - To connect as a user to the managed host, enter:

     ```bash
     # ansible-playbook -u user_name --ask-become-pass ~/adding-and-removing-ports.yml
     ```

     The `--ask-become-pass` option makes sure that the `ansible-playbook` command prompts for the `sudo` password of the user defined in the `-u user_name` option.

     If you do not specify the `-u user_name` option, `ansible-playbook` connects to the managed host as the user that is currently logged in to the control node.

Verification

1. Connect to the managed node:

   ```bash
   $ ssh user_name@node.example.com
   ```

2. Verify that the `443/tcp` port associated with the `HTTPS` service is open:
$ sudo firewall-cmd --list-ports
443/tcp

Additional resources
- /usr/share/ansible/roles/rhel-system-roles.network/README.md
- ansible-playbook(1) man page

7.16.4. Configuring a DMZ firewalld zone by using the firewalld RHEL System Role

As a system administrator, you can use the RHEL firewalld System Role to configure a dmz zone on the enp1s0 interface to permit HTTPS traffic to the zone. In this way, you enable external users to access your web servers.

Prerequisites
- Access and permissions to one or more managed nodes, which are systems you want to configure with the VPN System Role.
- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.
- An inventory file that lists the managed nodes.
- The ansible and rhel-system-roles packages are installed on the control node.
- If you use a different remote user than root when you run the playbook, this user has appropriate sudo permissions on the managed node.
- The managed nodes use NetworkManager to configure the network.

Procedure

1. Create the ~/configuring-a-dmz-using-the-firewall-system-role.yml playbook with the following content:

```yaml
---
- name: Creating a DMZ with access to HTTPS port and masquerading for hosts in DMZ
  hosts: node.example.com
  become: true

  tasks:
    - include_role:
        name: linux-system-roles.firewall

    vars:
      firewall:
        - zone: dmz
          interface: enp1s0
          service: https
          state: enabled
          runtime: true
          permanent: true
```
2. Run the playbook:
   - To connect as root user to the managed host, enter:
     ```shell
     $ ansible-playbook -u root ~/configuring-a-dmz-using-the-firewall-system-role.yml
     ```
   - To connect as a user to the managed host, enter:
     ```shell
     $ ansible-playbook -u user_name --ask-become-pass ~/configuring-a-dmz-using-the-firewall-system-role.yml
     ```
     The `--ask-become-pass` option makes sure that the `ansible-playbook` command prompts for the `sudo` password of the user defined in the `-u user_name` option.

   If you do not specify the `-u user_name` option, `ansible-playbook` connects to the managed host as the user that is currently logged in to the control node.

Verification

   - On the managed node, view detailed information about the dmz zone:
     ```bash
     # firewall-cmd --zone=dmz --list-all
     dmz (active)
     target: default
     icmp-block-inversion: no
     interfaces: enp1s0
     sources:
     services: https ssh
     ports:
     protocols:
     forward: no
     masquerade: no
     forward-ports:
     source-ports:
     icmp-blocks:
     ```

7.17. ADDITIONAL RESOURCES

   - firewalld(1) man page
   - firewalld.conf(5) man page
   - firewall-cmd(1) man page
   - firewall-config(1) man page
   - firewall-offline-cmd(1) man page
   - firewalld.icmptype(5) man page
   - firewalld.ipset(5) man page
   - firewalld.service(5) man page
   - firewalld.zone(5) man page
• `firewalld.direct(5)` man page
• `firewalld.lockdown-whitelist(5)`
• `firewalld.richlanguage(5)`
• `firewalld.zones(5)` man page
• `firewalld.dbus(5)` man page
CHAPTER 8. GETTING STARTED WITH NFTABLES

The nftables framework provides packet classification facilities. The most notable features are:

- built-in lookup tables instead of linear processing
- a single framework for both the IPv4 and IPv6 protocols
- rules all applied atomically instead of fetching, updating, and storing a complete rule set
- support for debugging and tracing in the rule set (nftrace) and monitoring trace events (in the nft tool)
- more consistent and compact syntax, no protocol-specific extensions
- a Netlink API for third-party applications

The nftables framework uses tables to store chains. The chains contain individual rules for performing actions. The libnftnl library can be used for low-level interaction with nftables Netlink API over the libmnl library.

To display the effect of rule set changes, use the nft list ruleset command. Since these tools add tables, chains, rules, sets, and other objects to the nftables rule set, be aware that nftables rule-set operations, such as the nft flush ruleset command, might affect rule sets installed using the formerly separate legacy commands.

8.1. MIGRATING FROM IPTABLES TO NFTABLES

If your firewall configuration still uses iptables rules, you can migrate your iptables rules to nftables.

8.1.1. When to use firewalld, nftables, or iptables

The following is a brief overview in which scenario you should use one of the following utilities:

- **firewalld**: Use the firewalld utility for simple firewall use cases. The utility is easy to use and covers the typical use cases for these scenarios.

- **nftables**: Use the nftables utility to set up complex and performance critical firewalls, such as for a whole network.

- **iptables**: The iptables utility on Red Hat Enterprise Linux uses the nf_tables kernel API instead of the legacy back end. The nf_tables API provides backward compatibility so that scripts that use iptables commands still work on Red Hat Enterprise Linux. For new firewall scripts, Red Hat recommends to use nftables.

**IMPORTANT**

To avoid that the different firewall services influence each other, run only one of them on a RHEL host, and disable the other services.

8.1.2. Converting iptables and ip6tables rule sets to nftables

Use the iptables-restore-translate and ip6tables-restore-translate utilities to translate iptables and ip6tables rule sets to nftables.
Prerequisites

- The nftables and iptables packages are installed.
- The system has iptables and ip6tables rules configured.

Procedure

1. Write the iptables and ip6tables rules to a file:

   ```bash
   # iptables-save >/root/iptables.dump
   # ip6tables-save >/root/ip6tables.dump
   ```

2. Convert the dump files to nftables instructions:

   ```bash
   # iptables-restore-translate -f /root/iptables.dump > /etc/nftables/ruleset-migrated-from-iptables.nft
   # ip6tables-restore-translate -f /root/ip6tables.dump > /etc/nftables/ruleset-migrated-from-ip6tables.nft
   ```

3. Review and, if needed, manually update the generated nftables rules.

4. To enable the nftables service to load the generated files, add the following to the /etc/sysconfig/nftables.conf file:

   ```bash
   include "/etc/nftables/ruleset-migrated-from-iptables.nft"
   include "/etc/nftables/ruleset-migrated-from-ip6tables.nft"
   ```

5. Stop and disable the iptables service:

   ```bash
   # systemctl disable --now iptables
   ```

   If you used a custom script to load the iptables rules, ensure that the script no longer starts automatically and reboot to flush all tables.

6. Enable and start the nftables service:

   ```bash
   # systemctl enable --now nftables
   ```

Verification

- Display the nftables rule set:

   ```bash
   # nft list ruleset
   ```

Additional resources

- Automatically loading nftables rules when the system boots

### 8.1.3. Converting single iptables and ip6tables rules to nftables

Red Hat Enterprise Linux provides the iptables-translate and ip6tables-translate utilities to convert an iptables or ip6tables rule into the equivalent one for nftables.
Prerequisites

- The nftables package is installed.

Procedure

- Use the iptables-translate or ip6tables-translate utility instead of iptables or ip6tables to display the corresponding nftables rule, for example:

```bash
# iptables-translate -A INPUT -s 192.0.2.0/24 -j ACCEPT
nft add rule ip filter INPUT ip saddr 192.0.2.0/24 counter accept
```

Note that some extensions lack translation support. In these cases, the utility prints the untranslated rule prefixed with the # sign, for example:

```bash
# iptables-translate -A INPUT -j CHECKSUM --checksum-fill
nft # -A INPUT -j CHECKSUM --checksum-fill
```

Additional resources

- iptables-translate --help

8.1.4. Comparison of common iptables and nftables commands

The following is a comparison of common iptables and nftables commands:

- Listing all rules:

<table>
<thead>
<tr>
<th>iptables</th>
<th>nftables</th>
</tr>
</thead>
<tbody>
<tr>
<td>iptables-save</td>
<td>nft list ruleset</td>
</tr>
</tbody>
</table>

- Listing a certain table and chain:

<table>
<thead>
<tr>
<th>iptables</th>
<th>nftables</th>
</tr>
</thead>
<tbody>
<tr>
<td>iptables -L</td>
<td>nft list table ip filter</td>
</tr>
<tr>
<td>iptables -L INPUT</td>
<td>nft list chain ip filter INPUT</td>
</tr>
<tr>
<td>iptables -t nat -L PREROUTING</td>
<td>nft list chain ip nat PREROUTING</td>
</tr>
</tbody>
</table>

The nft command does not pre-create tables and chains. They exist only if a user created them manually.

Example: Listing rules generated by firewalld

```bash
# nft list table inet firewalld
# nft list table ip firewalld
# nft list table ip6 firewalld
```
8.1.5. Additional resources

- iptables: The two variants and their relationship with nftables

8.2. WRITING AND EXECUTING NFTABLES SCRIPTS

The nftables framework provides a native scripting environment that brings a major benefit over using shell scripts to maintain firewall rules: the execution of scripts is atomic. This means that the system either applies the whole script or prevents the execution if an error occurs. This guarantees that the firewall is always in a consistent state.

Additionally, the nftables script environment enables administrators to:

- add comments
- define variables
- include other rule set files

This section explains how to use these features, as well as creating and executing nftables scripts.

When you install the nftables package, Red Hat Enterprise Linux automatically creates *.nft scripts in the /etc/nftables/ directory. These scripts contain commands that create tables and empty chains for different purposes.

8.2.1. Supported nftables script formats

The nftables scripting environment supports scripts in the following formats:

- You can write a script in the same format as the nft list ruleset command displays the rule set:

```bash
#!/usr/sbin/nft -f

# Flush the rule set
flush ruleset

table inet example_table {
    chain example_chain {
        # Chain for incoming packets that drops all packets that
        # are not explicitly allowed by any rule in this chain
        type filter hook input priority 0; policy drop;

        # Accept connections to port 22 (ssh)
tcp dport ssh accept
    }
}
```

- You can use the same syntax for commands as in nft commands:

```bash
#!/usr/sbin/nft -f

# Flush the rule set
flush ruleset

# Create a table
```
add table inet example_table

# Create a chain for incoming packets that drops all packets
# that are not explicitly allowed by any rule in this chain
add chain inet example_table example_chain { type filter hook input priority 0 ; policy drop ; }

# Add a rule that accepts connections to port 22 (ssh)
add rule inet example_table example_chain tcp dport ssh accept

8.2.2. Running nftables scripts

You can run nftables script either by passing it to the nft utility or execute the script directly.

Prerequisites

- The procedure of this section assumes that you stored an nftables script in the /etc/nftables/example_firewall.nft file.

Procedure

- To run an nftables script by passing it to the nft utility, enter:

  ```
  # nft -f /etc/nftables/example_firewall.nft
  ```

- To run an nftables script directly:
  
a. Steps that are required only once:

  i. Ensure that the script starts with the following shebang sequence:

  ```
  #!/usr/sbin/nft -f
  ```

  **IMPORTANT**

  If you omit the -f parameter, the nft utility does not read the script and displays: Error: syntax error, unexpected newline, expecting string.

  ii. Optional: Set the owner of the script to root:

  ```
  # chown root /etc/nftables/example_firewall.nft
  ```

  iii. Make the script executable for the owner:

  ```
  # chmod u+x /etc/nftables/example_firewall.nft
  ```

  b. Run the script:

  ```
  # /etc/nftables/example_firewall.nft
  ```

  If no output is displayed, the system executed the script successfully.
Even if **nft** executes the script successfully, incorrectly placed rules, missing parameters, or other problems in the script can cause that the firewall behaves not as expected.

### Additional resources

- **chown(1) man page**
- **chmod(1) man page**
- **Automatically loading nftables rules when the system boots**

### 8.2.3. Using comments in nftables scripts

The **nftables** scripting environment interprets everything to the right of a `#` character as a comment.

**Example 8.1. Comments in an nftables script**

Comments can start at the beginning of a line, as well as next to a command:

```nftables
... # Flush the rule set
flush ruleset

add table inet example_table # Create a table
...
```

### 8.2.4. Using variables in an nftables script

To define a variable in an **nftables** script, use the **define** keyword. You can store single values and anonymous sets in a variable. For more complex scenarios, use sets or verdict maps.

**Variables with a single value**

The following example defines a variable named **INET_DEV** with the value `enp1s0`:

```nftables
define INET_DEV = enp1s0
```

You can use the variable in the script by writing the `$` sign followed by the variable name:

```nftables
... add rule inet example_table example_chain iifname $INET_DEV tcp dport ssh accept ...
```

**Variables that contain an anonymous set**

The following example defines a variable that contains an anonymous set:

```nftables
define DNS_SERVERS = { 192.0.2.1, 192.0.2.2 }
```

You can use the variable in the script by writing the `$` sign followed by the variable name:
add rule inet example_table example_chain ip daddr $DNS_SERVERS accept

NOTE
Note that curly braces have special semantics when you use them in a rule because they indicate that the variable represents a set.

Additional resources
- Using sets in nftables commands
- Using verdict maps in nftables commands

8.2.5. Including files in an nftables script

The nftables scripting environment enables administrators to include other scripts by using the include statement.

If you specify only a file name without an absolute or relative path, nftables includes files from the default search path, which is set to /etc on Red Hat Enterprise Linux.

Example 8.2. Including files from the default search directory

To include a file from the default search directory:

```
include "example.nft"
```

Example 8.3. Including all *.nft files from a directory

To include all files ending with *.nft that are stored in the /etc/nftables/rulesets/ directory:

```
include "/etc/nftables/rulesets/*.nft"
```

Note that the include statement does not match files beginning with a dot.

Additional resources
- The Include files section in the nft(8) man page

8.2.6. Automatically loading nftables rules when the system boots

The nftables systemd service loads firewall scripts that are included in the /etc/sysconfig/nftables.conf file. This section explains how to load firewall rules when the system boots.

Prerequisites
- The nftables scripts are stored in the /etc/nftables/ directory.
Procedure

1. Edit the `/etc/sysconfig/nftables.conf` file.
   - If you enhance `.nft` scripts created in `/etc/nftables/` when you installed the `nftables` package, uncomment the `include` statement for these scripts.
   - If you write scripts from scratch, add `include` statements to include these scripts. For example, to load the `/etc/nftables/example.nft` script when the `nftables` service starts, add:
     ```
     include "/etc/nftables/example.nft"
     ```

2. Optionally, start the `nftables` service to load the firewall rules without rebooting the system:
   ```
   # systemctl start nftables
   ```

3. Enable the `nftables` service.
   ```
   # systemctl enable nftables
   ```

Additional resources

- Supported nftables script formats

8.3. CREATING AND MANAGING NFTABLES TABLES, CHAINS, AND RULES

This section explains how to display `nftables` rule sets, and how to manage them.

8.3.1. Standard chain priority values and textual names

When you create a chain, the `priority` you can either set an integer value or a standard name that specifies the order in which chains with the same `hook` value traverse.

The names and values are defined based on what priorities are used by `xtables` when registering their default chains.

NOTE

The `nft list chains` command displays textual priority values by default. You can view the numeric value by passing the `-y` option to the command.

Example 8.4. Using a textual value to set the priority

The following command creates a chain named `example_chain` in `example_table` using the standard priority value `50`:

```
# nft add chain inet example_table example_chain { type filter hook input priority 50 \; policy accept \; }
```

Because the priority is a standard value, you can alternatively use the textual value:
# nft add chain inet example_table example_chain { type filter hook input priority security \; policy accept \; } 

Table 8.1. Standard priority names, family, and hook compatibility matrix

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Families</th>
<th>Hooks</th>
</tr>
</thead>
<tbody>
<tr>
<td>raw</td>
<td>-300</td>
<td>ip, ip6, inet</td>
<td>all</td>
</tr>
<tr>
<td>mangle</td>
<td>-150</td>
<td>ip, ip6, inet</td>
<td>all</td>
</tr>
<tr>
<td>dstnat</td>
<td>-100</td>
<td>ip, ip6, inet</td>
<td>prerouting</td>
</tr>
<tr>
<td>filter</td>
<td>0</td>
<td>ip, ip6, inet, arp, netdev</td>
<td>all</td>
</tr>
<tr>
<td>security</td>
<td>50</td>
<td>ip, ip6, inet</td>
<td>all</td>
</tr>
<tr>
<td>srcnat</td>
<td>100</td>
<td>ip, ip6, inet</td>
<td>postrouting</td>
</tr>
</tbody>
</table>

All families use the same values, but the bridge family uses following values:

Table 8.2. Standard priority names, and hook compatibility for the bridge family

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Hooks</th>
</tr>
</thead>
<tbody>
<tr>
<td>dstnat</td>
<td>-300</td>
<td>prerouting</td>
</tr>
<tr>
<td>filter</td>
<td>-200</td>
<td>all</td>
</tr>
<tr>
<td>out</td>
<td>100</td>
<td>output</td>
</tr>
<tr>
<td>srcnat</td>
<td>300</td>
<td>postrouting</td>
</tr>
</tbody>
</table>

Additional resources

- The Chains section in the nft(8) man page

8.3.2. Displaying the nftables rule set

The rule sets of nftables contain tables, chains, and rules. This section explains how to display the rule set.

Procedure

- To display the rule set, enter:

  ```bash
  # nft list ruleset
  table inet example_table {
  chain example_chain {
  ```
NOTE

By default, nftables does not pre-create tables. As a consequence, displaying the rule set on a host without any tables, the nft list ruleset command shows no output.

8.3.3. Creating an nftables table

A table in nftables is a name space that contains a collection of chains, rules, sets, and other objects. This section explains how to create a table.

Each table must have an address family defined. The address family of a table defines what address types the table processes. You can set one of the following address families when you create a table:

- **ip**: Matches only IPv4 packets. This is the default if you do not specify an address family.
- **ip6**: Matches only IPv6 packets.
- **inet**: Matches both IPv4 and IPv6 packets.
- **arp**: Matches IPv4 address resolution protocol (ARP) packets.
- **bridge**: Matches packets that traverse a bridge device.
- **netdev**: Matches packets from ingress.

Procedure

1. Use the nft add table command to create a new table. For example, to create a table named example_table that processes IPv4 and IPv6 packets:

   ```
   # nft add table inet example_table
   ```

2. Optionally, list all tables in the rule set:

   ```
   # nft list tables
table inet example_table
   ```

Additional resources

- The Address families section in the nft(8) man page
- The Tables section in the nft(8) man page

8.3.4. Creating an nftables chain

Chains are containers for rules. The following two rule types exist:
- Base chain: You can use base chains as an entry point for packets from the networking stack.
- Regular chain: You can use regular chains as a jump target and to better organize rules.

The procedure describes how to add a base chain to an existing table.

**Prerequisites**
- The table to which you want to add the new chain exists.

**Procedure**

1. Use the `nft add chain` command to create a new chain. For example, to create a chain named `example_chain` in `example_table`:

   ```
   # nft add chain inet example_table example_chain { type filter hook input priority 0; policy accept; }
   ```

   **IMPORTANT**

   To avoid that the shell interprets the semicolons as the end of the command, prepend the semicolons the \ escape character.

   This chain filters incoming packets. The `priority` parameter specifies the order in which `nftables` processes chains with the same hook value. A lower priority value has precedence over higher ones. The `policy` parameter sets the default action for rules in this chain. Note that if you are logged in to the server remotely and you set the default policy to `drop`, you are disconnected immediately if no other rule allows the remote access.

2. Optionally, display all chains:

   ```
   # nft list chains
   table inet example_table {
   chain example_chain {
   type filter hook input priority filter; policy accept;
   }
   }
   ```

**Additional resources**
- The *Address families* section in the *nft(8)* man page
- The *Chains* section in the *nft(8)* man page

**8.3.5. Appending a rule to the end of an nftables chain**

This section explains how to append a rule to the end of an existing `nftables` chain.

**Prerequisites**
- The chain to which you want to add the rule exists.

**Procedure**
1. To add a new rule, use the `nft add rule` command. For example, to add a rule to the `example_chain` in the `example_table` that allows TCP traffic on port 22:

   ```
   # nft add rule inet example_table example_chain tcp dport 22 accept
   ```

   Instead of the port number, you can alternatively specify the name of the service. In the example, you could use `ssh` instead of the port number `22`. Note that a service name is resolved to a port number based on its entry in the `/etc/services` file.

2. Optionally, display all chains and their rules in `example_table`:

   ```
   # nft list table inet example_table
   table inet example_table {
     chain example_chain {
       type filter hook input priority filter; policy accept;
       tcp dport ssh accept
     }
   }
   ```

Additional resources

- The [Address families](#) section in the `nft(8)` man page
- The [Rules](#) section in the `nft(8)` man page

### 8.3.6. Inserting a rule at the beginning of an nftables chain

This section explains how to insert a rule at the beginning of an existing nftables chain.

**Prerequisites**

- The chain to which you want to add the rule exists.

**Procedure**

1. To insert a new rule, use the `nft insert rule` command. For example, to insert a rule to the `example_chain` in the `example_table` that allows TCP traffic on port 22:

   ```
   # nft insert rule inet example_table example_chain tcp dport 22 accept
   ```

   You can alternatively specify the name of the service instead of the port number. In the example, you could use `ssh` instead of the port number `22`. Note that a service name is resolved to a port number based on its entry in the `/etc/services` file.

2. Optionally, display all chains and their rules in `example_table`:

   ```
   # nft list table inet example_table
   table inet example_table {
     chain example_chain {
       type filter hook input priority filter; policy accept;
       tcp dport ssh accept
     }
   }
   ```
Additional resources

- The Address families section in the nft(8) man page
- The Rules section in the nft(8) man page

8.3.7. Inserting a rule at a specific position of an nftables chain

This section explains how to insert rules before and after an existing rule in an nftables chain. This way you can place new rules at the right position.

Prerequisites

- The chain to which you want to add the rules exists.

Procedure

1. Use the nft -a list ruleset command to display all chains and their rules in the example_table including their handle:

```
# nft -a list table inet example_table
table inet example_table { # handle 1
  chain example_chain { # handle 1
    type filter hook input priority filter; policy accept;
    tcp dport 22 accept # handle 2
    tcp dport 443 accept # handle 3
    tcp dport 389 accept # handle 4
  }
}
```

Using the -a displays the handles. You require this information to position the new rules in the next steps.

2. Insert the new rules to the example_chain chain in the example_table:

   - To insert a rule that allows TCP traffic on port 636 before handle 3, enter:

     ```
     # nft insert rule inet example_table example_chain position 3 tcp dport 636 accept
     ```

   - To add a rule that allows TCP traffic on port 80 after handle 3, enter:

     ```
     # nft add rule inet example_table example_chain position 3 tcp dport 80 accept
     ```

3. Optionally, display all chains and their rules in example_table:

```
# nft -a list table inet example_table
```
Additional resources

- The Address families section in the nft(8) man page
- The Rules section in the nft(8) man page

8.4. CONFIGURING NAT USING NFTABLES

With nftables, you can configure the following network address translation (NAT) types:

- Masquerading
- Source NAT (SNAT)
- Destination NAT (DNAT)
- Redirect

IMPORTANT

You can only use real interface names in iifname and oifname parameters, and alternative names (altname) are not supported.

8.4.1. The different NAT types: masquerading, source NAT, destination NAT, and redirect

These are the different network address translation (NAT) types:

Masquerading and source NAT (SNAT)

Use one of these NAT types to change the source IP address of packets. For example, Internet Service Providers do not route private IP ranges, such as 10.0.0.0/8. If you use private IP ranges in your network and users should be able to reach servers on the Internet, map the source IP address of packets from these ranges to a public IP address.

Both masquerading and SNAT are very similar. The differences are:

- Masquerading automatically uses the IP address of the outgoing interface. Therefore, use masquerading if the outgoing interface uses a dynamic IP address.
- SNAT sets the source IP address of packets to a specified IP and does not dynamically look up the IP of the outgoing interface. Therefore, SNAT is faster than masquerading. Use SNAT if the outgoing interface uses a fixed IP address.

Destination NAT (DNAT)

Use this NAT type to rewrite the destination address and port of incoming packets. For example, if your web server uses an IP address from a private IP range and is, therefore, not directly accessible from the Internet, you can set a DNAT rule on the router to redirect incoming traffic to this server.
Redirect

This type is a special case of DNAT that redirects packets to the local machine depending on the chain hook. For example, if a service runs on a different port than its standard port, you can redirect incoming traffic from the standard port to this specific port.

8.4.2. Configuring masquerading using nftables

Masquerading enables a router to dynamically change the source IP of packets sent through an interface to the IP address of the interface. This means that if the interface gets a new IP assigned, nftables automatically uses the new IP when replacing the source IP.

The following procedure describes how to replace the source IP of packets leaving the host through the ens3 interface to the IP set on ens3.

Procedure

1. Create a table:

   # nft add table nat

2. Add the prerouting and postrouting chains to the table:

   # nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }
   # nft add chain nat postrouting { type nat hook postrouting priority 100 \; }

   **IMPORTANT**

   Even if you do not add a rule to the prerouting chain, the nftables framework requires this chain to match incoming packet replies.

   Note that you must pass the -- option to the nft command to avoid that the shell interprets the negative priority value as an option of the nft command.

3. Add a rule to the postrouting chain that matches outgoing packets on the ens3 interface:

   # nft add rule nat postrouting oifname "ens3" masquerade

8.4.3. Configuring source NAT using nftables

On a router, Source NAT (SNAT) enables you to change the IP of packets sent through an interface to a specific IP address.

The following procedure describes how to replace the source IP of packets leaving the router through the ens3 interface to 192.0.2.1.

Procedure

1. Create a table:

   # nft add table nat

2. Add the prerouting and postrouting chains to the table:
# nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }  
# nft add chain nat postrouting { type nat hook postrouting priority 100 \; }

**IMPORTANT**

Even if you do not add a rule to the `postrouting` chain, the `nftables` framework requires this chain to match outgoing packet replies.

Note that you must pass the `--` option to the `nft` command to avoid that the shell interprets the negative priority value as an option of the `nft` command.

3. Add a rule to the `postrouting` chain that replaces the source IP of outgoing packets through `ens3` with `192.0.2.1`:

```bash  
# nft add rule nat postrouting ofname "ens3" snat to 192.0.2.1
```

**Additional resources**

- Forwarding incoming packets on a specific local port to a different host

### 8.4.4. Configuring destination NAT using nftables

Destination NAT enables you to redirect traffic on a router to a host that is not directly accessible from the Internet.

The following procedure describes how to redirect incoming traffic sent to port `80` and `443` of the router to the host with the `192.0.2.1` IP address.

**Procedure**

1. Create a table:

```bash  
# nft add table nat
```

2. Add the `prerouting` and `postrouting` chains to the table:

```bash  
# nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }  
# nft add chain nat postrouting { type nat hook postrouting priority 100 \; }
```

**IMPORTANT**

Even if you do not add a rule to the `postrouting` chain, the `nftables` framework requires this chain to match outgoing packet replies.

Note that you must pass the `--` option to the `nft` command to avoid that the shell interprets the negative priority value as an option of the `nft` command.

3. Add a rule to the `prerouting` chain that redirects incoming traffic on the `ens3` interface sent to port `80` and `443` to the host with the `192.0.2.1` IP:

```bash  
# nft add rule nat prerouting ofname ens3 tcp dport { 80, 443 } dnat to 192.0.2.1
```
4. Depending on your environment, add either a SNAT or masquerading rule to change the source address:

   a. If the `ens3` interface used dynamic IP addresses, add a masquerading rule:

   ```
   # nft add rule nat postrouting oifname "ens3" masquerade
   ```

   b. If the `ens3` interface uses a static IP address, add a SNAT rule. For example, if the `ens3` uses the `198.51.100.1` IP address:

   ```
   # nft add rule nat postrouting oifname "ens3" snat to 198.51.100.1
   ```

Additional resources

- The different NAT types: masquerading, source NAT, destination NAT, and redirect

8.4.5. Configuring a redirect using nftables

The redirect feature is a special case of destination network address translation (DNAT) that redirects packets to the local machine depending on the chain hook.

The following procedure describes how to redirect incoming and forwarded traffic sent to port 22 of the local host to port 2222.

**Procedure**

1. Create a table:

   ```
   # nft add table nat
   ```

2. Add the `prerouting` chain to the table:

   ```
   # nft -- add chain nat prerouting { type nat hook prerouting priority -100 \; }
   ```

   Note that you must pass the `--` option to the `nft` command to avoid that the shell interprets the negative priority value as an option of the `nft` command.

3. Add a rule to the `prerouting` chain that redirects incoming traffic on port 22 to port 2222:

   ```
   # nft add rule nat prerouting tcp dport 22 redirect to 2222
   ```

Additional resources

- The different NAT types: masquerading, source NAT, destination NAT, and redirect

**8.5. USING SETS IN NFTABLES COMMANDS**

The nftables framework natively supports sets. You can use sets, for example, if a rule should match multiple IP addresses, port numbers, interfaces, or any other match criteria.

**8.5.1. Using anonymous sets in nftables**
An anonymous set contain comma-separated values enclosed in curly brackets, such as \{ 22, 80, 443 \}, that you use directly in a rule. You can also use anonymous sets also for IP addresses or any other match criteria.

The drawback of anonymous sets is that if you want to change the set, you must replace the rule. For a dynamic solution, use named sets as described in Using named sets in nftables.

Prerequisites

- The example_chain chain and the example_table table in the inet family exists.

Procedure

1. For example, to add a rule to example_chain in example_table that allows incoming traffic to port 22, 80, and 443:

   ```
   # nft add rule inet example_table example_chain tcp dport \{ 22, 80, 443 \} accept
   ```

2. Optionally, display all chains and their rules in example_table:

   ```
   # nft list table inet example_table
   table inet example_table {
     chain example_chain {
       type filter hook input priority filter; policy accept;
       tcp dport \{ ssh, http, https \} accept
     }
   }
   ```

8.5.2. Using named sets in nftables

The nftables framework supports mutable named sets. A named set is a list or range of elements that you can use in multiple rules within a table. Another benefit over anonymous sets is that you can update a named set without replacing the rules that use the set.

When you create a named set, you must specify the type of elements the set contains. You can set the following types:

- `ipv4_addr` for a set that contains IPv4 addresses or ranges, such as `192.0.2.1` or `192.0.2.0/24`.
- `ipv6_addr` for a set that contains IPv6 addresses or ranges, such as `2001:db8:1::1` or `2001:db8:1::1/64`.
- `ether_addr` for a set that contains a list of media access control (MAC) addresses, such as `52:54:00:6b:66:42`.
- `inet_proto` for a set that contains a list of Internet protocol types, such as `tcp`.
- `inet_service` for a set that contains a list of Internet services, such as `ssh`.
- `mark` for a set that contains a list of packet marks. Packet marks can be any positive 32-bit integer value (0 to 2147483647).

Prerequisites

- The example_chain chain and the example_table table exists.
Procedure

1. Create an empty set. The following examples create a set for IPv4 addresses:
   - To create a set that can store multiple individual IPv4 addresses:
     ```
     # nft add set inet example_table example_set { type ipv4_addr ; }
     ```
   - To create a set that can store IPv4 address ranges:
     ```
     # nft add set inet example_table example_set { type ipv4_addr ; flags interval ; }
     ```

   **IMPORTANT**
   To avoid that the shell interprets the semicolons as the end of the command, you must escape the semicolons with a backslash.

2. Optionally, create rules that use the set. For example, the following command adds a rule to the `example_chain` in the `example_table` that will drop all packets from IPv4 addresses in `example_set`:
   ```
   # nft add rule inet example_table example_chain ip saddr @example_set drop
   ```
   Because `example_set` is still empty, the rule has currently no effect.

3. Add IPv4 addresses to `example_set`:
   - If you create a set that stores individual IPv4 addresses, enter:
     ```
     # nft add element inet example_table example_set { 192.0.2.1, 192.0.2.2 }
     ```
   - If you create a set that stores IPv4 ranges, enter:
     ```
     # nft add element inet example_table example_set { 192.0.2.0-192.0.2.255 }
     ```

   When you specify an IP address range, you can alternatively use the Classless Inter-Domain Routing (CIDR) notation, such as `192.0.2.0/24` in the above example.

8.5.3. Additional resources

   - The `Sets` section in the `nft(8)` man page

8.6. USING VERDICT MAPS IN NFTABLES COMMANDS

Verdict maps, which are also known as dictionaries, enable `nft` to perform an action based on packet information by mapping match criteria to an action.

8.6.1. Using anonymous maps in nftables

An anonymous map is a `{ match_criteria : action }` statement that you use directly in a rule. The statement can contain multiple comma-separated mappings.
The drawback of an anonymous map is that if you want to change the map, you must replace the rule. For a dynamic solution, use named maps as described in Using named maps in nftables.

The example describes how to use an anonymous map to route both TCP and UDP packets of the IPv4 and IPv6 protocol to different chains to count incoming TCP and UDP packets separately.

Procedure

1. Create the example_table:
   ```
   # nft add table inet example_table
   ```

2. Create the tcp_packets chain in example_table:
   ```
   # nft add chain inet example_table tcp_packets
   ```

3. Add a rule to tcp_packets that counts the traffic in this chain:
   ```
   # nft add rule inet example_table tcp_packets counter
   ```

4. Create the udp_packets chain in example_table:
   ```
   # nft add chain inet example_table udp_packets
   ```

5. Add a rule to udp_packets that counts the traffic in this chain:
   ```
   # nft add rule inet example_table udp_packets counter
   ```

6. Create a chain for incoming traffic. For example, to create a chain named incoming_traffic in example_table that filters incoming traffic:
   ```
   # nft add chain inet example_table incoming_traffic { type filter hook input priority 0 ; } 
   ```

7. Add a rule with an anonymous map to incoming_traffic:
   ```
   # nft add rule inet example_table incoming_traffic ip protocol vmap { tcp : jump tcp_packets, udp : jump udp_packets }
   ```

   The anonymous map distinguishes the packets and sends them to the different counter chains based on their protocol.

8. To list the traffic counters, display example_table:
   ```
   # nft list table inet example_table
   table inet example_table {
   chain tcp_packets {
     counter packets 36379 bytes 2103816
   }
   chain udp_packets {
     counter packets 10 bytes 1559
   }
   ```
chain incoming_traffic {
    type filter hook input priority filter; policy accept;
    ip protocol vmap { tcp : jump tcp_packets, udp : jump udp_packets }
}

The counters in the tcp_packets and udp_packets chain display both the number of received packets and bytes.

8.6.2. Using named maps in nftables

The nftables framework supports named maps. You can use these maps in multiple rules within a table. Another benefit over anonymous maps is that you can update a named map without replacing the rules that use it.

When you create a named map, you must specify the type of elements:

- **ipv4_addr** for a map whose match part contains an IPv4 address, such as \texttt{192.0.2.1}.
- **ipv6_addr** for a map whose match part contains an IPv6 address, such as \texttt{2001:db8:1::1}.
- **ether_addr** for a map whose match part contains a media access control (MAC) address, such as \texttt{52:54:00:6b:66:42}.
- **inet_proto** for a map whose match part contains an Internet protocol type, such as \texttt{tcp}.
- **inet_service** for a map whose match part contains an Internet services name port number, such as \texttt{ssh} or \texttt{22}.
- **mark** for a map whose match part contains a packet mark. A packet mark can be any positive 32-bit integer value (0 to \texttt{2147483647}).
- **counter** for a map whose match part contains a counter value. The counter value can be any positive 64-bit integer value.
- **quota** for a map whose match part contains a quota value. The quota value can be any positive 64-bit integer value.

The example describes how to allow or drop incoming packets based on their source IP address. Using a named map, you require only a single rule to configure this scenario while the IP addresses and actions are dynamically stored in the map. The procedure also describes how to add and remove entries from the map.

Procedure

1. Create a table. For example, to create a table named \texttt{example_table} that processes IPv4 packets:

   \begin{verbatim}
   # nft add table ip example_table
   \end{verbatim}

2. Create a chain. For example, to create a chain named \texttt{example_chain} in \texttt{example_table}:

   \begin{verbatim}
   # nft add chain ip example_table example_chain { type filter hook input priority 0 ; }
   \end{verbatim}
IMPORTANT

To avoid that the shell interprets the semicolons as the end of the command, you must escape the semicolons with a backslash.

3. Create an empty map. For example, to create a map for IPv4 addresses:

   ```sh
   # nft add map ip example_table example_map { type ipv4_addr : verdict ; }
   ```

4. Create rules that use the map. For example, the following command adds a rule to `example_chain` in `example_table` that applies actions to IPv4 addresses which are both defined in `example_map`:

   ```sh
   # nft add rule example_table example_chain ip saddr vmap @example_map
   ```

5. Add IPv4 addresses and corresponding actions to `example_map`:

   ```sh
   # nft add element ip example_table example_map { 192.0.2.1 : accept, 192.0.2.2 : drop }
   ```

   This example defines the mappings of IPv4 addresses to actions. In combination with the rule created above, the firewall accepts packet from 192.0.2.1 and drops packets from 192.0.2.2.

6. Optionally, enhance the map by adding another IP address and action statement:

   ```sh
   # nft add element ip example_table example_map { 192.0.2.3 : accept }
   ```

7. Optionally, remove an entry from the map:

   ```sh
   # nft delete element ip example_table example_map { 192.0.2.1 }
   ```

8. Optionally, display the rule set:

   ```sh
   # nft list ruleset table ip example_table { map example_map { type ipv4_addr : verdict elements = { 192.0.2.2 : drop, 192.0.2.3 : accept } } chain example_chain { type filter hook input priority filter; policy accept; ip saddr vmap @example_map } }
   ```

8.6.3. Additional resources

- The Maps section in the `nft(8)` man page

8.7. CONFIGURING PORT FORWARDING USING NFTABLES
Port forwarding enables administrators to forward packets sent to a specific destination port to a different local or remote port.

For example, if your web server does not have a public IP address, you can set a port forwarding rule on your firewall that forwards incoming packets on port 80 and 443 on the firewall to the web server. With this firewall rule, users on the internet can access the web server using the IP or host name of the firewall.

8.7.1. Forwarding incoming packets to a different local port

This section describes an example of how to forward incoming IPv4 packets on port 8022 to port 22 on the local system.

Procedure

1. Create a table named nat with the ip address family:

   ```
   # nft add table ip nat
   ```

2. Add the prerouting and postrouting chains to the table:

   ```
   # nft -- add chain ip nat prerouting { type nat hook prerouting priority -100 \; }
   ```

   **NOTE**
   
   Pass the -- option to the nft command to avoid that the shell interprets the negative priority value as an option of the nft command.

3. Add a rule to the prerouting chain that redirects incoming packets on port 8022 to the local port 22:

   ```
   # nft add rule ip nat prerouting tcp dport 8022 redirect to :22
   ```

8.7.2. Forwarding incoming packets on a specific local port to a different host

You can use a destination network address translation (DNAT) rule to forward incoming packets on a local port to a remote host. This enables users on the Internet to access a service that runs on a host with a private IP address.

The procedure describes how to forward incoming IPv4 packets on the local port 443 to the same port number on the remote system with the 192.0.2.1 IP address.

Prerequisites

- You are logged in as the root user on the system that should forward the packets.

Procedure

1. Create a table named nat with the ip address family:

   ```
   # nft add table ip nat
   ```
2. Add the **prerouting** and **postrouting** chains to the table:

```bash
# nft -- add chain ip nat prerouting { type nat hook prerouting priority -100 \; }
# nft add chain ip nat postrouting { type nat hook postrouting priority 100 \; }
```

**NOTE**
Pass the -- option to the `nft` command to avoid that the shell interprets the negative priority value as an option of the `nft` command.

3. Add a rule to the **prerouting** chain that redirects incoming packets on port **443** to the same port on **192.0.2.1**:

```bash
# nft add rule ip nat prerouting tcp dport 443 dnat to 192.0.2.1
```

4. Add a rule to the **postrouting** chain to masquerade outgoing traffic:

```bash
# nft add rule ip nat postrouting daddr 192.0.2.1 masquerade
```

5. Enable packet forwarding:

```bash
# echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
# sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
```

### 8.8. USING NFTABLES TO LIMIT THE AMOUNT OF CONNECTIONS

You can use **nftables** to limit the number of connections or to block IP addresses that attempt to establish a given amount of connections to prevent them from using too many system resources.

#### 8.8.1. Limiting the number of connections using nftables

The **ct count** parameter of the **nft** utility enables administrators to limit the number of connections. The procedure describes a basic example of how to limit incoming connections.

**Prerequisites**
- The base **example_chain** in **example_table** exists.

**Procedure**

1. Create a dynamic set for IPv4 addresses:

```bash
# nft add set inet example_table example_meter { type ipv4_addr\; flags dynamic \;}
```

2. Add a rule that allows only two simultaneous connections to the SSH port (22) from an IPv4 address and rejects all further connections from the same IP:

```bash
# nft add rule ip example_table example_chain tcp dport ssh meter example_meter { ip saddr \ct count over 2 \} counter reject
```

3. Optionally, display the set created in the previous step:
The `elements` entry displays addresses that currently match the rule. In this example, `elements` lists IP addresses that have active connections to the SSH port. Note that the output does not display the number of active connections or if connections were rejected.

### 8.8.2. Blocking IP addresses that attempt more than ten new incoming TCP connections within one minute

This section explains how you temporarily block hosts that are establishing more than ten IPv4 TCP connections within one minute.

**Procedure**

1. Create the `filter` table with the `ip` address family:

   ```sh
   # nft add table ip filter
   ```

2. Add the `input` chain to the `filter` table:

   ```sh
   # nft add chain ip filter input { type filter hook input priority 0 \; }
   ```

3. Add a rule that drops all packets from source addresses that attempt to establish more than ten TCP connections within one minute:

   ```sh
   # nft add rule ip filter input ip protocol tcp ct state new, untracked meter ratemeter { ip saddr timeout 5m limit rate over 10/minute } drop
   ```

   The `timeout 5m` parameter defines that `nftables` automatically removes entries after five minutes to prevent that the meter fills up with stale entries.

**Verification**

- To display the meter’s content, enter:

  ```sh
  # nft list meter ip filter ratemeter
  table ip filter {
    meter ratemeter {
      type ipv4_addr
      size 65535
      flags dynamic,timeout
      elements = { 192.0.2.1 limit rate over 10/minute timeout 5m expires 4m58s224ms }
    }
  }
  ```
8.9. DEBUGGING NFTABLES RULES

The nftables framework provides different options for administrators to debug rules and if packets match them. This section describes these options.

8.9.1. Creating a rule with a counter

To identify if a rule is matched, you can use a counter. This section describes how to create a new rule with a counter.

- For more information on a procedure that adds a counter to an existing rule, see Adding a counter to an existing rule in Configuring and managing networking

Prerequisites

- The chain to which you want to add the rule exists.

Procedure

1. Add a new rule with the counter parameter to the chain. The following example adds a rule with a counter that allows TCP traffic on port 22 and counts the packets and traffic that match this rule:

   ```
   # nft add rule inet example_table example_chain tcp dport 22 counter accept
   ```

2. To display the counter values:

   ```
   # nft list ruleset
table inet example_table {
    chain example_chain {
      type filter hook input priority filter; policy accept;
tcp dport ssh counter packets 6872 bytes 105448565 accept
    }
  }
   ```

8.9.2. Adding a counter to an existing rule

To identify if a rule is matched, you can use a counter. This section describes how to add a counter to an existing rule.

- For more information on a procedure that adds a new rule with a counter, see Creating a rule with the counter in Configuring and managing networking

Prerequisites

- The rule to which you want to add the counter exists.

Procedure

1. Display the rules in the chain including their handles:

   ```
   # nft --handle list chain inet example_table example_chain
table inet example_table {
  ```
2. Add the counter by replacing the rule but with the `counter` parameter. The following example replaces the rule displayed in the previous step and adds a counter:

```bash
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 counter accept
```

3. To display the counter values:

```bash
# nft list ruleset
```

```
inet example_table {
  chain example_chain {
    type filter hook input priority filter; policy accept;
    tcp dport ssh counter packets 6872 bytes 10548565 accept
  }
}
```

### 8.9.3. Monitoring packets that match an existing rule

The tracing feature in `nftables` in combination with the `nft monitor` command enables administrators to display packets that match a rule. The procedure describes how to enable tracing for a rule as well as monitoring packets that match this rule.

#### Prerequisites

- The rule to which you want to add the counter exists.

#### Procedure

1. Display the rules in the chain including their handles:

```bash
# nft --handle list chain inet example_table example_chain
```

```
inet example_table {
  chain example_chain {
    type filter hook input priority filter; policy accept;
    tcp dport ssh accept # handle 4
  }
}
```

2. Add the tracing feature by replacing the rule but with the `meta nftrace set 1` parameters. The following example replaces the rule displayed in the previous step and enables tracing:

```bash
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 meta nftrace set 1 accept
```

3. Use the `nft monitor` command to display the tracing. The following example filters the output of the command to display only entries that contain `inet example_table example_chain`:

```bash
# nft monitor | grep "inet example_table example_chain"
```
8.10. BACKING UP AND RESTORING THE NFTABLES RULE SET

This section describes how to backup nftables rules to a file, as well as restoring rules from a file.

Administrators can use a file with the rules to, for example, transfer the rules to a different server.

8.10.1. Backing up the nftables rule set to a file

This section describes how to back up the nftables rule set to a file.

Procedure

- To backup nftables rules:
  - In a format produced by nft list ruleset format:

    ```
    # nft list ruleset > file.nft
    ```
  - In JSON format:

    ```
    # nft -j list ruleset > file.json
    ```

8.10.2. Restoring the nftables rule set from a file

This section describes how to restore the nftables rule set.

Procedure

- To restore nftables rules:
  - If the file to restore is in the format produced by nft list ruleset or contains nft commands directly:

    ```
    # nft -f file.nft
    ```
If the file to restore is in JSON format:

```bash
# nft -j -f file.json
```

8.11. ADDITIONAL RESOURCES

- Using nftables in Red Hat Enterprise Linux 8
- What comes after iptables? Its successor, of course: nftables
- Firewalld: The Future is nftables
CHAPTER 9. SECURING NETWORK SERVICES

Red Hat Enterprise Linux 8 supports many different types of network servers. Their network services can expose the system security to risks of various types of attacks, such as denial of service attacks (DoS), distributed denial of service attacks (DDoS), script vulnerability attacks, and buffer overflow attacks.

To increase the system security against attacks, it is important to monitor active network services that you use. For example, when a network service is running on a machine, its daemon listens for connections on network ports, and this can reduce the security. To limit exposure to attacks over the network, all services that are unused should be turned off.

9.1. SECURING THE RPCBIND SERVICE

The rpcbind service is a dynamic port-assignment daemon for remote procedure calls (RPC) services such as Network Information Service (NIS) and Network File System (NFS). Because it has weak authentication mechanisms and can assign a wide range of ports for the services it controls, it is important to secure rpcbind.

You can secure rpcbind by restricting access to all networks and defining specific exceptions using firewall rules on the server.

NOTE

- The rpcbind service is required on NFSv2 and NFSv3 servers.
- NFSv4 does not require the rpcbind service to listen on the network.

Prerequisites

- The rpcbind package is installed.
- The firewalld package is installed and the service is running.

Procedure

1. Add firewall rules, for example:

   - Limit TCP connection and accept packages only from the 192.168.0.0/24 host via the 111 port:

     ```
     # firewall-cmd --add-rich-rule='rule family="ipv4" port port="111" protocol="tcp" source address="192.168.0.0/24" invert="True" drop'
     ```

   - Limit TCP connection and accept packages only from local host via the 111 port:

     ```
     # firewall-cmd --add-rich-rule='rule family="ipv4" port port="111" protocol="tcp" source address="127.0.0.1" accept'
     ```

   - Limit UDP connection and accept packages only from the 192.168.0.0/24 host via the 111 port:

     ```
     # firewall-cmd --permanent --add-rich-rule='rule family="ipv4" port port="111" protocol="udp" source address="192.168.0.0/24" invert="True" drop'
     ```
To make the firewall settings permanent, use the `--permanent` option when adding firewall rules.

2. Reload the firewall to apply the new rules:

```
# firewall-cmd --reload
```

**Verification steps**

- List the firewall rules:

```
# firewall-cmd --list-rich-rule
rule family="ipv4" port port="111" protocol="tcp" source address="192.168.0.0/24" invert="True" drop
rule family="ipv4" port port="111" protocol="tcp" source address="127.0.0.1" accept
rule family="ipv4" port port="111" protocol="udp" source address="192.168.0.0/24" invert="True" drop
```

**Additional resources**

- For more information about NFSv4-only servers, see the Configuring an NFSv4-only server section.
- Using and configuring firewalld

## 9.2. SECURING THE RPC.MOUNTD SERVICE

The `rpc.mountd` daemon implements the server side of the NFS mount protocol. The NFS mount protocol is used by NFS version 2 (RFC 1904) and NFS version 3 (RFC 1813).

You can secure the `rpc.mountd` service by adding firewall rules to the server. You can restrict access to all networks and define specific exceptions using firewall rules.

**Prerequisites**

- The `rpc.mountd` package is installed.
- The `firewalld` package is installed and the service is running.

**Procedure**

1. Add firewall rules to the server, for example:

   - Accept `mountd` connections from the `192.168.0.0/24` host:

     ```
     # firewall-cmd --add-rich-rule 'rule family="ipv4" service name="mountd" source address="192.168.0.0/24" invert="True" drop'
     ```

   - Accept `mountd` connections from the local host:

     ```
     # firewall-cmd --permanent --add-rich-rule 'rule family="ipv4" source address="127.0.0.1" service name="mountd" accept'
     ```
To make the firewall settings permanent, use the \texttt{--permanent} option when adding firewall rules.

2. Reload the firewall to apply the new rules:

\begin{verbatim}
# firewall-cmd --reload
\end{verbatim}

**Verification steps**

- List the firewall rules:

\begin{verbatim}
# firewall-cmd --list-rich-rule
rule family="ipv4" service name="mountd" source address="192.168.0.0/24" invert="True" drop
rule family="ipv4" source address="127.0.0.1" service name="mountd" accept
\end{verbatim}

**Additional resources**

- Using and configuring firewalld

### 9.3. SECURING THE NFS SERVICE

You can secure Network File System version 4 (NFSv4) by authenticating and encrypting all file system operations using Kerberos. When using NFSv4 with Network Address Translation (NAT) or a firewall, you can turn off the delegations by modifying the \texttt{/etc/default/nfs} file. Delegation is a technique by which the server delegates the management of a file to a client. In contrast, NFSv2 and NFSv3 do not use Kerberos for locking and mounting files.

The NFS service sends the traffic using TCP in all versions of NFS. The service supports Kerberos user and group authentication, as part of the \texttt{RPCSEC_GSS} kernel module.

NFS allows remote hosts to mount file systems over a network and interact with those file systems as if they are mounted locally. You can merge the resources on centralized servers and additionally customize NFS mount options in the \texttt{/etc/nfsmount.conf} file when sharing the file systems.

#### 9.3.1. Export options for securing an NFS server

The NFS server determines a list structure of directories and hosts about which file systems to export to which hosts in the \texttt{/etc/exports} file.
**WARNING**

Extra spaces in the syntax of the exports file can lead to major changes in the configuration.

In the following example, the `/tmp/nfs/` directory is shared with the `bob.example.com` host and has read and write permissions.

```
/tmp/nfs/ bob.example.com(rw)
```

The following example is the same as the previous one but shares the same directory to the `bob.example.com` host with read-only permissions and shares it to the *world* with read and write permissions due to a single space character after the hostname.

```
/tmp/nfs/ bob.example.com (rw)
```

You can check the shared directories on your system by entering the `showmount -e <hostname>` command.

Use the following export options on the `/etc/exports` file:

**WARNING**

Export an entire file system because exporting a subdirectory of a file system is not secure. An attacker can possibly access the unexported part of a partially-exported file system.

**ro**

Use the `ro` option to export the NFS volume as read-only.

**rw**

Use the `rw` option to allow read and write requests on the NFS volume. Use this option cautiously because allowing write access increases the risk of attacks.

**NOTE**

If your scenario requires to mount the directories with the `rw` option, make sure they are not writable for all users to reduce possible risks.

**root_squash**

Use the `root_squash` option to map requests from *uid/gid* 0 to the anonymous *uid/gid*. This does not apply to any other *uids* or *gids* that might be equally sensitive, such as the *bin* user or the *staff* group.
no_root_squash

Use the no_root_squash option to turn off root squashing. By default, NFS shares change the root user to the nobody user, which is an unprivileged user account. This changes the owner of all the root created files to nobody, which prevents the uploading of programs with the setuid bit set. When using the no_root_squash option, remote root users can change any file on the shared file system and leave applications infected by trojans for other users.

secure

Use the secure option to restrict exports to reserved ports. By default, the server allows client communication only through reserved ports. However, it is easy for anyone to become a root user on a client on many networks, so it is rarely safe for the server to assume that communication through a reserved port is privileged. Therefore the restriction to reserved ports is of limited value; it is better to rely on Kerberos, firewalls, and restriction of exports to particular clients.

Additionally, consider the following best practices when exporting an NFS server:

- Exporting home directories is a risk because some applications store passwords in plain text or in a weakly encrypted format. You can reduce the risk by reviewing and improving the application code.
- Some users do not set passwords on SSH keys which again leads to risks with home directories. You can reduce these risks by enforcing the use of passwords or using Kerberos.
- Restrict the NFS exports only to required clients. Use the showmount -e command on the NFS server to review what the server is exporting. Do not export anything that is not specifically required.
- Do not allow unnecessary users to log in to a server to reduce the risk of attacks. You can periodically check who and what can access the server.

Additional resources

- Secure NFS with Kerberos when using Red Hat Identity Management
- exports(5) and nfs(5) man pages

9.3.2. Mount options for securing an NFS client

You can pass the following options to the mount command to increase the security of NFS-based clients:

nosuid

Use the nosuid option to disable the set-user-identifier or set-group-identifier bits. This prevents remote users from gaining higher privileges by running a setuid program and you can use this option opposite to setuid option.

noexec

Use the noexec option to disable all executable files on the client. Use this to prevent users from accidentally executing files placed in the shared file system.

dev

Use the nodev option to prevent the client’s processing of device files as a hardware device.
Use the `resvport` option to restrict communication to a reserved port and you can use a privileged source port to communicate with the server. The reserved ports are reserved for privileged users and processes such as the `root` user.

**sec**

Use the `sec` option on the NFS server to choose the RPCGSS security flavor for accessing files on the mount point. Valid security flavors are `none`, `sys`, `krb5`, `krb5i`, and `krb5p`.

**IMPORTANT**

The MIT Kerberos libraries provided by the `krb5-libs` package do not support the Data Encryption Standard (DES) algorithm in new deployments. DES is deprecated and disabled by default in Kerberos libraries because of security and compatibility reasons. Use newer and more secure algorithms instead of DES, unless your environment requires DES for compatibility reasons.

### 9.3.3. Securing NFS with firewall

To secure the firewall on an NFS server, keep only the required ports open. Do not use the NFS connection port numbers for any other service.

**Prerequisites**

- The `nfs-utils` package is installed.
- The `firewalld` package is installed and running.

**Procedure**

- On NFSv4, the firewall must open TCP port **2049**.
- On NFSv3, open four additional ports with **2049**:
  1. `rpcbind` service assigns the NFS ports dynamically, which might cause problems when creating firewall rules. To simplify this process, use the `/etc/nfs.conf` file to specify which ports to use:
     a. Set TCP and UDP port for `mountd (rpc.mountd)` in the `[mountd]` section in `port=<value>` format.
     b. Set TCP and UDP port for `statd (rpc.statd)` in the `[statd]` section in `port=<value>` format.
  2. Set the TCP and UDP port for the NFS lock manager (`nlockmgr`) in the `/etc/nfs.conf` file:
     a. Set TCP port for `nlockmgr (rpc.statd)` in the `[lockd]` section in `port=value` format. Alternatively, you can use the `nlm_tcpport` option in the `/etc/modprobe.d/lockd.conf` file.
     b. Set UDP port for `nlockmgr (rpc.statd)` in the `[lockd]` section in `udp-port=value` format. Alternatively, you can use the `nlm_udpport` option in the `/etc/modprobe.d/lockd.conf` file.

**Verification steps**

- List the active ports and RPC programs on the NFS server:
$ rpcinfo -p

Additional resources

- Secure NFS with Kerberos when using Red Hat Identity Management
- exports(5) and nfs(5) man pages

9.4. SECURING THE FTP SERVICE

You can use the File Transfer Protocol (FTP) to transfer files over a network. Because all FTP transactions with the server, including user authentication, are unencrypted, you should ensure it is configured securely.

RHEL 8 provides two FTP servers:

- Red Hat Content Accelerator (tux) - a kernel-space web server with FTP capabilities.
- Very Secure FTP Daemon (vsftpd) - a standalone, security-oriented implementation of the FTP service.

The following security guidelines are for setting up the vsftpd FTP service.

9.4.1. Securing the FTP greeting banner

When a user connects to the FTP service, FTP shows a greeting banner, which by default includes version information that could be useful for attackers to identify weaknesses in a system. You can prevent the attackers from accessing this information by changing the default banner.

You can define a custom banner by editing the /etc/banners/ftp.msg file to either directly include a single-line message, or to refer to a separate file, which can contain a multi-line message.

Procedure

- To define a single line message, add the following option to the /etc/vsftpd/vsftpd.conf file:

  ftpd_banner=Hello, all activity on ftp.example.com is logged.

- To define a message in a separate file:
  - Create a .msg file which contains the banner message, for example /etc/banners/ftp.msg:

    ############ Hello, all activity on ftp.example.com is logged. ############

    To simplify the management of multiple banners, place all banners into the /etc/banners/ directory.
  - Add the path to the banner file to the banner_file option in the /etc/vsftpd/vsftpd.conf file:

    banner_file=/etc/banners/ftp.msg

Verification
Display the modified banner:

```
$ ftp localhost
Trying ::1…
Connected to localhost (::1).
Hello, all activity on ftp.example.com is logged.
```

### 9.4.2. Preventing anonymous access and uploads in FTP

By default, installing the `vsftpd` package creates the `/var/ftp/` directory and a directory tree for anonymous users with read-only permissions on the directories. Because anonymous users can access the data, do not store sensitive data in these directories.

To increase the security of the system, you can configure the FTP server to allow anonymous users to upload files to a specific directory and prevent anonymous users from reading data. In the following procedure, the anonymous user must be able to upload files in the directory owned by the `root` user but not change it.

**Procedure**

- Create a write–only directory in the `/var/ftp/pub/` directory:

  ```
  # mkdir /var/ftp/pub/upload
  # chmod 730 /var/ftp/pub/upload
  # ls -ld /var/ftp/pub/upload
  ```

- Add the following lines to the `/etc/vsftpd/vsftpd.conf` file:

  ```
  anon_upload_enable=YES
  anonymous_enable=YES
  ```

- Optional: If your system has SELinux enabled and enforcing, enable SELinux boolean attributes `allow_ftpd_anon_write` and `allow_ftpd_full_access`.

  **WARNING**
  
  Allowing anonymous users to read and write in directories might lead to the server becoming a repository for stolen software.

### 9.4.3. Securing user accounts for FTP

FTP transmits usernames and passwords unencrypted over insecure networks for authentication. You can improve the security of FTP by denying system users access to the server from their user accounts.

Perform as many of the following steps as applicable for your configuration.

**Procedure**
• Disable all user accounts in the vsftpd server, by adding the following line to the /etc/vsftpd/vsftpd.conf file:

  `local_enable=NO`

• Disable FTP access for specific accounts or specific groups of accounts, such as the root user and users with sudo privileges, by adding the usernames to the /etc/pam.d/vsftpd PAM configuration file.

• Disable user accounts, by adding the usernames to the /etc/vsftpd/ftpusers file.

9.4.4. Additional resources

• ftpd_selinux(8) man page

9.5. SECURING HTTP SERVERS

9.5.1. Security enhancements in httpd.conf

You can enhance the security of the Apache HTTP server by configuring security options in the /etc/httpd/conf/httpd.conf file.

Always verify that all scripts running on the system work correctly before putting them into production.

Ensure that only the root user has write permissions to any directory containing scripts or Common Gateway Interfaces (CGI). To change the directory ownership to root user with write permissions, enter the following commands:

```
# chown root directory-name
# chmod 755 directory-name
```

In the /etc/httpd/conf/httpd.conf file, you can configure the following options:

FollowSymLinks

This directive is enabled by default and follows symbolic links in the directory.

Indexes

This directive is enabled by default. Disable this directive to prevent visitors from browsing files on the server.

UserDir

This directive is disabled by default because it can confirm the presence of a user account on the system. To activate user directory browsing for all user directories other than /root/, use the UserDir enabled and UserDir disabled root directives. To add users to the list of disabled accounts, add a space-delimited list of users on the UserDir disabled line.

ServerTokens

This directive controls the server response header field which is sent back to clients. You can use the following parameters to customize the information:

ServerTokens Full

provides all available information such as web server version number, server operating system details, installed Apache modules, for example:

```
Apache/2.4.37 (Red Hat Enterprise Linux) MyMod/1.2
```
ServerTokens Full-Release
provides all available information with release versions, for example:

Apache/2.4.37 (Red Hat Enterprise Linux) (Release 41.module+el8.5.0+11772+c8e0c271)

ServerTokens Prod / ServerTokens ProductOnly
provides the web server name, for example:

Apache

ServerTokens Major
provides the web server major release version, for example:

Apache/2

ServerTokens Minor
provides the web server minor release version, for example:

Apache/2.4

ServerTokens Min / ServerTokens Minimal
provides the web server minimal release version, for example:

Apache/2.4.37

ServerTokens OS
provides the web server release version and operating system, for example:

Apache/2.4.37 (Red Hat Enterprise Linux)

Use the ServerTokens Prod option to reduce the risk of attackers gaining any valuable information about your system.

IMPORTANT
Do not remove the IncludesNoExec directive. By default, the Server Side Includes (SSI) module cannot execute commands. Changing this can allow an attacker to enter commands on the system.

Removing httpd modules
You can remove the httpd modules to limit the functionality of the HTTP server. To do so, edit configuration files in the /etc/httpd/conf.modules.d/ or /etc/httpd/conf.d/ directory. For example, to remove the proxy module:

```
echo '# All proxy modules disabled' > /etc/httpd/conf.modules.d/00-proxy.conf
```
Additional resources

- The Apache HTTP server
- Customizing the SELinux policy for the Apache HTTP server

9.5.2. Securing the Nginx server configuration

Nginx is a high-performance HTTP and proxy server. You can harden your Nginx configuration with the following configuration options.

Procedure

- To disable version strings, modify the `server_tokens` configuration option:

```bash
server_tokens off;
```

This option stops displaying additional details such as server version number. This configuration displays only the server name in all requests served by Nginx, for example:

```
$ curl -sI http://localhost | grep Server
Server: nginx
```

- Add extra security headers that mitigate certain known web application vulnerabilities in specific `/etc/nginx/` conf files:
  - For example, the `X-Frame-Options` header option denies any page outside of your domain to frame any content served by Nginx, mitigating clickjacking attacks:
    ```bash
    add_header X-Frame-Options "SAMEORIGIN";
    ```
  - For example, the `x-content-type` header prevents MIME-type sniffing in certain older browsers:
    ```bash
    add_header X-Content-Type-Options nosniff;
    ```
  - For example, the `X-XSS-Protection` header enables Cross-Site Scripting (XSS) filtering, which prevents browsers from rendering potentially malicious content included in a response by Nginx:
    ```bash
    add_header X-XSS-Protection "1; mode=block";
    ```

- You can limit the services exposed to the public and limit what they do and accept from the visitors, for example:

```bash
limit_except GET {
    allow 192.168.1.0/32;
    deny all;
}
```

The snippet will limit access to all methods except `GET` and `HEAD`.

- You can disable HTTP methods, for example:
You can configure SSL to protect the data served by your Nginx web server, consider serving it over HTTPS only. Furthermore, you can generate a secure configuration profile for enabling SSL in your Nginx server using the Mozilla SSL Configuration Generator. The generated configuration ensures that known vulnerable protocols (for example, SSLv2 and SSLv3), ciphers, and hashing algorithms (for example, 3DES and MD5) are disabled. You can also use the SSL Server Test to verify that your configuration meets modern security requirements.

Additional resources
- Mozilla SSL Configuration Generator
- SSL Server Test

9.6. SECURING POSTGRESQL BY LIMITING ACCESS TO AUTHENTICATED LOCAL USERS

PostgreSQL is an object-relational database management system (DBMS). In Red Hat Enterprise Linux, PostgreSQL is provided by the `postgresql-server` package.

You can reduce the risks of attacks by configuring client authentication. The `pg_hba.conf` configuration file stored in the database cluster’s data directory controls the client authentication. Follow the procedure to configure PostgreSQL for host-based authentication.

**Procedure**

1. **Install PostgreSQL:**
   
   ```bash
   # yum install postgresql-server
   ```

2. **Initialize a database storage area using one of the following options:**
   a. **Using the `initdb` utility:**
      
      ```bash
      $ initdb -D /home/postgresql/db1/
      ```
      
      The `initdb` command with the `-D` option creates the directory you specify if it does not already exist, for example `/home/postgresql/db1/`. This directory then contains all the data stored in the database and also the client authentication configuration file.

   b. **Using the `postgresql-setup` script:**
      
      ```bash
      $ postgresql-setup --initdb
      ```
      
      By default, the script uses the `/var/lib/pgsql/data/` directory. This script helps system administrators with basic database cluster administration.

3. **To allow any authenticated local users to access any database with their usernames, modify the following line in the `pg_hba.conf` file:**
4. Restart the database to apply the changes:

```bash
# systemctl restart postgresql
```

The previous command updates the database and also verifies the syntax of the configuration file.

9.7. SECURING THE MEMCACHED SERVICE

Memcached is an open source, high-performance, distributed memory object caching system. It can improve the performance of dynamic web applications by lowering database load.

Memcached is an in-memory key-value store for small chunks of arbitrary data, such as strings and objects, from results of database calls, API calls, or page rendering. Memcached allows assigning memory from underutilized areas to applications that require more memory.

In 2018, vulnerabilities of DDoS amplification attacks by exploiting Memcached servers exposed to the public internet were discovered. These attacks took advantage of Memcached communication using the UDP protocol for transport. The attack was effective because of the high amplification ratio where a request with the size of a few hundred bytes could generate a response of a few megabytes or even hundreds of megabytes in size.

In most situations, the `memcached` service does not need to be exposed to the public Internet. Such exposure may have its own security problems, allowing remote attackers to leak or modify information stored in Memcached.

Follow the section to harden the system using Memcached service against possible DDoS attacks.

9.7.1. Hardening Memcached against DDoS

To mitigate security risks, perform as many of the following steps as applicable for your configuration.

**Procedure**

- Configure a firewall in your LAN. If your Memcached server should be accessible only in your local network, do not route external traffic to ports used by the `memcached` service. For example, remove the default port 11211 from the list of allowed ports:

  ```bash
  # firewall-cmd --remove-port=11211/udp
  # firewall-cmd --runtime-to-permanent
  ```

- If you use a single Memcached server on the same machine as your application, set up `memcached` to listen to localhost traffic only. Modify the `OPTIONS` value in the `/etc/sysconfig/memcached` file:

  ```text
  OPTIONS="-l 127.0.0.1,::1"
  ```

- Enable Simple Authentication and Security Layer (SASL) authentication:
1. Modify or add the `/etc/sasl2/memcached.conf` file:

```
sasldb_path: /path.to/memcached.sasldb
```

2. Add an account in the SASL database:

```
# saslpasswd2 -a memcached -c cacheuser -f /path.to/memcached.sasldb
```

3. Ensure that the database is accessible for the `memcached` user and group:

```
# chown memcached:memcached /path.to/memcached.sasldb
```

4. Enable SASL support in Memcached by adding the `-S` value to the `OPTIONS` parameter in the `/etc/sysconfig/memcached` file:

```
OPTIONS="-S"
```

5. Restart the Memcached server to apply the changes:

```
# systemctl restart memcached
```

6. Add the username and password created in the SASL database to the Memcached client configuration of your application.

- Encrypt communication between Memcached clients and servers with TLS:

  1. Enable encrypted communication between Memcached clients and servers with TLS by adding the `-Z` value to the `OPTIONS` parameter in the `/etc/sysconfig/memcached` file:

```
OPTIONS="-Z"
```

  2. Add the certificate chain file path in the PEM format using the `-o ssl_chain_cert` option.

  3. Add a private key file path using the `-o ssl_key` option.