



Red Hat Enterprise Linux 8

Configuring and managing networking

A guide to configuring and managing networking in Red Hat Enterprise Linux 8

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Abstract

This document describes how to manage networking on Red Hat Enterprise Linux 8.

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PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

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CHAPTER 1. OVERVIEW OF NETWORKING TOPICS



NOTE

The following sections mention some commands to be performed. The commands that need to be entered by the **root** user have **~]#** in the prompt, while the commands that can be performed by a regular user, have **~]\$** in their prompt.

1.1. IP VERSUS NON-IP NETWORKS

A network is a system of interconnected devices that can communicate sharing information and resources, such as files, printers, applications, and Internet connection. Each of these devices has a unique Internet Protocol (IP) address to send and receive messages between two or more devices using a set of rules called protocol.

Categories of network communication

IP networks

Networks that communicate through IP addresses. An IP network is implemented in the Internet and most internal networks. Ethernet, cable modems, DSL modems, dial-up modems, wireless networks, and VPN connections are typical examples.

non-IP networks

Networks that are used to communicate through a lower layer rather than the transport layer. Note that these networks are rarely used. InfiniBand is a non-IP network.

1.2. STATIC VERSUS DYNAMIC IP ADDRESSING

Static IP addressing

When a device is assigned a static IP address, the address does not change over time unless changed manually. Use static **IP** addressing if you want:

- To ensure network address consistency for servers such as **DNS**, and authentication servers.
- To use out-of-band management devices that work independently of other network infrastructure.

All the configuration tools listed in [Section 6.1, "Selecting network configuration methods"](#) allow assigning static **IP** addresses manually.

Dynamic IP addressing

When a device is assigned a dynamic IP address, the address changes over time. For this reason, it is recommended for devices that connect to the network occasionally because IP address might be changed after rebooting the machine.

Dynamic IP addresses are more flexible, easier to set up and administer. The **Dynamic Host Control Protocol (DHCP)** is a traditional method of dynamically assigning network configurations to hosts.



NOTE

There is no strict rule defining when to use static or dynamic IP address. It depends on user's needs, preferences and the network environment.

1.3. CONFIGURING THE DHCP CLIENT BEHAVIOR

A Dynamic Host Configuration Protocol (DHCP) client requests the dynamic IP address and corresponding configuration information from a DHCP server each time a client connects to the network.

Configuring the DHCP timeout

When a **DHCP** connection is started, a dhcp client requests an IP address from a **DHCP** server. The time that a dhcp client waits for this request to be completed is 45 seconds by default. This procedure describes how you can configure the **ipv4.dhcp-timeout** property using the **nmcli** tool or the **IPV4_DHCP_TIMEOUT** option in the **/etc/sysconfig/network-scripts/ifcfg-*ifname*** file. For example, using **nmcli**:

```
~]# nmcli connection modify enp1s0 ipv4.dhcp-timeout 10
```

If an address cannot be obtained during this interval, the IPv4 configuration fails. The whole connection may fail, too, and this depends on the **ipv4.may-fail** property:

- If **ipv4.may-fail** is set to **yes** (default), the state of the connection depends on IPv6 configuration:
 - a. If the IPv6 configuration is enabled and successful, the connection is activated, but the IPv4 configuration can never be retried again.
 - b. If the IPv6 configuration is disabled or does not get configured, the connection fails.
- If **ipv4.may-fail** is set to **no** the connection is deactivated. In this case:
 - a. If the **autoconnect** property of the connection is enabled, **NetworkManager** retries to activate the connection as many times as set in the **autoconnect-retries** property. The default is 4.
 - b. If the connection still cannot acquire the dhcp address, auto-activation fails.
Note that after 5 minutes, the auto-connection process starts again and the dhcp client retries to acquire an address from the dhcp server.

Lease renewal and expiration

After a DHCP lease is acquired successfully, **NetworkManager** configures the interface with parameters received from the DHCP server for the given time, and tries to renew the lease periodically. When the lease expires and cannot be renewed, **NetworkManager** continues trying to contact the server up to 8 minutes. If the other IP configuration, either IPv4 or IPv6 is successful, DHCP requests continue as long as the connection is active.

1.3.1. Making DHCPv4 persistent

To make DHCPv4 persistent both at startup and during the lease renewal processes, set the **ipv4.dhcp-timeout** property either to the maximum for a 32-bit integer (MAXINT32), which is **2147483647**, or to the **infinity** value:

```
~]$ nmcli connection modify enp1s0 ipv4.dhcp-timeout infinity
```

As a result, **NetworkManager** never stops trying to get or renew a lease from a DHCP server until it is successful.

To ensure a DHCP persistent behavior only during the lease renewal process, you can manually add a static IP to the **IPADDR** property in the `/etc/sysconfig/network-scripts/ifcfg-device_name` configuration file or by using **nmcli**:

```
~]$ nmcli connection modify enp1s0 ipv4.address 192.168.122.88/24
```

When an IP address lease expires, the static IP preserves the IP state as configured or partially configured – you can have an IP address, but you are not connected to the Internet.

1.4. INFINIBAND AND RDMA NETWORKS

For details about InfiniBand and Remote Direct Memory Access (RDMA) networks, see the [Configuring InfiniBand and RDMA networks](#) documentation.

1.5. SETTING THE WIRELESS REGULATORY DOMAIN

In Red Hat Enterprise Linux, the **crda** package contains the Central Regulatory Domain Agent that provides the kernel with the wireless regulatory rules for a given jurisdiction. It is used by certain **udev** scripts and should not be run manually unless debugging **udev** scripts. The kernel runs **crda** by sending a **udev** event upon a new regulatory domain change. Regulatory domain changes are triggered by the Linux wireless subsystem (IEEE-802.11). This subsystem uses the **regulatory.bin** file to keep its regulatory database information.

The **setregdomain** utility sets the regulatory domain for your system. **Setregdomain** takes no arguments and is usually called through system script such as **udev** rather than manually by the administrator. If a country code look-up fails, the system administrator can define the **COUNTRY** environment variable in the `/etc/sysconfig/regdomain` file.

Additional resources

See the following man pages for more information about the regulatory domain:

- **setregdomain(1)** man page – Sets regulatory domain based on country code.
- **crda(8)** man page – Sends to the kernel a wireless regulatory domain for a given ISO or IEC 3166 alpha2.
- **regulatory.bin(5)** man page – Shows the Linux wireless regulatory database.
- **iw(8)** man page – Shows or manipulates wireless devices and their configuration.

1.6. USING NETWORK KERNEL TUNABLES WITH SYSCTL

Using certain kernel tunables through the **sysctl** utility, you can adjust network configuration on a running system and directly affect the networking performance.

To change network settings, use the **sysctl** commands. For permanent changes that persist across system restarts, add lines to the `/etc/sysctl.conf` file.

To display a list of all available **sysctl** parameters, enter as **root**:

```
~]# sysctl -a
```

1.7. MANAGING DATA USING THE NCAT UTILITY

The **ncat** networking utility replaces **netcat** in Red Hat Enterprise Linux 7. **ncat** is a reliable back-end tool that provides network connectivity to other applications and users. It reads and writes data across the network from the command line, and uses Transmission Control Protocol (TCP), User Datagram Protocol (UDP), Stream Control Transmission Protocol (SCTP) or Unix sockets for communication. **ncat** can deal with both **IPv4** and **IPv6**, open connections, send packets, perform port scanning, and supports higher-level features such as **SSL**, and connection broker.

The **nc** command can also be entered as **ncat**, using the identical options. For more information about the **ncat** options, see [the *New networking utility \(ncat\)* section in the *Migration Planning Guide*](#) and the **ncat(1)** man page.

Installing ncat

To install the **ncat** package, enter as **root**:

```
~]# yum install nmap-ncat
```

Brief selection of ncat use cases

Example 1.1. Enabling communication between a client and a server

1. Set a client machine to listen for connections on TCP port 8080:

```
~]$ ncat -l 8080
```

2. On a server machine, specify the IP address of the client and use the same port number:

```
~]$ ncat 10.0.11.60 8080
```

You can send messages on either side of the connection and they appear on both local and remote machines.

3. Press **Ctrl+D** to close the TCP connection.



NOTE

To check a UDP port, use the same **nc** commands with the **-u** option. For example:

```
~]$ ncat -u -l 8080
```

Example 1.2. Sending files

Instead of printing information on the screen, as mentioned in the previous example, you can send all information to a file. For example, to send a file over TCP port 8080 from a client to a server:

1. On a client machine, to listen a specific port transferring a file to the server machine:

```
~]$ ncat -l 8080 > outputfile
```

2. On a server machine, specify the IP address of the client, the port and the file which is to be transferred:

```
~]$ ncat -l 10.0.11.60 8080 < inputfile
```

After the file is transferred, the connection closes automatically.



NOTE

You can transfer a file in the other direction as well:

```
~]$ ncat -l 8080 < inputfile
```

```
~]$ ncat -l 10.0.11.60 8080 > outputfile
```

Example 1.3. Creating an HTTP proxy server

To create an HTTP proxy server on localhost port 8080:

```
~]$ ncat -l --proxy-type http localhost 8080
```

Example 1.4. Port scanning

To view which ports are open, use the **-z** option and specify a range of ports to scan:

```
~]$ ncat -z 10.0.11.60 80-90
Connection to 192.168.0.1 80 port [tcp/http] succeeded!
```

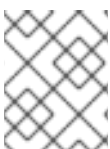
Example 1.5. Setting up secure client-server communication using SSL

Set up **SSL** on a server:

```
~]$ ncat -e /bin/bash -k -l 8080 --ssl
```

On a client machine:

```
~]$ ncat --ssl 10.0.11.60 8080
```



NOTE

To ensure true confidentiality of the **SSL** connection, the server requires the **--ssl-cert** and **--ssl-key** options, and the client requires the **--ssl-verify** and **--ssl-trustfile** options.

Additional resources

For more examples, see the *ncat(1)* man page.

CHAPTER 2. CONSISTENT NETWORK INTERFACE DEVICE NAMING

Red Hat Enterprise Linux 8 provides methods for consistent and predictable device naming for network interfaces. These features help locating and differentiating network interfaces.

The kernel assigns names to network interfaces by concatenating a fixed prefix and a number that increases as the kernel initialize the network devices. For instance, **eth0** would represent the first device being probed on start-up. However, these names do not necessarily correspond to labels on the chassis. Modern server platforms with multiple network adapters can encounter non-deterministic and counter-intuitive naming of these interfaces. This affects both network adapters embedded on the system board and add-in adapters.

In Red Hat Enterprise Linux 8, the **udev** device manager supports a number of different naming schemes. By default, **udev** assigns fixed names based on firmware, topology, and location information. This has the following advantages:

- Device names are fully predictable.
- Device names stay fixed even if you add or remove hardware, because no re-enumeration takes places.
- Defective hardware can be seamlessly replaced.

2.1. NETWORK INTERFACE DEVICE NAMING HIERARCHY

If consistent device naming is enabled, which is the default in Red Hat Enterprise Linux 8, the **udev** device manager generates device names based on the following schemes:

Scheme	Description	Example
1	Device names incorporate firmware or BIOS-provided index numbers for onboard devices. If this information is not available or applicable, udev uses scheme 2.	eno1
2	Device names incorporate firmware or BIOS-provided PCI Express (PCIe) hot plug slot index numbers. If this information is not available or applicable, udev uses scheme 3.	ens1
3	Device names incorporate the physical location of the connector of the hardware. If this information is not available or applicable, udev uses scheme 5.	enp2s0
4	Device names incorporate the MAC address. Red Hat Enterprise Linux does not use this scheme by default, but administrators can optionally use it.	enx525400d5e0fb
5	The traditional unpredictable kernel naming scheme. If udev cannot apply any of the other schemes, the device manager uses this scheme.	eth0

By default, Red Hat Enterprise Linux selects the device name based on the **NamePolicy** setting in the **/usr/lib/systemd/network/99-default.link** file. The order of the values in **NamePolicy** is important.

Red Hat Enterprise Linux uses the first device name that is both specified in the file and that **udev** generated.

If you manually configured **udev** rules to change the name of kernel devices, those rules take precedence.

2.2. HOW THE NETWORK DEVICE RENAMING WORKS

By default, consistent device naming is enabled in Red Hat Enterprise Linux 8. The **udev** device manager processes different rules to rename the devices. The following list describes the order in which **udev** processes these rules and what actions these rules are responsible for:

1. The **/usr/lib/udev/rules.d/60-net.rules** file defines that the **/lib/udev/rename_device** helper utility searches for the **HWADDR** parameter in **/etc/sysconfig/network-scripts/ifcfg-*** files. If the value set in the variable matches the MAC address of an interface, the helper utility renames the interface to the name set in the **DEVICE** parameter of the file.
2. The **/usr/lib/udev/rules.d/71-biosdevname.rules** file defines that the **biosdevname** utility renames the interface according to its naming policy, provided that it was not renamed in the previous step.
3. The **/usr/lib/udev/rules.d/75-net-description.rules** file defines that **udev** examines the network interface device and sets the properties in **udev**-internal variables, that will be processed in the next step. Note that some of these properties might be undefined.
4. The **/usr/lib/udev/rules.d/80-net-setup-link.rules** file calls the **net_setup_link udev** built-in which then applies the policy. The following is the default policy that is stored in the **/usr/lib/systemd/network/99-default.link** file:

```
[Link]
NamePolicy=kernel database onboard slot path
MACAddressPolicy=persistent
```

With this policy, if the kernel uses a persistent name, **udev** does not rename the interface. If the kernel does not use a persistent name, **udev** renames the interface to the name provided by the hardware database of **udev**. If this database is not available, Red Hat Enterprise Linux falls back to the mechanisms described above.

Alternatively, set the **NamePolicy** parameter in this file to **mac** for media access control (MAC) address-based interface names.

5. The **/usr/lib/udev/rules.d/80-net-setup-link.rules** file defines that **udev** renames the interface based on the **udev**-internal parameters in the following order:
 - a. **ID_NET_NAME_ONBOARD**
 - b. **ID_NET_NAME_SLOT**
 - c. **ID_NET_NAME_PATH**

If one parameter is not set, **udev** uses the next one. If none of the parameters are set, the interface is not renamed.

Steps 3 and 4 implement the naming schemes 1 to 4 described in [Section 2.1, “Network interface device naming hierarchy”](#).

Additional resources

- For details about setting custom prefixes for consistent naming, see [Section 2.7, “Using prefixdevname for naming of Ethernet network interfaces”](#).
- For details about the **NamePolicy** parameter, see the **systemd.link(5)** man page.

2.3. PREDICTABLE NETWORK INTERFACE DEVICE NAMES ON THE X86_64 PLATFORM EXPLAINED

When the consistent network device name feature is enabled, the **udev** device manager creates the names of devices based on different criteria. This section describes the naming scheme when Red Hat Enterprise Linux 8 is installed on a x86_64 platform.

The interface name starts with a two-character prefix based on the type of interface:

- **en** for Ethernet
- **wl** for wireless LAN (WLAN)
- **ww** for wireless wide area network (WWAN)

Additionally, one of the following is appended to one of the above-mentioned prefix based on the schema the **udev** device manager applies:

- **o<on-board_index_number>**
- **s<hot_plug_slot_index_number>[f<function>][d<device_id>]**
Note that all multi-function PCI devices have the **[f<function>]** number in the device name, including the function **0** device.
- **x<MAC_address>**
- **[P<domain_number>]p<bus>s<slot>[f<function>][d<device_id>]**
The **[P<domain_number>]** part defines the PCI geographical location. This part is only set if the domain number is not **0**.
- **[P<domain_number>]p<bus>s<slot>[f<function>][u<usb_port>][...][c<config>][i<interface>]**
For USB devices, the full chain of port numbers of hubs is composed. If the name is longer than the maximum (15 characters), the name is not exported. If there are multiple USB devices in the chain, **udev** suppresses the default values for USB configuration descriptors (**c1**) and USB interface descriptors (**i0**).

2.4. PREDICTABLE NETWORK INTERFACE DEVICE NAMES ON THE SYSTEM Z PLATFORM EXPLAINED

When the consistent network device name feature is enabled, the **udev** device manager on the System z platform creates the names of devices based on the bus ID. The bus ID identifies a device in the s390 channel subsystem.

For a channel command word (CCW) device, the bus ID is the device number with a leading **0.n** prefix where **n** is the subchannel set ID.

Ethernet interfaces are named, for example, **enccw0.0.1234**. Serial Line Internet Protocol (SLIP) channel-to-channel (CTC) network devices are named, for example, **slccw0.0.1234**.

Use the **znetconf -c** or the **lscss -a** commands to display available network devices and their bus IDs.

2.5. DISABLING CONSISTENT INTERFACE DEVICE NAMING DURING THE INSTALLATION

This section describes how to disable consistent interface device naming during the installation.



WARNING

Red Hat recommends not to disable consistent device naming. Disabling consistent device naming can cause different kind of problems. For example, if you add another network interface card to the system, the assignment of the kernel device names, such as **eth0**, is no longer fixed. Consequently, after a reboot, the Kernel can name the device differently.

Procedure

1. Boot the Red Hat Enterprise Linux 8 installation media.
2. In the boot manager, select **Install Red Hat Enterprise Linux 8**, and press the **Tab** key to edit the entry.
3. Append the **net.ifnames=0** parameter to the kernel command line:

```
■ vmlinuz... net.ifnames=0
```

4. Press **Enter** to start the installation.

Additional resources

- [Is it safe to set net.ifnames=0 in RHEL 7 and RHEL 8?](#)
- [How to perform an in-place upgrade to RHEL 8 when using kernel NIC names on RHEL 7](#)

2.6. DISABLING CONSISTENT INTERFACE DEVICE NAMING ON AN INSTALLED SYSTEM

This section describes how to disable consistent interface device naming on a system that is already installed.

**WARNING**

Red Hat recommends not to disable consistent device naming. Disabling consistent device naming can cause different kind of problems. For example, if you add another network interface card to the system, the assignment of the kernel device names, such as **eth0**, is no longer fixed. Consequently, after a reboot, the Kernel can name the device differently.

Prerequisites

- The system uses consistent interface device naming, which is the default.

Procedure

1. Edit the **/etc/default/grub** file and append the **net.ifnames=0** parameter to the **GRUB_CMDLINE_LINUX** variable:

```
GRUB_CMDLINE_LINUX="... *net.ifnames=0"
```

2. Rebuild the **grub.cfg** file:

- On a system with UEFI boot mode:

```
# grub2-mkconfig -o /boot/efi/EFI/redhat/grub.cfg
```

- On a system with legacy boot mode:

```
# grub2-mkconfig -o /boot/grub2/grub.cfg
```

3. If you use interface names in configuration files or scripts, you must manually update them.
4. Reboot the host:

```
# reboot
```

2.7. USING PREFIXDEVNAME FOR NAMING OF ETHERNET NETWORK INTERFACES

This documentation describes how to set the prefixes for consistent naming of Ethernet network interfaces in case that you do not want to use the default naming scheme of such interfaces.

However, Red Hat recommends to use the default naming scheme, which is the same as in Red Hat Enterprise Linux 7.

For more details about this scheme, see [Consistent Network Device Naming](#).

2.7.1. Introduction to prefixdevname

The **prefixdevname** tool is a udev helper utility that enables you to define your own prefix used for naming of the Ethernet network interfaces.

2.7.2. Setting prefixdevname

The setting of the prefix with **prefixdevname** is done during system installation.

To set and activate the required prefix for your Ethernet network interfaces, use the following procedure.

Procedure

- Add the following string on the kernel command line:

```
net.ifnames.prefix=<required prefix>
```



WARNING

Red Hat does not support the use of **prefixdevname** on already deployed systems.

After the prefix was once set, and the operating system was rebooted, the prefix is effective every time when a new network interface appears. The new device is assigned a name in the form of **<PREFIX> <INDEX>**. For example, if your selected prefix is **net**, and the interfaces with **net0** and **net1** prefixes already exist on the system, the new interface is named **net2**. The **prefixdevname** utility then generates the new **.link** file in the **/etc/systemd/network** directory that applies the name to the interface with the MAC address that just appeared. The configuration is persistent across reboots.

2.7.3. Limitations of prefixdevname

There are certain limitations for prefixes of Ethernet network interfaces.

The prefix that you choose must meet the following requirements:

- Be ASCII string
- Be alphanumeric string
- Be shorter than 16 characters



WARNING

The prefix cannot conflict with any other well-known prefix used for network interface naming on Linux. Specifically, you cannot use these prefixes: **eth**, **eno**, **ens**, **em**.

2.8. RELATED INFORMATION

- See the **udev(7)** man page for details about the **udev** device manager.

CHAPTER 3. NETCONSOLE

The netconsole kernel module enables logging of kernel messages over the network to another computer. It allows kernel debugging when disk logging fails or when using the serial console is not possible.

3.1. CONFIGURING NETCONSOLE

This procedure describes how you can configure netconsole in Red Hat Enterprise Linux (RHEL) 8.

Prerequisites

The **netconsole-service** package is installed.

```
~]# yum install netconsole-service
```

Procedure

1. Set the **SYSLOGADDR** to the IP address of the **syslogd** server in the **/etc/sysconfig/netconsole** file to match the IP address of the **syslogd** server. For example:

```
SYSLOGADDR=192.168.0.1
```

2. Restart the **netconsole.service**.

```
~]# systemctl restart netconsole.service
```

3. Enable **netconsole.service** to run after rebooting the system.

```
~]# systemctl enable netconsole.service
```

4. View the **netconsole** messages from the client in the **/var/log/messages** file (default) or in the file specified in **rsyslog.conf**.

```
~]# cat /var/log/messages
```

Additional resources

[How to configure netconsole under Red Hat Enterprise Linux 8 ?](#)

CHAPTER 4. OVERVIEW OF NETWORK.TARGET AND NETWORK-ONLINE.TARGET

NetworkManager configures the network during the system boot process. However, in the cases of booting with a remote root (/), such as if the root directory is stored on an iSCSI device, the network settings are applied in the initial RAM disk (**initrd**) before RHEL is started. For example, if the network configuration is specified on the kernel command line using **rd.netnet=1** or a configuration is specified to mount remote file systems, then the network settings are applied on **initrd**.

This section describes different targets such as **network**, **network-online**, and **NetworkManager-wait-online** service that are used while applying network settings.

4.1. DIFFERENCES BETWEEN THE NETWORK AND NETWORK-ONLINE SYSTEMD TARGET

Systemd maintains the **network** and **network-online** target units. The special units such as **NetworkManager-wait-online.service**, have **WantedBy=network-online.target** and **Before=network-online.target** parameters. If enabled, these units get started with **network-online.target** and delay the target to be reached until some form of network connectivity is established. In other words, they delay the **network-online** target until the network is connected.

The **network-online** target starts a service, which adds substantial delays to further execution. Systemd automatically adds dependencies with **Wants** and **After** parameters for this target unit to all the System V (SysV) **init** script service units with an Linux Standard Base (LSB) header referring to the **\$network** facility. The LSB header is metadata for **init** scripts. You can use it to specify dependencies. This is similar to the **systemd** target.

The **network** target does not significantly delay the execution of the boot process. Reaching the **network** target means that the service that is responsible for setting up the network has been started. However, it does not mean that any network device was configured. This target is important during the shutdown of the system. For example, if you have a service that is ordered after the **network** target during bootup, then this dependency is reversed during the shutdown. The network does not get disconnected until your service has been stopped. All mount units for remote network file systems automatically start the **network-online** target unit and order themselves after it.



NOTE

The **network-online** target unit is only useful during the system starts. After the system has completed booting up, this target does not track the online state of the network anymore. Therefore, you cannot use **network-online** to monitor the network connection. This target provides a one-time system startup concept.

4.2. OVERVIEW OF NETWORKMANAGER-WAIT-ONLINE

The synchronous legacy network scripts iterate through all configuration files to set up devices. They apply all network-related configurations and ensure that the network is online.

The **NetworkManager-wait-online** service waits with a timeout for the network to be configured. This network configuration involves an Ethernet device to be plugged in, a Wi-Fi device scanning to be completed, and so forth. NetworkManager automatically activates suitable profiles that are configured to start automatically. The failure of the automatic activation process due to a DHCP timeout or any such event can keep NetworkManager busy for a longer time. Depending on the configuration, NetworkManager retries activating the same profile or a different profile.

When the startup completes, either all profiles are in a disconnected state or successfully activated. You can configure profiles to auto-connect. The following are a few examples of parameters that set timeouts or define when the connection is considered active:

- **connection.wait-device-timeout** – sets the timeout for the driver to detect the device
- **ipv4.may-fail** and **ipv6.may-fail** – sets activation with one IP address family ready, or whether a particular address family must have completed configuration.
- **ipv4.gateway-ping-timeout** – delays activation.

Additional resources

- The **nm-settings(5)** man page

4.3. CONFIGURING A SYSTEMD SERVICE TO START AFTER THE NETWORK HAS BEEN STARTED

Red Hat Enterprise Linux installs **systemd** service files in the `/usr/lib/systemd/system/` directory. This procedure creates a drop-in snippet for a service file in `/etc/systemd/system/service_name.service.d/` that is used together with the service file in `/usr/lib/systemd/system/`. The drop-in snippet has a higher priority if settings in the drop-in snippet overlap with the ones in the service file in `/usr/lib/systemd/system/`.

Procedure

1. To open an editor to add a drop-in snippet for a service file, enter:
systemctl edit service_name
2. Enter the following entry, and save the changes:

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

3. Reload the systemd configuration.
systemctl daemon-reload

CHAPTER 5. GETTING STARTED WITH MANAGING NETWORKING WITH NETWORKMANAGER

5.1. OVERVIEW OF NETWORKMANAGER

Red Hat Enterprise Linux 8 uses the default networking service, **NetworkManager**, which is a dynamic network control and configuration daemon to keep network devices and connections up and active when they are available. The traditional **ifcfg** type configuration files are still supported.

Each network device corresponds to a **NetworkManager** device. The configuration of a network device is completely stored in a single **NetworkManager** connection. You can perform a network configuration applying a **NetworkManager** connection to a **NetworkManager** device.

5.1.1. Benefits of using NetworkManager

The main benefits of using NetworkManager are:

- Offering an API through D-Bus which allows to query and control network configuration and state. In this way, networking can be checked and configured by multiple applications ensuring a synced and up-to-date networking status. For example, the RHEL web console, which monitors and configures servers through a web browser, uses the **NetworkManager** D-BUS interface to configure networking, as well as the **Gnome GUI**, the **nmcli** and the **nm-connection-editor** tools. Each change made in one of these tools is detected by all the others.
- Making Network management easier: **NetworkManager** ensures that network connectivity works. When it detects that there is no network configuration in a system but there are network devices, **NetworkManager** creates temporary connections to provide connectivity.
- Providing easy setup of connection to the user: **NetworkManager** offers management through different tools – **GUI**, **nmtui**, **nmcli**
- Supporting configuration flexibility. For example, configuring a WiFi interface, **NetworkManager** scans and shows the available wifi networks. You can select an interface, and **NetworkManager** displays the required credentials providing automatic connection after the reboot process. **NetworkManager** can configure network aliases, IP addresses, static routes, DNS information, and VPN connections, as well as many connection-specific parameters. You can modify the configuration options to reflect your needs.
- Maintaining the state of devices after the reboot process and taking over interfaces which are set into managed mode during restart.
- Handling devices which are not explicitly set unmanaged but controlled manually by the user or another network service.

Additional resources

- [Section 5.5, “NetworkManager tools”](#)
- For more information on installing and using the RHEL 8 web console, see [Managing systems using the RHEL 8 web console](#).

5.2. INSTALLING NETWORKMANAGER

NetworkManager is installed by default on Red Hat Enterprise Linux 8 . If it is not, enter as **root**:

```
~]# yum install NetworkManager
```

Additional resources

- [Section 5.1, “Overview of NetworkManager”](#)
- [Section 5.1.1, “Benefits of using NetworkManager”](#)

5.3. CHECKING THE STATUS OF NETWORKMANAGER

To check whether **NetworkManager** is running:

```
~]$ systemctl status NetworkManager
NetworkManager.service - Network Manager
   Loaded: loaded (/lib/systemd/system/NetworkManager.service; enabled)
   Active: active (running) since Fri, 08 Mar 2013 12:50:04 +0100; 3 days ago
```

Note that the **systemctl status** command displays **Active: inactive (dead)** when **NetworkManager** is not running.

5.4. STARTING NETWORKMANAGER

To start **NetworkManager**:

```
~]# systemctl start NetworkManager
```

To enable **NetworkManager** automatically at boot time:

```
~]# systemctl enable NetworkManager
```

5.5. NETWORKMANAGER TOOLS

Table 5.1. A summary of NetworkManager tools and applications

Application or Tool	Description
nmcli	A command-line tool which enables users and scripts to interact with NetworkManager . Note that nmcli can be used on systems without a GUI such as servers to control all aspects of NetworkManager . It provides a deeper functionality as GUI tools.
nmtui	A simple curses-based text user interface (TUI) for NetworkManager

Application or Tool	Description
nm-connection-editor	A graphical user interface tool for certain tasks not yet handled by the control-center utility such as configuring bonds and teaming connections. You can add, remove, and modify network connections stored by NetworkManager . To start it, enter nm-connection-editor in a terminal.
control-center	A graphical user interface tool provided by the GNOME Shell, available for desktop users. It incorporates a Network settings tool. To start it, press the Super key to enter the Activities Overview, type Network and then press Enter . The Network settings tool appears.
network connection icon	A graphical user interface tool provided by the GNOME Shell representing network connection states as reported by NetworkManager . The icon has multiple states that serve as visual indicators for the type of connection you are currently using.

Additional resources

- [Chapter 7, Configuring IP networking with nmtui](#)
- [Chapter 8, Getting started with nmcli](#)
- [Chapter 9, Getting started with configuring networking using the GNOME GUI](#)

5.6. RUNNING DISPATCHER SCRIPTS

NetworkManager provides a way to run additional custom scripts to start or stop services based on the connection status. By default, the **/etc/NetworkManager/dispatcher.d/** directory exists and **NetworkManager** runs scripts there, in alphabetical order. Each script must be an executable file owned by **root** and must have **write permission** only for the file owner.

Additional resources

- For more information about running NetworkManager dispatcher scripts, see the Red Hat Knowledgebase solution [How to write a NetworkManager dispatcher script to apply ethtool commands](#).

5.7. USING NETWORKMANAGER WITH SYSCONFIG FILES

The **/etc/sysconfig/** directory is a location for configuration files and scripts. Most network configuration information is stored there, with the exception of VPN, mobile broadband and PPPoE configuration, which are stored in the **/etc/NetworkManager/** subdirectories. For example, interface-specific information is stored in the **ifcfg** files in the **/etc/sysconfig/network-scripts/** directory.

Information for VPNs, mobile broadband and PPPoE connections is stored in **/etc/NetworkManager/system-connections/**.

In Red Hat Enterprise Linux 8, if you edit an **ifcfg** file, **NetworkManager** is not automatically aware of the change and has to be prompted to notice the change. If you use one of the tools to update **NetworkManager** profile settings, **NetworkManager** does not implement those changes until you reconnect using that profile. For example, if configuration files have been changed using an editor, **NetworkManager** must read the configuration files again.

To ensure this, enter as **root** to reload all connection profiles:

```
~]# nmcli connection reload
```

Alternatively, to reload **only one** changed file, **ifcfg-ifname**:

```
~]# nmcli con load /etc/sysconfig/network-scripts/ifcfg-ifname
```

Note that you can specify multiple file names using the above command.

To restart the connection after changes are made, use:

```
~]# nmcli con up connection-name
```

5.7.1. Legacy network scripts support

Network scripts are deprecated in Red Hat Enterprise Linux 8 and are no longer provided by default. The basic installation provides a new version of the **ifup** and **ifdown** scripts which call **NetworkManager** through the **nmcli** tool. In Red Hat Enterprise Linux 8, to run the **ifup** and the **ifdown** scripts, **NetworkManager** must be running.

NOTE

Custom commands in **/sbin/ifup-local**, **ifdown-pre-local** and **ifdown-local** scripts are not executed.

If any of these scripts are required, the installation of the deprecated network scripts in the system is still possible with the following command:

```
~]# yum install network-scripts
```

The **ifup** and the **ifdown** scripts link to the installed legacy network scripts.

Calling the legacy network scripts shows a warning about their deprecation.

Additional resources

- **NetworkManager(8)** man page – Describes the network management daemon.
- **NetworkManager.conf(5)** man page – Describes the **NetworkManager** configuration file.
- **/usr/share/doc/initscripts/sysconfig.txt** – Describes **ifcfg** configuration files and their directives as understood by the legacy network service.
- **ifcfg(8)** man page – Describes briefly the **ifcfg** command.

CHAPTER 6. OVERVIEW OF NETWORK CONFIGURATION METHODS

The following section provides an overview of network configuration methods that are available in Red Hat Enterprise Linux 8.

6.1. SELECTING NETWORK CONFIGURATION METHODS

- To configure a network interface using **NetworkManager**, use one of the following tools:
 - the text user interface tool, **nmtui**.
 - the command-line tool, **nmcli**.
 - the graphical user interface tools, **GNOME GUI**.
- To configure a network interface **without** using **NetworkManager**:
 - edit the **ifcfg** files manually.
- To configure the network settings when the root filesystem is **not** local:
 - use the kernel command-line.

Additional resources

- [Chapter 7, Configuring IP networking with nmtui](#)
- [Chapter 8, Getting started with nmcli](#)
- [Chapter 9, Getting started with configuring networking using the GNOME GUI](#)

CHAPTER 7. CONFIGURING IP NETWORKING WITH NMTUI

The following section provides how you can configure a network interface using the **NetworkManager**'s tool, **nmtui**.

7.1. GETTING STARTED WITH NMTUI

nmtui is a simple curses-based text user interface (TUI) for **NetworkManager**.

This procedure describes how to start the text user interface tool, **nmtui**.

Prerequisites

- The **nmtui** tool is used in a terminal window. It is contained in the **NetworkManager-tui** package, but it is not installed along with **NetworkManager** by default. To install **NetworkManager-tui**:

```
~]# yum install NetworkManager-tui
```

- To verify that **NetworkManager** is running, see [Section 5.3, "Checking the status of NetworkManager"](#)

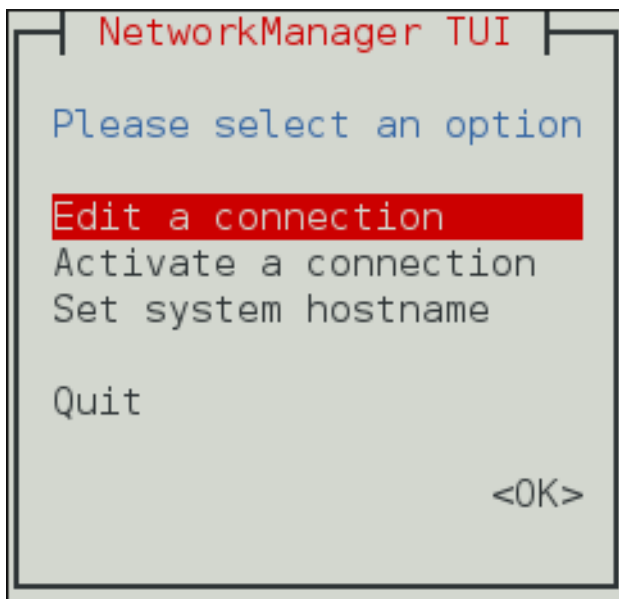
Procedure

1. Start the **nmtui** tool:

```
~]$ nmtui
```

The text user interface appears.

Figure 7.1. The NetworkManager text user interface starting menu



2. To navigate, use the arrow keys or press **Tab** to step forwards and press **Shift+Tab** to step back through the options. Press **Enter** to select an option. The **Space** bar toggles the status of a check box.

7.1.1. Adding a connection profile using nmtui

The **nmtui** application provides a text user interface to NetworkManager. This procedure describes how to add a new connection profile.

Prerequisites

- The **NetworkManager-tui** package is installed.

Procedure

1. Start the NetworkManager text user interface utility:

```
# nmtui
```

2. Select the **Edit a connection** menu entry, and press **Enter**.
3. Select the **Add** button, and press **Enter**.
4. Select **Ethernet**, and press **Enter**.
5. Fill the fields with the connection details.

Edit Connection

Profile name enpls0
 Device enpls0 (52:54:00:DF:55:D1)

= ETHERNET <Show>

= IPv4 CONFIGURATION <Manual> <Hide>

Addresses 192.0.2.1/24
<Add...>
 Gateway 192.0.2.254
 DNS servers 192.0.2.254
<Add...>
 Search domains <Add...>

 Routing (No custom routes) <Edit...>

☐ Never use this network for default route
☐ Ignore automatically obtained routes
☐ Ignore automatically obtained DNS parameters

☐ Require IPv4 addressing for this connection

<Remove>
<Remove>

= IPv6 CONFIGURATION <Manual> <Hide>

Addresses 2001:db8:1::1/64
<Add...>
 Gateway 2001:db8:1::fffe
 DNS servers 2001:db8:1::fffe
<Add...>
 Search domains <Add...>

 Routing (No custom routes) <Edit...>

☐ Never use this network for default route
☐ Ignore automatically obtained routes
☐ Ignore automatically obtained DNS parameters

☐ Require IPv6 addressing for this connection

<Remove>
<Remove>

☒ Automatically connect
☒ Available to all users

<Cancel> <OK>

6. Select **OK** to save the changes.
7. Select **Back** to return to the main menu.
8. Select **Activate a connection**, and press **Enter**.
9. Select the new connection entry, and press **Enter** to activate the connection.
10. Select **Back** to return to the main menu.
11. Select **Quit**.

Verification steps

1. Display the status of the devices and connections:

```
# nmcli device status
DEVICE   TYPE   STATE   CONNECTION
enp7s0   ethernet connected Example-Connection
```

2. To display all settings of the connection profile:

```
# nmcli connection show Example-Connection
connection.id:      Example-Connection
connection.uuid:    b6cdfa1c-e4ad-46e5-af8b-a75f06b79f76
connection.stable-id: --
connection.type:    802-3-ethernet
connection.interface-name: enp7s0
...
```

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- For further details about the **nmcli** application, see the **nmcli(1)** man page.
- If the configuration on the disk does not match the configuration on the device, starting or restarting NetworkManager creates an in-memory connection that reflects the configuration of the device. For further details and how to avoid this problem, see [NetworkManager duplicates a connection after restart of NetworkManager service](#).

7.1.2. Applying changes to a modified connection with nmcli

To apply changes after a modified connection which is already active requires a reactivation of the connection. In this case, follow the procedure below:

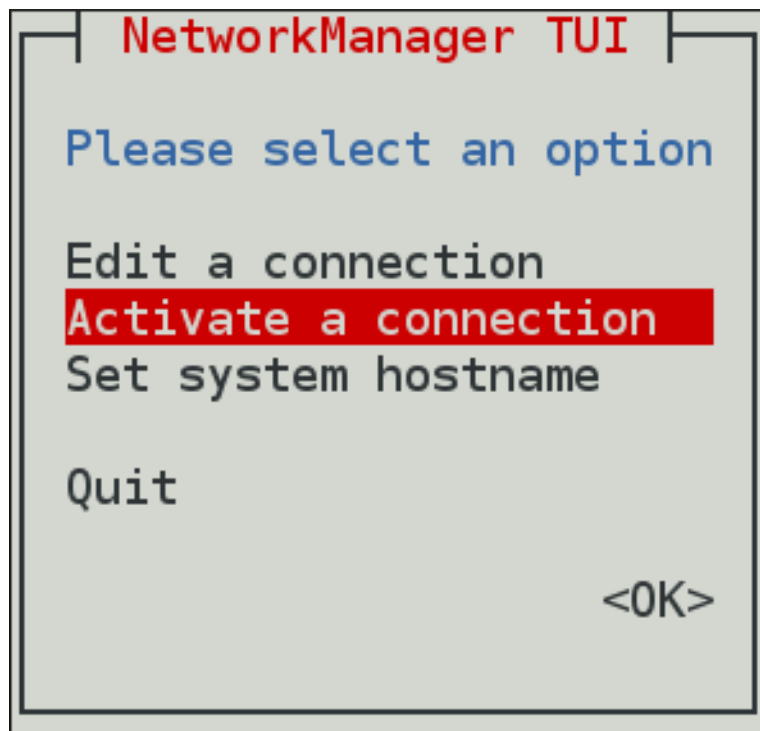
Prerequisites

- [Section 7.1, "Getting started with nmcli"](#)

Procedure

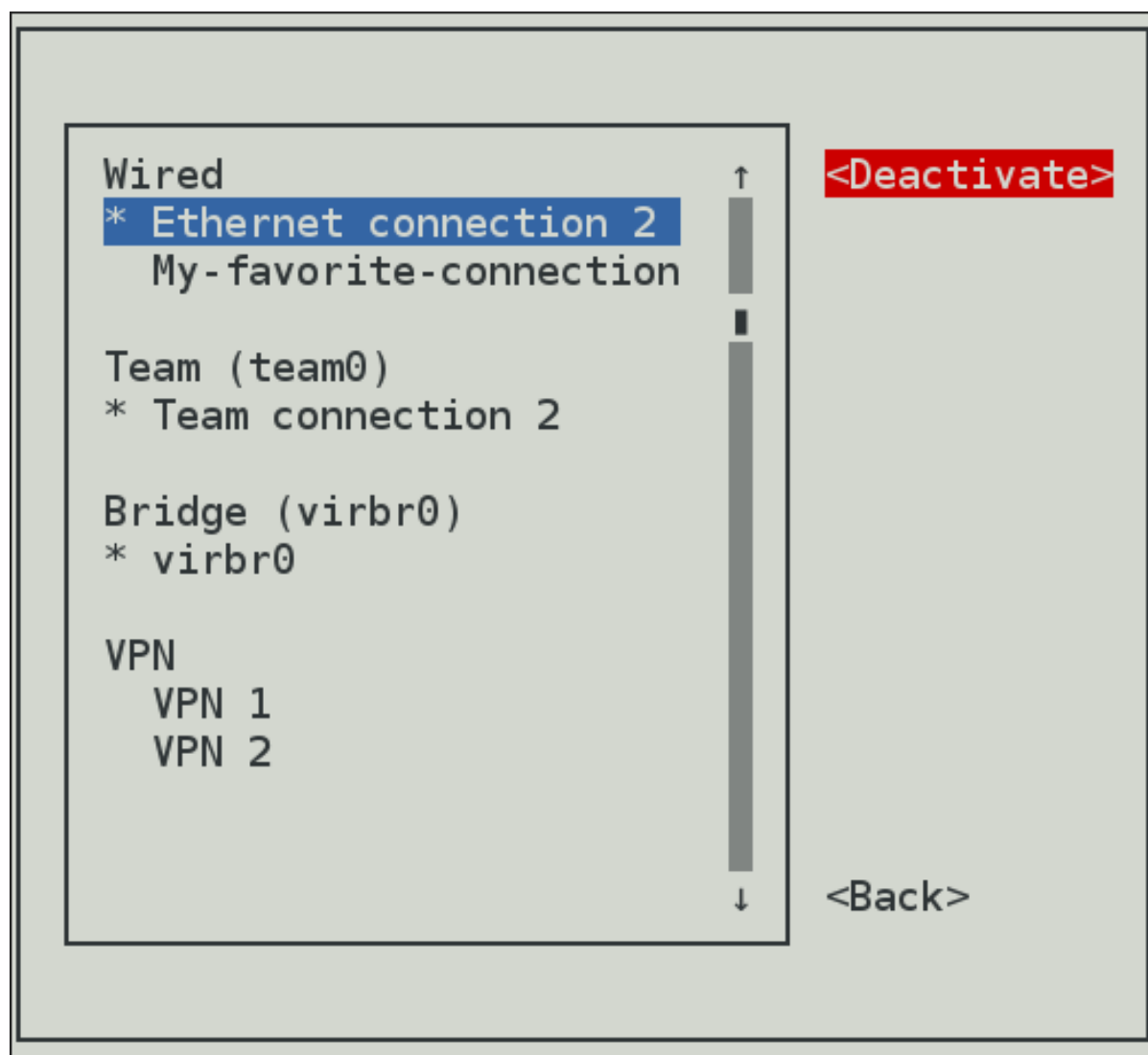
1. Select the **Activate a connection** menu entry.

Figure 7.2. Activating a connection with nmtui



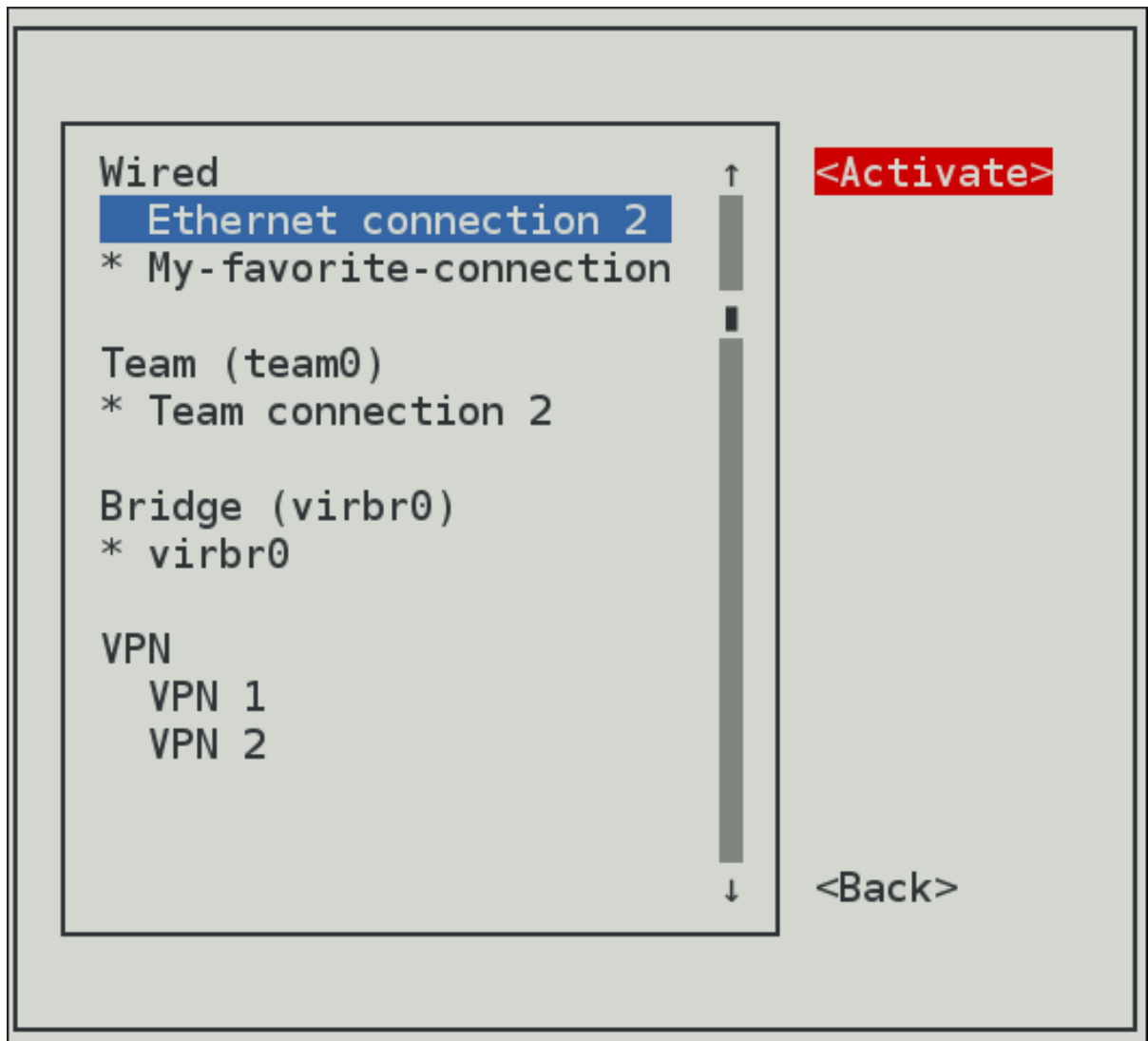
2. Select the modified connection. On the right, click the **Deactivate** button.

Figure 7.3. Deactivating a modified connection with nmtui



3. Choose the connection again and click the **Activate** button.

Figure 7.4. Reactivating a modified connection with nmtui



The following commands are also available:

```
~]$ nmtui edit connection-name
```

If no connection name is supplied, the selection menu appears. If the connection name is supplied and correctly identified, the relevant **Edit connection** screen appears.

```
~]$ nmtui connect connection-name
```

If no connection name is supplied, the selection menu appears. If the connection name is supplied and correctly identified, the relevant connection is activated. Any invalid command prints a usage message.

Note that **nmtui** does not support all types of connections. In particular, you cannot edit VPNs, wireless network connections using WPA Enterprise, or Ethernet connections using **802.1X**.

Additional resources

- For more information about the **NetworkManager's** tools, see [Section 5.5, "NetworkManager tools"](#)

CHAPTER 8. GETTING STARTED WITH NMCLI

This section describes general information about the **nmcli** utility.

8.1. UNDERSTANDING NMCLI

nmcli (NetworkManager Command Line Interface) is the command-line utility to configure networking through **NetworkManager**. **nmcli** is used to create, display, edit, delete, activate, and deactivate network connections, as well as control and display network device status.

The **nmcli** utility can be used by both users and scripts:

- For servers, headless machines, and terminals, **nmcli** can be used to control **NetworkManager** directly, without GUI.
- For scripts, **nmcli** supports options to change the output to a format better suited for script processing.

Each network device corresponds to a **NetworkManager** device. The configuration of a network device is completely stored in a single **NetworkManager** connection. You can perform a network configuration applying a **NetworkManager** connection to a **NetworkManager** device.

To get started with **nmcli** the most common **nmcli** commands are **nmcli device** and **nmcli connection**:

- The **nmcli device** command lists the available network devices in the system.

A device can be:

1. **managed** - under the **NetworkManager** control. A **managed** device may be **connected**, meaning that it is activated and configured, or **disconnected**, meaning that it is not configured but ready to be activated again.
2. **unmanaged** - **NetworkManager** does not control it.

For more details on setting a **managed** or **unmanaged** device, see [Section 8.4, “Setting a device managed or unmanaged with nmcli”](#).

The **nmcli device** command can take many arguments. Most notable are: **status**, **show**, **set**, **connect**, **disconnect**, **modify**, **delete**, **wifi**. Enter the **nmcli device help** command to see the full list.

- The **nmcli connection** command lists the available connection profiles in **NetworkManager**.

Every connection that is active is displayed as green on top of the list. The inactive connections are displayed as white. The **DEVICE** field identifies the device on which the connection is applied on.

The **nmcli connection** command can take many arguments to manage connection profiles. Most notable are: **show**, **up**, **down**, **add**, **modify**, **delete**. Enter the **nmcli connection help** command to see the full list.

IMPORTANT

If you use the **nmcli** commands, it is recommended to type a partial **nmcli** command, and then press the **Tab** key to auto-complete the command sequence. If multiple completions are possible, then **Tab** lists them all. This helps users to type commands faster and easier. To enable the **nmcli** auto-complete feature be sure to install the **bash-completion** package:

```
~]# yum install bash-completion
```

After the package installation, **nmcli auto-complete** will be available next time you login into a console. To activate it also in the current console, enter:

```
~]$ source /etc/profile.d/bash_completion.sh
```

The basic format of using **nmcli** is:

```
nmcli [OPTIONS] OBJECT { COMMAND | help }
```

- where [OPTIONS] can include:

-t, terse

This mode can be used for computer script processing as you can see a terse output displaying only the values.

Example 8.1. Viewing a terse output

```
~]$ nmcli -t device
ens3:ethernet:connected:Profile 1
lo:loopback:unmanaged:
```

-f, field

This option specifies what fields can be displayed in output. For example, NAME,UUID,TYPE,AUTOCONNECT,ACTIVE,DEVICE,STATE. You can use one or more fields. If you want to use more, do not use space after comma to separate the fields.

Example 8.2. Specifying fields in the output

```
~]$ nmcli -f DEVICE,TYPE device
DEVICE TYPE
ens3  ethernet
lo    loopback
```

or even better for scripting:

```
~]$ nmcli -t -f DEVICE,TYPE device
ens3:ethernet
lo:loopback
```

-p, pretty

This option causes **nmcli** to produce human-readable output. For example, values are aligned and headers are printed.

Example 8.3. Viewing an output in pretty mode

```
~]$ nmcli -p device
=====
Status of devices
=====
DEVICE TYPE    STATE    CONNECTION
-----
ens3  ethernet connected Profile 1
lo    loopback  unmanaged --
```

-h, help

Prints help information.

- where OBJECT can be one of the following: **general**, **networking**, **radio**, **connection**, **device**, **agent**, or **monitor**.



NOTE

You can use any prefix of the above options in your commands. For example, **nmcli con help**, **nmcli c help**, **nmcli connection help** generate the same output.

- where COMMAND, the required **nmcli** command.
- where *help* is to list available actions related to a specified object:

```
~]$ nmcli OBJECT help
```

For example,

```
~]$ nmcli c help
```

Additional resources

- [Section 5.5, “NetworkManager tools”](#)
- the *nmcli(1)* man page.
- [Section 8.3, “Brief selection of nmcli commands”](#)
- [Section 8.5, “Creating a connection profile with nmcli”](#)

8.2. OVERVIEW OF NMCLI PROPERTY NAMES AND ALIASES

Prerequisites

Property names are specific names that **NetworkManager** uses to identify a common option. Following are some of the important **nmcli property** names:

connection.type

A type of a specific connection. Allowed values are: **adsl**, **bond**, **bond-slave**, **bridge**, **bridge-slave**, **bluetooth**, **cdma**, **ethernet**, **gsm**, **infiniband**, **olpc-mesh**, **team**, **team-slave**, **vlan**, **wifi**, **wimax**. Each connection type has type-specific command options. You can see the **TYPE_SPECIFIC_OPTIONS** list in the *nmcli(1)* man page. For example, a **gsm** connection requires the access point name specified in an **apn**. A **wifi** device requires the service set identifier specified in a **ssid**.

connection.interface-name

A device name relevant for the connection. For example, *enp1s0*.

connection.id

A name used for the connection profile. If you do not specify a connection name, one will be generated as follows:

```
connection.type -connection.interface-name
```

The **connection.id** is the name of a *connection profile* and should not be confused with the interface name which denotes a device (**wlan0**, **ens3**, **em1**). However, users can name the connections after interfaces, but they are not the same thing. There can be multiple connection profiles available for a device. This is particularly useful for mobile devices or when switching a network cable back and forth between different devices. Rather than edit the configuration, create different profiles and apply them to the interface as needed. The **id** option also refers to the connection profile name.

The most important options for **nmcli** commands such as **show**, **up**, **down** are:

id

An identification string assigned by the user to a connection profile. Id can be used in **nmcli** connection commands to identify a connection. The NAME field in the command output always denotes the connection id. It refers to the same connection profile name that the con-name does.

uuid

A unique identification string assigned by the system to a connection profile. The **uuid** can be used in **nmcli connection** commands to identify a connection.

Aliases and property names

An **alias** is an alternative name for a **property** name – aliases are translated to properties internally in **nmcli**. **Aliases** are more readable but **property names** are preferable to use. Both can be used interchangeably.

Alias	Example	Property	Example	Definition
type	type <i>bond</i>	connection.type	connection.type <i>bond</i>	type of a specific connection. Some of the connection types are: bond , bridge , ethernet , wifi , infiniband , vlan
ifname	ifname <i>enp1s0</i>	connection.interface-name	connection.interface-name <i>enp1s0</i>	name of the device to which a connection belongs to

Alias	Example	Property	Example	Definition
con-name	con-name "My Connection"	connection.id	connection.id "My Connection"	name of a connection

8.3. BRIEF SELECTION OF NMCLI COMMANDS

IMPORTANT

If you use the **nmcli** commands, it is recommended to type a partial **nmcli** command, and then press the **Tab** key to auto-complete the command sequence. If multiple completions are possible, then **Tab** lists them all. This helps users to type commands faster and easier. To enable the **nmcli** auto-complete feature be sure to install the **bash-completion** package:

```
~]# yum install bash-completion
```

After the package installation, **nmcli auto-complete** will be available next time you login into a console. To activate it also in the current console, enter:

```
~]$ source /etc/profile.d/bash_completion.sh
```

The following examples show how to use **nmcli** in specific use cases:

Example 8.4. Viewing all connections

```
~]$ nmcli connection show
NAME      UUID                                  TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet  ens3
bond0     aaf6eb56-73e5-4746-9037-eed42caa8a65  ethernet  --
```

Example 8.5. Viewing only currently active connections

```
~]$ nmcli connection show --active
NAME      UUID                                  TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet  ens3
```

Example 8.6. Activating a connection

Use the **up** argument to activate a connection.

```
~]$ nmcli connection show
NAME      UUID                                  TYPE      DEVICE
Profile 1  db1060e9-c164-476f-b2b5-caec62dc1b05  ethernet  ens3
bond0     aaf6eb56-73e5-4746-9037-eed42caa8a65  ethernet  --
```

```
~]$ nmcli connection up id bond0
Connection successfully activated (D-Bus active path:
/org/freedesktop/NetworkManager/ActiveConnection/4)
```

```
~]$ nmcli connection show
NAME      UUID                                  TYPE      DEVICE
Profile 1 db1060e9-c164-476f-b2b5-caec62dc1b05 ethernet  ens3
bond0     aaf6eb56-73e5-4746-9037-eed42caa8a65 ethernet  bond0
```

Example 8.7. Deactivating a specific active connection

Use the **down** argument to deactivate a specific active connection:

```
~]$ nmcli connection down id bond0
```

```
~]$ nmcli connection show
NAME      UUID                                  TYPE      DEVICE
Profile 1 db1060e9-c164-476f-b2b5-caec62dc1b05 ethernet  ens3
bond0     aaf6eb56-73e5-4746-9037-eed42caa8a65 ethernet  --
```

Example 8.8. Disconnecting a device preventing it from automatically started again

```
~]$ nmcli device disconnect id bond0
```

NOTE

The **nmcli connection down** command, deactivates a connection from a device without preventing the device from further auto-activation. The **nmcli device disconnect** command, disconnects a device and prevent the device from automatically activating further connections without manual intervention. If the connection has the **connection.autoconnect** flag set to **yes**, the connection automatically starts on the disconnected device again. In this case, use the **nmcli device disconnect** command instead of the **nmcli connection down** command.

Example 8.9. Viewing only devices recognized by NetworkManager and their state

```
~]$ nmcli device status
DEVICE TYPE   STATE   CONNECTION
ens3  ethernet connected Profile 1
lo    loopback unmanaged --
```

Example 8.10. Viewing general information for a device

```
~]$ nmcli device show
GENERAL.DEVICE:      ens3
GENERAL.TYPE:        ethernet
```

```
GENERAL.HWADDR:          52:54:00:0A:2F:ED
GENERAL.MTU:              1500
GENERAL.STATE:            100 (connected)
GENERAL.CONNECTION:       ens3
[...]
```

Example 8.11. Checking the overall status of NetworkManager

```
~]$ nmcli general status
STATE    CONNECTIVITY WIFI-HW  WIFI   WWAN-HW  WWAN
connected full      enabled enabled enabled enabled
```

In terse mode:

```
~]$ nmcli -t -f STATE general
connected
```

Example 8.12. Viewing NetworkManager logging status

```
~]$ nmcli general logging
LEVEL DOMAINS
INFO  PLATFORM,RFKILL,ETHER,WIFI,BT,MB,DHCP4,DHCP6,PPP,WIFI_SCAN,IP4,IP6,
      UTOIP4,DNS,VPN,SHARING,SUPPLICANT,AGENTS,SETTINGS,SUSPEND,CORE,DEVICE,OL
      PC,
      WIMAX,INFINIBAND,FIREWALL,ADSL,BOND,VLAN,BRIDGE,DBUS_PROPS,TEAM,CONCHECK
      ,DC
      B,DISPATCH
```

You can also use the following abbreviations of the **nmcli** commands:

Table 8.1. Abbreviations of some nmcli commands

nmcli command	abbreviation
nmcli general status	nmcli g
nmcli general logging	nmcli g log
nmcli connection show	nmcli con show or nmcli c
nmcli connection show --active	nmcli con show -a or nmcli c -a
nmcli device status	nmcli dev or nmcli d
nmcli device show	nmcli dev show or nmcli d show

Additional resources

- For more information on the comprehensive list of **nmcli** options, see the *nmcli(1)* man page.
- For more examples, see the *nmcli-examples(5)* man page.
- [Section 8.5, “Creating a connection profile with nmcli”](#)

8.4. SETTING A DEVICE MANAGED OR UNMANAGED WITH NMCLI

Prerequisites

- [Section 8.1, “Understanding nmcli”](#)
- [Section 8.2, “Overview of nmcli property names and aliases”](#)

Procedure

1. To list the currently available network connections:

```
~]$ nmcli con show
NAME                UUID                                  TYPE      DEVICE
Auto Ethernet      9b7f2511-5432-40ae-b091-af2457dfd988 802-3-ethernet --
ens3                fb157a65-ad32-47ed-858c-102a48e064a2 802-3-ethernet ens3
MyWiFi              91451385-4eb8-4080-8b82-720aab8328dd 802-11-wireless wlan0
```

Note that the **NAME** field in the output always denotes the **connection ID** (name). It is not the interface name even though it might look the same. In the second connection shown above, *ens3* in the **NAME** field is the **connection ID** given by the user to the profile applied to the interface *ens3*. In the last connection shown, the user has assigned the connection ID *MyWiFi* to the interface *wlan0*.

Adding an Ethernet connection means creating a configuration profile which is then assigned to a device. Before creating a new profile, review the available devices as follows:

```
~]$ nmcli device status
DEVICE TYPE   STATE      CONNECTION
ens3   ethernet disconnected --
ens9   ethernet disconnected --
lo     loopback  unmanaged  --
```

2. To set the device unmanaged by the **NetworkManager**:

```
~]$ nmcli device set ifname managed no
```

For example, to set *enp1s0* unmanaged:

```
~]$ nmcli device status
DEVICE TYPE   STATE      CONNECTION
bond0   bond    connected bond0
virbr0   bridge  connected virbr0
enp7s0   ethernet connected bond-slave-enp7s0
enp1s0   ethernet connected bond-slave-enp1s0
enp8s0   ethernet unmanaged  --
```

```
~]$ nmcli device set enp1s0 managed no
```

```
~]$ nmcli device status
```

DEVICE	TYPE	STATE	CONNECTION
bond0	bond	connected	bond0
virbr0	bridge	connected	virbr0
enp7s0	ethernet	connected	bond-slave-enp7s0
enp1s0	ethernet	unmanaged	--
enp8s0	ethernet	unmanaged	--



NOTE

When you set the device unmanaged, **NetworkManager** does not control it. If the device you want to configure is listed as unmanaged, no **nmcli** command has any effect on this device. However, the device is still connected.

Additional resources

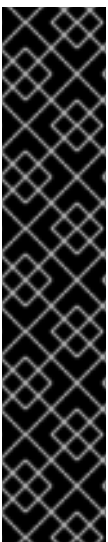
- For more information, see the *nmcli(1)* man page.

8.5. CREATING A CONNECTION PROFILE WITH NMCLI

You can create a connection profile to be associated with a device.

Prerequisites

- [Section 8.1, “Understanding nmcli”](#)
- [Section 8.2, “Overview of nmcli property names and aliases”](#)



IMPORTANT

If you use the **nmcli** commands, it is recommended to type a partial **nmcli** command, and then press the **Tab** key to auto-complete the command sequence. If multiple completions are possible, then **Tab** lists them all. This helps users to type commands faster and easier. To enable the **nmcli** auto-complete feature be sure to install the **bash-completion** package:

```
~]# yum install bash-completion
```

After the package installation, **nmcli auto-complete** will be available next time you login into a console. To activate it also in the current console, enter:

```
~]$ source /etc/profile.d/bash_completion.sh
```

Procedure

The basic format to **create** a new profile for **NetworkManager** using **nmcli**:

```
nmcli c add {COMMON_OPTIONS} [IP_OPTIONS]/[NETMASK] [GATEWAY]
```

- a. where **{COMMON_OPTIONS}** are the aliases or property names, see [Aliases and Property names](#).
- b. where **[IP_OPTIONS]** are the IP addresses:
 - For IPv4 addresses: **ip4**
 - For IPv6 addresses: **ip6**
- c. where **[NETMASK]** is the network mask width. For example, **255.255.255.0** is the network mask for the prefix *198.51.100.0/24*.
- d. where **[GATEWAY]** is the gateway information:
 - For IPv4 addresses: **gw4**
 - For IPv6 addresses: **gw6**

nmcli connection add type ethernet con-name connection-name ifname interface-name ip4 address/network mask gw4 address

1. To create a connection profile with an IPv4 address:

```
~]$ nmcli c add type ethernet ifname enp1s0 con-name "My Connection" ip4
192.168.2.100/24 gw4 192.168.2.1
Connection 'My Connection' (f0c23472-1aec-4e84-8f1b-be8a2ecbeade) successfully added.
```

2. To activate the created connection:

```
~]$ nmcli c up _"My Connection"
```

3. To view the created connection:

```
~]$ nmcli c show "My Connection"
```

Note that the **nmcli c show con-name** command displays all the properties present in the connection, even those that are empty or have a default value. If the output is longer than a terminal page, **nmcli** generates a pager to allow an easy navigation on the output. In the pager, use arrows to move up and down and the **q** key to quit.

For a more compact display of the connection, use the **-o** option:

```
~]$ nmcli -o c show "My Connection"
```

The **nmcli -o c show con-name** command still displays the connection content, but omits empty properties or those that are set to a default value. This usually results in a shorter output that is more readable.

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- See the **nm-settings(5)** man page for more information on properties and their settings.

8.6. USING THE NMCLI INTERACTIVE CONNECTION EDITOR

The **nmcli** tool has an interactive connection editor. It allows you to change connection parameters according to your needs. To use it:

```
~]$ nmcli con edit
```

You should enter a valid **connection type** from the list displayed. Then, you are able to modify its parameters.

```
~]$ nmcli con edit
```

Valid connection types: generic, 802-3-ethernet (ethernet), pppoe, 802-11-wireless (wifi), wimax, gsm, cdma, infiniband, adsl, bluetooth, vpn, 802-11-olpc-mesh (olpc-mesh), vlan, bond, team, bridge, bond-slave, team-slave, bridge-slave, no-slave, tun, ip-tunnel, macsec, macvlan, vxlan, dummy

Enter connection type: **ethernet**

```
===| nmcli interactive connection editor |===
```

Adding a new '802-11-wireless' connection

Type 'help' or '?' for available commands.

Type 'describe [<setting>.<prop>]' for detailed property description.

You may edit the following settings: connection, 802-11-wireless (wifi), 802-11-wireless-security (wifi-sec), 802-1x, ipv4, ipv6, proxy

```
nmcli>
```

It is possible now to edit the **ethernet** connection settings. To get the list of available commands, type **help** or **?**:

```
nmcli> ?
```

```
-----  
---[ Main menu ]---
```

```
goto  [<setting> | <prop>]      :: go to a setting or property  
remove <setting>.<prop> | <prop> :: remove setting or reset property value  
set   [<setting>.<prop> <value>] :: set property value  
describe [<setting>.<prop>]      :: describe property  
print  [all | <setting>.<prop>]  :: print the connection  
verify [all | fix]              :: verify the connection  
save   [persistent|temporary]   :: save the connection  
activate [<ifname>] [/<ap>|<nsp>] :: activate the connection  
back   :: go one level up (back)  
help/? [<command>]              :: print this help  
nmcli  <conf-option> <value>    :: nmcli configuration  
quit   :: exit nmcli  
-----
```

```
nmcli>
```

To exit, enter the **quit** command.

Example 8.13. Adding a new Ethernet connection using the nmcli interactive connection editor

```
~]$ nmcli con edit
```

Valid connection types: generic, 802-3-ethernet (ethernet), pppoe, 802-11-wireless (wifi), wimax,

gsm, cdma, infiniband, adsl, bluetooth, vpn, 802-11-olpc-mesh (olpc-mesh), vlan, bond, team, bridge, bond-slave, team-slave, bridge-slave, no-slave, tun, ip-tunnel, macsec, macvlan, vxlan, dummy

Enter connection type: **ethernet**

===| nmcli interactive connection editor |===

Adding a new '802-3-ethernet' connection

Type 'help' or '?' for available commands.

Type 'describe [<setting>.<prop>]' for detailed property description.

You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, dcb, ipv4, ipv6, proxy

nmcli> **set connection.id new_enp7s0**

nmcli> **set connection.interface-name enp7s0**

nmcli> **set connection.autoconnect yes**

nmcli> **save**

Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the connection.

Do you still want to save? (yes/no) [yes] **yes**

Connection 'new_enp7s0' (34ac8f9a-e9d8-4e0b-9751-d5dc87cc0467) successfully saved.

nmcli> **quit**

A new network interface configuration file is created in the **/etc/sysconfig/network-scripts** directory:

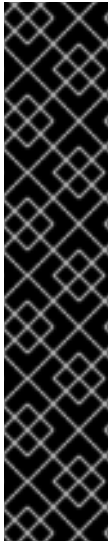
```
~]# ls -lrt /etc/sysconfig/network-scripts/ifcfg*
-rw-r--r--. 1 root root 254 Aug 15 2017 /etc/sysconfig/network-scripts/ifcfg-lo
-rw-r--r--. 1 root root 304 Apr 26 22:14 /etc/sysconfig/network-scripts/ifcfg-ens3
-rw-r--r--. 1 root root 266 Aug 6 11:03 /etc/sysconfig/network-scripts/ifcfg-new_enp7s0
```

8.7. MODIFYING A CONNECTION PROFILE WITH NMCLI

You can modify the existing configuration of a connection profile.

Prerequisites

- [Section 8.1, “Understanding nmcli”](#)
- [Section 8.2, “Overview of nmcli property names and aliases”](#)
- [Section 8.5, “Creating a connection profile with nmcli”](#)



IMPORTANT

If you use the **nmcli** commands, it is recommended to type a partial **nmcli** command, and then press the **Tab** key to auto-complete the command sequence. If multiple completions are possible, then **Tab** lists them all. This helps users to type commands faster and easier. To enable the **nmcli** auto-complete feature be sure to install the **bash-completion** package:

```
~]# yum install bash-completion
```

After the package installation, **nmcli auto-complete** will be available next time you login into a console. To activate it also in the current console, enter:

```
~]$ source /etc/profile.d/bash_completion.sh
```

Procedure

1. To modify one or more properties of a connection profile, use the following command:

```
~]$ nmcli c modify
```

For example, to change the **connection.id** from *"My Connection"* to *"My favorite connection"* and the **connection.interface-name** to *enp7s0*:

```
~]$ nmcli c modify "My Connection" connection.id "My favorite connection"
connection.interface-name enp7s0
```

2. To **apply** changes after a modified connection using **nmcli**, activate again the connection by entering:

```
~]$ nmcli con up "My favorite connection"
Connection successfully activated (D-Bus active path:
/org/freedesktop/NetworkManager/ActiveConnection/16)
```

3. To view the modified connection, enter the **nmcli con show con-name** command.

CHAPTER 9. GETTING STARTED WITH CONFIGURING NETWORKING USING THE GNOME GUI

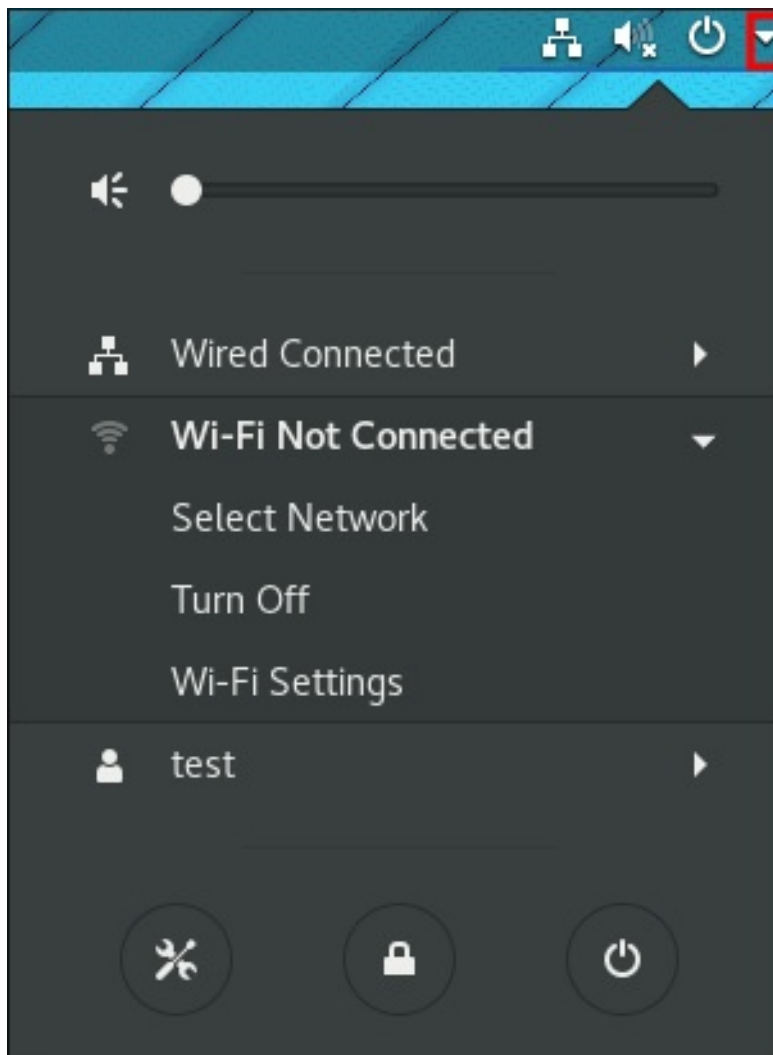
You can configure a network interface using the following **Graphical User Interface (GUI)** ways:

- the GNOME Shell **network connection icon** on the top right of the desktop
- the GNOME **control-center** application
- the GNOME **nm-connection-editor** application

9.1. CONNECTING TO A NETWORK USING THE GNOME SHELL NETWORK CONNECTION ICON

To access the **Network** settings, click on the GNOME Shell **network connection icon** in the top right-hand corner of the screen to open its menu:

Figure 9.1. The network connection icon menu



When you click on the GNOME Shell network connection icon, you can see:

- A list of categorized networks you are currently connected to (such as **Wired** and **Wi-Fi**).
- A list of all **Available Networks** that **NetworkManager** has detected. If you are connected to a network, this is indicated on the left of the connection name.

- Options for connecting to any configured Virtual Private Networks (VPNs) and
- An option for selecting the **Network Settings** menu entry.

9.2. CREATING A NETWORK CONNECTION USING CONTROL-CENTER

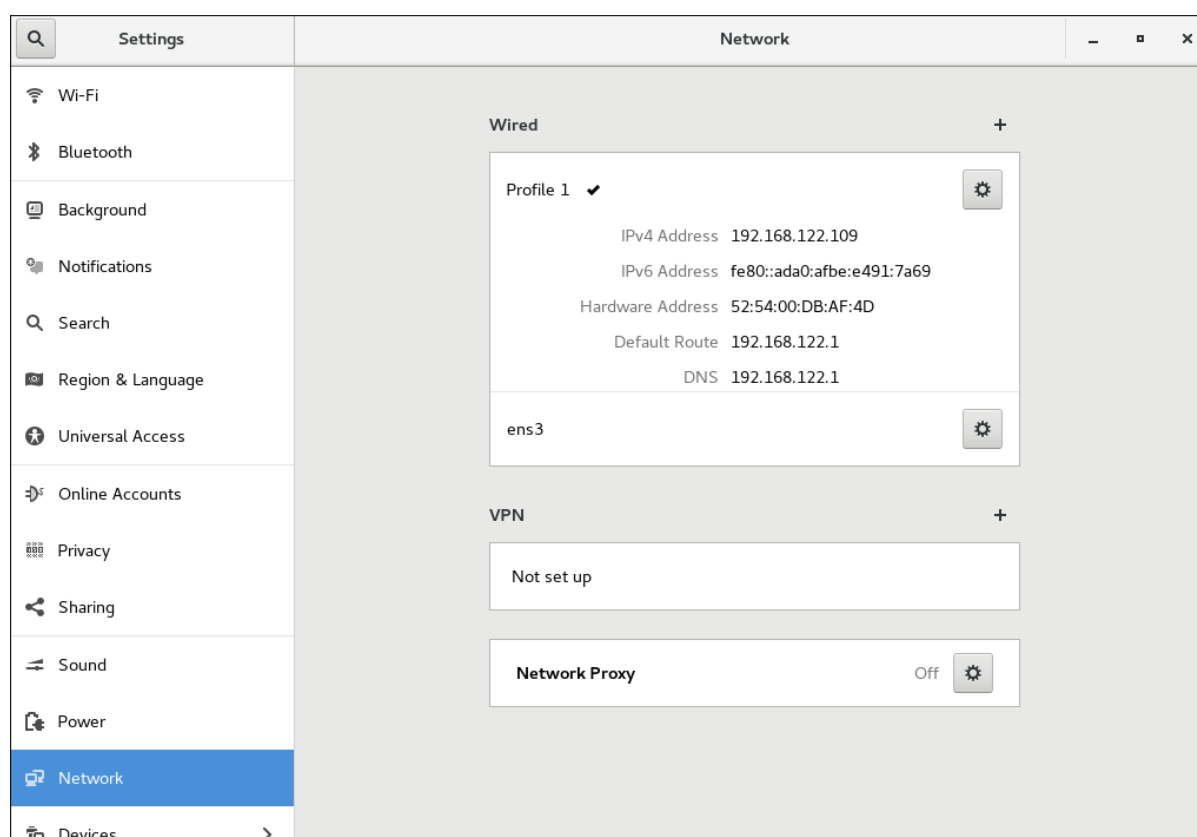
You can create a network connection through the GNOME **control-center** application, which is a graphical user interface that provides a view of available network devices and their current configuration.

This procedure describes how to create a new **wired**, **wireless**, **vpn** connection using **control-center**:

Procedure

1. Press the **Super** key to enter the Activities Overview, type **Settings**, and press **Enter**. Then, select the **Network** tab on the left-hand side, and the **Network** settings tool appears:

Figure 9.2. Opening the network settings window



2. Click the plus button to add a new connection:
 - For **Wired** connections, click the plus button next to **Wired** entry and configure the connection.
 - For **VPN** connections, click the plus button next to **VPN** entry. If you want to add an **IPsec VPN**, click on **IPsec based VPN** and configure the connection.
 - For **Wi-Fi** connections, click the **Wi-Fi** entry on the left-hand side in the **Settings** menu and configure the connection.

CHAPTER 10. CONFIGURING AN ETHERNET CONNECTION

This section describes how to configure an Ethernet connection with static and dynamic IP addresses.

10.1. ADDING A STATIC ETHERNET CONNECTION USING NMCLI

This procedure describes adding an Ethernet connection with the following settings:

- A static IPv4 address – **192.0.2.1** with a **/24** subnet mask
- A static IPv6 address – **2001:db8:1::1** with a **/64** subnet mask
- An IPv4 default gateway – **192.0.2.254**
- An IPv6 default gateway – **2001:db8:1::fffe**
- An IPv4 DNS server – **192.0.2.200**
- An IPv6 DNS server – **2001:db8:1::ffbb**
- A DNS search domain – **example.com**

Procedure

1. Add a new NetworkManager connection profile for the Ethernet connection:

```
# nmcli connection add con-name Example-Connection ifname enp7s0 type ethernet
ipv4.addresses 192.0.2.1/24
```

The further steps modify the **Example-Connection** connection profile you created.

2. Set the IPv6 address:

```
# nmcli connection modify Example-Connection ipv6.addresses 2001:db8:1::1/64
```

3. Set the IPv4 and IPv6 connection method to **manual**:

```
# nmcli connection modify Example-Connection ipv4.method manual
# nmcli connection modify Example-Connection ipv6.method manual
```

4. Set the IPv4 and IPv6 default gateways:

```
# nmcli connection modify Example-Connection ipv4.gateway 192.0.2.254
# nmcli connection modify Example-Connection ipv6.gateway 2001:db8:1::fffe
```

5. Set the IPv4 and IPv6 DNS server addresses:

```
# nmcli connection modify Example-Connection ipv4.dns "192.0.2.200"
# nmcli connection modify Example-Connection ipv6.dns "2001:db8:1::ffbb"
```

To set multiple DNS servers, specify them space-separated and enclosed in quotes.

6. Set the DNS search domain for the IPv4 and IPv6 connection:

```
# nmcli connection modify Example-Connection ipv4.dns-search example.com
# nmcli connection modify Example-Connection ipv6.dns-search example.com
```

7. Active the connection profile:

```
# nmcli connection up Example-Connection
Connection successfully activated (D-Bus active path:
/org/freedesktop/NetworkManager/ActiveConnection/13)
```

Verification steps

1. Display the status of the devices and connections:

```
# nmcli device status
DEVICE    TYPE    STATE    CONNECTION
enp7s0    ethernet connected Example-Connection
```

2. To display all settings of the connection profile:

```
# nmcli connection show Example-Connection
connection.id:      Example-Connection
connection.uuid:    b6cdfa1c-e4ad-46e5-af8b-a75f06b79f76
connection.stable-id: --
connection.type:    802-3-ethernet
connection.interface-name: enp7s0
...
```

3. Use the **ping** utility to verify that this host can send packets to other hosts.

- Ping an IP address in the same subnet.
For IPv4:

```
# ping 192.0.2.3
```

For IPv6:

```
# ping 2001:db8:2::1
```

If the command fails, verify the IP and subnet settings.

- Ping an IP address in a remote subnet.
For IPv4:

```
# ping 198.162.3.1
```

For IPv6:

```
# ping 2001:db8:2::1
```

- If the command fails, ping the default gateway to verify settings.
For IPv4:

```
# ping 192.0.2.254
```

For IPv6:

```
# ping 2001:db8:1::fffe
```

4. Use the **host** utility to verify that name resolution works. For example:

```
# host client.example.com
```

If the command returns any error, such as **connection timed out** or **no servers could be reached**, verify your DNS settings.

Troubleshooting steps

1. If the connection fails or if the network interface switches between an up and down status:
 - Make sure that the network cable is plugged-in to the host and a switch.
 - Check whether the link failure exists only on this host or also on other hosts connected to the same switch the server is connected to.
 - Verify that the network cable and the network interface are working as expected. Perform hardware diagnosis steps and replace defect cables and network interface cards.

Additional resources

- See the **nm-settings(5)** man page for more information on connection profile properties and their settings.
- For further details about the **nmcli** utility, see the **nmcli(1)** man page.
- If the configuration on the disk does not match the configuration on the device, starting or restarting NetworkManager creates an in-memory connection that reflects the configuration of the device. For further details and how to avoid this problem, see [NetworkManager duplicates a connection after restart of NetworkManager service](#).

10.2. CONFIGURING A STATIC ETHERNET CONNECTION USING THE NMCLI INTERACTIVE EDITOR

To configure a static Ethernet connection using the **nmcli** interactive editor:

```
~]$ nmcli con edit type ethernet con-name ens3
```

```
===| nmcli interactive connection editor |===
```

Adding a new '802-3-ethernet' connection

Type 'help' or '?' for available commands.

Type 'describe [>setting<.>prop<'] for detailed property description.

You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, ipv4, ipv6, dcb
nmcli> **set ipv4.addresses 192.168.122.88/24**

Do you also want to set 'ipv4.method' to 'manual'? [yes]: **yes**

```
nmcli> set ipv4.dns 192.168.122.1
nmcli> set ipv4.dns-search example.com
nmcli> save persistent
Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the
connection.
Do you still want to save? [yes] yes
Connection 'ens3' (704a5666-8cbd-4d89-b5f9-fa65a3dbc916) successfully saved.
nmcli> quit
```

The default action is to save the connection profile as persistent. If required, the profile can be held in memory only, until the next restart, by means of the **save temporary** command.

10.3. CONFIGURING A DYNAMIC ETHERNET CONNECTION WITH NMCLI

Prerequisites

- [Section 8.1, “Understanding nmcli”](#)
- [Section 8.5, “Creating a connection profile with nmcli”](#)

Procedure

1. To change the host name sent by a host to a **DHCP** server, modify the **dhcp-hostname** property:

```
~]$ nmcli con modify my-office my-office ipv4.dhcp-hostname host-name ipv6.dhcp-
hostname host-name
```

2. To change the **IPv4** client ID sent by a host to a **DHCP** server, modify the **dhcp-client-id** property:

```
~]$ nmcli con modify my-office my-office ipv4.dhcp-client-id client-ID-string
```

There is no **dhcp-client-id** property for **IPv6**, **dhclient** to create an identifier for **IPv6**. See the **dhclient(8)** man page for details.

3. To ignore the **DNS** servers sent to a host by a **DHCP** server, modify the **ignore-auto-dns** property:

```
~]$ nmcli con modify my-office my-office ipv4.ignore-auto-dns yes ipv6.ignore-auto-
dns yes
```

10.4. CONFIGURING A DYNAMIC ETHERNET CONNECTION USING THE INTERACTIVE EDITOR

To configure a dynamic Ethernet connection using the interactive editor:

```
~]$ nmcli con edit type ethernet con-name ens3

===| nmcli interactive connection editor |===
```

Adding a new '802-3-ethernet' connection

Type 'help' or '?' for available commands.

Type 'describe [<setting>.<prop>]' for detailed property description.

You may edit the following settings: connection, 802-3-ethernet (ethernet), 802-1x, ipv4, ipv6, dcb
nmcli> **describe ipv4.method**

=== [method] ===

[NM property description]

IPv4 configuration method. If 'auto' is specified then the appropriate automatic method (DHCP, PPP, etc) is used for the interface and most other properties can be left unset. If 'link-local' is specified, then a link-local address in the 169.254/16 range will be assigned to the interface. If 'manual' is specified, static IP addressing is used and at least one IP address must be given in the 'addresses' property. If 'shared' is specified (indicating that this connection will provide network access to other computers) then the interface is assigned an address in the 10.42.x.1/24 range and a DHCP and forwarding DNS server are started, and the interface is NAT-ed to the current default network connection. 'disabled' means IPv4 will not be used on this connection. This property must be set.

nmcli> **set ipv4.method auto**

nmcli> **save**

Saving the connection with 'autoconnect=yes'. That might result in an immediate activation of the connection.

Do you still want to save? [yes] **yes**

Connection 'ens3' (090b61f7-540f-4dd6-bf1f-a905831fc287) successfully saved.

nmcli> **quit**

The default action is to save the connection profile as persistent. If required, the profile can be held in memory only, until the next restart, by means of the **save temporary** command.

Additional resources

- See the **nm-settings(5)** man page for more information on properties and their settings.

10.5. CONFIGURING AN ETHERNET CONNECTION USING CONTROL-CENTER

You can configure a network connection through the GNOME **control-center** application.

Procedure

1. Press the **Super** key to enter the Activities Overview, type **Settings** and press **Enter**. Then, select the **Network** menu entry on the left-hand side, and the **Network** settings tool appears, see [Opening the Network Settings Window](#)
2. Select the **Wired** network interface
The system creates and configures a single wired *connection profile* called **Wired** by default. More than one profile can be created for an interface and applied as needed. The default profile cannot be deleted but its settings can be changed.
3. Edit the default **Wired** profile by clicking the gear wheel icon to edit an existing connection or click the plus button and then set the configuration options for a new connection.

**NOTE**

When you add a new connection by clicking the plus button, **NetworkManager** creates a new configuration file for that connection and then opens the same dialog that is used for editing an existing connection. The difference between these dialogs is that an existing connection profile has a **Details** menu entry.

Basic configuration options

You can see the following configuration settings in the **Wired** dialog, by selecting the **Identity** menu entry:

Figure 10.1. Basic configuration options of a wired connection

The screenshot shows the 'New Profile' dialog box. At the top, there are 'Cancel', 'New Profile', and 'Add' buttons. Below the title bar, there are four tabs: 'Identity', 'IPv4', 'IPv6', and 'Security'. The 'Identity' tab is selected and highlighted with a red box. The main area of the dialog contains the following fields:

- Name:** A text input field containing the text 'Test'.
- MAC Address:** A text input field with a dropdown arrow on the right.
- Cloned Address:** A text input field.
- MTU:** A text input field containing the text 'automatic', with minus and plus buttons on the right.

- **Name** – Enter a descriptive name for your network connection. This name will be used to list this connection in the menu of the **Network** window.
- **MAC Address** – Select the MAC address of the interface this profile must be applied to.
- **Cloned Address** – If required, enter a different MAC address to use.
- **MTU** – If required, enter a specific *maximum transmission unit (MTU)* to use. The MTU value represents the size in bytes of the largest packet that the link layer will transmit. This value defaults to **1500** and does not generally need to be specified or changed.

Configuring IPv4 settings for wired with control-center

You can further configure **IPv4** settings in a wired connection. In the **Wired** dialog, click the **IPv4** menu entry:

Figure 10.2. Configuring IPv4 Settings

New Profile

Cancel Add

Identity **IPv4** IPv6 Security

IPv4 Method

☒ Automatic (DHCP) ☐ Link-Local Only

☐ Manual ☐ Disable

DNS Automatic **ON**

Separate IP addresses with commas

Routes Automatic **ON**

Address	Netmask	Gateway	Metric

☐ Use this connection only for resources on its network

The **IPv4** menu entry allows you to configure:

- the **IPv4 Method** used to connect to a network
- **DNS** and
- **Routes**

IPv4 Method

Automatic (DHCP) – Choose this option if the network you are connecting to uses Router Advertisements (RA) or a **DHCP** server to assign dynamic **IP** addresses.

Link-Local Only – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per [RFC 3927](#) with prefix **169.254/16**.

Manual – Choose this option if you want to assign **IP** addresses manually.

Disable – **IPv4** is disabled for this connection.

DNS

In the **DNS** section, when **Automatic** is **ON**. Switch Automatic to **OFF** to enter the IP address of a DNS server you want to use separating the IPs by comma.

Routes

**NOTE**

In the **Routes** section, when **Automatic** is **ON**, routes from Router Advertisements (RA) or DHCP are used, but you can also add additional static routes. When **OFF**, only static routes are used.

Address – Enter the **IP** address of a remote network, sub-net, or host.

Netmask – The netmask or prefix length of the **IP** address entered above.

Gateway – The **IP** address of the gateway leading to the remote network, sub-net, or host entered above.

Metric – A network cost, a preference value to give to this route. Lower values will be preferred over higher values.

Use this connection only for resources on its network

Select this check box to prevent the connection from becoming the default route. Typical examples are where a connection is a VPN tunnel or a leased line to a head office and you do not want any Internet-bound traffic to pass over the connection. Selecting this option means that only traffic specifically destined for routes learned automatically over the connection or entered here manually will be routed over the connection.

Configuring IPv6 settings for wired with control center

Alternatively, to configure **IPv6** settings in a wired connection, click the **IPv6** menu entry:

Figure 10.3. Configuring IPv6 settings

New Profile

Cancel Add

Identity IPv4 **IPv6** Security

IPv6 Method

☒ Automatic ☐ Automatic, DHCP only

☐ Link-Local Only ☐ Manual

☐ Disable

DNS Automatic ☒ ON

Separate IP addresses with commas

Routes Automatic ☒ ON

Address	Prefix	Gateway	Metric

☐ Use this connection only for resources on its network

The **IPv6** menu entry allows you to configure:

- the **IPv6 Method** used to connect to a network
- **DNS** and
- **Routes**

IPv6 Method

Automatic – Choose this option to use **IPv6** Stateless Address AutoConfiguration (SLAAC) to create an automatic, stateless configuration based on the hardware address and Router Advertisements (RA).

Automatic, DHCP only – Choose this option to not use RA, but request information from **DHCPv6** directly to create a stateful configuration.

Link-Local Only – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per [RFC 4862](#) with prefix **FE80::0**.

Manual – Choose this option if you want to assign **IP** addresses manually.

Disabled – **IPv6** is disabled for this connection.

Configuring 802.1X security for wired with control-center

802.1X security is the name of the IEEE standard for *port-based Network Access Control (PNAC)*. It is also called *WPA Enterprise*. 802.1X security is a way of controlling access to a *logical network* from a physical one. All clients who want to join the logical network must authenticate with the server (a router, for example) using the correct 802.1X authentication method.

To configure **802.1X Security** settings in a wired connection, click the **Security** menu entry:

Figure 10.4. Configuring 802.1X security for a wired with control-center

The screenshot shows the 'New Profile' dialog box with the 'Security' tab selected. The '802.1x Security' toggle is turned 'ON'. The 'Authentication' dropdown menu is set to 'TLS'. The 'Identity' text field is empty and has a red border around it. Below it, 'User certificate' and 'CA certificate' are both set to '(None)'. There is a checkbox labeled 'No CA certificate is required' which is unchecked. 'Private key' is also set to '(None)'. The 'Private key password' field is empty, and the 'Show password' checkbox is unchecked.

To enable settings configuration, set the symbolic power button to **ON**, and select from one of following authentication methods:

- **TLS** for *Transport Layer Security* and proceed to [Configuring TLS Settings](#)
- **PWD** for *Password* and proceed to [Configuring PWD Settings](#)
- **FAST** for *Flexible Authentication through Secure Tunneling* and proceed to [Configuring FAST Settings](#)
- Select **Tunneled TLS** for *Tunneled Transport Layer Security*, otherwise known as TTLS, or EAP-TTLS and proceed to [Configuring Tunneled TLS Settings](#)
- Select **Protected EAP (PEAP)** for *Protected Extensible Authentication Protocol* and proceed to [Configuring Protected EAP PEAP Settings](#)

Configuring TLS settings

With Transport Layer Security (TLS), the client and server mutually authenticate using the TLS protocol.

Using TLS security requires the overhead of a public key infrastructure (PKI) to manage certificates. The benefit of using TLS security is that a compromised password does not allow access to the (W)LAN: an intruder must also have access to the authenticating client's private key.

NetworkManager does not determine the version of TLS supported. **NetworkManager** gathers the parameters entered by the user and passes them to the daemon, **wpa_supplicant**, that handles the procedure. It in turn uses OpenSSL to establish the TLS tunnel. OpenSSL itself negotiates the SSL/TLS protocol version. It uses the highest version both ends support.

To configure TLS settings, follow the procedure described in [Section 10.5, "Configuring an Ethernet connection using control-center"](#). The following configuration settings are available:

Identity

Provide the identity of this server.

User certificate

Click to browse for, and select, a personal X.509 certificate file encoded with *Distinguished Encoding Rules (DER)* or *Privacy Enhanced Mail (PEM)*.

CA certificate

Click to browse for, and select, an X.509 *certificate authority* certificate file encoded with *Distinguished Encoding Rules (DER)* or *Privacy Enhanced Mail (PEM)*.

Private key

Click to browse for, and select, a *private key* file encoded with *Distinguished Encoding Rules (DER)*, *Privacy Enhanced Mail (PEM)*, or the *Personal Information Exchange Syntax Standard (PKCS #12)*.

Private key password

Enter the password for the private key in the **Private key** field. Select **Show password** to make the password visible as you type it.

Configuring PWD settings

With Password (PWD), you can specify the username and the password.

Username

Enter the user name to be used in the authentication process.

Password

Enter the password to be used in the authentication process.

Configuring FAST settings

To configure FAST settings, follow the procedure described in [Section 10.5, "Configuring an Ethernet connection using control-center"](#). The following configuration settings are available:

Anonymous Identity

Provide the identity of this server.

Allow automatic PAC provisioning

Select the check box to enable and then select from Anonymous, Authenticated, and Both.

PAC file

Click to browse for, and select, a *protected access credential (PAC)* file.

Inner authentication

GTC – Generic Token Card.

MSCHAPv2 – Microsoft Challenge Handshake Authentication Protocol version 2.

Username

Enter the user name to be used in the authentication process.

Password

Enter the password to be used in the authentication process.

Configuring tunneled TLS settings

To configure Tunneled TLS settings, follow the procedure described in [Section 10.5, “Configuring an Ethernet connection using control-center”](#). The following configuration settings are available:

Anonymous identity

This value is used as the unencrypted identity.

CA certificate

Click to browse for, and select, a Certificate Authority’s certificate.

Inner authentication

PAP – Password Authentication Protocol.

MSCHAP – Challenge Handshake Authentication Protocol.

MSCHAPv2 – Microsoft Challenge Handshake Authentication Protocol version 2.

MSCHAPv2 (no EAP) – Microsoft Challenge Handshake Authentication Protocol version 2 without Extensive Authentication Protocol.

CHAP – Challenge Handshake Authentication Protocol.

MD5 – Message Digest 5, a cryptographic hash function.

GTC – Generic Token Card.

Username

Enter the user name to be used in the authentication process.

Password

Enter the password to be used in the authentication process.

Configuring protected EAP (PEAP) settings

To configure Protected EAP (PEAP) settings, follow the procedure described in [Section 10.5, “Configuring an Ethernet connection using control-center”](#). The following configuration settings are available:

Anonymous Identity

This value is used as the unencrypted identity.

CA certificate

Click to browse for, and select, a Certificate Authority’s certificate.

PEAP version

The version of Protected EAP to use. Automatic, 0 or 1.

Inner authentication

MSCHAPv2 – Microsoft Challenge Handshake Authentication Protocol version 2.

MD5 – Message Digest 5, a cryptographic hash function.

GTC – Generic Token Card.

Username

Enter the user name to be used in the authentication process.

Password

Enter the password to be used in the authentication process.

10.6. CONFIGURING AN ETHERNET CONNECTION USING NM-CONNECTION-EDITOR

Ethernet connections are the most frequently used connection types in physical or virtual servers. This section describes how to configure this connection type in Red Hat Enterprise Linux.

Prerequisites

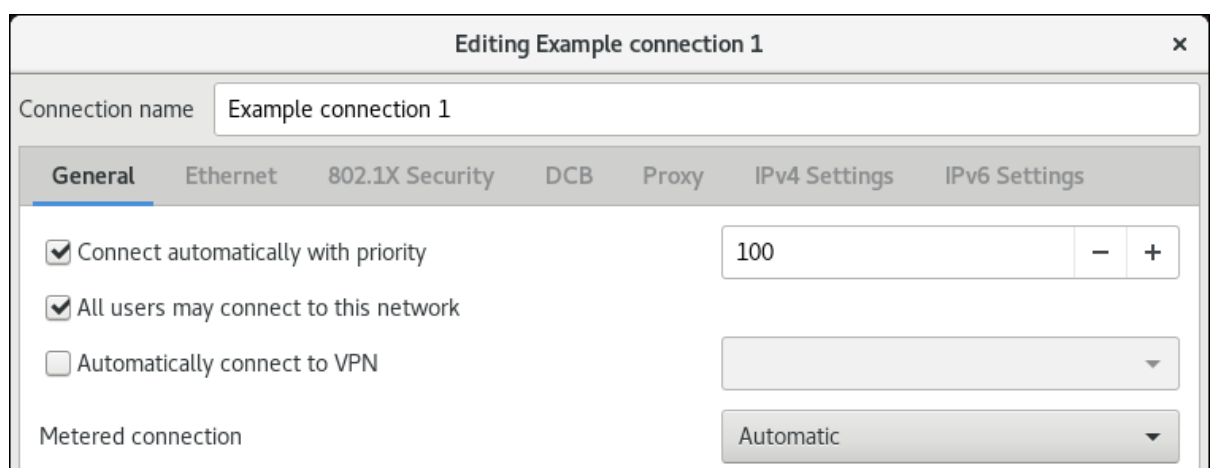
- A physical or virtual Ethernet device exists in the server's configuration.

Procedure

1. Open a terminal, and enter:

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **Ethernet** connection type, and click **Create**.
4. On the **General** tab:
 - a. To automatically enable this connection when the system boots or when you restart the **NetworkManager** service:
 - i. Select **Connect automatically with priority**.
 - ii. Optional: Change the priority value next to **Connect automatically with priority**.
If multiple connection profiles exist for the same device, NetworkManager enables only one profile. By default, NetworkManager activates the last-used profile that has auto-connect enabled. However, if you set priority values in the profiles, NetworkManager activates the profile with the highest priority.
 - b. Clear the **All users may connect to this network** check box if the profile should be available only to the user that created the connection profile.



5. On the **Ethernet** tab, select a device and, optionally, further Ethernet-related settings.

The screenshot shows the 'Editing Ethernet connection 1' window with the 'Ethernet' tab selected. The 'Connection name' is 'Ethernet connection 1'. The 'Device' is set to 'enp1s0 (52:54:00:6B:74:BE)'. The 'Cloned MAC address' is empty. The 'MTU' is set to 'automatic'. The 'Wake on LAN' section has 'Default' checked, with 'Phy', 'Unicast', 'Multicast', 'Ignore', 'Broadcast', 'Arp', and 'Magic' all unchecked. The 'Wake on LAN password' is empty. The 'Link negotiation' is set to 'Ignore'. The 'Speed' is set to '100 Mb/s' and the 'Duplex' is set to 'Full'.

6. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, and DNS server:

The screenshot shows the IPv4 Settings tab. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one entry:

Address	Netmask	Gateway
192.0.2.1	24	192.0.2.254

Buttons for 'Add' and 'Delete' are to the right of the table. Below the table, the 'DNS servers' field contains '192.0.2.1'.

7. On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, and DNS server:

The screenshot shows the IPv6 Settings tab. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one entry:

Address	Prefix	Gateway
2001:db8:1::1	64	2001:db8:1::fff3

Buttons for 'Add' and 'Delete' are to the right of the table. Below the table, the 'DNS servers' field contains '2001:db8:1::fffd'.

8. Save the connection.

9. Close **nm-connection-editor**.

Verification steps

1. Use the **ping** utility to verify that this host can send packets to other hosts.

- Ping an IP address in the same subnet.
For IPv4:

```
# ping 192.0.2.3
```

For IPv6:

```
# ping 2001:db8:2::1
```

If the command fails, verify the IP and subnet settings.

- Ping an IP address in a remote subnet.
For IPv4:

```
# ping 198.162.3.1
```

For IPv6:

```
# ping 2001:db8:2::1
```

- If the command fails, ping the default gateway to verify settings.
For IPv4:

```
# ping 192.0.2.254
```

For IPv6:

```
# ping 2001:db8:1::fff3
```

- Use the **host** utility to verify that name resolution works. For example:

```
# host client.example.com
```

If the command returns any error, such as **connection timed out** or **no servers could be reached**, verify your DNS settings.

CHAPTER 11. MANAGING WI-FI CONNECTIONS

This section describes how to configure and manage Wi-Fi connections.

11.1. CONFIGURING A WI-FI CONNECTION USING NMCLI

This procedure describes how to configure a Wi-fi connection profile using nmcli.

Prerequisites

- The **nmcli** utility to be installed.
- Make sure that the WiFi radio is on (default):

```
~]$ nmcli radio wifi on
```

Procedure

1. To create a Wi-Fi connection profile with static **IP** configuration:

```
~]$ nmcli con add con-name MyCafe ifname wlan0 type wifi ssid MyCafe ` ` ipv4
192.168.100.101/24 gw4 192.168.100.1
```

2. Set a DNS server. For example, to set **192.160.100.1** as the DNS server:

```
~]$ nmcli con modify con-name MyCafe ipv4.dns "192.160.100.1"
```

3. Optionally, set a DNS search domain. For example, to set the search domain to **example.com**:

```
~]$ nmcli con modify con-name MyCafe ipv4.dns-search "example.com"
```

4. To check a specific property, for example **mtu**:

```
~]$ nmcli connection show id MyCafe | grep mtu
802-11-wireless.mtu:          auto
```

5. To change the property of a setting:

```
~]$ nmcli connection modify id MyCafe 802-11-wireless.mtu 1350
```

6. To verify the change:

```
~]$ nmcli connection show id MyCafe | grep mtu
802-11-wireless.mtu:          1350
```

Verification steps

1. Use the **ping** utility to verify that this host can send packets to other hosts.
 - Ping an IP address in the same subnet. For example:

```
# ping 192.168.100.103
```


■

If the command fails, verify the IP and subnet settings.

- Ping an IP address in a remote subnet. For example:

```
# ping 198.51.16.3
```

- If the command fails, ping the default gateway to verify settings.

```
# ping 192.168.100.1
```

2. Use the **host** utility to verify that name resolution works. For example:

```
# host client.example.com
```

If the command returns any error, such as **connection timed out** or **no servers could be reached**, verify your DNS settings.

Additional resources

- See the **nm-settings(5)** man page for more information on properties and their settings.
- If the configuration on the disk does not match the configuration on the device, starting or restarting NetworkManager creates an in-memory connection that reflects the configuration of the device. For further details and how to avoid this problem, see [NetworkManager duplicates a connection after restart of NetworkManager service](#).

11.2. CONFIGURING A WI-FI CONNECTION USING CONTROL-CENTER

When you connect to a **Wi-Fi**, the network settings are prefilled depending on the current network connection. This means that the settings will be detected automatically when the interface connects to a network.

This procedure describes how to use **control-center** to manually configure the **Wi-Fi** settings.

Procedure

1. Press the **Super** key to enter the **Activities Overview**, type **Wi-Fi** and press **Enter**. In the left-hand-side menu entry you see the list of available networks.
2. Select the gear wheel icon to the right of the **Wi-Fi** connection name that you want to edit, and the editing connection dialog appears. The **Details** menu window shows the connection details where you can make further configuration.

Options

- a. If you select **Connect automatically**, **NetworkManager** auto-connects to this connection whenever **NetworkManager** detects that it is available. If you do not want **NetworkManager** to connect automatically, clear the check box. Note that when the check box is clear, you have to select that connection manually in the network connection icon's menu to cause it to connect.
- b. To make a connection available to other users, select the **Make available to other users** check box.
- c. You can also control the background data usage. If you leave **Restrict background data**

usage unspecified (default), then **NetworkManager** tries to download data that you are actively using. Otherwise, select the check box and **NetworkManager** sets the connection as metered, and applies restriction on the background data usage.



NOTE

To delete a **Wi-Fi** connection, click the **Forget Connection** red box.

3. Select the **Identity** menu entry to see the basic configuration options.

SSID – The *Service Set Identifier* (SSID) of the access point (AP).

BSSID – The *Basic Service Set Identifier* (BSSID) is the MAC address, also known as a *hardware address*, of the specific wireless access point you are connecting to when in **Infrastructure** mode. This field is blank by default, and you are able to connect to a wireless access point by **SSID** without having to specify its **BSSID**. If the BSSID is specified, it will force the system to associate to a specific access point only. For ad-hoc networks, the **BSSID** is generated randomly by the **mac80211** subsystem when the ad-hoc network is created. It is not displayed by **NetworkManager**.

MAC address – The *MAC address* allows you to associate a specific wireless adapter with a specific connection (or connections).

Cloned Address – A cloned MAC address to use in place of the real hardware address. Leave blank unless required.

4. For further IP address configuration, select the **IPv4** and **IPv6** menu entries.

By default, both **IPv4** and **IPv6** are set to automatic configuration depending on current network settings. This means that addresses such as the local IP address, DNS address, and other settings will be detected automatically when the interface connects to a network. If a DHCP server assigns the IP configuration in this network, this is sufficient, but you can also provide static configuration in the **IPv4** and **IPv6** Settings. In the **IPv4** and **IPv6** menu entries, you can see the following settings:

- **IPv4 Method**

- **Automatic (DHCP)** – Choose this option if the network you are connecting to uses Router Advertisements (RA) or a **DHCP** server to assign dynamic IP addresses. You can see the assigned IP address in the **Details** menu entry.
- **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign IP addresses manually. Random addresses will be assigned as per [RFC 3927](#) with prefix **169.254/16**.
- **Manual** – Choose this option if you want to assign IP addresses manually.
- **Disable** – **IPv4** is disabled for this connection.

- **DNS**

If **Automatic** is **ON**, and no DHCP server is available that assigns DNS servers to this connection, switch it to **OFF** to enter the IP address of a DNS server separating the IPs by comma.

- **Routes**

Note that in the **Routes** section, when **Automatic** is **ON**, routes from Router Advertisements (RA) or DHCP are used, but you can also add additional static routes. When **OFF**, only static routes are used.

- **Address** – Enter the **IP** address of a remote network, sub-net, or host.
- **Netmask** – The netmask or prefix length of the IP address entered above.
- **Gateway** – The IP address of the gateway leading to the remote network, sub-net, or host entered above.
- **Metric** – A network cost, a preference value to give to this route. Lower values will be preferred over higher values.
- **Use this connection only for resources on its network**
Select this check box to prevent the connection from becoming the default route.

Alternatively, to configure **IPv6** settings in a **Wi-Fi** connection, select the **IPv6** menu entry:

- **IPv6 Method**
 - **Automatic** – Choose this option to use **IPv6** Stateless Address AutoConfiguration (SLAAC) to create an automatic, stateless configuration based on the hardware address and Router Advertisements (RA).
 - **Automatic, DHCP only** – Choose this option to not use RA, but request information from **DHCPv6** directly to create a stateful configuration.
 - **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign IP addresses manually. Random addresses will be assigned as per [RFC 4862](#) with prefix **FE80::0**.
 - **Manual** – Choose this option if you want to assign IP addresses manually.
 - **Disable** – **IPv6** is disabled for this connection.
 - The **DNS, Routes, Use this connection only for resources on its network** fields are common to **IPv4** settings.
5. To configure **Security** settings in a **Wi-Fi** connection, select the **Security** menu entry. The following configuration options are available:
- **Security**
 - **None** – Do not encrypt the Wi-Fi connection.
 - **WEP 40/128-bit Key** – Wired Equivalent Privacy (WEP), from the IEEE 802.11 standard. Uses a single pre-shared key (PSK).
 - **WEP 128-bit Passphrase** – An MD5 hash of the passphrase to derive a WEP key.



WARNING

If the **Wi-Fi** use no encryption, **WEP**, or **WPA**, do not use the network because it is insecure and everyone can read the data you send over this network.

- **LEAP** – Lightweight Extensible Authentication Protocol, from Cisco Systems.
- **Dynamic WEP (802.1X)** – WEP keys are changed dynamically.
- **WPA & WPA2 Personal** – Wi-Fi Protected Access (WPA), from the draft IEEE 802.11i standard. A replacement for WEP. Wi-Fi Protected Access II (WPA2), from the 802.11i-2004 standard. Personal mode uses a pre-shared key (WPA-PSK).
- **WPA & WPA2 Enterprise** – WPA for use with a RADIUS authentication server to provide IEEE 802.1X network access control.
- **Password** – Enter the password to be used in the authentication process.

6. Once you have finished the configuration, click the **Apply** button to save it.



NOTE

When you add a new connection by clicking the **plus** button, **NetworkManager** creates a new configuration file for that connection and then opens the same dialog that is used for editing an existing connection. The difference between these dialogs is that an existing connection profile has a **Details** menu entry.

11.3. CONNECTING TO A WI-FI NETWORK WITH NMCLI

This procedure describes how to connect to a **wireless** connection using the **nmcli** utility.

Prerequisites

- The **nmcli** utility to be installed.
- Make sure that the WiFi radio is on (default):

```
~]$ nmcli radio wifi on
```

Procedure

1. To refresh the available Wi-Fi connection list:

```
~]$ nmcli device wifi rescan
```

2. To view the available Wi-Fi access points:

```
~]$ nmcli dev wifi list
```

IN-USE	SSID	MODE	CHAN	RATE	SIGNAL	BARS	SECURITY
...	MyCafe	Infra	3	405 Mbit/s	85	<div style="width: 85%; height: 10px; background-color: black;"></div>	WPA1 WPA2

3. To connect to a Wi-Fi connection using **nmcli**:

```
~]$ nmcli dev wifi connect SSID-Name password wireless-password
```

For example:

-

```
~]$ nmcli dev wifi connect MyCafe password wireless-password
```

Note that if you want to disable the Wi-Fi state:

```
~]$ nmcli radio wifi off
```

11.4. CONNECTING TO A HIDDEN WI-FI NETWORK USING NMCLI

All access points have a Service Set Identifier (SSID) to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is hidden, and will not show up in **NetworkManager's** list of Available networks.

This procedure shows how you can connect to a hidden network using the **nmcli** tool.

Prerequisites

- The **nmcli** utility to be installed. *
- To know the SSID, and password of the **Wi-Fi** connection.
- Make sure that the WiFi radio is on (default):

```
~]$ nmcli radio wifi on
```

Procedure

Connect to the SSID that is hidden:

```
~]$ nmcli dev wifi connect SSID_Name password wireless_password hidden yes
```

11.5. CONNECTING TO A WI-FI NETWORK USING THE GNOME GUI

This procedure describes how you can connect to a wireless network to get access to the internet.

Procedure

1. Open the [GNOME Shell network connection icon menu](#) from the top right-hand corner of the screen.
2. Select **Wi-Fi Not Connected**.
3. Click the **Select Network** option.
4. Click the name of the network to which you want to connect, and then click **Connect**.
Note that if you do not see the network, the network might be hidden.
5. If the network is protected by a password or encryption keys are required, enter the password and click **Connect**.
Note that if you do not know the password, contact the administrator of the Wi-Fi network.
6. If the connection is successful, the name of the network is visible in the connection icon menu and the wireless indicator is on the top right-hand corner of the screen.

Additional resources

- [Configuring a Wi-Fi connection using control center](#) .

11.6. CONFIGURING 802.1X SECURITY FOR WI-FI WITH NMCLI

This procedure describes how to set the network security settings in a **wireless** or a **Wired** connection using the **nmcli** utility.

Prerequisites

- The **nmcli** utility is installed.

Procedure

1. For a **wireless** connection, set the authenticated **key-mgmt** (key management) protocol. It configures the keying mechanism for a secure **wifi** connection.
2. Configure the 802-1x authentication settings.

Table 11.1. The 802-1x authentication settings

802-1x authentication setting	Name
802-1x.identity	Identity
802-1x.ca-cert	CA certificate
802-1x.client-cert	User certificate
802-1x.private-key	Private key
802-1x.private-key-password	Private key password

For example, to configure WPA2 Enterprise using the EAP-TLS authentication method, apply the following settings:

```
~]$ nmcli c add type wifi ifname wlan0 con-name 'My Wifi Network' \
802-11-wireless.ssid 'My Wifi' \
802-11-wireless-security.key-mgmt wpa-eap \
802-1x.eap tls \
802-1x.identity identity@example.com \
802-1x.ca-cert /etc/pki/my-wifi/ca.crt \
802-1x.client-cert /etc/pki/my-wifi/client.crt \
802-1x.private-key /etc/pki/my-wifi/client.key \
802-1x.private-key-password s3cr3t
```



NOTE

To configure a **wired** connection using the **nmcli** tool, follow the same procedure as for a **wireless** connection, except the **802-11-wireless.ssid** and **802-11-wireless-security key-mgmt** settings.

CHAPTER 12. SETTING A DEFAULT GATEWAY OF AN EXISTING CONNECTION

In most situations, administrators set the default gateway when they create a connection. However, you can also set the default gateway after creating the connection.

This section describes how to set the default gateway of an existing network connection.

12.1. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING NMCLI

In most situations, administrators set the default gateway when they create a connection as explained in, for example, [Section 10.1, “Adding a static Ethernet connection using nmcli”](#).

This section describes how to set or update the default gateway on a previously created connection using the **nmcli** utility.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.
- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, user must have **root** permissions.

Procedure

1. Set the IP address of the default gateway.
For example, to set the IPv4 address of the default gateway on the **example** connection to **192.0.2.1**:

```
$ sudo nmcli connection modify example ipv4.gateway "192.0.2.1"
```

For example, to set the IPv6 address of the default gateway on the **example** connection to **2001:db8:1::1**:

```
$ sudo nmcli connection modify example ipv6.gateway "2001:db8:1::1"
```

2. Restart the network connection for changes to take effect. For example, to restart the **example** connection using the command line:

```
$ sudo nmcli connection up example
```



WARNING

All connections currently using this network connection are temporarily interrupted during the restart.

3. Optionally, verify that the route is active.

To display the IPv4 default gateway:

```
$ ip -4 route  
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```
$ ip -6 route  
default via 2001:db8:1::1 dev example proto static metric 100 pref medium
```

Additional resources

- [Section 10.1, “Adding a static Ethernet connection using nmcli”](#)

12.2. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING THE NMCLI INTERACTIVE MODE

In most situations, administrators set the default gateway when they create a connection as explained in, for example, [Section 10.4, “Configuring a dynamic Ethernet connection using the interactive editor”](#).

This section describes how to set or update the default gateway on a previously created connection using the interactive mode of the **nmcli** utility.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.
- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the user must have **root** permissions.

Procedure

1. Open the **nmcli** interactive mode for the required connection. For example, to open the **nmcli** interactive mode for the *example* connection:

```
$ sudo nmcli connection edit example
```

2. Set the default gateway.
For example, to set the IPv4 address of the default gateway on the *example* connection to **192.0.2.1**:

```
nmcli> set ipv4.gateway 192.0.2.1
```

For example, to set the IPv6 address of the default gateway on the *example* connection to **2001:db8:1::1**:

```
nmcli> set ipv6.gateway 2001:db8:1::1
```

3. Optionally, verify that the default gateway was set correctly:


```
nmcli> print
...
ipv4.gateway:          192.0.2.1
...
ipv6.gateway:          2001:db8:1::1
...
```

4. Save the configuration:

```
nmcli> save persistent
```

5. Restart the network connection for changes to take effect:

```
nmcli> activate example
```



WARNING

All connections currently using this network connection are temporarily interrupted during the restart.

6. Leave the **nmcli** interactive mode:

```
nmcli> quit
```

7. Optionally, verify that the route is active.
To display the IPv4 default gateway:

```
$ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```
$ ip -6 route
default via 2001:db8:1::1 dev example proto static metric 100 pref medium
```

Additional resources

- [Section 10.4, “Configuring a dynamic Ethernet connection using the interactive editor”](#)

12.3. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING NM-CONNECTION-EDITOR

In most situations, administrators set the default gateway when they create a connection as explained in, for example, [Section 10.5, “Configuring an Ethernet connection using control-center”](#).

This section describes how to set or update the default gateway on a previously created connection using the **nm-connection-editor** application.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.

Procedure

- Open a terminal, and enter **nm-connection-editor**:

```
$ nm-connection-editor
```

- Select the connection to modify, and click the gear wheel icon to edit the existing connection.
- Set the IPv4 default gateway. For example, to set the IPv4 address of the default gateway on the connection to **192.0.2.1**:

- Open the **IPv4 Settings** tab.

- Enter the address in the **gateway** field next to the IP range the gateway's address is within:

Addresses		
Address	Netmask	Gateway
192.0.2.123	24	192.0.2.1

- Set the IPv6 default gateway. For example, to set the IPv6 address of the default gateway on the connection to **2001:db8:1::1**:

- Open the **IPv6** tab.

- Enter the address in the **gateway** field next to the IP range the gateway's address is within:

Addresses		
Address	Prefix	Gateway
2001:db8:1::5	64	2001:db8:1::1

- Click **OK**.
- Click **Save**.
- Restart the network connection for changes to take effect. For example, to restart the **example** connection using the command line:

```
$ sudo nmcli connection up example
```



WARNING

All connections currently using this network connection are temporarily interrupted during the restart.

8. Optionally, verify that the route is active.

To display the IPv4 default gateway:

```
$ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```
$ ip -6 route
default via 2001:db8:1::1 dev example proto static metric 100 pref medium
```

Additional resources

- [Section 10.5, “Configuring an Ethernet connection using control-center”](#)

12.4. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION USING CONTROL-CENTER

In most situations, administrators set the default gateway when they create a connection as explained in, for example, [Section 10.5, “Configuring an Ethernet connection using control-center”](#).

This section describes how to set or update the default gateway on a previously created connection using the **control-center** application.

Prerequisites

- At least one static IP address must be configured on the connection on which the default gateway will be set.
- The network configuration of the connection is open in the **control-center** application. See [Section 10.5, “Configuring an Ethernet connection using control-center”](#).

Procedure

1. Set the IPv4 default gateway. For example, to set the IPv4 address of the default gateway on the connection to **192.0.2.1**:
 - a. Open the **IPv4** tab.
 - b. Enter the address in the **gateway** field next to the IP range the gateway’s address is within:

Addresses		
Address	Netmask	Gateway
192.0.2.123	255.255.255.0	192.0.2.1

2. Set the IPv6 default gateway. For example, to set the IPv6 address of the default gateway on the connection to **2001:db8:1::1**:
 - a. Open the **IPv6** tab.
 - b. Enter the address in the **gateway** field next to the IP range the gateway’s address is within:

Addresses		
Address	Prefix	Gateway
2001:db8:1::5	64	2001:db8:1::1

- Click **Apply**.
- Back in the **Network** window, disable and re-enable the connection by switching the button for the connection to **Off** and back to **On** for changes to take effect.

**WARNING**

All connections currently using this network connection are temporarily interrupted during the restart.

- Optionally, verify that the route is active.
To display the IPv4 default gateway:

```
$ ip -4 route
default via 192.0.2.1 dev example proto static metric 100
```

To display the IPv6 default gateway:

```
$ ip -6 route
default via 2001:db8:1::1 dev example proto static metric 100 pref medium
```

Additional resources

- [Section 10.5, “Configuring an Ethernet connection using control-center”](#)

12.5. SETTING THE DEFAULT GATEWAY ON AN EXISTING CONNECTION WHEN USING THE LEGACY NETWORK SCRIPTS

This procedure describes how to configure a default gateway when you use the legacy network scripts. The example sets the default gateway to **192.0.2.1** that is reachable via the **enp1s0** interface.

Prerequisites

- The **NetworkManager** package is not installed, or the **NetworkManager** service is disabled.
- The **network-scripts** package is installed.

Procedure

- Set the **GATEWAY** parameter in the `/etc/sysconfig/network-scripts/ifcfg-enp1s0` file to **192.0.2.1**:

```
GATEWAY=192.0.2.1
```

2. Add the **default** entry in the `/etc/sysconfig/network-scripts/route-enp0s1` file:

```
default via 192.0.2.1
```

3. Restart the network:

```
# systemctl restart network
```

CHAPTER 13. CONFIGURING A STATIC ROUTE

By default, and if a default gateway is configured, Red Hat Enterprise Linux forwards traffic for networks that are not directly connected to the host to the default gateway. Using a static route, you can configure that Red Hat Enterprise Linux forwards the traffic for a specific host or network to a different router than the default gateway. This section describes how to configure a static route.

13.1. HOW TO USE THE NMCLI COMMAND TO CONFIGURE A STATIC ROUTE

To configure a static route, use the **nmcli** utility with the following syntax:

```
$ nmcli connection modify connection_name ipv4.routes "ip[/prefix] [next_hop] [metric]  
[attribute=value] [attribute=value] ..."
```

The command supports the following route attributes:

- **table=*n***
- **src=*address***
- **tos=*n***
- **onlink=true|false**
- **window=*n***
- **cwnd=*n***
- **mtu=*n***
- **lock-window=true|false**
- **lock-cwnd=true|false**
- **lock-mtu=true|false**

If you use the **ipv4.routes** sub-command, **nmcli** overrides all current settings of this parameter. To add an additional route, use the **nmcli connection modify *connection_name* +ipv4.routes "..."** command. In a similar way, you can use **nmcli connection modify *connection_name* -ipv4.routes "..."** to remove a specific route.

13.2. CONFIGURING A STATIC ROUTE USING AN NMCLI COMMAND

You can add a static route to the configuration of a network connection using the **nmcli connection modify** command.

The procedure in this section describes how to add a route to the **192.0.2.0/24** network that uses the gateway running on **198.51.100.1**, which is reachable through the **example** connection.

Prerequisites

- The network is configured
- The gateway for the static route must be directly reachable on the interface.

- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the command requires **root** permissions.

Procedure

1. Add the static route to the **example** connection:

```
$ sudo nmcli connection modify example +ipv4.routes "192.0.2.0/24 198.51.100.1"
```

To set multiple routes in one step, pass the individual routes comma-separated to the command. For example, to add a route to the **192.0.2.0/24** and **203.0.113.0/24** networks, both routed through the **198.51.100.1** gateway, enter:

```
$ sudo nmcli connection modify example +ipv4.routes "192.0.2.0/24 198.51.100.1, 203.0.113.0/24 198.51.100.1"
```

2. Optionally, verify that the routes were added correctly to the configuration:

```
$ nmcli connection show example
...
ipv4.routes:    { ip = 192.0.2.1/24, nh = 198.51.100.1 }
...
```

3. Restart the network connection:

```
$ sudo nmcli connection up example
```



WARNING

Restarting the connection briefly disrupts connectivity on that interface.

4. Optionally, verify that the route is active:

```
$ ip route
...
192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
```

Additional resources

- For further details about **nmcli**, see the **nmcli(1)** man page.

13.3. CONFIGURING A STATIC ROUTE USING CONTROL-CENTER

You can use **control-center** in GNOME to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the **192.0.2.0/24** network that uses the gateway running on **198.51.100.1**.

Prerequisites

- The network is configured.
- The gateway for the static route must be directly reachable on the interface.
- The network configuration of the connection is opened in the **control-center** application. See [Section 10.5, “Configuring an Ethernet connection using control-center”](#).

Procedure

1. Open the **IPv4** tab.
2. Optionally, disable automatic routes by clicking the **On** button in the **Routes** section of the **IPv4** tab to use only static routes. If automatic routes are enabled, Red Hat Enterprise Linux uses static routes and routes received from a DHCP server.
3. Enter the address, netmask, gateway, and optionally a metric value:

Routes			Automatic <input type="checkbox"/> OFF	
Address	Netmask	Gateway	Metric	
192.0.2.0	24	198.51.100.1		<input type="button" value="x"/>

4. Click **Apply**.
5. Back in the **Network** window, disable and re-enable the connection by switching the button for the connection to **Off** and back to **On** for changes to take effect.



WARNING

Restarting the connection briefly disrupts connectivity on that interface.

6. Optionally, verify that the route is active:

```
$ ip route
```

```
...
```

```
192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
```

13.4. CONFIGURING A STATIC ROUTE USING NM-CONNECTION-EDITOR

You can use the **nm-connection-editor** application to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the **192.0.2.0/24** network that uses the gateway running on **198.51.100.1**, which is reachable through the **example** connection.

Prerequisites

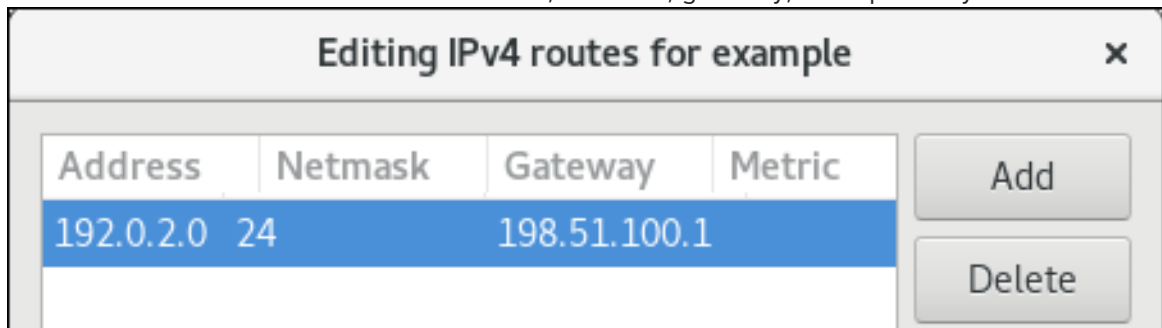
- The network is configured.
- The gateway for the static route must be directly reachable on the interface.

Procedure

1. Open a terminal and enter **nm-connection-editor**:

```
$ nm-connection-editor
```

2. Select the **example** connection and click the gear wheel icon to edit the existing connection.
3. Open the **IPv4** tab.
4. Click the **Routes** button.
5. Click the **Add** button and enter the address, netmask, gateway, and optionally a metric value.



6. Click **OK**.
7. Click **Save**.
8. Restart the network connection for changes to take effect. For example, to restart the **example** connection using the command line:

```
$ sudo nmcli connection up example
```

9. Optionally, verify that the route is active:

```
$ ip route
...
192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
```

13.5. CONFIGURING A STATIC ROUTE USING THE NMCLI INTERACTIVE MODE

You can use the interactive mode of the **nmcli** utility to add a static route to the configuration of a network connection.

The procedure in this section describes how to add a route to the **192.0.2.0/24** network that uses the gateway running on **198.51.100.1**, which is reachable through the **example** connection.

Prerequisites

- The network is configured
- The gateway for the static route must be directly reachable on the interface.
- If the user is logged in on a physical console, user permissions are sufficient. Otherwise, the command requires **root** permissions.

Procedure

1. Open the **nmcli** interactive mode for the **example** connection:

```
$ sudo nmcli connection edit example
```

2. Add the static route:

```
nmcli> set ipv4.routes 192.0.2.0/24 198.51.100.1
```

3. Optionally, verify that the routes were added correctly to the configuration:

```
nmcli> print
...
ipv4.routes:    { ip = 192.0.2.1/24, nh = 198.51.100.1 }
...
```

The **ip** attribute displays the network to route and the **nh** attribute the gateway (next hop).

4. Save the configuration:

```
nmcli> save persistent
```

5. Restart the network connection:

```
nmcli> activate example
```



WARNING

When you restart the connection, all connections currently using this connection will be temporarily interrupted.

6. Leave the **nmcli** interactive mode:

```
nmcli> quit
```

7. Optionally, verify that the route is active:

```
$ ip route
...
192.0.2.0/24 via 198.51.100.1 dev example proto static metric 100
```

Additional resources

- For the list of commands available in the interactive mode, enter **help** in the interactive shell.

13.6. CREATING STATIC ROUTES CONFIGURATION FILES IN KEY-VALUE-FORMAT WHEN USING THE LEGACY NETWORK SCRIPTS

This procedure describes how to manually create a routing configuration file for an IPv4 route to the **192.0.2.0/24** network when you use the legacy network scripts instead of NetworkManager. In this example, the corresponding gateway with the IP address **198.51.100.1** is reachable via the **enp1s0** interface.

The example in this procedure uses configuration entries in key-value-format.



NOTE

The legacy network scripts support the key-value-format only for static IPv4 routes. For IPv6 routes, use the **ip-command-format**. See [Section 13.7, "Creating static routes configuration files in ip-command-format when using the legacy network scripts"](#).

Prerequisites

- The gateway for the static route must be directly reachable on the interface.
- The **NetworkManager** package is not installed, or the **NetworkManager** service is disabled.
- The **network-scripts** package is installed.

Procedure

1. Add the static IPv4 route to the **/etc/sysconfig/network-scripts/route-enp0s1** file:

```
ADDRESS0=192.0.2.0
NETMASK0=255.255.255.0
GATEWAY0=198.51.100.1
```

- The **ADDRESS0** variable defines the network of the first routing entry.
- The **NETMASK0** variable defines the netmask of the first routing entry.
- The **GATEWAY0** variable defines the IP address of the gateway to the remote network or host for the first routing entry.
If you add multiple static routes, increase the number in the variable names. Note that the variables for each route must be numbered sequentially. For example, **ADDRESS0**, **ADDRESS1**, **ADDRESS3**, and so on.

2. Restart the network:

```
# systemctl restart network
```

Additional resources

- For further details about configuring legacy network scripts, see the **/usr/share/doc/network-scripts/sysconfig.txt** file.

13.7. CREATING STATIC ROUTES CONFIGURATION FILES IN IP-COMMAND-FORMAT WHEN USING THE LEGACY NETWORK SCRIPTS

This procedure describes how to manually create a routing configuration file for the following static routes when you use legacy network scripts:

- An IPv4 route to the **192.0.2.0/24** network. The corresponding gateway with the IP address **198.51.100.1** is reachable via the **enp1s0** interface.
- An IPv6 route to the **2001:db8:1::/64** network. The corresponding gateway with the IP address **2001:db8:2::1** is reachable via the **enp1s0** interface.

The example in this procedure uses configuration entries in **ip-command-format**.

Prerequisites

- The gateway for the static route must be directly reachable on the interface.
- The **NetworkManager** package is not installed, or the **NetworkManager** service is disabled.
- The **network-scripts** package is installed.

Procedure

1. Add the static IPv4 route to the **/etc/sysconfig/network-scripts/route-enp0s1** file:

```
192.0.2.0/24 via 198.51.100.1 dev enp0s1
```

2. Add the static IPv6 route to the **/etc/sysconfig/network-scripts/route6-enp0s1** file:

```
2001:db8:1::/64 via 2001:db8:2::1 dev enp0s1
```

3. Restart the network:

```
# systemctl restart network
```

Additional Resources

- For further details about configuring legacy network scripts, see the **/usr/share/doc/network-scripts/sysconfig.txt** file.

CHAPTER 14. CONFIGURING POLICY-BASED ROUTING TO DEFINE ALTERNATIVE ROUTES

By default, the kernel in RHEL decides where to forward network packets based on the destination address using a routing table. Policy-based routing enables you to configure complex routing scenarios. For example, you can route packets based on various criteria, such as the source address, packet metadata, or protocol.

This section describes of how to configure policy-based routing using NetworkManager.



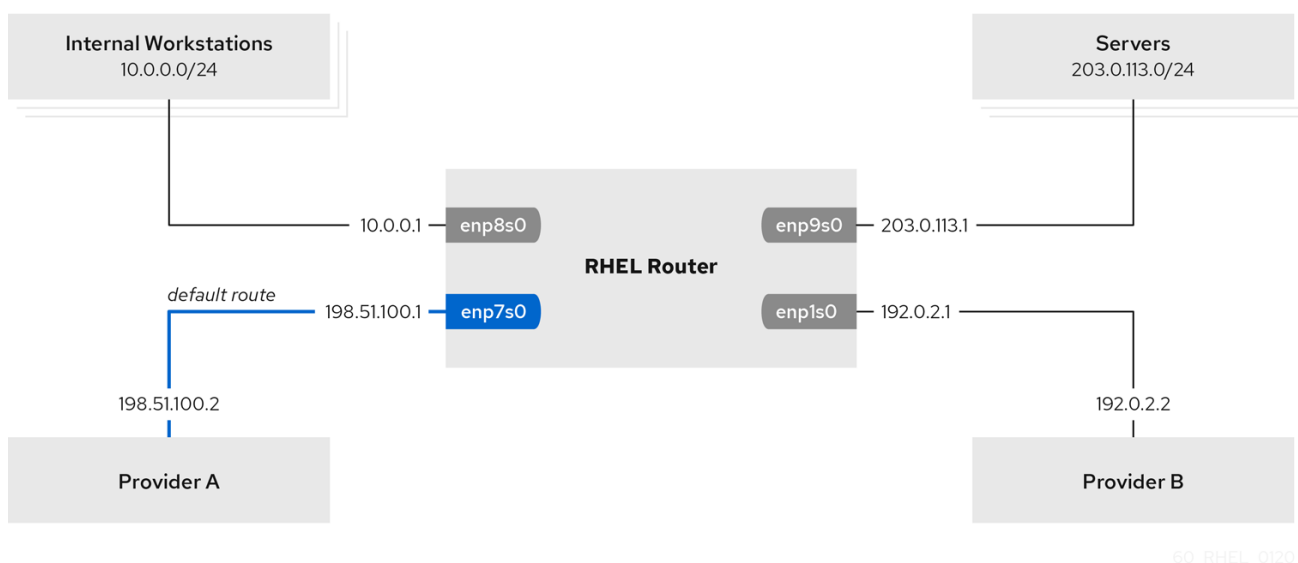
NOTE

On systems that use NetworkManager, only the **nmcli** utility supports setting routing rules and assigning routes to specific tables.

14.1. ROUTING TRAFFIC FROM A SPECIFIC SUBNET TO A DIFFERENT DEFAULT GATEWAY USING NETWORKMANAGER

This section describes how to configure RHEL as a router that, by default, routes all traffic to internet provider A using the default route. Using policy-based routing, RHEL routes traffic received from the internal workstations subnet to provider B.

The procedure assumes the following network topology:



Prerequisites

- The RHEL router you want to set up in the procedure has four network interfaces:
 - The **enp7s0** interface is connected to the network of provider A. The gateway IP in the provider's network is **198.51.100.2**, and the network uses a **/30** network mask.
 - The **enp1s0** interface is connected to the network of provider B. The gateway IP in the provider's network is **192.0.2.2**, and the network uses a **/30** network mask.
 - The **enp8s0** interface is connected to the **10.0.0.0/24** subnet with internal workstations.

- The **enp9s0** interface is connected to the **203.0.113.0/24** subnet with the company's servers.
- Hosts in the internal workstations subnet use **10.0.0.1** as default gateway. In the procedure, you assign this IP address to the **enp8s0** network interface of the router.
- Hosts in the server subnet use **203.0.113.1** as default gateway. In the procedure, you assign this IP address to the **enp9s0** network interface of the router.
- The **firewalld** service is enabled and active, which is the default.

Procedure

1. Configure the network interface to provider A:

```
# nmcli connection add type ethernet con-name Provider-A ifname enp7s0 ipv4.method manual ipv4.addresses 198.51.100.1/30 ipv4.gateway 198.51.100.2 ipv4.dns 198.51.100.200 connection.zone external
```

The **nmcli connection add** command creates a NetworkManager connection profile. The following list describes the options of the command:

- **type ethernet**: Defines that the connection type is Ethernet.
 - **con-name *connection_name***: Sets the name of the profile. Use a meaningful name to avoid confusion.
 - **ifname *network_device***: Sets the network interface.
 - **ipv4.method manual**: Enables to configure a static IP address.
 - **ipv4.addresses *IP_address/subnet_mask***: Sets the IPv4 addresses and subnet mask.
 - **ipv4.gateway *IP_address***: Sets the default gateway address.
 - **ipv4.dns *IP_of_DNS_server***: Sets the IPv4 address of the DNS server.
 - **connection.zone *firewalld_zone***: Assigns the network interface to the defined **firewalld** zone. Note that **firewalld** automatically enables masquerading interfaces assigned to the **external** zone.
2. Configure the network interface to provider B:

```
# nmcli connection add type ethernet con-name Provider-B ifname enp1s0 ipv4.method manual ipv4.addresses 192.0.2.1/30 ipv4.routes "0.0.0.0/1 192.0.2.2 table=5000, 128.0.0.0/1 192.0.2.2 table=5000" connection.zone external
```

This command uses the **ipv4.routes** parameter instead of **ipv4.gateway** to set the default gateway. This is required to assign the default gateway for this connection to a different routing table (**5000**) than the default. NetworkManager automatically creates this new routing table when the connection is activated.



NOTE

The **nmcli** utility does not support using **0.0.0.0/0** for the default gateway in **ipv4.gateway**. To work around this problem, the command creates separate routes for both the **0.0.0.0/1** and **128.0.0.0/1** subnets, which covers also the full IPv4 address space.

3. Configure the network interface to the internal workstations subnet:

```
# nmcli connection add type ethernet con-name Internal-Workstations ifname enp8s0
ipv4.method manual ipv4.addresses 10.0.0.1/24 ipv4.routes "10.0.0.0/24 src=192.0.2.1
table=5000" ipv4.routing-rules "priority 5 from 10.0.0.0/24 table 5000" connection.zone
internal
```

This command uses the **ipv4.routes** parameter to add a static route to the routing table with ID **5000**. This static route for the **10.0.0.0/24** subnet uses the IP of the local network interface to provider B (**192.0.2.1**) as next hop.

Additionally, the command uses the **ipv4.routing-rules** parameter to add a routing rule with priority **5** that routes traffic from the **10.0.0.0/24** subnet to table **5000**. Low values have a high priority.

Note that the syntax in the **ipv4.routing-rules** parameter is the same as in an **ip route add** command, except that **ipv4.routing-rules** always requires specifying a priority.

4. Configure the network interface to the server subnet:

```
# nmcli connection add type ethernet con-name Servers ifname enp9s0 ipv4.method manual
ipv4.addresses 203.0.113.1/24 connection.zone internal
```

Verification steps

1. On a RHEL host in the internal workstation subnet:

- a. Install the **traceroute** package:

```
# yum install traceroute
```

- b. Use the **traceroute** utility to display the route to a host on the internet:

```
# traceroute redhat.com
traceroute to redhat.com (209.132.183.105), 30 hops max, 60 byte packets
 1 10.0.0.1 (10.0.0.1)  0.337 ms 0.260 ms 0.223 ms
 2 192.0.2.1 (192.0.2.1) 0.884 ms 1.066 ms 1.248 ms
 ...
```

The output of the command displays that the router sends packets over **192.0.2.1**, which is the network of provider B.

2. On a RHEL host in the server subnet:

- a. Install the **traceroute** package:

```
# yum install traceroute
```

- b. Use the **tracert** utility to display the route to a host on the internet:

```
# tracert redhat.com
tracert to redhat.com (209.132.183.105), 30 hops max, 60 byte packets
 1 203.0.113.1 (203.0.113.1)  2.179 ms  2.073 ms  1.944 ms
 2 198.51.100.2 (198.51.100.2) 1.868 ms  1.798 ms  1.549 ms
 ...
```

The output of the command displays that the router sends packets over **198.51.100.2**, which is the network of provider A.

Troubleshooting steps

On the RHEL router:

1. Display the rule list:

```
# ip rule list
0: from all lookup local
5: from 10.0.0.0/24 lookup 5000
32766: from all lookup main
32767: from all lookup default
```

By default, RHEL contains rules for the tables **local**, **main**, and **default**.

2. Display the routes in table **5000**:

```
# ip route list table 5000
0.0.0.0/1 via 192.0.2.2 dev enp1s0 proto static metric 100
10.0.0.0/24 dev enp8s0 proto static scope link src 192.0.2.1 metric 102
128.0.0.0/1 via 192.0.2.2 dev enp1s0 proto static metric 100
```

3. Display which interfaces are assigned to which firewall zones:

```
# firewall-cmd --get-active-zones
external
  interfaces: enp1s0 enp7s0
internal
  interfaces: enp8s0 enp9s0
```

4. Verify that the **external** zone has masquerading enabled:

```
# firewall-cmd --info-zone=external
external (active)
  target: default
  icmp-block-inversion: no
  interfaces: enp1s0 enp7s0
  sources:
  services: ssh
  ports:
  protocols:
masquerade: yes
...
```

Additional resources

- For further details about the **ipv4.*** parameters you can set in the **nmcli connection add** command, see the **IPv4 settings** section in the **nm-settings(5)** man page.
- For further details about the **connection.*** parameters you can set in the **nmcli connection add** command, see the **Connection settings** section in the **nm-settings(5)** man page.
- For further details about managing NetworkManager connections using **nmcli**, see the **Connection management commands** section in the **nmcli(1)** man page.

14.2. OVERVIEW OF CONFIGURATION FILES INVOLVED IN POLICY-BASED ROUTING WHEN USING THE LEGACY NETWORK SCRIPTS

If you use the legacy network scripts instead of NetworkManager to configure your network, you can also configure policy-based routing.



NOTE

Configuring the network using the legacy network scripts provided by the **network-scripts** package is deprecated in RHEL 8. Red Hat recommends that you use NetworkManager to configure policy-based routing. For an example, see [Section 14.1, “Routing traffic from a specific subnet to a different default gateway using NetworkManager”](#).

The following configuration files are involved in policy-based routing when you use the legacy network scripts:

- **/etc/sysconfig/network-scripts/route-interface**: This file defines the IPv4 routes. Use the **table** option to specify the routing table. For example:

```
192.0.2.0/24 via 198.51.100.1 table 1
203.0.113.0/24 via 198.51.100.2 table 2
```

- **/etc/sysconfig/network-scripts/route6-interface**: This file defines the IPv6 routes.
- **/etc/sysconfig/network-scripts/rule-interface**: This file defines the rules for IPv4 source networks for which the kernel routes traffic to specific routing tables. For example:

```
from 192.0.2.0/24 lookup 1
from 203.0.113.0/24 lookup 2
```

- **/etc/sysconfig/network-scripts/rule6-interface**: This file defines the rules for IPv6 source networks for which the kernel routes traffic to specific routing tables.
- **/etc/iproute2/rt_tables**: This file defines the mappings if you want to use names instead of numbers to refer to specific routing tables. For example:

```
1 Provider_A
2 Provider_B
```

Additional resources

- For further details about IP routing, see the **ip-route(8)** man page.

- For further details about routing rules, see the **ip-rule(8)** man page.

CHAPTER 15. CONFIGURING VLAN TAGGING

This section describes how to configure Virtual Local Area Network (VLAN). A VLAN is a logical network within a physical network. The VLAN interface tags packets with the VLAN ID as they pass through the interface, and removes tags of returning packets.

You create a VLAN interface on top of another interface, such as Ethernet, bond, team, or bridge. This interface is called the **parent interface**.

15.1. CONFIGURING VLAN TAGGING USING NM-CONNECTION-EDITOR

This section describes how to configure Virtual Local Area Network (VLAN) tagging using the **nm-connection-editor** application.

Prerequisites

- The interface you plan to use as a parent to the virtual VLAN interface supports VLAN tags.
- If you configure the VLAN on top of a bond interface:
 - The slaves of the bond are up.
 - The bond is not configured with the **fail_over_mac=follow** option. A VLAN virtual device cannot change its MAC address to match the parent's new MAC address. In such a case, the traffic would still be sent with the then incorrect source MAC address.
- The switch the host is connected to is configured to support VLAN tags. For details, see the documentation of your switch.

Procedure

1. Open a terminal, and enter **nm-connection-editor**:

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **VLAN** connection type, and click **Create**.
4. On the **VLAN** tab:
 - a. Select the parent interface.
 - b. Select the VLAN id. Note that the VLAN must be within the range from **0** to **4094**.
 - c. By default, the VLAN connection inherits the maximum transmission unit (MTU) from the parent interface. Optionally, set a different MTU value.
 - d. Optionally, set the name of the VLAN interface and further VLAN-specific options.

Editing VLAN connection 1 ✕

Connection name:

General **VLAN** Proxy IPv4 Settings IPv6 Settings

Parent interface: ▼

VLAN id: – +

VLAN interface name:

Cloned MAC address: ▼

MTU: – + bytes

Flags: ☒ Reorder headers ☐ GVRP ☐ Loose binding ☐ MVRP

- On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, and DNS server:

Editing VLAN connection 1 ✕

Connection name:

General **VLAN** Proxy **IPv4 Settings** IPv6 Settings

Method: ▼

Addresses

Address	Netmask	Gateway
192.0.2.1	24	192.0.2.254

DNS servers:

- On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, and DNS server:

Editing VLAN connection 1

Connection name:

General **VLAN** Proxy IPv4 Settings **IPv6 Settings**

Method:

Addresses

Address	Prefix	Gateway
2001:db8:1::1	64	2001:db8:1::ff3

DNS servers:

- Click **Save** to save the VLAN connection.
- Close **nm-connection-editor**.

Verification steps

- Verify the settings:

```
# ip -d addr show vlan10
4: vlan10@enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue
state UP group default qlen 1000
    link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff:ff promiscuity 0
    vlan protocol 802.1Q id 10 <REORDER_HDR> numtxqueues 1 numrxqueues 1
gso_max_size 65536 gso_max_segs 65535
    inet 192.0.2.1/24 brd 192.0.2.255 scope global noprefixroute vlan10
        valid_lft forever preferred_lft forever
    inet6 fe80::8dd7:9030:6f8e:89e6/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
```

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).

15.2. CONFIGURING VLAN TAGGING USING NMCLI COMMANDS

This section describes how to configure Virtual Local Area Network (VLAN) tagging using **nmcli** commands.

Prerequisites

- The interface you plan to use as a parent to the virtual VLAN interface supports VLAN tags.
- If you configure the VLAN on top of a bond interface:

- The slaves of the bond are up.
- The bond is not configured with the **fail_over_mac=follow** option. A VLAN virtual device cannot change its MAC address to match the parent's new MAC address. In such a case, the traffic would still be sent with the then incorrect source MAC address.
- The switch the host is connected to is configured to support VLAN tags. For details, see the documentation of your switch.

Procedure

1. Optionally, display the available network interfaces:

```
# ip address show
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group
default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
        valid_lft forever preferred_lft forever
2: enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP
group default qlen 1000
    link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff:ff
```

2. Create the VLAN interface. For example, to create a VLAN interface named **vlan10** that uses **enp1s0** as its parent interface and that tags packets with VLAN ID **10**, enter:

```
# nmcli connection add type vlan con-name vlan10 ifname vlan10 vlan.parent enp1s0 vlan.id
10
```

Note that the VLAN must be within the range from **0** to **4094**.

3. By default, the VLAN connection inherits the maximum transmission unit (MTU) from the parent interface. Optionally, set a different MTU value:

```
# nmcli connection modify vlan10 802-3-ethernet.mtu 2000
```

4. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, and DNS server to the **vlan10** connection, enter:

```
# nmcli connection modify vlan10 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify vlan10 ipv4.gateway '192.0.2.254'
# nmcli connection modify vlan10 ipv4.dns '192.0.2.253'
# nmcli connection modify vlan10 ipv4.method manual
```

5. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, and DNS server to the **vlan10** connection, enter:

```
# nmcli connection modify vlan10 ipv6.addresses '2001:db8:1::1/32'
# nmcli connection modify vlan10 ipv6.gateway '2001:db8:1::fffe'
# nmcli connection modify vlan10 ipv6.dns '2001:db8:1::fffd'
# nmcli connection modify vlan10 ipv6.method manual
```

Verification steps

1. Verify the settings.

```
# ip -d addr show vlan10
4: vlan10@enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue
state UP group default qlen 1000
    link/ether 52:54:00:d5:e0:fb brd ff:ff:ff:ff:ff:ff promiscuity 0
    vlan protocol 802.1Q id 10 <REORDER_HDR> numtxqueues 1 numrxqueues 1
gso_max_size 65536 gso_max_segs 65535
    inet 192.0.2.1/24 brd 192.0.2.255 scope global noprefixroute vlan10
        valid_lft forever preferred_lft forever
    inet6 fe80::8dd7:9030:6f8e:89e6/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
```

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- For **nmcli** examples, see the **nmcli-examples(7)** man page.
- For all vlan properties you can set, see the **vlan setting** section in the **nm-settings(5)** man page.

CHAPTER 16. CONFIGURING A NETWORK BRIDGE

A network bridge is a link-layer device which forwards traffic between networks based on MAC addresses. The bridge device decides on forwarding packets based on a table of MAC addresses. The bridge builds the MAC addresses table by listening to network traffic and thereby learning what hosts are connected to each network.

For example, you can use a software bridge on a Red Hat Enterprise Linux 8 host:

- To emulate a hardware bridge
- In virtualization environments, to integrate virtual machines (VM) to the same network as the host

Due to the IEEE 802.11 standard which specifies the use of 3-address frames in Wi-Fi for the efficient use of airtime, you cannot configure a bridge over Wi-Fi networks operating in Ad-Hoc or Infrastructure modes.

16.1. CONFIGURING A NETWORK BRIDGE USING NMCLI COMMANDS

This section explains how to configure a network bridge using the **nmcli** utility.

Prerequisites

- Two or more physical or virtual network devices are installed in the server.
- You are logged in as the **root** user.

Procedure

1. Create a bridge interface. For example, to create the bridge interface named **bridge0**, enter:

```
# nmcli connection add type bridge con-name bridge0 ifname bridge0
```

2. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain of the **bridge0** connection, enter:

```
# nmcli connection modify bridge0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify bridge0 ipv4.gateway '192.0.2.254'
# nmcli connection modify bridge0 ipv4.dns '192.0.2.253'
# nmcli connection modify bridge0 ipv4.dns-search 'example.com'
# nmcli connection modify bridge0 ipv4.method manual
```

3. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain of the **bridge0** connection, enter:

```
# nmcli connection modify bridge0 ipv6.addresses '2001:db8:1::1/64'
# nmcli connection modify bridge0 ipv6.gateway '2001:db8:1::fffe'
# nmcli connection modify bridge0 ipv6.dns '2001:db8:1::fffd'
# nmcli connection modify bridge0 ipv6.dns-search 'example.com'
# nmcli connection modify bridge0 ipv6.method manual
```

4. Optionally, configure further properties of the bridge. For example, to set the Spanning Tree Protocol (STP) priority of **bridge0** to **16384**, enter:


```
# nmcli connection modify bridge0 bridge.priority '16384'
```

By default, STP is enabled.

5. Optionally, display the network interfaces, and note the names of the interfaces you want to add to the bridge as a slave in the next step:

```
# nmcli device
DEVICE TYPE    STATE    CONNECTION
enp1s0 ethernet connected enp1s0
enp7s0 ethernet disconnected --
enp8s0 ethernet disconnected --
lo      loopback unmanaged --
```

6. Assign the port interfaces to the bridge's connection. For example, to add the interfaces named **enp7s0** and **enp8s0** to the **bridge0** connection, enter:

```
# nmcli connection add type ethernet slave-type bridge con-name bridge0-port1 ifname
enp7s0 master bridge0
# nmcli connection add type ethernet slave-type bridge con-name bridge0-port2 ifname
enp8s0 master bridge0
```

7. Activate the connection. For example, to activate the **bridge0** connection, enter:

```
# nmcli connection up bridge0
```

8. Verify that the slave devices are connected, and the **CONNECTION** column displays the slave's connection name:

```
# nmcli device
DEVICE TYPE    STATE    CONNECTION
...
enp7s0 ethernet connected bridge0-port1
enp8s0 ethernet connected bridge0-port2
```

Red Hat Enterprise Linux activates master and slave devices when the system boots. By activating any slave connection, the master is also activated. However, in this case, only one slave connection is activated. By default, activating the master does not automatically activate the slaves. However, you can enable this behavior by setting:

- a. Enable the **connection.autoconnect-slaves** parameter of the bridge connection:

```
# nmcli connection modify bridge0 connection.autoconnect-slaves 1
```

- b. Reactivate the bridge:

```
# nmcli connection up bridge0
```

Verification steps

- Display the link status of Ethernet devices that are slaves of a specific bridge:

```
# ip link show master bridge0
```

```
3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:62:61:0e brd ff:ff:ff:ff:ff:ff
4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:9e:f1:ce brd ff:ff:ff:ff:ff:ff
```

- Display the status of Ethernet devices that are slaves to any bridge device:

```
# bridge link show
3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state
forwarding priority 32 cost 100
4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state
listening priority 32 cost 100
5: enp9s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state
forwarding priority 32 cost 100
6: enp11s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state
blocking priority 32 cost 100
...
```

To display the status for a specific Ethernet device, use the **bridge link show dev *ethernet_device_name*** command.

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- For **nmcli** examples, see the **nmcli-examples(7)** man page.
- For all bridge properties you can set, see the **bridge settings** section in the **nm-settings(5)** man page.
- For all bridge port properties you can set, see the **bridge-port settings** section in the **nm-settings(5)** man page.
- For details about the **bridge** utility, see the **bridge(8)** man page.
- If the configuration on the disk does not match the configuration on the device, starting or restarting NetworkManager creates an in-memory connection that reflects the configuration of the device. For further details and how to avoid this problem, see [NetworkManager duplicates a connection after restart of NetworkManager service](#).

16.2. CONFIGURING A NETWORK BRIDGE USING NM-CONNECTION-EDITOR

This section explains how to configure a network bridge using the **nm-connection-editor** application.

Prerequisites

- Two or more physical or virtual network devices are installed in the server.

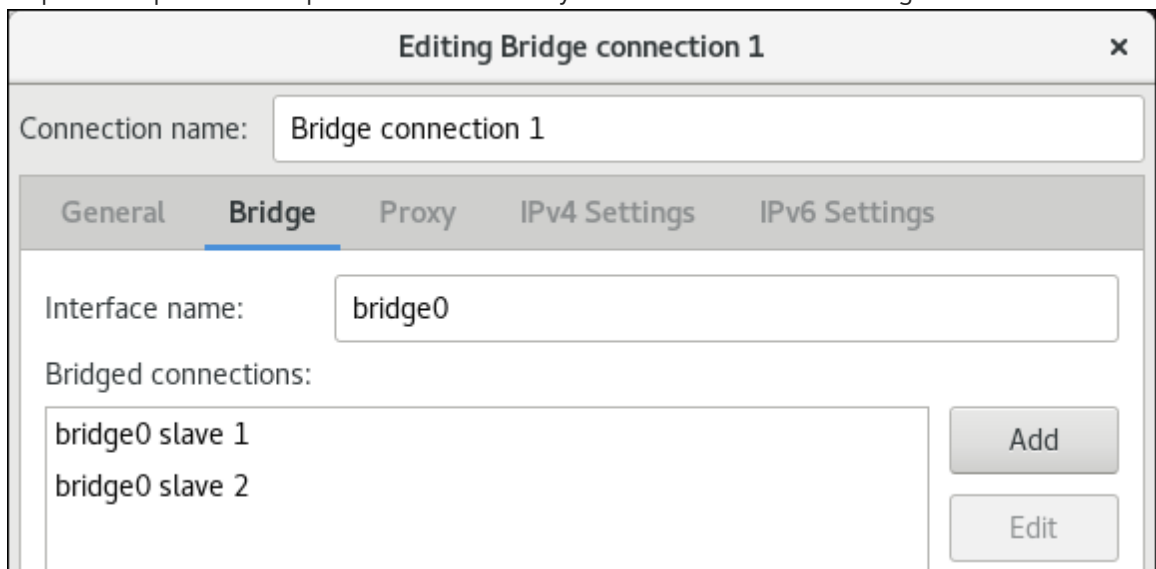
Procedure

1. Open a terminal, and enter **nm-connection-editor**:

—

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **Bridge** connection type, and click **Create**.
 - a. Optionally, set the name of the bridge interface in the **Interface name** field.
 - b. Click the **Add** button to add a network interface as a slave to the bridge.
 - i. Select the connection type of the interface. For example, select **Ethernet** for a wired connection.
 - ii. Optionally, set a connection name for the slave device.
 - iii. In the **Device** field on the **Ethernet** tab, select the network interface you want to add as a slave to the bridge.
 - iv. Click **Save**.
 - c. Repeat the previous step for each interface you want to add to the bridge.



- d. Optionally, configure further bridge settings, such as Spanning Tree Protocol (STP) options.

- On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

The screenshot shows the 'Editing Bridge connection 1' dialog box with the 'IPv4 Settings' tab selected. The 'Connection name' is 'Bridge connection 1'. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one row: Address '192.0.2.1', Netmask '24', and Gateway '192.0.2.254'. Below the table, 'DNS servers' is '192.0.2.1' and 'Search domains' is 'example.com'.

Address	Netmask	Gateway
192.0.2.1	24	192.0.2.254

- On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:

The screenshot shows the 'Editing Bridge connection 1' dialog box with the 'IPv6 Settings' tab selected. The 'Connection name' is 'Bridge connection 1'. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one row: Address '2001:db8:1::1', Prefix '64', and Gateway '2001:db8:1::fff3'. Below the table, 'DNS servers' is '2001:db8:1::fffd' and 'Search domains' is 'example.com'.

Address	Prefix	Gateway
2001:db8:1::1	64	2001:db8:1::fff3

- Save the bridge connection.

7. Close **nm-connection-editor**.

Verification steps

- Display the link status of Ethernet devices that are slaves of a specific bridge.

```
# ip link show master bridge0
3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:62:61:0e brd ff:ff:ff:ff:ff:ff
4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
bridge0 state UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:9e:f1:ce brd ff:ff:ff:ff:ff:ff
```

- Display the status of Ethernet devices that are slaves to any bridge device:

```
# bridge link show
3: enp7s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state
forwarding priority 32 cost 100
4: enp8s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge0 state
listening priority 32 cost 100
5: enp9s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state
forwarding priority 32 cost 100
6: enp11s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master bridge1 state
blocking priority 32 cost 100
...
```

To display the status for a specific Ethernet device, use the **bridge link show dev *ethernet_device_name*** command.

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).

CHAPTER 17. CONFIGURING NETWORK TEAMING

This section describes the basics of network teaming, the differences between bonding and teaming, and how to configure a network team on Red Hat Enterprise Linux 8.

Prerequisites

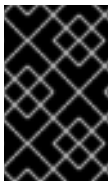
- Red Hat Enterprise Linux 8 is installed.
- The system has an active subscription assigned.

17.1. UNDERSTANDING NETWORK TEAMING

Network teaming is a feature that combines or aggregates network interfaces to provide a logical interface with higher throughput or redundancy.

Network teaming uses a kernel driver to implement fast handling of packet flows, as well as user-space libraries and services for other tasks. This way, network teaming is an easily extensible and scalable solution for load-balancing and redundancy requirements.

Note that in the context of network teaming, the term **port** is also known as **slave**. In the **teamd** service, the term **port** is preferred while in the **NetworkManager** service, the term **slave** refers to interfaces which create a team.



IMPORTANT

Certain network teaming features, such as the fail-over mechanism, do not support direct cable connections without a network switch. For further details, see [Is bonding supported with direct connection using crossover cables?](#)

17.2. UNDERSTANDING THE DEFAULT BEHAVIOR OF MASTER AND SLAVE INTERFACES

Consider the following default behavior of, when managing or troubleshooting team or bond port interfaces using the **NetworkManager** service:

- Starting the master interface does not automatically start the port interfaces.
- Starting a port interface always starts the master interface.
- Stopping the master interface also stops the port interface.
- A master without ports can start static IP connections.
- A master without ports waits for ports when starting DHCP connections.
- A master with a DHCP connection waiting for ports completes when you add a port with a carrier.
- A master with a DHCP connection waiting for ports continues waiting when you add a port without carrier.

17.3. COMPARISON OF NETWORK TEAMING AND BONDING FEATURES

The following table compares features supported in network teams and network bonds:

Feature	Network bond	Network team
Broadcast Tx policy	Yes	Yes
Round-robin Tx policy	Yes	Yes
Active-backup Tx policy	Yes	Yes
LACP (802.3ad) support	Yes (active only)	Yes
Hash-based Tx policy	Yes	Yes
User can set hash function	No	Yes
Tx load-balancing support (TLB)	Yes	Yes
LACP hash port select	Yes	Yes
Load-balancing for LACP support	No	Yes
Ethtool link monitoring	Yes	Yes
ARP link monitoring	Yes	Yes
NS/NA (IPv6) link monitoring	No	Yes
Ports up/down delays	Yes	Yes
Port priorities and stickiness ("primary" option enhancement)	No	Yes
Separate per-port link monitoring setup	No	Yes
Multiple link monitoring setup	Limited	Yes
Lockless Tx/Rx path	No (rwlock)	Yes (RCU)
VLAN support	Yes	Yes
User-space runtime control	Limited	Yes
Logic in user-space	No	Yes

Feature	Network bond	Network team
Extensibility	Hard	Easy
Modular design	No	Yes
Performance overhead	Low	Very low
D-Bus interface	No	Yes
Multiple device stacking	Yes	Yes
Zero config using LLDP	No	(in planning)
NetworkManager support	Yes	Yes

17.4. UNDERSTANDING THE TEAMD SERVICE, RUNNERS, AND LINK-WATCHERS

The team service, **teamd**, controls one instance of the team driver. This instance of the driver adds instances of a hardware device driver to form a team of network interfaces. The team driver presents a network interface, for example **team0**, to the kernel.

The **teamd** service implements the common logic to all methods of teaming. Those functions are unique to the different load sharing and backup methods, such as round-robin, and implemented by separate units of code referred to as **runners**. Administrators specify runners in JavaScript Object Notation (JSON) format, and the JSON code is compiled into an instance of **teamd** when the instance is created. Alternatively, when using **NetworkManager**, you can set the runner in the **team.runner** parameter, and **NetworkManager** auto-creates the corresponding JSON code.

The following runners are available:

- **broadcast**: Transmits data over all ports.
- **roundrobin**: Transmits data over all ports in turn.
- **activebackup**: Transmits data over one port while the others are kept as a backup.
- **loadbalance**: Transmits data over all ports with active Tx load balancing and Berkeley Packet Filter (BPF)-based Tx port selectors.
- **random**: Transmits data on a randomly selected port.
- **lacp**: Implements the 802.3ad Link Aggregation Control Protocol (LACP).

The **teamd** services uses a link watcher to monitor the state of subordinate devices. The following link-watchers are available:

- **ethtool**: The **libteam** library uses the **ethtool** utility to watch for link state changes. This is the default link-watcher.

- **arp_ping**: The **libteam** library uses the **arp_ping** utility to monitor the presence of a far-end hardware address using Address Resolution Protocol (ARP).
- **nsna_ping**: On IPv6 connections, the **libteam** library uses the Neighbor Advertisement and Neighbor Solicitation features from the IPv6 Neighbor Discovery protocol to monitor the presence of a neighbor's interface.

Each runner can use any link watcher, with the exception of **lACP**. This runner can only use the **ethtool** link watcher.

17.5. INSTALLING THE TEAMD SERVICE

To configure a network team in **NetworkManager**, you require the **teamd** service and the team plug-in for **NetworkManager**. Both are installed on Red Hat Enterprise Linux 8 by default. This section describes how you install the required packages in case that you remove them.

Prerequisites

- An active Red Hat subscription is assigned to the host.

Procedure

1. Install the **teamd** and **NetworkManager-team** packages:

```
# yum install teamd NetworkManager-team
```

17.6. CONFIGURING A NETWORK TEAM USING NMCLI COMMANDS

This section describes how you configure a network team using **nmcli** commands.

Prerequisites

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

Procedure

1. Create the team interface. For example, to create a team interface that uses the **activebackup** runner and both the interface and connection named **team0**, enter:

```
# nmcli connection add type team con-name team0 ifname team0 team.runner activebackup
```

2. Optionally, set a link watcher. For example, to set the **ethtool** link watcher, modify the **team0** connection:

```
# nmcli connection modify team0 team.link-watchers "name=ethtool"
```

Link watchers support different parameters. To set parameters for a link watcher, specify them space-separated in the **name** property. Note that the name property must be surrounded by quotes. For example, to use the **ethtool** link watcher and set its **delay-up** parameter to **2500** milliseconds (2.5 seconds):

```
# nmcli connection modify team0 team.link-watchers "name=ethtool delay-up=2500"
```

To set multiple link watchers and each of them with specific parameters, the link watchers must be separated by a comma. The following example sets the **ethtool** link watcher with the **delay-up** parameter and the **arp_ping** link watcher with the **source-host** and **target-host** parameter:

```
# nmcli connection modify team0 team.link-watchers "name=ethtool delay-up=2,
name=arp_ping source-host=192.0.2.1 target-host=192.0.2.2"
```

3. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain of the **team0** connection, enter:

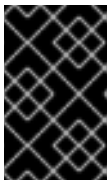
```
# nmcli connection modify team0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify team0 ipv4.gateway '192.0.2.254'
# nmcli connection modify team0 ipv4.dns '192.0.2.253'
# nmcli connection modify team0 ipv4.dns-search 'example.com'
# nmcli connection modify team0 ipv4.method manual
```

4. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain of the **team0** connection, enter:

```
# nmcli connection modify team0 ipv6.addresses '2001:db8:1::1/64'
# nmcli connection modify team0 ipv6.gateway '2001:db8:1::fffe'
# nmcli connection modify team0 ipv6.dns '2001:db8:1::fffd'
# nmcli connection modify team0 ipv6.dns-search 'example.com'
# nmcli connection modify team0 ipv6.method manual
```

5. Optionally, display the network interfaces, and note the names of the interfaces you want to add to the team in the next step:

```
# nmcli device
DEVICE TYPE    STATE    CONNECTION
enp1s0 ethernet connected enp1s0
enp7s0 ethernet disconnected --
enp8s0 ethernet disconnected --
lo    loopback unmanaged  --
```



IMPORTANT

You can only use network interfaces in a team that are not assigned to any connection. In the above example, you can only use the **enp7s0** and **enp8s0** interfaces.

6. Assign the port interfaces to the team's connection. For example, to add the interfaces named **enp7s0** and **enp8s0** to the **team0** connection:

```
# nmcli connection add type ethernet slave-type team con-name team0-port1 ifname enp7s0
master team0
# nmcli connection add type ethernet slave-type team con-name team0-port2 ifname enp8s0
master team0
```

7. Activate the connection. For example, to activate the **team0** connection:

■

```
# nmcli connection up team0
```

Verification steps

- View the status of the team.

```
# teamdctl team0 state
setup:
  runner: activebackup
ports:
  enp7s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
  enp8s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
runner:
  active port: enp7s0
```

In the example, both ports are up.

Additional resources

- For more information on testing connections, see [Chapter 33, *Testing basic network settings*](#).
- [Section 17.4, “Understanding the teamd service, runners, and link-watchers”](#).
- For **nmcli** examples, see the **nmcli-examples(7)** man page.
- For all team properties you can set, see the **team** section in the **nm-settings(5)** man page.
- For parameters you can set in the JSON configuration, as well as JSON examples, see the **teamd.conf(5)** man page.

17.7. CONFIGURING A NETWORK TEAM USING NM-CONNECTION-EDITOR

This section describes how you configure a network team using the **nm-connection-editor** application.

Prerequisites

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

Procedure

1. Open a terminal, and enter **nm-connection-editor**:

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **Team** connection type, and click **Create**.
4. On the **Team** tab:
 - a. Optionally, set the name of the team interface in the **Interface name** field.
 - b. Click the **Add** button to add a network interface as a slave to the team.
 - i. Select the connection type of the interface. For example, select **Ethernet** for a wired connection.
 - ii. Optionally, set a connection name for the slave device.
 - iii. In the **Device** field on the **Ethernet** tab, select the network interface you want to add as a slave to the team.



IMPORTANT

You can only use network interfaces in a team that are not configured.

- iv. Click **Save**.
- c. Repeat the previous step for each interface you want to add to the team.

- d. Click the **Advanced** button to set advanced options to the team connection.
 - i. On the **Runner** tab, select the runner.
 - ii. On the **Link Watcher** tab, set the link link watcher and its optional settings.
 - iii. Click **OK**.

- On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

The screenshot shows the 'Editing Team connection 1' dialog box with the 'IPv4 Settings' tab selected. The 'Connection name' is 'Team connection 1'. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one entry: Address '192.0.2.1', Netmask '24', and Gateway '192.0.2.254'. Below the table, 'DNS servers' is '192.0.2.253' and 'Search domains' is 'example.com'.

Address	Netmask	Gateway
192.0.2.1	24	192.0.2.254

DNS servers: 192.0.2.253

Search domains: example.com

- On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:

The screenshot shows the 'Editing Team connection 1' dialog box with the 'IPv6 Settings' tab selected. The 'Connection name' is 'Team connection 1'. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one entry: Address '2001:db8:1::1', Prefix '64', and Gateway '2001:db8:1::fff3'. Below the table, 'DNS servers' is '2001:db8:1::fffd' and 'Search domains' is 'example.com'.

Address	Prefix	Gateway
2001:db8:1::1	64	2001:db8:1::fff3

DNS servers: 2001:db8:1::fffd

Search domains: example.com

- Click **Save** to save the team connection.

8. Close **nm-connection-editor**.

Verification steps

- View the status of the team.

```
# teamdctl team0 state
setup:
  runner: activebackup
ports:
  enp7s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
  enp8s0
    link watches:
      link summary: up
      instance[link_watch_0]:
        name: ethtool
        link: up
        down count: 0
runner:
  active port: enp7s0
```

Additional resources

- For more information on testing connections, see [Chapter 33, *Testing basic network settings*](#).
- [Section 17.4, “Understanding the teamd service, runners, and link-watchers”](#).
- If the configuration on the disk does not match the configuration on the device, starting or restarting NetworkManager creates an in-memory connection that reflects the configuration of the device. For further details and how to avoid this problem, see [NetworkManager duplicates a connection after restart of NetworkManager service](#).

CHAPTER 18. CONFIGURING NETWORK BONDING

This section describes the basics of network bonding, the differences between bonding and teaming, and how to configure a network bond on Red Hat Enterprise Linux 8.

18.1. UNDERSTANDING NETWORK BONDING

Network bonding is a method to combine or aggregate network interfaces to provide a logical interface with higher throughput or redundancy.

The **active-backup**, **balance-tlb**, and **balance-alb** modes do not require any specific configuration of the network switch. However, other bonding modes require configuring the switch to aggregate the links. For example, Cisco switches requires **EtherChannel** for modes 0, 2, and 3, but for mode 4, the Link Aggregation Control Protocol (LACP) and **EtherChannel** are required.

For further details, see the documentation of your switch and <https://www.kernel.org/doc/Documentation/networking/bonding.txt>.



IMPORTANT

Certain network bonding features, such as the fail-over mechanism, do not support direct cable connections without a network switch. For further details, see the [ls bonding supported with direct connection using crossover cables?](#) KCS solution.

18.2. UNDERSTANDING THE DEFAULT BEHAVIOR OF MASTER AND SLAVE INTERFACES

Consider the following default behavior of, when managing or troubleshooting team or bond port interfaces using the **NetworkManager** service:

- Starting the master interface does not automatically start the port interfaces.
- Starting a port interface always starts the master interface.
- Stopping the master interface also stops the port interface.
- A master without ports can start static IP connections.
- A master without ports waits for ports when starting DHCP connections.
- A master with a DHCP connection waiting for ports completes when you add a port with a carrier.
- A master with a DHCP connection waiting for ports continues waiting when you add a port without carrier.

18.3. COMPARISON OF NETWORK TEAMING AND BONDING FEATURES

The following table compares features supported in network teams and network bonds:

Feature	Network bond	Network team
Broadcast Tx policy	Yes	Yes
Round-robin Tx policy	Yes	Yes
Active-backup Tx policy	Yes	Yes
LACP (802.3ad) support	Yes (active only)	Yes
Hash-based Tx policy	Yes	Yes
User can set hash function	No	Yes
Tx load-balancing support (TLB)	Yes	Yes
LACP hash port select	Yes	Yes
Load-balancing for LACP support	No	Yes
Ethtool link monitoring	Yes	Yes
ARP link monitoring	Yes	Yes
NS/NA (IPv6) link monitoring	No	Yes
Ports up/down delays	Yes	Yes
Port priorities and stickiness ("primary" option enhancement)	No	Yes
Separate per-port link monitoring setup	No	Yes
Multiple link monitoring setup	Limited	Yes
Lockless Tx/Rx path	No (rwlock)	Yes (RCU)
VLAN support	Yes	Yes
User-space runtime control	Limited	Yes
Logic in user-space	No	Yes
Extensibility	Hard	Easy
Modular design	No	Yes

Feature	Network bond	Network team
Performance overhead	Low	Very low
D-Bus interface	No	Yes
Multiple device stacking	Yes	Yes
Zero config using LLDP	No	(in planning)
NetworkManager support	Yes	Yes

18.4. UPSTREAM SWITCH CONFIGURATION DEPENDING ON THE BONDING MODES

The following table describes which settings you must apply to the upstream switch depending on the bonding mode:

Bonding mode	Configuration on the switch
0 - balance-rr	Requires static Etherchannel enabled (not LACP-negotiated)
1 - active-backup	Requires autonomous ports
2 - balance-xor	Requires static Etherchannel enabled (not LACP-negotiated)
3 - broadcast	Requires static Etherchannel enabled (not LACP-negotiated)
4 - 802.3ad	Requires LACP-negotiated Etherchannel enabled
5 - balance-tlb	Requires autonomous ports
6 - balance-alb	Requires autonomous ports

For configuring these settings on your switch, see the switch documentation.

18.5. CONFIGURING A NETWORK BOND USING NMCLI COMMANDS

This section describes how to configure a network bond using **nmcli** commands.

Prerequisites

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

Procedure

1. Create a bond interface. For example, to create a bond interface that uses the **active-backup** mode and both the interface and the connection are named **bond0**, enter:

```
# nmcli connection add type bond con-name bond0 ifname bond0 bond.options
"mode=active-backup"
```

To additionally set a Media Independent Interface (MII) monitoring interval, add the **miimon=interval** option to the **bond.options** property. For example, to use the same command but, additionally, set the MII monitoring interval to **1000** milliseconds (1 second), enter:

```
# nmcli connection add type bond con-name bond0 ifname bond0 bond.options
"mode=active-backup,miimon=1000"
```

2. Configure the IPv4 settings. For example, to set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain to the **bond0** connection, enter:

```
# nmcli connection modify bond0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify bond0 ipv4.gateway '192.0.2.254'
# nmcli connection modify bond0 ipv4.dns '192.0.2.253'
# nmcli connection modify bond0 ipv4.dns-search 'example.com'
# nmcli connection modify bond0 ipv4.method manual
```

3. Configure the IPv6 settings. For example, to set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain to the **bond0** connection, enter:

```
# nmcli connection modify bond0 ipv6.addresses '2001:db8:1::1/64'
# nmcli connection modify bond0 ipv6.gateway '2001:db8:1::fffe'
# nmcli connection modify bond0 ipv6.dns '2001:db8:1::fffd'
# nmcli connection modify bond0 ipv6.dns-search 'example.com'
# nmcli connection modify bond0 ipv6.method manual
```

4. Optionally, display the network interfaces, and note names of interfaces you plan to add to the bond:

```
# nmcli device
DEVICE TYPE    STATE    CONNECTION
enp1s0 ethernet connected enp1s0
enp7s0 ethernet disconnected --
enp8s0 ethernet disconnected --
lo    loopback unmanaged  --
```

5. Assign port interfaces to the bond's connection. For example, to add the interfaces named **enp7s0** and **enp8s0** to the **bond0** connection:

```
# nmcli connection add type ethernet slave-type bond con-name bond0-port1 ifname enp7s0
master bond0
# nmcli connection add type ethernet slave-type bond con-name bond0-port2 ifname enp8s0
master bond0
```

6. Activate the connection. For example, to activate the **bond0** connection:

```
# nmcli connection up bond0
```

7. Verify that the slave devices are connected, and the **CONNECTION** column displays the slave's connection name:

```
# nmcli device
DEVICE  TYPE    STATE    CONNECTION
...
enp7s0  ethernet connected bond0-port1
enp8s0  ethernet connected bond0-port2
```

Red Hat Enterprise Linux activates master and slave devices when the system boots. By activating any slave connection, the master is also activated. However, in this case, only one slave connection is activated. By default, activating the master does not automatically activate the slaves. However, you can enable this behavior by setting:

- a. Enable the **connection.autoconnect-slaves** parameter of the bond's connection:

```
# nmcli connection modify bond0 connection.autoconnect-slaves 1
```

- b. Reactivate the bridge:

```
# nmcli connection up bond0
```

Verification steps

- Display the status of the bond.

```
# cat /proc/net/bonding/bond0
Ethernet Channel Bonding Driver: v3.7.1 (April 27, 2011)

Bonding Mode: fault-tolerance (active-backup)
Primary Slave: None
Currently Active Slave: enp7s0
MII Status: up
MII Polling Interval (ms): 100
Up Delay (ms): 0
Down Delay (ms): 0

Slave Interface: enp7s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:d5:e0:fb
Slave queue ID: 0

Slave Interface: enp8s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:b2:e2:63
Slave queue ID: 0
```

In the example, both ports are up.

Verification steps:

1. To verify that bonding failover works:
 - a. Temporarily remove the network cable from the host. Note that there is no method to properly test link failure events using the command line.
 - b. Display the status of the bond:

```
# cat /proc/net/bonding/bond0
```

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- For **nmcli** examples, see the **nmcli-examples(7)** man page.
- For a list of options you can set in the **bond.options** parameter of the **nmcli** command when you create a bond, see <https://www.kernel.org/doc/Documentation/networking/bonding.txt>.

18.6. CONFIGURING A NETWORK BOND USING NM-CONNECTION-EDITOR

This section describes how to configure a network bond using the **nm-connection-editor** application.

Prerequisites

- Two or more network cards are installed in the server.
- The network cards are connected to a switch.

Procedure

1. Open a terminal, and enter **nm-connection-editor**:

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **Bond** connection type, and click **Create**.
4. On the **Bond** tab:
 - a. Optionally, set the name of the bond interface in the **Interface name** field.
 - b. Click the **Add** button to add a network interface as a slave to the bond.
 - i. Select the connection type of the interface. For example, select **Ethernet** for a wired connection.
 - ii. Optionally, set a connection name for the slave device.
 - iii. In the **Device** field on the **Ethernet** tab, select the network interface you want to add as a slave to the bond.

**IMPORTANT**

You can only use network interfaces in a bond that are not configured.

- iv. Click **Save**.
- c. Repeat the previous step for each interface you want to add to the bond:

The screenshot shows the 'Editing Bond connection 1' window with the 'Bond' tab selected. The 'Connection name' is 'Bond connection 1'. The 'Interface name' is 'bond0'. Under 'Bonded connections', there is a list with 'bond0 slave 1' and 'bond0 slave 2'. To the right of the list are 'Add' and 'Edit' buttons.

- d. Optionally, set other options, such as the Media Independent Interface (MII) monitoring interval.
- 5. On the **IPv4 Settings** tab, configure the IPv4 settings. For example, set a static IPv4 address, network mask, default gateway, DNS server, and DNS search domain:

The screenshot shows the 'Editing Bond connection 1' window with the 'IPv4 Settings' tab selected. The 'Connection name' is 'Bond connection 1'. The 'Method' is set to 'Manual'. Under 'Addresses', there is a table with one row: Address '192.0.2.1', Netmask '24', and Gateway '192.0.2.254'. To the right of the table are 'Add' and 'Delete' buttons. Below the table, the 'DNS servers' field contains '192.0.2.253' and the 'Search domains' field contains 'example.com'.

Address	Netmask	Gateway
192.0.2.1	24	192.0.2.254

- On the **IPv6 Settings** tab, configure the IPv6 settings. For example, set a static IPv6 address, network mask, default gateway, DNS server, and DNS search domain:

Editing Bond connection 1

Connection name: Bond connection 1

General Bond Proxy IPv4 Settings **IPv6 Settings**

Method: Manual

Addresses

Address	Prefix	Gateway
2001:db8:1::1	64	2001:db8:1::ff3

Add Delete

DNS servers: 2001:db8:1::fffd

Search domains: example.com

- Click **Save** to save the bond connection.
- Close **nm-connection-editor**.

Verification steps

- View the status of the bond.

```
$ cat /proc/net/bonding/_bond0_
Ethernet Channel Bonding Driver: v3.7.1 (April 27, 2011)
```

```
Bonding Mode: fault-tolerance (active-backup)
Primary Slave: None
Currently Active Slave: enp7s0
MII Status: up
MII Polling Interval (ms): 100
Up Delay (ms): 0
Down Delay (ms): 0
```

```
Slave Interface: enp7s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:d5:e0:fb
Slave queue ID: 0
```

```
Slave Interface: enp8s0
```

```

MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 0
Permanent HW addr: 52:54:00:b2:e2:63
Slave queue ID: 0

```

In the example, both ports are up.

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).

18.7. CREATING A NETWORK BOND TO ENABLE SWITCHING BETWEEN AN ETHERNET AND WIRELESS CONNECTION WITHOUT INTERRUPTING THE VPN

RHEL users who connect their workstation to their company's network typically use a VPN to access remote resources. However, if the workstation switches between an Ethernet and Wi-Fi connection, for example, if you release a laptop from a docking station with an Ethernet connection, the VPN connection is interrupted. To avoid this problem, you can create a network bond that uses the Ethernet and Wi-Fi connection in **active-backup** mode.

Prerequisites

- The host contains an Ethernet and a Wi-Fi device.
- An Ethernet and Wi-Fi NetworkManager connection profile has been created and both connections work independently.
This procedure uses the following connection profiles to create a network bond named **bond0**:
 - **Docking_station** associated with the **enp11s0u1** Ethernet device
 - **Wi-Fi** associated with the **wlp61s0** Wi-Fi device

Procedure

1. Create a bond interface in **active-backup** mode:

```
# nmcli connection add type bond con-name bond0 ifname bond0 bond.options
"mode=active-backup"
```

This command names both the interface and connection profile **bond0**.

2. Configure the IPv4 settings of the bond:

- If a DHCP server in your network assigns IPv4 addresses to hosts, no action is required.
- If your local network requires static IPv4 addresses, set the address, network mask, default gateway, DNS server, and DNS search domain to the **bond0** connection:

```
# nmcli connection modify bond0 ipv4.addresses '192.0.2.1/24'
# nmcli connection modify bond0 ipv4.gateway '192.0.2.254'
# nmcli connection modify bond0 ipv4.dns '192.0.2.253'
```

```
# nmcli connection modify bond0 ipv4.dns-search 'example.com'
# nmcli connection modify bond0 ipv4.method manual
```

3. Configure the IPv6 settings of the bond:

- If your router or a DHCP server in your network assigns IPv6 addresses to hosts, no action is required.
- If your local network requires static IPv6 addresses, set the address, network mask, default gateway, DNS server, and DNS search domain to the **bond0** connection:

```
# nmcli connection modify bond0 ipv6.addresses '2001:db8:1::1/64'
# nmcli connection modify bond0 ipv6.gateway '2001:db8:1::fffe'
# nmcli connection modify bond0 ipv6.dns '2001:db8:1::fffd'
# nmcli connection modify bond0 ipv6.dns-search 'example.com'
# nmcli connection modify bond0 ipv6.method manual
```

4. Display the connection profiles:

```
# nmcli connection show
NAME          UUID                                  TYPE    DEVICE
Docking_station 256dd073-fecc-339d-91ae-9834a00407f9 ethernet enp11s0u1
Wi-Fi          1f1531c7-8737-4c60-91af-2d21164417e8 wifi     wlp61s0
...
```

You require the names of the connection profiles and the Ethernet device name in the next steps.

5. Assign the connection profile of the Ethernet connection to the bond:

```
# nmcli connection modify Docking_station master bond0
```

6. Assign the connection profile of the Wi-Fi connection to the bond:

```
# nmcli connection modify Wi-Fi master bond0
```

7. If your Wi-Fi network uses MAC filtering to allow only MAC addresses on a white list to access the network, configure that NetworkManager dynamically assigns the MAC address of the active slave device to the bond:

```
# nmcli connection modify bond0 +bond.options fail_over_mac=1
```

With this setting, you must set only the MAC address of the Wi-Fi device to the white list instead of the MAC address of both the Ethernet and Wi-Fi device.

8. Set the device associated with the Ethernet connection as primary device of the bond:

```
# nmcli con modify bond0 +bond.options "primary=enp11s0u1"
```

With this setting, the bond always uses the Ethernet connection if it is available.

9. Configure that NetworkManager automatically activates slave devices when the **bond0** device is activated:


```
# nmcli connection modify bond0 connection.autoconnect-slaves 1
```

10. Activate the **bond0** connection:

```
# nmcli connection up bond0
```

Verification steps

- Display the currently active device, the status of the bond and its slave devices:

```
# cat /proc/net/bonding/bond0
Ethernet Channel Bonding Driver: v3.7.1 (April 27, 2011)

Bonding Mode: fault-tolerance (active-backup) (fail_over_mac active)
Primary Slave: enp11s0u1 (primary_reselect always)
Currently Active Slave: enp11s0u1
MII Status: up
MII Polling Interval (ms): 1
Up Delay (ms): 0
Down Delay (ms): 0
Peer Notification Delay (ms): 0

Slave Interface: enp11s0u1
MII Status: up
Speed: 1000 Mbps
Duplex: full
Link Failure Count: 0
Permanent HW addr: 00:53:00:59:da:b7
Slave queue ID: 0

Slave Interface: wlp61s0
MII Status: up
Speed: Unknown
Duplex: Unknown
Link Failure Count: 2
Permanent HW addr: 00:53:00:b3:22:ba
Slave queue ID: 0
```

Additional resources

- [Chapter 10, Configuring an Ethernet connection](#)
- [Chapter 11, Managing Wi-Fi connections](#)
- [Chapter 18, Configuring network bonding](#)

CHAPTER 19. CONFIGURING A VPN CONNECTION

This section explains how to configure a VPN connection.

19.1. CONFIGURING A VPN CONNECTION WITH CONTROL-CENTER

A Virtual Private Network (VPN) is a way of connecting to a local network over the internet. **IPsec**, provided by **Libreswan**, is the preferred method for creating a VPN. **Libreswan** is an open-source, user-space **IPsec** implementation for VPN. A Virtual Private Network (VPN) enables communication between your Local Area Network (LAN), and another, remote LAN. This is done by setting up a tunnel across an intermediate network such as the Internet. The VPN tunnel that is set up typically uses authentication and encryption.

This procedure describes how to configure a VPN connection using **control-center**.

Prerequisites

- The **NetworkManager-libreswan-gnome** package is installed.
- Start for adding a **VPN** connection as explained [Section 9.2, “Creating a network connection using control-center”](#).

Procedure

1. Select the **Identity** menu entry to see the basic configuration options:

General

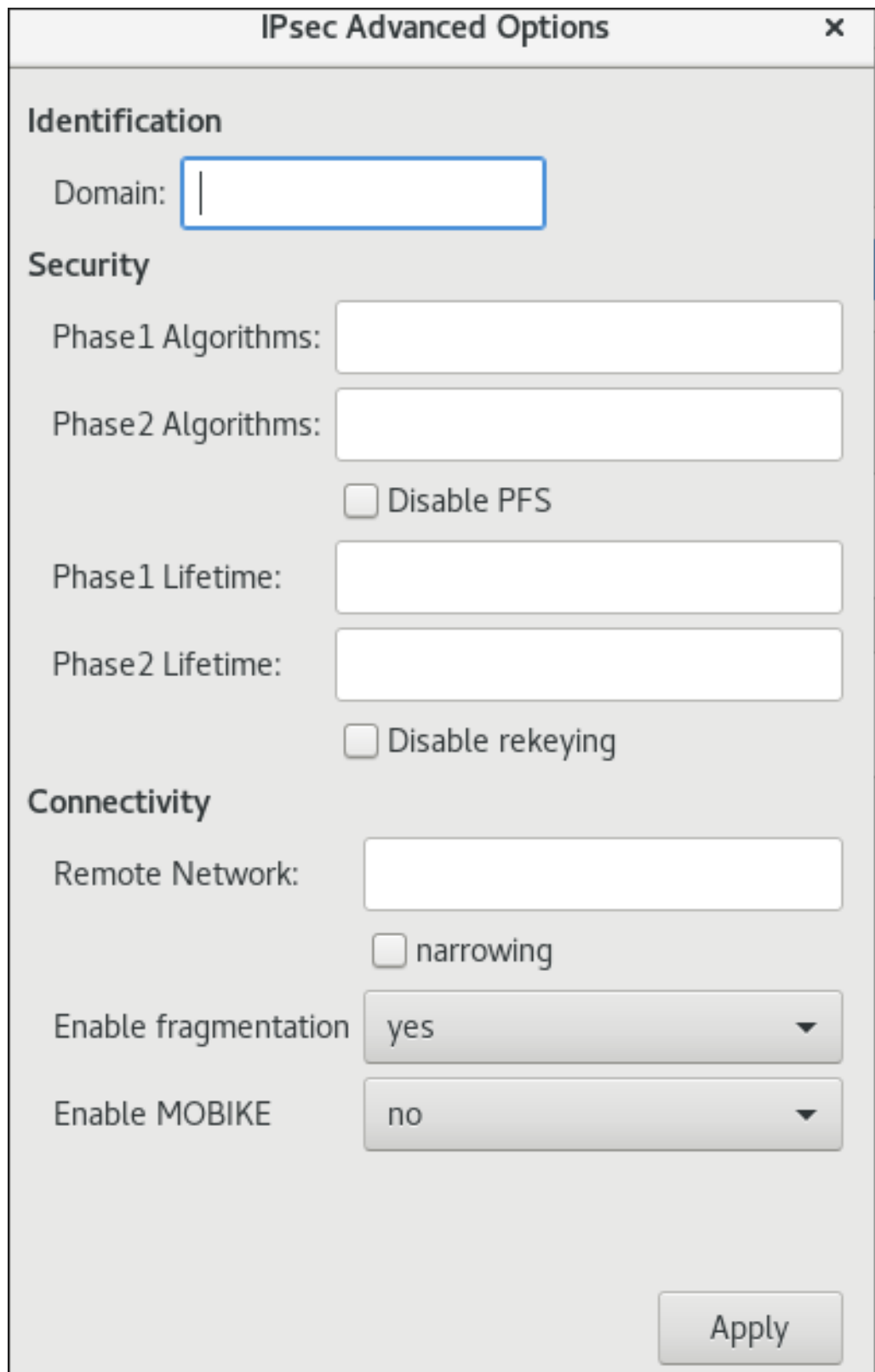
Gateway – The name or **IP** address of the remote VPN gateway.

Authentication

Type

- **IKEv2 (Certificate)**– client is authenticated by certificate. It is more secure (default).
- **IKEv1 (XAUTH)** – client is authenticated by username and password, or secret (PSK).
The following configuration settings are available under the **Advanced** section:

Figure 19.1. Advanced options of a VPN connection



The image shows a dialog box titled "IPsec Advanced Options" with a close button (X) in the top right corner. The dialog is divided into three sections: Identification, Security, and Connectivity. The Identification section has a "Domain:" label followed by a text input field. The Security section has "Phase1 Algorithms:" and "Phase2 Algorithms:" labels followed by text input fields. Below these are two checkboxes: "Disable PFS" and "Disable rekeying". The Connectivity section has a "Remote Network:" label followed by a text input field, and another checkbox labeled "narrowing". Below these are two dropdown menus: "Enable fragmentation" with "yes" selected, and "Enable MOBIKE" with "no" selected. An "Apply" button is located at the bottom right of the dialog.

IPsec Advanced Options [X]

Identification

Domain:

Security

Phase1 Algorithms:

Phase2 Algorithms:

☐ Disable PFS

Phase1 Lifetime:

Phase2 Lifetime:

☐ Disable rekeying

Connectivity

Remote Network:

☐ narrowing

Enable fragmentation

Enable MOBIKE

Apply

**WARNING**

When configuring an **IPsec based VPN** connection using the **gnome-control-center** application, the **Advanced** dialog will only display the configuration, but will not allow doing any change. As a consequence, users cannot change any advanced IPsec options. Use the **nm-connection-editor** or **nmcli** tools instead to perform configuration of the advanced properties.

Identification

Domain – If required, enter the Domain Name.

Security

- **Phase1 Algorithms** – corresponds to the **ike** Libreswan parameter – enter the algorithms to be used to authenticate and set up an encrypted channel.
- **Phase2 Algorithms** – corresponds to the **esp** Libreswan parameter – enter the algorithms to be used for the **IPsec** negotiations.
 - Check the **Disable PFS** field to turn off Perfect Forward Secrecy (PFS) to ensure compatibility with old servers that do not support PFS.
- **Phase1 Lifetime** – corresponds to the **ikelifetime** Libreswan parameter – how long the key used to encrypt the traffic will be valid.
- **Phase2 Lifetime** – corresponds to the **salifetime** Libreswan parameter – how long how long a particular instance of a connection should last before expiring. Note that the encryption key should be changed from time to time for security reasons.
- **Remote network** – corresponds to the **rightsubnet** Libreswan parameter – the destination private remote network that should be reached through the VPN.
 - Check the **narrowing** field to enable narrowing. Note that it is only effective in IKEv2 negotiation.
- **Enable fragmentation** – corresponds to the **fragmentation** Libreswan parameter – whether or not to allow IKE fragmentation. Valid values are **yes** (default), or **no**.
- **Enable Mobike** – corresponds to the **mobike** Libreswan parameter – whether to allow MOBIKE (RFC 4555) to enable a connection to migrate its endpoint without needing to restart the connection from scratch. This is used on mobile devices that switch between wired, wireless or mobile data connections. The values are **no** (default) or **yes**.

2. For further configuration, select the **IPv4** menu entry:

- **IPv4 Method**
 - **Automatic (DHCP)** – Choose this option if the network you are connecting to uses Router Advertisements (RA) or a **DHCP** server to assign dynamic **IP** addresses.

- **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per [RFC 3927](#) with prefix **169.254/16**.
 - **Manual** – Choose this option if you want to assign **IP** addresses manually.
 - **Disable** – **IPv4** is disabled for this connection.
- **DNS**
In the **DNS** section, when **Automatic** is **ON**, switch it to **OFF** to enter the IP address of a DNS server you want to use separating the IPs by comma.
- **Routes**
Note that in the **Routes** section, when **Automatic** is **ON**, routes from Router Advertisements (RA) or DHCP are used, but you can also add additional static routes. When **OFF**, only static routes are used.
 - **Address** – Enter the **IP** address of a remote network, sub-net, or host.
 - **Netmask** – The netmask or prefix length of the **IP** address entered above.
 - **Gateway** – The **IP** address of the gateway leading to the remote network, sub-net, or host entered above.
 - **Metric** – A network cost, a preference value to give to this route. Lower values will be preferred over higher values.
 - **Use this connection only for resources on its network**
Select this check box to prevent the connection from becoming the default route. Selecting this option means that only traffic specifically destined for routes learned automatically over the connection or entered here manually will be routed over the connection.
3. Alternatively, to configure **IPv6** settings in a **VPN** connection, select the **IPv6** menu entry:
- **IPv6 Method**
 - **Automatic** – Choose this option to use **IPv6** Stateless Address AutoConfiguration (SLAAC) to create an automatic, stateless configuration based on the hardware address and Router Advertisements (RA).
 - **Automatic, DHCP only** – Choose this option to not use RA, but request information from **DHCPv6** directly to create a stateful configuration.
 - **Link-Local Only** – Choose this option if the network you are connecting to does not have a **DHCP** server and you do not want to assign **IP** addresses manually. Random addresses will be assigned as per [RFC 4862](#) with prefix **FE80::0**.
 - **Manual** – Choose this option if you want to assign **IP** addresses manually.
 - **Disable** – **IPv6** is disabled for this connection.
Note that **DNS**, **Routes**, **Use this connection only for resources on its network** are common to **IPv4** settings.
4. Once you have finished editing the **VPN** connection, click the **Add** button to customize the configuration or the **Apply** button to save it for the existing one.
5. Switch the profile to **ON** to active the **VPN** connection.



NOTE

When you add a new connection by clicking the plus button, **NetworkManager** creates a new configuration file for that connection and then opens the same dialog that is used for editing an existing connection. The difference between these dialogs is that an existing connection profile has a **Details** menu entry.

Additional resources

- For more details on the supported **Libreswan** parameters, see the **nm-settings-libreswan** man page.

19.2. CONFIGURING A VPN CONNECTION USING NM-CONNECTION-EDITOR

This procedure describes how to configure a VPN connection using **nm-connection-editor**

Prerequisites

- The **NetworkManager-libreswan-gnome** package is installed.
- If you configure an Internet Key Exchange version 2 (IKEv2) connection:
 - The certificate is imported into the IPsec network security services (NSS) database.
 - The nickname of the certificate in the NSS database is known.

Procedure

1. Open a terminal, and enter:

```
$ nm-connection-editor
```

2. Click the **+** button to add a new connection.
3. Select the **IPsec based VPN** connection type, and click **Create**.
4. On the **VPN** tab:
 - a. Enter the host name or IP address of the VPN gateway into the **Gateway** field, and select an authentication type. Based on the authentication type, you must enter different additional information:
 - **IKEv2 (Certificate)** authenticates the client by using a certificate, which is more secure. This setting requires:
 - The nickname of the certificate in the IPsec NSS database
 - **IKEv1 (XAUTH)** authenticates the user by using a user name and password (pre-shared key). This setting requires that you enter the following values:
 - User name
 - Password
 - Group name

- Secret
- b. If the remote server specifies a local identifier for the IKE exchange, enter the exact string in the **Remote ID** field. In the remote server runs Libreswan, this value is set in the server's **leftid** parameter.

Editing VPN connection 1 [X]

Connection name: VPN connection 1

General | **VPN** | Proxy | IPv4 Settings

General

Gateway: vpn.example.com

Authentication

Type: IKEv2 (Certificate) ▼

Certificate name: cert_name_in_IPSec_DB

Remote ID:

[Advanced...]

- c. Optionally, configure additional settings by clicking the **Advanced** button. You can configure the following settings:
 - Identification
 - **Domain** – If required, enter the domain name.
 - Security
 - **Phase1 Algorithms** corresponds to the **ike** Libreswan parameter. Enter the algorithms to be used to authenticate and set up an encrypted channel.
 - **Phase2 Algorithms** corresponds to the **esp** Libreswan parameter. Enter the algorithms to be used for the **IPsec** negotiations.
 - Check the **Disable PFS** field to turn off Perfect Forward Secrecy (PFS) to ensure compatibility with old servers that do not support PFS.
 - **Phase1 Lifetime** corresponds to the **ikelifetime** Libreswan parameter. This parameter defines how long the key used to encrypt the traffic is valid.

- **Phase2 Lifetime** corresponds to the **salifetime** Libreswan parameter. This parameter defines how long a security association is valid.
- Connectivity
 - **Remote network** corresponds to the **rightsubnet** Libreswan parameter and defines the destination private remote network that should be reached through the VPN.
 - Check the **narrowing** field to enable narrowing. Note that it is only effective in the IKEv2 negotiation.
 - **Enable fragmentation** corresponds to the **fragmentation** Libreswan parameter and defines whether or not to allow IKE fragmentation. Valid values are **yes** (default), or **no**.
 - **Enable Mobike** corresponds to the **mobike** Libreswan parameter. The parameter defines whether to allow Mobility and Multihoming Protocol (MOBIKE) (RFC 4555) to enable a connection to migrate its endpoint without needing to restart the connection from scratch. This is used on mobile devices that switch between wired, wireless or mobile data connections. The values are **no** (default) or **yes**.
- 5. On the **IPv4 Settings** tab, select the IP assignment method and, optionally, set additional static addresses, DNS servers, search domains, and routes.

Editing VPN connection 1 [X]

Connection name: VPN connection 1

General | VPN | Proxy | **IPv4 Settings**

Method: Automatic (VPN) ▼

Additional static addresses

Address	Netmask	Gateway

Add
Delete

Additional DNS servers:

Additional search domains:

Routes...

6. Save the connection.
7. Close **nm-connection-editor**.

Additional resources

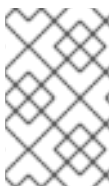
- For further details on the supported IPsec parameters, see the **nm-settings-libreswan(5)** man page.

CHAPTER 20. CREATING A DUMMY INTERFACE

As a Red Hat Enterprise Linux user, you can create and use dummy network interfaces for debugging and testing purposes. A dummy interface provides a device to route packets without actually transmitting them. It enables you to create additional loopback-like devices managed by NetworkManager and makes an inactive SLIP (Serial Line Internet Protocol) address look like a real address for local programs.

20.1. CREATING A DUMMY INTERFACE WITH BOTH AN IPV4 AND IPV6 ADDRESS USING NMCLI

You can create a dummy interface with various settings. This procedure describes how to create a dummy interface with both an IPv4 and IPv6 address. After creating the dummy interface, NetworkManager automatically assigns it to the default **public** firewall zone.



NOTE

To configure a dummy interface without IPv4 or IPv6 address, set the **ipv4.method** and **ipv6.method** parameters to **disabled**. Otherwise, IP auto-configuration fails, and NetworkManager deactivates the connection and removes the dummy device.

Procedure

1. To create a dummy interface named *dummy0* with static IPv4 and IPv6 addresses, enter:

```
# nmcli connection add type dummy ifname dummy0 ipv4.method manual
ipv4.addresses 192.0.2.1/24 ipv6.method manual ipv6.addresses 2001:db8:2::1/64
```

2. Optional: To view the dummy interface, enter:

```
# nmcli connection show
NAME          UUID                                  TYPE    DEVICE
enp1s0        db1060e9-c164-476f-b2b5-caec62dc1b05 ethernet ens3
dummy-dummy0  aaf6eb56-73e5-4746-9037-eed42caa8a65 dummy   dummy0
```

Additional resources

- The `nm-settings(5)` man page

CHAPTER 21. CONFIGURING THE ORDER OF DNS SERVERS

Most applications use the **getaddrinfo()** function of the **glibc** library to resolve DNS requests. By default, **glibc** sends all DNS requests to the first DNS server specified in the **/etc/resolv.conf** file. If this server does not reply, Red Hat Enterprise Linux uses the next server in this file.

This section describes how to customize the order of DNS servers.

21.1. HOW NETWORKMANAGER ORDERS DNS SERVERS IN /ETC/RESOLV.CONF

NetworkManager orders DNS servers in the **/etc/resolv.conf** file based on the following rules:

- If only one connection profile exists, NetworkManager uses the order of IPv4 and IPv6 DNS server specified in that connection.
- If multiple connection profiles are activated, NetworkManager orders DNS servers based on a DNS priority value. If you set DNS priorities, the behavior of NetworkManager depends on the value set in the **dns** parameter. You can set this parameter in the **[main]** section in the **/etc/NetworkManager/NetworkManager.conf** file:
 - **dns=default** or if the **dns** parameter is not set:
NetworkManager orders the DNS servers from different connections based on the **ipv4.dns-priority** and **ipv6.dns-priority** parameter in each connection.

If you set no value or you set **ipv4.dns-priority** and **ipv6.dns-priority** to **0**, NetworkManager uses the global default value. See [the section called “Default values of DNS priority parameters”](#).
 - **dns=dnsmasq** or **dns=systemd-resolved**:
When you use one of these settings, NetworkManager sets either **127.0.0.1** for **dnsmasq** or **127.0.0.53** as **nameserver** entry in the **/etc/resolv.conf** file.

Both the **dnsmasq** and **systemd-resolved** services forward queries for the search domain set in a NetworkManager connection to the DNS server specified in that connection, and forwards queries to other domains to the connection with the default route. When multiple connections have the same search domain set, **dnsmasq** and **systemd-resolved** forward queries for this domain to the DNS server set in the connection with the lowest priority value.

Default values of DNS priority parameters

NetworkManager uses the following default values for connections:

- **50** for VPN connections
- **100** for other connections

Valid DNS priority values:

You can set both the global default and connection-specific **ipv4.dns-priority** and **ipv6.dns-priority** parameters to a value between **-2147483647** and **2147483647**.

- A lower value has a higher priority.
- Negative values have the special effect of excluding other configurations with a greater value. For example, if at least one connection with a negative priority value exists, NetworkManager uses only the DNS servers specified in the connection profile with the lowest priority.

- If multiple connections have the same DNS priority, NetworkManager prioritizes the DNS in the following order:
 - a. VPN connections
 - b. Connection with an active default route. The active default route is the default route the lowest metric.

Additional resources

- For further details about how NetworkManager orders DNS server entries in the `/etc/resolv.conf` file, see the **dns-priority** parameter description in the **ipv4** and **ipv6** sections in the **nm-settings(5)** man page.
- For details about using **systemd-resolved** to use different DNS servers for different domains, see [Chapter 28, Using different DNS servers for different domains](#).

21.2. SETTING A NETWORKMANAGER-WIDE DEFAULT DNS SERVER PRIORITY VALUE

NetworkManager uses the following DNS priority default values for connections:

- **50** for VPN connections
- **100** for other connections

This section describes how to override these system-wide defaults with a custom default value for IPv4 and IPv6 connections.

Procedure

1. Edit the `/etc/NetworkManager/NetworkManager.conf` file:

- a. Add the **[connection]** section, if it does not exist:

```
[connection]
```

- b. Add the custom default values to the **[connection]** section. For example, to set the new default for both IPv4 and IPv6 to **200**, add:

```
ipv4.dns-priority=200
ipv6.dns-priority=200
```

You can set the parameters to a value between **-2147483647** and **2147483647**. Note that setting the parameters to **0** enables the built-in defaults (**50** for VPN connections and **100** for other connections).

2. Reload the **NetworkManager** service:

```
# systemctl reload NetworkManager
```

Additional resources

- For additional details about setting default values for all NetworkManager connections, see **Connection Section** in the **NetworkManager.conf(5)** man page.

21.3. SETTING THE DNS PRIORITY OF A NETWORKMANAGER CONNECTION

This section describes how to define the order of DNS servers when NetworkManager creates or updates the **/etc/resolv.conf** file.

Note that setting DNS priorities makes only sense if you have multiple connections with different DNS servers configured. If you have only one connection with multiple DNS servers configured, manually set the DNS servers in the preferred order in the connection profile.

Prerequisites

- The system has multiple NetworkManager connections configured.
- The system either has no **dns** parameter set in the **/etc/NetworkManager/NetworkManager.conf** file or the parameter is set to **default**.

Procedure

1. Optionally, display the available connections:

```
# nmcli connection show
NAME          UUID                                  TYPE    DEVICE
Example_con_1 d17ee488-4665-4de2-b28a-48befab0cd43 ethernet enp1s0
Example_con_2 916e4f67-7145-3ffa-9f7b-e7cada8f6bf7 ethernet enp7s0
...
```

2. Set the **ipv4.dns-priority** and **ipv6.dns-priority** parameters. For example, to set both parameters to **10** for the **Example_con_1** connection:

```
# nmcli connection modify Example_con_1 ipv4.dns-priority 10 ipv6.dns-priority 10
```

3. Optionally, repeat the previous step for other connections.
4. Re-activate the connection you updated:

```
# nmcli connection up Example_con_1
```

Verification steps

- Display the contents of the **/etc/resolv.conf** file to verify that the DNS server order is correct:

```
# cat /etc/resolv.conf
```

CHAPTER 22. CONFIGURING IP NETWORKING WITH IFCFG FILES

This section describes how to configure a network interface manually by editing the **ifcfg** files.

Interface configuration (ifcfg) files control the software interfaces for individual network devices. As the system boots, it uses these files to determine what interfaces to bring up and how to configure them. These files are usually named **ifcfg-name**, where the suffix *name* refers to the name of the device that the configuration file controls. By convention, the **ifcfg** file's suffix is the same as the string given by the **DEVICE** directive in the configuration file itself.

22.1. CONFIGURING AN INTERFACE WITH STATIC NETWORK SETTINGS USING IFCFG FILES

This procedure describes how to configure a network interface using **ifcfg** files.

Procedure

To configure an interface with static network settings using **ifcfg** files, for an interface with the name **enp1s0**, create a file with the name **ifcfg-enp1s0** in the **/etc/sysconfig/network-scripts/** directory that contains:

- For **IPv4** configuration:

```
DEVICE=enp1s0
BOOTPROTO=none
ONBOOT=yes
PREFIX=24
IPADDR=10.0.1.27
GATEWAY=10.0.1.1
```

- For **IPv6** configuration:

```
DEVICE=enp1s0
BOOTPROTO=none
ONBOOT=yes
IPV6INIT=yes
IPV6ADDR=2001:db8:1::2/64
```

Additional resources

- For more information on testing connections, see [Chapter 33, Testing basic network settings](#).
- For more **IPv6** ifcfg configuration options, see **nm-settings-ifcfg-rh(5)** man page.

22.2. CONFIGURING AN INTERFACE WITH DYNAMIC NETWORK SETTINGS USING IFCFG FILES

This this procedure describes how to configure a network interface with dynamic network settings using **ifcfg** files.

Procedure

1. To configure an interface named *em1* with dynamic network settings using **ifcfg** files, create a file with the name **ifcfg-em1** in the **/etc/sysconfig/network-scripts/** directory that contains:

```
DEVICE=em1
BOOTPROTO=dhcp
ONBOOT=yes
```

2. To configure an interface to send a different host name to the **DHCP** server, add the following line to the **ifcfg** file:

```
DHCP_HOSTNAME=hostname
```

3. To configure an interface to send a different fully qualified domain name (FQDN) to the **DHCP** server, add the following line to the **ifcfg** file:

```
DHCP_FQDN=fully.qualified.domain.name
```



NOTE

Only one directive, either **DHCP_HOSTNAME** or **DHCP_FQDN**, should be used in a given **ifcfg** file. In case both **DHCP_HOSTNAME** and **DHCP_FQDN** are specified, only the latter is used.

4. To configure an interface to use particular **DNS** servers, add the following lines to the **ifcfg** file:

```
PEERDNS=no
DNS1=ip-address
DNS2=ip-address
```

where *ip-address* is the address of a **DNS** server. This will cause the network service to update **/etc/resolv.conf** with the specified **DNS** servers specified. Only one **DNS** server address is necessary, the other is optional.

22.3. MANAGING SYSTEM-WIDE AND PRIVATE CONNECTION PROFILES WITH IFCFG FILES

This procedure describes how to configure **ifcfg** files to manage the system-wide and private connection profiles.

Procedure

The permissions correspond to the **USERS** directive in the **ifcfg** files. If the **USERS** directive is not present, the network profile will be available to all users.

1. As an example, modify the **ifcfg** file with the following row, which will make the connection available only to the users listed:

```
USERS="joe bob alice"
```

CHAPTER 23. DISABLING IPV6 ON A SYSTEM THAT USES NETWORKMANAGER

This section describes how to disable the IPv6 protocol on a system that uses NetworkManager to manage network interfaces. If you disable IPv6, NetworkManager automatically sets the corresponding **sysctl** values in the Kernel.



NOTE

The NetworkManager service sets certain **sysctl** values when it starts a connection. To avoid unexpected behavior, do not manually set **sysctl** values to disable IPv6.

Prerequisites

- The system uses NetworkManager to manage network interfaces, which is the default on Red Hat Enterprise Linux 8.
- The system runs Red Hat Enterprise Linux 8.1 or later.

23.1. DISABLING IPV6 ON A CONNECTION USING NMCLI

Use this section to disable the IPv6 protocol using the **nmcli** utility.

Procedure

1. Optionally, display the list of network connections:

```
# nmcli connection show
NAME    UUID                                  TYPE    DEVICE
Example 7a7e0151-9c18-4e6f-89ee-65bb2d64d365 ethernet enp1s0
...
```

2. Set the **ipv6.method** parameter of the connection to **disabled**:

```
# nmcli connection modify Example ipv6.method "disabled"
```

3. Restart the network connection:

```
# nmcli connection up Example
```

Verification steps

1. Enter the **ip address show** command to display the IP settings of the device:

```
# ip address show enp1s0
2: enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP
group default qlen 1000
    link/ether 52:54:00:6b:74:be brd ff:ff:ff:ff:ff:ff
    inet 192.0.2.1/24 brd 192.10.2.255 scope global noprefixroute enp1s0
        valid_lft forever preferred_lft forever
```

If no **inet6** entry is displayed, IPv6 is disabled on the device.

2. Verify that the **/proc/sys/net/ipv6/conf/enp1s0/disable_ipv6** file now contains the value **1**:

```
# cat /proc/sys/net/ipv6/conf/enp1s0/disable_ipv6  
1
```

The value **1** means that IPv6 is disabled for the device.

CHAPTER 24. MANUALLY CONFIGURING THE /ETC/RESOLV.CONF FILE

By default, NetworkManager on Red Hat Enterprise Linux (RHEL) 8 dynamically updates the **/etc/resolv.conf** file with the DNS settings from active NetworkManager connection profiles. This section describes different options on how to disable this feature to manually configure DNS settings in **/etc/resolv.conf**.

24.1. DISABLING DNS PROCESSING IN THE NETWORKMANAGER CONFIGURATION

This section describes how to disable DNS processing in the NetworkManager configuration to manually configure the **/etc/resolv.conf** file.

Procedure

1. Create the **/etc/NetworkManager/conf.d/90-dns-none.conf** file with the following content:

```
[main]
dns=none
```

2. Reload the **NetworkManager** service:

```
# systemctl reload NetworkManager
```



NOTE

After you reload the service, NetworkManager no longer updates the **/etc/resolv.conf** file. However, the last contents of the file are preserved.

3. Optionally, remove the **Generated by NetworkManager** comment from **/etc/resolv.conf** to avoid confusion.

Verification steps

1. Edit the **/etc/resolv.conf** file and manually update the configuration.
2. Reload the **NetworkManager** service:

```
# systemctl reload NetworkManager
```

3. Display the **/etc/resolv.conf** file:

```
# cat /etc/resolv.conf
```

If you successfully disabled DNS processing, NetworkManager did not override the manually configured settings.

Additional resources

- For further details, see the description of the **dns** parameter in the **NetworkManager.conf(5)** man page.

24.2. REPLACING /ETC/RESOLV.CONF WITH A SYMBOLIC LINK TO MANUALLY CONFIGURE DNS SETTINGS

NetworkManager does not automatically update the DNS configuration if **/etc/resolv.conf** is a symbolic link. This section describes how to replace **/etc/resolv.conf** with a symbolic link to an alternative file with the DNS configuration.

Prerequisites

- The **rc-manager** option is not set to **file**. To verify, use the **NetworkManager --print-config** command.

Procedure

1. Create a file, such as **/etc/resolv.conf.manually-configured**, and add the DNS configuration for your environment to it. Use the same parameters and syntax as in the original **/etc/resolv.conf**.
2. Remove the **/etc/resolv.conf** file:

```
# rm /etc/resolv.conf
```

3. Create a symbolic link named **/etc/resolv.conf** that refers to **/etc/resolv.conf.manually-configured**:

```
# ln -s /etc/resolv.conf.manually-configured /etc/resolv.conf
```

Additional resources

- For details about parameters you can set in **/etc/resolv.conf**, see the **resolv.conf(5)** man page.
- For further details about why NetworkManager does not process DNS settings if **/etc/resolv.conf** is a symbolic link, see the description of the **rc-manager** parameter in the **NetworkManager.conf(5)** man page.

CHAPTER 25. CONFIGURING 802.3 LINK SETTINGS

You can configure the 802.3 link settings of an Ethernet connection by modifying the following configuration parameters:

- **802-3-ethernet.auto-negotiate**
- **802-3-ethernet.speed**
- **802-3-ethernet.duplex**

You can configure the 802.3 link settings to the following main modes:

- Ignore link negotiation
- Enforce the auto-negotiation activation
- Manually set the **speed** and **duplex** link settings

25.1. CONFIGURING 802.3 LINK SETTINGS WITH NMCLI TOOL

This procedure describes how to configure 802.3 link settings using the **nmcli** tool.

Prerequisites

- The **NetworkManager** must be installed and running.

Procedure

1. To ignore link negotiation, set the following parameters:

```
~]# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate no 802-3-ethernet.speed 0 802-3-ethernet.duplex ""
```

Note, that the auto-negotiation parameter is not disabled even if the speed and duplex parameters are not set and the auto-negotiation parameter is set to no.

2. To enforce the auto-negotiation activation, enter the following command:

```
~]# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate yes 802-3-ethernet.speed 0 802-3-ethernet.duplex ""
```

That allows to negotiate all the available speed and duplex modes supported by the NIC.

You can also enable auto-negotiation while advertising and allowing only one speed/duplex mode. This can be useful if you want to enforce **1000BASE-T** and **10GBASE-T** Ethernet link configuration, as these standards mandate auto-negotiation enabled. To enforce **1000BASE-T** standard:

```
~]# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate yes 802-3-ethernet.speed 1000 802-3-ethernet.duplex full
```

3. To manually set the speed and duplex link settings, enter the following command:

```
~]# nmcli connection modify connection_name 802-3-ethernet.auto-negotiate no 802-3-ethernet.speed [speed in Mbit/s] 802-3-ethernet.duplex [full|half]
```

CHAPTER 26. CONFIGURING ETHTOOL OFFLOAD FEATURES USING NETWORKMANAGER

Network interface cards can use the TCP offload engine (TOE) to offload processing certain operations to the network controller to improve the network throughput.

This section describes what offload features NetworkManager supports and how to set them.

26.1. OFFLOAD FEATURES SUPPORTED BY NETWORKMANAGER

You can set the following **ethtool** offload features using NetworkManager:

- `ethtool.feature-esp-hw-offload`
- `ethtool.feature-esp-tx-csum-hw-offload`
- `ethtool.feature-fcoe-mtu`
- `ethtool.feature-gro`
- `ethtool.feature-gso`
- `ethtool.feature-highdma`
- `ethtool.feature-hw-tc-offload`
- `ethtool.feature-l2-fwd-offload`
- `ethtool.feature-loopback`
- `ethtool.feature-lro`
- `ethtool.feature-ntuple`
- `ethtool.feature-rx`
- `ethtool.feature-rx-all`
- `ethtool.feature-rx-fcs`
- `ethtool.feature-rx-gro-hw`
- `ethtool.feature-rx-udp_tunnel-port-offload`
- `ethtool.feature-rx-vlan-filter`
- `ethtool.feature-rx-vlan-stag-filter`
- `ethtool.feature-rx-vlan-stag-hw-parse`
- `ethtool.feature-rxhash`
- `ethtool.feature-rxvlan`
- `ethtool.feature-sg`

- `ethtool.feature-tls-hw-record`
- `ethtool.feature-tls-hw-tx-offload`
- `ethtool.feature-tso`
- `ethtool.feature-tx`
- `ethtool.feature-tx-checksum-fcoe-crc`
- `ethtool.feature-tx-checksum-ip-generic`
- `ethtool.feature-tx-checksum-ipv4`
- `ethtool.feature-tx-checksum-ipv6`
- `ethtool.feature-tx-checksum-sctp`
- `ethtool.feature-tx-esp-segmentation`
- `ethtool.feature-tx-fcoe-segmentation`
- `ethtool.feature-tx-gre-csum-segmentation`
- `ethtool.feature-tx-gre-segmentation`
- `ethtool.feature-tx-gso-partial`
- `ethtool.feature-tx-gso-robust`
- `ethtool.feature-tx-ipxip4-segmentation`
- `ethtool.feature-tx-ipxip6-segmentation`
- `ethtool.feature-tx-nocache-copy`
- `ethtool.feature-tx-scatter-gather`
- `ethtool.feature-tx-scatter-gather-fraglist`
- `ethtool.feature-tx-sctp-segmentation`
- `ethtool.feature-tx-tcp-ecn-segmentation`
- `ethtool.feature-tx-tcp-mangleid-segmentation`
- `ethtool.feature-tx-tcp-segmentation`
- `ethtool.feature-tx-tcp6-segmentation`
- `ethtool.feature-tx-udp-segmentation`
- `ethtool.feature-tx-udp_tnl-csum-segmentation`
- `ethtool.feature-tx-udp_tnl-segmentation`
- `ethtool.feature-tx-vlan-stag-hw-insert`

- `ethtool.feature-txvlan`

For details about the individual offload features, see the documentation of the **ethtool** utility and the kernel documentation.

26.2. CONFIGURING AN ETHTOOL OFFLOAD FEATURE USING NETWORKMANAGER

This section describes how you enable and disable **ethtool** offload features using NetworkManager, as well as how you remove the setting for a feature from a NetworkManager connection profile.

Procedure

1. For example, to enable the RX offload feature and disable TX offload in the **enp0s1** connection profile, enter:

```
# nmcli con modify enp0s1 ethtool.feature-rx on ethtool.feature-tx off
```

This command explicitly enables RX offload and disables TX offload.

2. To remove the setting of an offload feature that you previously enabled or disabled, set the feature's parameter to **ignore**. For example, to remove the configuration for TX offload, enter:

```
# nmcli con modify enp0s1 ethtool.feature-tx ignore
```

3. Reactivate the network profile:

```
# nmcli connection up enp0s1
```

Verification steps

1. Use the **ethtool -k** command to display the current offload features of a network device:

```
# ethtool -k network_device
```

Additional resources

- For a list of **ethtool** offload features NetworkManager supports, see [Section 26.1, "Offload features supported by NetworkManager"](#).

CHAPTER 27. CONFIGURING MACSEC

The following section provides information on how to configure **Media Control Access Security (MACsec)**, which is an 802.1AE IEEE standard security technology for secure communication in all traffic on Ethernet links.

27.1. INTRODUCTION TO MACSEC

Media Access Control Security (MACsec), IEEE 802.1AE) encrypts and authenticates all traffic in LANs with the GCM-AES-128 algorithm. **MACsec** can protect not only **IP** but also Address Resolution Protocol (ARP), Neighbor Discovery (ND), or **DHCP**. While **IPsec** operates on the network layer (layer 3) and **SSL** or **TLS** on the application layer (layer 7), **MACsec** operates in the data link layer (layer 2). Combine **MACsec** with security protocols for other networking layers to take advantage of different security features that these standards provide.

27.2. USING MACSEC WITH NMCLI TOOL

This procedure shows how to configure **MACsec** with **nmcli** tool.

Prerequisites

- The **NetworkManager** must be running.
- You already have a 16-byte hexadecimal CAK (**\$MKA_CAK**) and a 32-byte hexadecimal CKN (**\$MKA_CKN**).

Procedure

```
~]# nmcli connection add type macsec \
con-name test-macsec+ ifname macsec0 \
connection.autoconnect no \
macsec.parent enp1s0 macsec.mode psk \
macsec.mka-cak $MKA_CAK \
macsec.mka-ckn $MKA_CKN

~]# nmcli connection up test-macsec+
```

After this step, the *macsec0* device is configured and can be used for networking.

27.3. USING MACSEC WITH WPA_SUPPLICANT

This procedure shows how to enable **MACsec** with a switch that performs authentication using a pre-shared Connectivity Association Key/CAK Name (CAK/CKN) pair.

Procedure

1. Create a CAK/CKN pair. For example, the following command generates a 16-byte key in hexadecimal notation:

```
~]$ dd if=/dev/urandom count=16 bs=1 2> /dev/null | hexdump -e '1/2 "%02x"'
```

2. Create the **wpa_supplicant.conf** configuration file and add the following lines to it:


```
ctrl_interface=/var/run/wpa_supplicant
eapol_version=3
ap_scan=0
fast_reauth=1

network={
    key_mgmt=NONE
    eapol_flags=0
    macsec_policy=1

    mka_cak=0011... # 16 bytes hexadecimal
    mka_ckn=2233... # 32 bytes hexadecimal
}
```

Use the values from the previous step to complete the **mka_cak** and **mka_ckn** lines in the **wpa_supplicant.conf** configuration file.

For more information, see the **wpa_supplicant.conf(5)** man page.

3. Assuming you are using *wlp61s0* to connect to your network, start **wpa_supplicant** using the following command:

```
~]# wpa_supplicant -i wlp61s0 -Dmacsec_linux -c wpa_supplicant.conf
```

27.4. RELATED INFORMATION

For more details, see the [What's new in MACsec: setting up MACsec using wpa_supplicant and \(optionally\) NetworkManager](#) article. In addition, see the [MACsec: a different solution to encrypt network traffic](#) article for more information about the architecture of a **MACsec** network, use case scenarios, and configuration examples.

CHAPTER 28. USING DIFFERENT DNS SERVERS FOR DIFFERENT DOMAINS

By default, Red Hat Enterprise Linux (RHEL) sends all DNS requests to the first DNS server specified in the **/etc/resolv.conf** file. If this server does not reply, RHEL uses the next server in this file.

In environments where one DNS server cannot resolve all domains, administrators can configure RHEL to send DNS requests for a specific domain to a selected DNS server. For example, you can configure one DNS server to resolve queries for **example.com** and another DNS server to resolve queries for **example.net**. For all other DNS requests, RHEL uses the DNS server configured in the connection with the default gateway.

28.1. SENDING DNS REQUESTS FOR A SPECIFIC DOMAIN TO A SELECTED DNS SERVER

This section configures **systemd-resolved** service and NetworkManager to send DNS queries for a specific domain to a selected DNS server.

If you complete the procedure in this section, RHEL uses the DNS service provided by **systemd-resolved** in the **/etc/resolv.conf** file. The **systemd-resolved** service starts a DNS service that listens on port **53** IP address **127.0.0.53**. The service dynamically routes DNS requests to the corresponding DNS servers specified in NetworkManager.



NOTE

The **127.0.0.53** address is only reachable from the local system and not from the network.

Prerequisites

- The system has multiple NetworkManager connections configured.
- A DNS server and search domain are configured in the NetworkManager connections that are responsible for resolving a specific domain
For example, if the DNS server specified in a VPN connection should resolve queries for the **example.com** domain, the VPN connection profile must have:
 - Configured a DNS server that can resolve **example.com**
 - Configured the search domain to **example.com** in the **ipv4.dns-search** and **ipv6.dns-search** parameters

Procedure

1. Start and enable the **systemd-resolved** service:

```
# systemctl --now enable systemd-resolved
```

2. Edit the **/etc/NetworkManager/NetworkManager.conf** file, and set the following entry in the **[main]** section:

```
dns=systemd-resolved
```

3. Reload the **NetworkManager** service:

```
# systemctl reload NetworkManager
```

Verification steps

1. Verify that the **nameserver** entry in the **/etc/resolv.conf** file refers to **127.0.0.53**:

```
# cat /etc/resolv.conf
nameserver 127.0.0.53
```

2. Verify that the **systemd-resolved** service listens on port **53** on the local IP address **127.0.0.53**:

```
# netstat -tulpn | grep "127.0.0.53:53"
tcp  0  0 127.0.0.53:53  0.0.0.0:*  LISTEN  1050/systemd-resolv
udp  0  0 127.0.0.53:53  0.0.0.0:*  1050/systemd-resolv
```

Additional resources

- For further details, see the description of the **dns** parameter in the **NetworkManager.conf(5)** man page.

CHAPTER 29. GETTING STARTED WITH IPVLAN

This document describes the IPVLAN driver.

29.1. IPVLAN OVERVIEW

IPVLAN is a driver for a virtual network device that can be used in container environment to access the host network. IPVLAN exposes a single MAC address to the external network regardless the number of IPVLAN device created inside the host network. This means that a user can have multiple IPVLAN devices in multiple containers and the corresponding switch reads a single MAC address. IPVLAN driver is useful when the local switch imposes constraints on the total number of MAC addresses that it can manage.

29.2. IPVLAN MODES

The following modes are available for IPVLAN:

- **L2 mode**

In **IPVLAN L2 mode**, virtual devices receive and respond to Address Resolution Protocol (ARP) requests. The **netfilter** framework runs only inside the container that owns the virtual device. No **netfilter** chains are executed in the default namespace on the containerized traffic. Using **L2 mode** provides good performance, but less control on the network traffic.

- **L3 mode**

In **L3 mode**, virtual devices process only **L3** traffic and above. Virtual devices do not respond to ARP request and users must configure the neighbour entries for the IPVLAN IP addresses on the relevant peers manually. The egress traffic of a relevant container is landed on the **netfilter** POSTROUTING and OUTPUT chains in the default namespace while the ingress traffic is threaded in the same way as **L2 mode**. Using **L3 mode** provides good control but decreases the network traffic performance.

- **L3S mode**

In **L3S mode**, virtual devices process the same way as in **L3 mode**, except that both egress and ingress traffics of a relevant container are landed on **netfilter** chain in the default namespace. **L3S mode** behaves in a similar way to **L3 mode** but provides greater control of the network.



NOTE

The IPVLAN virtual device does not receive broadcast and multicast traffic in case of **L3** and **L3S modes**.

29.3. OVERVIEW OF MACVLAN

The MACVLAN driver allows to create multiple virtual network devices on top of a single NIC, each of them identified by its own unique MAC address. Packets which land on the physical NIC are demultiplexed towards the relevant MACVLAN device via MAC address of the destination. MACVLAN devices do not add any level of encapsulation.

29.4. COMPARISON OF IPVLAN AND MACVLAN

The following table shows the major differences between MACVLAN and IPVLAN.

MACVLAN	IPVLAN
Uses MAC address for each MACVLAN device. The overlimit of MAC addresses of MAC table in switch might cause loosing the connectivity.	Uses single MAC address which does not limit the number of IPVLAN devices.
Netfilter rules for global namespace cannot affect traffic to or from MACVLAN device in a child namespace.	It is possible to control traffic to or from IPVLAN device in L3 mode and L3S mode .

Note that both IPVLAN and MACVLAN do not require any level of incapsulation.

29.5. CONFIGURING IPVLAN NETWORK

29.5.1. Creating and configuring the IPVLAN device using iproute2

This procedure shows how to set up the IPVLAN device using iproute2.

Procedure

1. To create an IPVLAN device, enter the following command:

```
~]# ip link add link real_NIC_device name IPVLAN_device type ipvlan mode l2
```

Note that network interface controller (NIC) is a hardware component which connects a computer to a network.

Example 29.1. Creating an IPVLAN device

```
~]# ip link add link enp0s31f6 name my_ipvlan type ipvlan mode l2
~]# ip link
47: my_ipvlan@enp0s31f6: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state
DOWN mode DEFAULT group default qlen 1000 link/ether e8:6a:6e:8a:a2:44 brd
ff:ff:ff:ff:ff:ff
```

2. To assign an **IPv4** or **IPv6** address to the interface, enter the following command:

```
~]# ip addr add dev IPVLAN_device IP_address/subnet_mask_prefix
```

3. In case of configuring an IPVLAN device in **L3 mode** or **L3S mode**, make the following setups:
 - a. Configure the neighbor setup for the remote peer on the remote host:

```
~]# ip neigh add dev peer_device IPVLAN_device IP_address lladdr MAC_address
```

where *MAC_address* is the MAC address of the real NIC on which an IPVLAN device is based on.

- b. Configure an IPVLAN device for **L3 mode** with the following command:

```
~]# ip neigh add dev real_NIC_device peer IP_address lladdr peer_MAC_address
```

For **L3S mode**:

```
~]# ip route dev add real_NIC_device peer IP_address/32
```

where IP-address represents the address of the remote peer.

4. To set an IPVLAN device active, enter the following command:

```
~]# ip link set dev IPVLAN_device up
```

5. To check if the IPVLAN device is active, execute the following command on the remote host:

```
~]# ping IP_address
```

where the *IP_address* uses the IP address of the IPVLAN device.

CHAPTER 30. CONFIGURING VIRTUAL ROUTING AND FORWARDING (VRF)

With Virtual routing and forwarding (VRF), Administrators can use multiple routing tables simultaneously on the same host. For that, VRF partitions a network at layer 3. This enables the administrator to isolate traffic using separate and independent route tables per VRF domain. This technique is similar to virtual LANs (VLAN), which partitions a network at layer 2, where the operating system uses different VLAN tags to isolate traffic sharing the same physical medium.

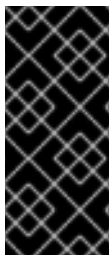
One benefit of VRF over partitioning on layer 2 is that routing scales better considering the number of peers involved.

Red Hat Enterprise Linux uses a virtual **vrt** device for each VRF domain and adds routes to a VRF domain by enslaving existing network devices to a VRF device. Addresses and routes previously attached to the enslaved device will be moved inside the VRF domain.

Note that each VRF domain is isolated from each other.

30.1. TEMPORARILY REUSING THE SAME IP ADDRESS ON DIFFERENT INTERFACES

The procedure in this section describes how to temporarily use the same IP address on different interfaces in one server by using the virtual routing and forwarding (VRF) feature. Use this procedure only for testing purposes, because the configuration is temporary and lost after you reboot the system.



IMPORTANT

To enable remote peers to contact both VRF interfaces while reusing the same IP address, the network interfaces must belong to different broadcasting domains. A broadcast domain in a network is a set of nodes which receive broadcast traffic sent by any of them. In most configurations, all nodes connected to the same switch belong to the same broadcasting domain.

Prerequisites

- You are logged in as the **root** user.
- The network interfaces are not configured.

Procedure

1. Create and configure the first VRF device:
 - a. Create the VRF device and assign it to a routing table. For example, to create a VRF device named **blue** that is assigned to the **1001** routing table:

```
# ip link add dev blue type vrf table 1001
```

- b. Enable the **blue** device:

```
# ip link set dev blue up
```

- c. Assign a network device to the VRF device. For example, to add the **enp1s0** Ethernet device to the **blue** VRF device:

```
# ip link set dev enp1s0 master blue
```

- d. Enable the **enp1s0** device:

```
# ip link set dev enp1s0 up
```

- e. Assign an IP address and subnet mask to the **enp1s0** device. For example, to set it to **192.0.2.1/24**:

```
# ip addr add dev enp1s0 192.0.2.1/24
```

2. Create and configure the next VRF device:

- a. Create the VRF device and assign it to a routing table. For example, to create a VRF device named **red** that is assigned to the **1002** routing table:

```
# ip link add dev red type vrf table 1002
```

- b. Enable the **red** device:

```
# ip link set dev red up
```

- c. Assign a network device to the VRF device. For example, to add the **enp7s0** Ethernet device to the **red** VRF device:

```
# ip link set dev enp7s0 master red
```

- d. Enable the **enp7s0** device:

```
# ip link set dev enp7s0 up
```

- e. Assign the same IP address and subnet mask to the **enp7s0** device as you used for **enp1s0** in the **blue** VRF domain:

```
# ip addr add dev enp7s0 192.0.2.1/24
```

3. Optionally, create further VRF devices as described above.

30.2. RELATED INFORMATION

- <https://www.kernel.org/doc/Documentation/networking/vrf.txt>

CHAPTER 31. SETTING THE ROUTING PROTOCOLS FOR YOUR SYSTEM

This section describes how to use the **Free Range Routing** (**FRRouting**, or **FRR**) feature to enable and set the required routing protocols for your system.

31.1. INTRODUCTION TO FRROUTING

Free Range Routing (**FRRouting**, or **FRR**) is a routing protocol stack, which is provided by the **frr** package available in the **AppStream** repository.

FRR replaces **Quagga** that was used on previous RHEL versions. As such, **FRR** provides TCP/IP-based routing services with support for multiple IPv4 and IPv6 routing protocols.

The supported protocols are:

- Border Gateway Protocol (**BGP**)
- Intermediate System to Intermediate System (**IS-IS**)
- Open Shortest Path First (**OSPF**)
- Protocol-Independent Multicast (**PIM**)
- Routing Information Protocol (**RIP**)
- Routing Information Protocol next generation (**RIPng**)
- Enhanced Interior Gateway Routing Protocol (**EIGRP**)
- Next Hop Resolution Protocol (**NHRP**)
- Bidirectional Forwarding Detection (**BFD**)
- Policy-based Routing (**PBR**)

FRR is a collection of the following services:

- zebra
- bgpd
- isisd
- ospfd
- ospf6d
- pimd
- ripd
- ripngd
- eigrpd

- nhrpd
- bfdd
- pbrd
- staticd
- fabricd

If **frr** is installed, the system can act as a dedicated router, which exchanges routing information with other routers in either internal or external network using the routing protocols.

31.2. SETTING UP FRROUTING

Prerequisites

- Make sure that the **frr** package is installed on your system:

```
# yum install frr
```

Procedure

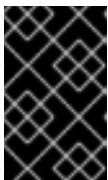
1. Edit the **/etc/frr/daemons** configuration file, and enable the required daemons for your system. For example, to enable the **ripd** daemon, include the following line:

```
ripd=yes
```



WARNING

The **zebra** daemon must always be enabled, so that you must set **zebra=yes** to be able to use **FRR**.



IMPORTANT

By default, **/etc/frr/daemons** contains **[daemon_name]=no** entries for all daemons. Therefore, all daemons are disabled, and starting **FRR** after a new installation of the system has no effect.

2. Start the **frr** service:

```
# systemctl start frr
```

3. Optionally, you can also set **FRR** to start automatically on boot:

```
# systemctl enable frr
```

31.3. MODIFYING THE CONFIGURATION OF FRR

This section describes:

- How to enable an additional daemon after you set up **FRR**
- How to disable a daemon after you set up **FRR**

Enabling an additional daemon

Prerequisites

- **FRR** is set up as described in [Section 31.2, "Setting up FRRouting"](#).

Procedure

To enable one or more additional daemons:

1. Edit the **/etc/frr/daemons** configuration file, and modify the line for the required daemons to state **yes** instead of **no**.

For example, to enable the **ripd** daemon:

```
ripd=yes
```

2. Reload the **frr** service:

```
# systemctl reload frr
```

Disabling a daemon

Prerequisites

- **FRR** is set up as described in [Section 31.2, "Setting up FRRouting"](#).

Procedure

To disable one or more daemons:

1. Edit the **/etc/frr/daemons** configuration file, and modify the line for the required daemons to state **no** instead of **yes**.

For example, to disable the **ripd** daemon:

```
ripd=no
```

2. Reload the **frr** service:

```
# systemctl reload frr
```

31.4. MODIFYING A CONFIGURATION OF A PARTICULAR DAEMON

With the default configuration, every routing daemon in **FRR** can only act as a plain router.

For any additional configuration of a daemon, use the following procedure.

Procedure

1. Within the **/etc/frr/** directory, create a configuration file for the required daemon, and name the file as follows:

```
[daemon_name].conf
```

For example, to further configure the **eigrpd** daemon, create the **eigrpd.conf** file in the mentioned directory.

2. Populate the new file with the required content.
For configuration examples of particular **FRR** daemons, see the **/usr/share/doc/frr/** directory.
3. Reload the **frr** service:

```
# systemctl reload frr
```

CHAPTER 32. MONITORING AND TUNING THE RX RING BUFFER

Receive (RX) ring buffers are shared buffers between the device driver and Network Interface Card (NIC), and store incoming packets until the device driver can process them.

You can increase the size of the Ethernet device RX ring buffer if the packet drop rate causes applications to report:

- a loss of data,
- cluster fence,
- slow performance,
- timeouts, and
- failed backups.

This section describes how to identify the number of dropped packets and increase the RX ring buffer to reduce a high packet drop rate.

32.1. DISPLAYING THE NUMBER OF DROPPED PACKETS

The **ethtool** utility enables administrators to query, configure, or control network driver settings.

The exhaustion of the RX ring buffer causes an increment in the counters, such as "discard" or "drop" in the output of **ethtool -S interface_name**. The discarded packets indicate that the available buffer is filling up faster than the kernel can process the packets.

This procedure describes how to display drop counters using **ethtool**.

Procedure

- To display drop counters for the **enp1s0** interface, enter:

```
$ ethtool -S enp1s0
```

32.2. INCREASING THE RX RING BUFFER TO REDUCE A HIGH PACKET DROP RATE

The **ethtool** utility helps to increase the RX buffer to reduce a high packet drop rate.

Procedure

1. To view the maximum RX ring buffer size:

```
# ethtool -g enp1s0
Ring parameters for enp1s0:
Pre-set maximums:
RX:          4080
RX Mini:      0
RX Jumbo:     16320
```

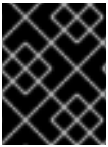
```
TX:          255
Current hardware settings:
RX:          255
RX Mini:     0
RX Jumbo:    0
TX:          255
```

2. If the values in the **Pre-set maximums** section are higher than in the **Current hardware settings** section, increase RX ring buffer:

- To temporary change the RX ring buffer of the **enp1s0** device to **4080**, enter:

```
# ethtool -G enp1s0 rx 4080
```

- To permanently change the RX ring buffer create a NetworkManager dispatcher script. For details, see the [How to make NIC ethtool settings persistent \(apply automatically at boot\)](#) article and create a dispatcher script.



IMPORTANT

Depending on the driver your network interface card uses, changing in the ring buffer can shortly interrupt the network connection.

Additional resources

- For further information about statistics that cover more reasons for discards of unwanted packets, see the [ifconfig and ip commands report packet drops in RHEL7](#) article.
- [Should I be concerned about a 0.05% packet drop rate?](#)
- The **ethtool(8)** man page.

CHAPTER 33. TESTING BASIC NETWORK SETTINGS

This section describes how to perform basic network testing.

33.1. USING THE PING UTILITY TO VERIFY THE IP CONNECTION TO OTHER HOSTS

The **ping** utility sends ICMP packets to a remote host. You can use this functionality to test if the IP connection to a different host works.

Procedure

- Ping the IP address of a host in the same subnet, such as your default gateway:

```
# ping 192.0.2.3
```

If the command fails, verify the default gateway settings.

- Ping an IP address of a host in a remote subnet:

```
# ping 198.162.3.1
```

If the command fails, verify the default gateway settings, and ensure that the gateway forwards packets between the connected networks.

33.2. USING THE HOST UTILITY TO VERIFY NAME RESOLUTION

This procedure describes how to verify name resolution in Red Hat Enterprise Linux 8.

Procedure

- Use the **host** utility to verify that name resolution works. For example, to resolve the **client.example.com** hostname to an IP address, enter:

```
# host client.example.com
```

If the command returns an error, such as **connection timed out** or **no servers could be reached**, verify your DNS settings.

CHAPTER 34. INSTALLING AND UPDATING THE KERNEL

The kernel is a core part of a Linux operating system that manages the system resources, and provides the interface between hardware and software applications. The Red Hat kernel is a custom-built kernel based on the upstream Linux mainline kernel that Red Hat engineers further develop and harden with a focus on stability and compatibility with the latest technologies and hardware.

This section describes how to install, update, and select a kernel in the GRUB boot loader.

34.1. INSTALLING THE KERNEL

The following procedure describes how to install new kernels using the **yum** package manager.

Procedure

- To install a specific kernel version, use the following:

```
# yum install kernel-{version}
```

Additional resources

- For a list of available kernels, refer to [Red Hat Code Browser](#).
- For a list of release dates of specific kernel versions, see [this article](#).

34.2. UPDATING THE KERNEL

The following procedure describes how to update the kernel using the **yum** package manager.

Procedure

1. To update the kernel, use the following:

```
# yum update kernel
```

This command updates the kernel along with all dependencies to the latest available version.

2. Reboot your system for the changes to take effect.



NOTE

When upgrading from Red Hat Enterprise Linux 7 to Red Hat Enterprise Linux 8, follow relevant sections of the [Upgrading from RHEL 7 to RHEL 8](#) document.

34.3. STARTING RHEL USING A PREVIOUS KERNEL VERSION

By default, after you update, the system boots the latest version of the kernel. Red Hat Enterprise Linux allows to have three kernel versions installed at the same time. This is defined in the **/etc/dnf/dnf.conf** file (**installonly_limit=3**).

If you observe any issues when the system is loaded with the new kernel, you can reboot it with the previous kernel and restore the production machine. Contact support for troubleshooting the issue.

Procedure

1. Start the system.
2. In the GRUB boot loader, you see the installed kernels. Use the ↑ and ↓ keys to select a kernel, and press **Enter** to boot it.

Additional resources

- [Changing the default kernel to boot using the **grubby** tool.](#)

CHAPTER 35. PROVIDING DHCP SERVICES

The Dynamic Host Configuration Protocol (DHCP) is a network protocol that automatically assigns IP information to clients.

This section explains general information on the **dhcpcd** service, as well as how to set up a DHCP server and DHCP relay.

If a procedure requires different steps for providing DHCP in IPv4 and IPv6 networks, the sections in this chapter contain procedures for both protocols.

35.1. THE DIFFERENCES WHEN USING DHCPD FOR DHCPV4 AND DHCPV6

The **dhcpcd** service supports providing both DHCPv4 and DHCPv6 on one server. However, you need a separate instance of **dhcpcd** with separate configuration files to provide DHCP for each protocol.

DHCPv4

- Configuration file: **/etc/dhcp/dhcpd.conf**
- Systemd service name: **dhcpcd**

DHCPv6

- Configuration file: **/etc/dhcp/dhcpd6.conf**
- Systemd service name: **dhcpcd6**

35.2. THE LEASE DATABASE OF THE DHCPD SERVICE

A DHCP lease is the time period for which the **dhcpcd** service allocates a network address to a client. The **dhcpcd** service stores the DHCP leases in the following databases:

- For DHCPv4: **/var/lib/dhcpd/dhcpd.leases**
- For DHCPv6: **/var/lib/dhcpd/dhcpd6.leases**



WARNING

Manually updating the database files can corrupt the databases.

The lease databases contain information about the allocated leases, such as the IP address assigned to a media access control (MAC) address or the time stamp when the lease expires. Note that all time stamps in the lease databases are in Coordinated Universal Time (UTC).

The **dhcpcd** service recreates the databases periodically:

1. The service renames the existing files:

- `/var/lib/dhcpd/dhcpd.leases` to `/var/lib/dhcpd/dhcpd.leases~`
 - `/var/lib/dhcpd/dhcpd6.leases` to `/var/lib/dhcpd/dhcpd6.leases~`
2. The service writes all known leases to the newly created `/var/lib/dhcpd/dhcpd.leases` and `/var/lib/dhcpd/dhcpd6.leases` files.

Additional resources

- For further details about what is stored in the lease database, see the **dhcpd.leases(5)** man page.
- [Section 35.9, “Restoring a corrupt lease database”](#)

35.3. DYNAMIC IP ADDRESS ASSIGNMENT IN IPV6 NETWORKS

In an IPv6 network, only router advertisement messages provide information on an IPv6 default gateway. As a consequence, if you want to use DHCPv6 in subnets that require a default gateway setting, you must additionally configure a router advertisement service, such as Router Advertisement Daemon (**radvd**).

The **radvd** service uses flags in router advertisement packets to announce the availability of a DHCPv6 server.

This section compares DHCPv6 and **radvd**, and provides information about configuring **radvd**.

35.3.1. Comparison of DHCPv6 to radvd

	DHCPv6	radvd
Provides information on the default gateway	no	yes
Guarantees random addresses to protect privacy	yes	no
Sends further network configuration options	yes	no
Maps media access control (MAC) addresses to IPv6 addresses	yes	no

35.3.2. Configuring the radvd service for IPv6 routers

The router advertisement daemon (**radvd**) sends router advertisement messages that are required for IPv6 stateless autoconfiguration. This enables users to automatically configure their addresses, settings, routes, and to choose a default router based on these advertisements.

The procedure in this section explains how to configure **radvd**.

Prerequisites

- You are logged in as the **root** user.

Procedure

1. Install the **radvd** package:

```
# yum install radvd
```

2. Edit the **/etc/radvd.conf** file, and add the following configuration:

```
interface enp1s0
{
    AdvSendAdvert on;
    AdvManagedFlag on;
    AdvOtherConfigFlag on;

    prefix 2001:db8:0:1::/64 {
    };
};
```

These settings configures **radvd** to send router advertisement messages on the **enp1s0** device for the **2001:db8:0:1::/64** subnet. The **AdvManagedFlag on** setting defines that the client should receive the IP address from a DHCP server, and the **AdvOtherConfigFlag** parameter set to **on** defines that clients should receive non-address information from the DHCP server as well.

3. Optionally, configure that **radvd** automatically starts when the system boots:

```
# systemctl enable radvd
```

4. Start the **radvd** service:

```
# systemctl start radvd
```

5. Optionally, display the content of router advertisement packages and the configured values **radvd** sends:

```
# radvdump
```

Additional resources

- For further details about configuring **radvd**, see the **radvd.conf(5)** man page.
- For an example configuration of **radvd**, see the **/usr/share/doc/radvd/radvd.conf.example** file.

35.4. SETTING NETWORK INTERFACES FOR THE DHCP SERVERS

By default, the **dhcpcd** service processes requests only on network interfaces that have an IP address in the subnet defined in the configuration file of the service.

For example, in the following scenario, **dhcpcd** listens only on the **enp0s1** network interface:

- You have only a **subnet** definition for the 192.0.2.0/24 network in the **/etc/dhcp/dhpcd.conf** file.
- The **enp0s1** network interface is connected to the 192.0.2.0/24 subnet.
- The **enp7s0** interface is connected to a different subnet.

Only follow the procedure in this section if the DHCP server contains multiple network interfaces connected to the same network but the service should listen only on specific interfaces.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- You are logged in as the **root** user.
- The **dhcp-server** package is installed.

For IPv4 networks

1. Copy the **/usr/lib/systemd/system/dhcpd.service** file to the **/etc/systemd/system/** directory:

```
# cp /usr/lib/systemd/system/dhcpd.service /etc/systemd/system/
```

Do not edit the **/usr/lib/systemd/system/dhcpd.service** file. Future updates of the **dhcp-server** package can override the changes.

2. Edit the **/etc/systemd/system/dhcpd.service** file, and append the names of the interface, that **dhcpd** should listen on to the command in the **ExecStart** parameter:

```
ExecStart=/usr/sbin/dhcpd -f -cf /etc/dhcp/dhcpd.conf -user dhcpd -group dhcpd --no-pid
$DHCPDARGS enp0s1 enp7s0
```

This example configures that **dhcpd** listens only on the **enp0s1** and **enp7s0** interfaces.

3. Reload the **systemd** manager configuration:

```
# systemctl daemon-reload
```

4. Restart the **dhcpd** service:

```
# systemctl restart dhcpd.service
```

For IPv6 networks

1. Copy the **/usr/lib/systemd/system/dhcpd6.service** file to the **/etc/systemd/system/** directory:

```
# cp /usr/lib/systemd/system/dhcpd6.service /etc/systemd/system/
```

Do not edit the **/usr/lib/systemd/system/dhcpd6.service** file. Future updates of the **dhcp-server** package can override the changes.

2. Edit the **/etc/systemd/system/dhcpd6.service** file, and append the names of the interface, that **dhcpd** should listen on to the command in the **ExecStart** parameter:

```
ExecStart=/usr/sbin/dhcpd -f -6 -cf /etc/dhcp/dhcpd6.conf -user dhcpd -group dhcpd --no-pid
$DHCPDARGS enp0s1 enp7s0
```

This example configures that **dhcpcd** listens only on the **enp0s1** and **enp7s0** interfaces.

3. Reload the **systemd** manager configuration:

```
# systemctl daemon-reload
```

4. Restart the **dhcpcd** service:

```
# systemctl restart dhcpcd.service
```

35.5. SETTING UP THE DHCP SERVICE FOR SUBNETS DIRECTLY CONNECTED TO THE DHCP SERVER

Use the following procedure if the DHCP server is directly connected to the subnet for which the server should answer DHCP requests. This is the case if a network interface of the server has an IP address of this subnet assigned.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- You are logged in as the **root** user.
- The **dhcpcd-server** package is installed.

For IPv4 networks

1. Edit the **/etc/dhcp/dhcpcd.conf** file:

- a. Optionally, add global parameters that **dhcpcd** uses as default if no other directives contain these settings:

```
option domain-name "example.com";
default-lease-time 86400;
```

This example sets the default domain name for the connection to **example.com**, and the default lease time to **86400** seconds (1 day).

- b. Add the **authoritative** statement on a new line:

```
authoritative;
```



IMPORTANT

Without the **authoritative** statement, the **dhcpcd** service does not answer **DHCPREQUEST** messages with **DHCPNAK** if a client asks for an address that is outside of the pool.

- c. For each IPv4 subnet directly connected to an interface of the server, add a **subnet** declaration:

```
subnet 192.0.2.0 netmask 255.255.255.0 {
    range 192.0.2.20 192.0.2.100;
    option domain-name-servers 192.0.2.1;
    option routers 192.0.2.1;
    option broadcast-address 192.0.2.255;
    max-lease-time 172800;
}
```

This example adds a subnet declaration for the 192.0.2.0/24 network. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from this subnet:

- A free IPv4 address from the range defined in the **range** parameter
- IP of the DNS server for this subnet: **192.0.2.1**
- Default gateway for this subnet: **192.0.2.1**
- Broadcast address for this subnet: **192.0.2.255**
- The maximum lease time, after which clients in this subnet release the IP and send a new request to the server: **172800** seconds (2 days)

2. Optionally, configure that **dhcpcd** starts automatically when the system boots:

```
# systemctl enable dhcpcd
```

3. Start the **dhcpcd** service:

```
# systemctl start dhcpcd
```

For IPv6 networks

1. Edit the **/etc/dhcp/dhcpd6.conf** file:

- a. Optionally, add global parameters that **dhcpcd** uses as default if no other directives contain these settings:

```
option dhcp6.domain-search "example.com";
default-lease-time 86400;
```

This example sets the default domain name for the connection to **example.com**, and the default lease time to **86400** seconds (1 day).

- b. Add the **authoritative** statement on a new line:

```
authoritative;
```



IMPORTANT

Without the **authoritative** statement, the **dhcpcd** service does not answer **DHCPREQUEST** messages with **DHCPNAK** if a client asks for an address that is outside of the pool.

- c. For each IPv6 subnet directly connected to an interface of the server, add a **subnet** declaration:

```
subnet6 2001:db8:0:1::/64 {
    range6 2001:db8:0:1::20 2001:db8:0:1::100;
    option dhcp6.name-servers 2001:db8:0:1::1;
    max-lease-time 172800;
}
```

This example adds a subnet declaration for the 2001:db8:0:1::/64 network. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from this subnet:

- A free IPv6 address from the range defined in the **range6** parameter.
- The IP of the DNS server for this subnet is **2001:db8:0:1::1**.
- The maximum lease time, after which clients in this subnet release the IP and send a new request to the server is **172800** seconds (2 days).
Note that IPv6 requires uses router advertisement messages to identify the default gateway.

2. Optionally, configure that **dhcpcd6** starts automatically when the system boots:

```
# systemctl enable dhcpcd6
```

3. Start the **dhcpcd6** service:

```
# systemctl start dhcpcd6
```

Additional resources

- For a list of all parameters you can set in **/etc/dhcp/dhcpd.conf** and **/etc/dhcp/dhcpd6.conf**, see the **dhcpcd-options(5)** man page.
- For further details about the **authoritative** statement, see **The authoritative statement** section in the **dhcpcd.conf(5)** man page.
- For example configurations, see the **/usr/share/doc/dhcp-server/dhcpd.conf.example** and **/usr/share/doc/dhcp-server/dhcpd6.conf.example** files.
- For details about configuring the **radvd** service for IPv6 router advertisement, see [Section 35.3.2, “Configuring the radvd service for IPv6 routers”](#)

35.6. SETTING UP THE DHCP SERVICE FOR SUBNETS THAT ARE NOT DIRECTLY CONNECTED TO THE DHCP SERVER

Use the following procedure if the DHCP server is not directly connected to the subnet for which the

server should answer DHCP requests. This is the case if a DHCP relay agent forwards requests to the DHCP server, because none of the DHCP server's interfaces is directly connected to the subnet the server should serve.

Depending on whether you want to provide DHCP for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- You are logged in as the **root** user.
- The **dhcpcd-server** package is installed.

For IPv4 networks

1. Edit the **/etc/dhcp/dhcpd.conf** file:

- a. Optionally, add global parameters that **dhcpcd** uses as default if no other directives contain these settings:

```
option domain-name "example.com";
default-lease-time 86400;
```

This example sets the default domain name for the connection to **example.com**, and the default lease time to **86400** seconds (1 day).

- b. Add the **authoritative** statement on a new line:

```
authoritative;
```



IMPORTANT

Without the **authoritative** statement, the **dhcpcd** service does not answer **DHCPREQUEST** messages with **DHCPNAK** if a client asks for an address that is outside of the pool.

- c. Add a **shared-network** declaration, such as the following, for IPv4 subnets that are not directly connected to an interface of the server:

```
shared-network example {
    option domain-name-servers 192.0.2.1;
    ...

    subnet 192.0.2.0 netmask 255.255.255.0 {
        range 192.0.2.20 192.0.2.100;
        option routers 192.0.2.1;
    }

    subnet 198.51.100.0 netmask 255.255.255.0 {
        range 198.51.100.20 198.51.100.100;
        option routers 198.51.100.1;
    }
}
```

```
}
...
}
```

This example adds a shared network declaration, that contains a **subnet** declaration for both the 192.0.2.0/24 and 198.51.100.0/24 networks. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from one of these subnets:

- The IP of the DNS server for clients from both subnets is: **192.0.2.1**.
 - A free IPv4 address from the range defined in the **range** parameter, depending on from which subnet the client sent the request.
 - The default gateway is either **192.0.2.1** or **198.51.100.1** depending on from which subnet the client sent the request.
- d. Add a **subnet** declaration for the subnet the server is directly connected to and that is used to reach the remote subnets specified in **shared-network** above:

```
subnet 203.0.113.0 netmask 255.255.255.0 {
}
```



NOTE

If the server does not provide DHCP service to this subnet, the **subnet** declaration must be empty as shown in the example. Without a declaration for the directly connected subnet, **dhcpcd** does not start.

2. Optionally, configure that **dhcpcd** starts automatically when the system boots:

```
# systemctl enable dhcpcd
```

3. Start the **dhcpcd** service:

```
# systemctl start dhcpcd
```

For IPv6 networks

1. Edit the **/etc/dhcp/dhcpd6.conf** file:

- a. Optionally, add global parameters that **dhcpcd** uses as default if no other directives contain these settings:

```
option dhcp6.domain-search "example.com";
default-lease-time 86400;
```

This example sets the default domain name for the connection to **example.com**, and the default lease time to **86400** seconds (1 day).

- b. Add the **authoritative** statement on a new line:

```
authoritative;
```



IMPORTANT

Without the **authoritative** statement, the **dhcpcd** service does not answer **DHCPREQUEST** messages with **DHCPNAK** if a client asks for an address that is outside of the pool.

- c. Add a **shared-network** declaration, such as the following, for IPv6 subnets that are not directly connected to an interface of the server:

```
shared-network example {
    option domain-name-servers 2001:db8:0:1::1:1
    ...

    subnet6 2001:db8:0:1::1:0/120 {
        range6 2001:db8:0:1::1:20 2001:db8:0:1::1:100
    }

    subnet6 2001:db8:0:1::2:0/120 {
        range6 2001:db8:0:1::2:20 2001:db8:0:1::2:100
    }
    ...
}
```

This example adds a shared network declaration that contains a **subnet6** declaration for both the 2001:db8:0:1::1:0/120 and 2001:db8:0:1::2:0/120 networks. With this configuration, the DHCP server assigns the following settings to a client that sends a DHCP request from one of these subnets:

- The IP of the DNS server for clients from both subnets is **2001:db8:0:1::1:1**.
- A free IPv6 address from the range defined in the **range6** parameter, depending on from which subnet the client sent the request.
Note that IPv6 requires uses router advertisement messages to identify the default gateway.

- d. Add a **subnet6** declaration for the subnet the server is directly connected to and that is used to reach the remote subnets specified in **shared-network** above:

```
subnet6 2001:db8:0:1::50:0/120 {
}
```



NOTE

If the server does not provide DHCP service to this subnet, the **subnet6** declaration must be empty as shown in the example. Without a declaration for the directly connected subnet, **dhcpcd** does not start.

2. Optionally, configure that **dhcpcd6** starts automatically when the system boots:

```
# systemctl enable dhcpcd6
```

3. Start the **dhcpcd6** service:

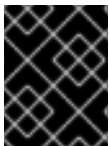
```
# systemctl start dhcpcd6
```

Additional resources

- For a list of all parameters you can set in `/etc/dhcp/dhcpd.conf` and `/etc/dhcp/dhcpd6.conf`, see the **dhcp-options(5)** man page.
- For further details about the **authoritative** statement, see **The authoritative statement** section in the **dhcpd.conf(5)** man page.
- For example configurations, see the `/usr/share/doc/dhcp-server/dhcpd.conf.example` and `/usr/share/doc/dhcp-server/dhcpd6.conf.example` files.
- For details about configuring the **radvd** service for IPv6 router advertisement, see [Section 35.3.2, “Configuring the radvd service for IPv6 routers”](#)
- [Section 35.10, “Setting up a DHCP relay agent”](#)

35.7. ASSIGNING A STATIC ADDRESS TO A HOST USING DHCP

Using a **host** declaration, you can configure the DHCP server to assign a fixed IP address to a media access control (MAC) address of a host. For example, use this method to always assign the same IP address to a server or network device.



IMPORTANT

If you configure a fixed IP address for a MAC address, the IP address must be outside of the address pool you specified in the **fixed-address** and **fixed-address6** parameters.

Depending on whether you want to configure fixed addresses for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- The **dhcpd** service is configured and running.
- You are logged in as the **root** user.

For IPv4 networks

1. Edit the `/etc/dhcp/dhcpd.conf` file:
 - a. Add a **host** declaration:

```
host server.example.com {  
    hardware ethernet 52:54:00:72:2f:6e;  
    fixed-address 192.0.2.130;  
}
```

This example configures the DHCP server to always assigns the **192.0.2.130** IP address to the host with the **52:54:00:72:2f:6e** MAC address.

The **dhcpd** service identifies systems by the MAC address specified in the **fixed-address** parameter, and not by the name in the **host** declaration. As a consequence, you can set this

name to any string that does not match other **host** declarations. To configure the same system for multiple networks, use a different name, otherwise, **dhcpcd** fails to start.

- b. Optionally, add further settings to the **host** declaration that are specific for this host.

2. Restart the **dhcpcd** service:

```
# systemctl start dhcpcd
```

For IPv6 networks

1. Edit the **/etc/dhcp/dhpcpd6.conf** file:

- a. Add a **host** declaration:

```
host server.example.com {
    hardware ethernet 52:54:00:72:2f:6e;
    fixed-address6 2001:db8:0:1::200;
}
```

This example configures the DHCP server to always assign the **2001:db8:0:1::20** IP address to the host with the **52:54:00:72:2f:6e** MAC address.

The **dhcpcd** service identifies systems by the MAC address specified in the **fixed-address6** parameter, and not by the name in the **host** declaration. As a consequence, you can set this name to any string, as long as it is unique to other **host** declarations. To configure the same system for multiple networks, use a different name because, otherwise, **dhcpcd** fails to start.

- b. Optionally, add further settings to the **host** declaration that are specific for this host.

2. Restart the **dhcpcd6** service:

```
# systemctl start dhcpcd6
```

Additional resources

- For a list of all parameters you can set in **/etc/dhcp/dhpcpd.conf** and **/etc/dhcp/dhpcpd6.conf**, see the **dhcpc-options(5)** man page.
- For example configurations, see the **/usr/share/doc/dhcp-server/dhpcpd.conf.example** and **/usr/share/doc/dhcp-server/dhpcpd6.conf.example** files.

35.8. USING A GROUP DECLARATION TO APPLY PARAMETERS TO MULTIPLE HOSTS, SUBNETS, AND SHARED NETWORKS AT THE SAME TIME

Using a **group** declaration, you can apply the same parameters to multiple hosts, subnets, and shared networks.

Note that the procedure in this section describes using a **group** declaration for hosts, but the steps are the same for subnets and shared networks.

Depending on whether you want to configure a group for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- The **dhcpcd** service is configured and running.
- You are logged in as the **root** user.

For IPv4 networks

1. Edit the **/etc/dhcp/dhcpd.conf** file:
 - a. Add a **group** declaration:

```
group {
    option domain-name-servers 192.0.2.1;

    host server1.example.com {
        hardware ethernet 52:54:00:72:2f:6e;
        fixed-address 192.0.2.130;
    }

    host server2.example.com {
        hardware ethernet 52:54:00:1b:f3:cf;
        fixed-address 192.0.2.140;
    }
}
```

This **group** definition groups two **host** entries. The **dhcpcd** service applies the value set in the **option domain-name-servers** parameter to both hosts in the group.

- b. Optionally, add further settings to the **group** declaration that are specific for these hosts.
2. Restart the **dhcpcd** service:

```
# systemctl start dhcpcd
```

For IPv6 networks

1. Edit the **/etc/dhcp/dhcpd6.conf** file:
 - a. Add a **group** declaration:

```
group {
    option dhcp6.domain-search "example.com";

    host server1.example.com {
        hardware ethernet 52:54:00:72:2f:6e;
        fixed-address 2001:db8:0:1::200;
    }

    host server2.example.com {
        hardware ethernet 52:54:00:1b:f3:cf;
    }
}
```

```

    fixed-address 2001:db8:0:1::ba3;
}
}

```

This **group** definition groups two **host** entries. The **dhcpcd** service applies the value set in the **option dhcp6.domain-search** parameter to both hosts in the group.

b. Optionally, add further settings to the **group** declaration that are specific for these hosts.

2. Restart the **dhcpcd6** service:

```
# systemctl start dhcpcd6
```

Additional resources

- For a list of all parameters you can set in **/etc/dhcp/dhcpd.conf** and **/etc/dhcp/dhcpd6.conf**, see the **dhcp-options(5)** man page.
- For example configurations, see the **/usr/share/doc/dhcp-server/dhcpd.conf.example** and **/usr/share/doc/dhcp-server/dhcpd6.conf.example** files.

35.9. RESTORING A CORRUPT LEASE DATABASE

If the DHCP server logs an error that is related to the lease database, such as **Corrupt lease file - possible data loss!**, you can restore the lease database from the copy the **dhcpcd** service created. Note that this copy might not reflect the latest status of the database.



WARNING

If you remove the lease database instead of replacing it with a backup, you lose all information about the currently assigned leases. As a consequence, the DHCP server could assign leases to clients that have been previously assigned to other hosts and are not expired yet. This leads to IP conflicts.

Depending on whether you want to restore the DHCPv4, DHCPv6, or both databases, see the procedure for:

- [Restoring the DHCPv4 lease database](#)
- [Restoring the DHCPv6 lease database](#)

Prerequisites

- You are logged in as the **root** user.
- The lease database is corrupt.

Restoring the DHCPv4 lease database

1. Stop the **dhcpcd** service:

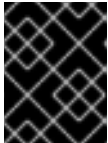
```
# systemctl stop dhcpd
```

2. Rename the corrupt lease database:

```
# mv /var/lib/dhcpd/dhcpd.leases /var/lib/dhcpd/dhcpd.leases.corrupt
```

3. Restore the copy of the lease database that the **dhcp** service created when it refreshed the lease database:

```
# cp -p /var/lib/dhcpd/dhcpd.leases~ /var/lib/dhcpd/dhcpd.leases
```



IMPORTANT

If you have a more recent backup of the lease database, restore this backup instead.

4. Start the **dhcpd** service:

```
# systemctl start dhcpd
```

Restoring the DHCPv6 lease database

1. Stop the **dhcpd6** service:

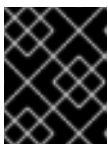
```
# systemctl stop dhcpd6
```

2. Rename the corrupt lease database:

```
# mv /var/lib/dhcpd/dhcpd6.leases /var/lib/dhcpd/dhcpd6.leases.corrupt
```

3. Restore the copy of the lease database that the **dhcp** service created when it refreshed the lease database:

```
# cp -p /var/lib/dhcpd/dhcpd6.leases~ /var/lib/dhcpd/dhcpd6.leases
```



IMPORTANT

If you have a more recent backup of the lease database, restore this backup instead.

4. Start the **dhcpd6** service:

```
# systemctl start dhcpd6
```

Additional resources

- [Section 35.2, “The lease database of the dhcpd service”](#)

35.10. SETTING UP A DHCP RELAY AGENT

The DHCP Relay Agent (**dhcrelay**) enables the relay of DHCP and BOOTP requests from a subnet with no DHCP server on it to one or more DHCP servers on other subnets. When a DHCP client requests information, the DHCP Relay Agent forwards the request to the list of DHCP servers specified. When a DHCP server returns a reply, the DHCP Relay Agent forwards this request to the client.

Depending on whether you want to set up a DHCP relay for IPv4, IPv6, or both protocols, see the procedure for:

- [IPv4 networks](#)
- [IPv6 networks](#)

Prerequisites

- You are logged in as the **root** user.

For IPv4 networks

1. Install the **dhcpc-relay** package:

```
# yum install dhcpc-relay
```

2. Copy the **/lib/systemd/system/dhcrelay.service** file to the **/etc/systemd/system/** directory:

```
# cp /lib/systemd/system/dhcrelay.service /etc/systemd/system/
```

Do not edit the **/usr/lib/systemd/system/dhcrelay.service** file. Future updates of the **dhcpc-relay** package can override the changes.

3. Edit the **/etc/systemd/system/dhcrelay.service** file, and append the **-i interface** parameter, together with a list of IP addresses of DHCPv4 servers that are responsible for the subnet:

```
ExecStart=/usr/sbin/dhcrelay -d --no-pid -i enp1s0 192.0.2.1
```

With these additional parameters, **dhcrelay** listens for DHCPv4 requests on the **enp1s0** interface and forwards them to the DHCP server with the IP **192.0.2.1**.

4. Reload the **systemd** manager configuration:

```
# systemctl daemon-reload
```

5. Optionally, configure that the **dhcrelay** service starts when the system boots:

```
# systemctl enable dhcrelay.service
```

6. Start the **dhcrelay** service:

```
# systemctl start dhcrelay.service
```

For IPv6 networks

1. Install the **dhcpc-relay** package:

```
# yum install dhcpc-relay
```

2. Copy the **/lib/systemd/system/dhcrelay.service** file to the **/etc/systemd/system/** directory and name the file **dhcrelay6.service**:

```
# cp /lib/systemd/system/dhcrelay.service /etc/systemd/system/dhcrelay6.service
```

Do not edit the **/usr/lib/systemd/system/dhcrelay.service** file. Future updates of the **dhcprelay** package can override the changes.

3. Edit the **/etc/systemd/system/dhcrelay6.service** file, and append the **-l receiving_interface** and **-u outgoing_interface** parameters:

```
ExecStart=/usr/sbin/dhcrelay -d --no-pid -l enp1s0 -u enp7s0
```

With these additional parameters, **dhcrelay** listens for DHCPv6 requests on the **enp1s0** interface and forwards them to the network connected to the **enp7s0** interface.

4. Reload the **systemd** manager configuration:

```
# systemctl daemon-reload
```

5. Optionally, configure that the **dhcrelay6** service starts when the system boots:

```
# systemctl enable dhcrelay6.service
```

6. Start the **dhcrelay6** service:

```
# systemctl start dhcrelay6.service
```

Additional resources

- For further details about **dhcrelay**, see the **dhcrelay(8)** man page.

Additional resources

- [Section 35.1, “The differences when using dhcpcd for DHCPv4 and DHCPv6”](#)

CHAPTER 36. USING AND CONFIGURING FIREWALLD

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.

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

36.1. 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 to configure a firewall on workstations. The utility is easy to use and covers the typical use cases for this scenario.
- **nftables**: Use the **nftables** utility to set up complex firewalls, such as for a whole network.
- **iptables**: The **iptables** utility is deprecated in Red Hat Enterprise Linux 8. Use instead **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.

36.2. GETTING STARTED WITH FIREWALLD

36.2.1. firewalld

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.

Additional resources

- **firewalld(1)** man page

36.2.2. 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

- **firewalld.zone(5)** man page

36.2.3. 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

- **firewalld.service(5)** man page

36.3. INSTALLING THE FIREWALL-CONFIG GUI CONFIGURATION TOOL

To use the **firewall-config** GUI configuration tool, install the **firewall-config** package.

Procedure

1. Enter the following command as **root**:

```
# yum install firewall-config
```

Alternatively, in **GNOME**, use the **Super** key and type **Software** to launch the **Software Sources** application. Type **firewall** to the search box, which appears after selecting the search button in the top-right corner. Select the **Firewall** item from the search results, and click on the **Install** button.

2. To run **firewall-config**, use either the **firewall-config** command or press the **Super** key to enter the **Activities Overview**, type **firewall**, and press **Enter**.

36.4. VIEWING THE CURRENT STATUS AND SETTINGS OF FIREWALLD

36.4.1. Viewing the current status of firewalld

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

Procedure

1. To see the status of the service:

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

2. For more information about the service status, use the **systemctl status** sub-command:

```
# systemctl status firewalld
firewalld.service - firewalld - dynamic firewall daemon
  Loaded: loaded (/usr/lib/systemd/system/firewalld.service; enabled; vendor pr
  Active: active (running) since Mon 2017-12-18 16:05:15 CET; 50min ago
    Docs: man:firewalld(1)
  Main PID: 705 (firewalld)
    Tasks: 2 (limit: 4915)
   CGroup: /system.slice/firewalld.service
           └─705 /usr/bin/python3 -Es /usr/sbin/firewalld --nofork --nopid
```

Additional resources

It is important to know how **firewalld** is set up and which rules are in force before you try to edit the settings. To display the firewall settings, see [Section 36.4.2, “Viewing current firewalld settings”](#)

36.4.2. Viewing current firewalld settings

36.4.2.1. 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.

Alternatively, to start the graphical firewall configuration tool using the command-line, enter the following command:

```
$ 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.

36.4.2.2. 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.

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
... [trimmed for clarity]
```

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

Usage: firewall-cmd [OPTIONS...]

General Options
-h, --help          Prints a short help text and exists
-V, --version       Print the version string of firewalld
-q, --quiet         Do not print status messages

Status Options
--state             Return and print firewalld state
--reload            Reload firewall and keep state information
... [trimmed for clarity]
```

For example, to see which services are allowed in the current zone:

```
# firewall-cmd --list-services
ssh dhcpv6-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.

36.5. 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
```

36.6. STOPPING FIREWALLD

Procedure

1. To stop **firewalld**, enter the following command as **root**:

```
# systemctl stop firewalld
```

2. To prevent **firewalld** from starting automatically at system start:

```
# 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**:

```
# systemctl mask firewalld
```

36.7. RUNTIME AND PERMANENT SETTINGS

Any changes committed in *runtime* mode only apply while **firewalld** is running. When **firewalld** is restarted, the settings revert to their *permanent* values.

To make the changes persistent across reboots, apply them again using the **--permanent** option. Alternatively, to make changes persistent while **firewalld** is running, use the **--runtime-to-permanent firewall-cmd** option.

If you set the rules while **firewalld** is running using only the **--permanent** option, they do not become effective before **firewalld** is restarted. However, restarting **firewalld** closes all open ports and stops the networking traffic.

Modifying settings in runtime and permanent configuration using CLI

Using the CLI, you do not modify the firewall settings in both modes at the same time. You only modify either runtime or permanent mode. To modify the firewall settings in the permanent mode, use the **--permanent** option with the **firewall-cmd** command.

```
# firewall-cmd --permanent <other options>
```

Without this option, the command modifies runtime mode.

To change settings in both modes, you can use two methods:

1. Change runtime settings and then make them permanent as follows:

```
# firewall-cmd <other options>
# firewall-cmd --runtime-to-permanent
```

2. Set permanent settings and reload the settings into runtime mode:

```
# firewall-cmd --permanent <other options>
# firewall-cmd --reload
```

The first method allows you to test the settings before you apply them to the permanent mode.



NOTE

It is possible, especially on remote systems, that an incorrect setting results in a user locking themselves out of a machine. To prevent such situations, use the **--timeout** option. After a specified amount of time, any change reverts to its previous state. Using this options excludes the **--permanent** option.

For example, to add the **SSH** service for 15 minutes:

```
# firewall-cmd --add-service=ssh --timeout 15m
```

36.8. 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:

```
# firewall-cmd --check-config
success
```

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:

■

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

36.9. CONTROLLING NETWORK TRAFFIC USING FIREWALLD

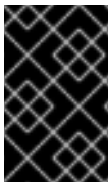
36.9.1. Disabling all traffic in case of emergency using CLI

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
```



IMPORTANT

Enabling panic mode stops all networking traffic. From 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.

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

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

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

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

36.9.2. 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
```

36.9.3. Controlling traffic with predefined services using GUI

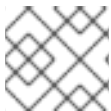
To enable or disable a predefined or custom service:

1. Start the **firewall-config** tool and select the network zone whose services are to be configured.
2. Select the **Services** tab.
3. Select the check box for each type of service you want to trust or clear the check box to block a service.

To edit a service:

1. Start the **firewall-config** tool.
2. Select **Permanent** from the menu labeled **Configuration**. Additional icons and menu buttons appear at the bottom of the **Services** window.
3. 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 **Runtime** mode.

36.9.4. 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.

36.9.5. 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.

36.9.5.1. 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:

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

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

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

3. Make the new settings persistent:

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

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

36.9.5.2. 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:

```
# 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:

```
# firewall-cmd --remove-port=port-number/port-type
```

3. Make the new settings persistent:

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

36.9.6. Opening ports using GUI

To permit traffic through the firewall to a certain port:

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.

36.9.7. Controlling traffic with protocols using GUI

To permit traffic through the firewall using a certain protocol:

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.

36.9.8. Opening source ports using GUI

To permit traffic through the firewall from a certain port:

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.

36.10. 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.

36.10.1. Listing zones

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
```

36.10.2. Modifying firewalld settings for a certain zone

The [Section 36.9.2, “Controlling traffic with predefined services using CLI”](#) and [Section 36.9.5, “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

1. 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
```

36.10.3. Changing the default zone

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.

36.10.4. 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
```

36.10.5. 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 profile modify connection.zone zone_name
```

2. Reload the connection:

```
# nmcli connection up profile
```

36.10.6. 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

1. 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
```

36.10.7. 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

To create a new zone:

1. Create a new zone:

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

36.10.8. 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 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"/>
```



```
<port port="1025-65535" protocol="tcp"/>
<port port="1025-65535" protocol="udp"/>
</zone>
```

To change settings for that zone, add or remove sections to add ports, forward ports, services, and so on.

Additional resources

- For more information, see the **firewalld.zone** manual pages.

36.10.9. 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 behaviour is defined by setting the target of the zone. There are four options – **default**, **ACCEPT**, **REJECT**, and **DROP**. By setting the target to **ACCEPT**, you accept all incoming packets except those disabled by a specific rule. If you set the target to **REJECT** or **DROP**, you disable all incoming packets except those that you have allowed in specific rules. When packets are rejected, the source machine is informed about the rejection, while there is no information sent when the packets are dropped.

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 --zone=zone-name --set-target=<default|ACCEPT|REJECT|DROP>
```

36.11. USING ZONES TO MANAGE INCOMING TRAFFIC DEPENDING ON A SOURCE

36.11.1. 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.

36.11.2. Adding a source

To route incoming traffic into a specific source, 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.

- 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
```

36.11.3. 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
```

36.11.4. 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

1. To add a source port:

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

36.11.5. Removing a source port

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

Procedure

1. To remove a source port:

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

36.11.6. 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 traffic from *192.168.1.0/24* to be able to reach the *HTTP* service while any other traffic is blocked.

Procedure

1. List all available zones:

```
# firewall-cmd --get-zones
block dmz drop external home internal public trusted work
```

2. Add the source to the trusted zone to route the traffic originating from the source through the zone:

```
# firewall-cmd --zone=trusted --add-source=192.168.1.0/24
```

3. Add the *http* service in the trusted zone:

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

4. Make the new settings persistent:

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

5. Check that the trusted zone is active and that the service is allowed in it:

```
# firewall-cmd --zone=trusted --list-all
trusted (active)
target: ACCEPT
sources: 192.168.1.0/24
services: http
```

36.11.7. Configuring traffic accepted by a zone based on a protocol

You can allow incoming traffic to be accepted by a zone based on a protocol. All traffic using the specified protocol is accepted by a zone, in which you can apply further rules and filtering.

36.11.7.1. Adding a protocol to a zone

By adding a protocol to a certain zone, you allow all traffic with this protocol to be accepted by this zone.

Procedure

1. To add a protocol to a zone:

```
# firewall-cmd --zone=zone-name --add-protocol=port-name/tcp|udp|sctp|dccp|igmp
```



NOTE

To receive multicast traffic, use the **igmp** value with the **--add-protocol** option.

36.11.7.2. Removing a protocol from a zone

By removing a protocol from a certain zone, you stop accepting all traffic based on this protocol by the zone.

Procedure

1. To remove a protocol from a zone:

```
# firewall-cmd --zone=zone-name --remove-protocol=port-name/tcp|udp|sctp|dccp|igmp
```

36.12. 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, repeat the command adding the **--permanent** option.

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

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

36.13. 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](#).

36.13.1. Adding a port to redirect

Using **firewall-d**, you can set up ports 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

To redirect a port to another port:

```
# firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp|sctp|dccp:toport=port-number
```

To redirect a port to another port at a different IP address:

1. Add the port to be forwarded:

```
# firewall-cmd --add-forward-port=port=port-number:proto=tcp|udp:toport=port-number:toaddr=IP/mask
```

2. Enable masquerade:

```
# firewall-cmd --add-masquerade
```

36.13.2. 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
```

36.13.3. Removing a redirected port

To remove a redirected port:

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

■

To remove a forwarded port redirected to a different address, use the following procedure.

Procedure

1. Remove the forwarded port:

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

2. Disable masquerade:

```
~]# firewall-cmd --remove-masquerade
```

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

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
```

36.14. 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.

36.14.1. 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-icmp-types
```

- The **ICMP** request can be used by IPv4, IPv6, or by both protocols. To see for which protocol the **ICMP** request is used:

```
# firewall-cmd --info-icmp-type=<icmp-type>
```

- 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=<icmp-type>
```

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=<icmp-type>
```

- To block an **ICMP** request:

```
# firewall-cmd --add-icmp-block=<icmp-type>
```

- To remove the block for an **ICMP** request:

```
# firewall-cmd --remove-icmp-block=<icmp-type>
```

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:

1. Set the target of your zone to **DROP**:

```
# firewall-cmd --set-target=DROP
```

2. Make the new settings persistent:

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

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 --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. Those that were blocked are not blocked. Which means that if you need 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 --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
```

36.14.2. 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 edit an **ICMP** type, start the **firewall-config** tool and select **Permanent** mode from the menu labeled **Configuration**. Additional icons appear at the bottom of the **Services** window. Select **Yes** in the following dialog to enable masquerading and to make forwarding to another machine working.
- 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.

36.15. SETTING AND CONTROLLING IP SETS USING FIREWALLD

To see the list of IP set types supported by **firewalld**, enter the following command as root.

```
~]# firewall-cmd --get-ipset-types
hash:ip hash:ip,mark hash:ip,port hash:ip,port,ip hash:ip,port,net hash:mac hash:net hash:net,iface
hash:net,net hash:net,port hash:net,port,net
```

36.15.1. 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**:

```
# firewall-cmd --permanent --get-ipsets
```

- To add a new IP set, use the following command using the permanent environment as **root**:

```
# 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**:

```
# firewall-cmd --permanent --get-ipsets
test
```

- To get more information about the IP set, use the following command as **root**:

```
# 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**:

```
# 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**:

```
# firewall-cmd --permanent --ipset=test --get-entries
192.168.0.1
```

- Generate a file containing a list of IP addresses, for example:

```
# 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**:

```
# 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**:

```
# 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**:

```
# 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**:

```
# 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.



WARNING

Red Hat does not recommend using IP sets that are not managed through **firewalld**. To use such IP sets, a permanent direct rule is required to reference the set, and a custom service must be added to create these IP sets. This service needs to be started before **firewalld** starts, otherwise **firewalld** is not able to add the direct rules using these sets. You can add permanent direct rules with the **/etc/firewalld/direct.xml** file.

36.16. 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.

36.16.1. 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.

36.16.2. 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:

```
# 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:

```
# nft list chain inet firewalld filter_IN_public_post
table inet firewalld {
```

```
chain filter_IN_public_post {
    log prefix "UNEXPECTED: " limit rate 5/minute
}
```

36.17. 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 whitelist 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.

36.17.1. Configuring lockdown with using CLI

- 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
```

36.17.2. Configuring lockdown whitelist options using CLI

The lockdown whitelist can contain commands, security contexts, users and user IDs. If a command entry on the whitelist 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 on the whitelist, enter the following command as **root**:

```
# firewall-cmd --list-lockdown-whitelist-commands
```

- To add a command *command* to the whitelist, 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 whitelist, 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 on the whitelist, 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 on the whitelist, enter the following command as **root**:

```
# firewall-cmd --list-lockdown-whitelist-contexts
```

- To add a context *context* to the whitelist, enter the following command as **root**:

```
# firewall-cmd --add-lockdown-whitelist-context=context
```

- To remove a context *context* from the whitelist, enter the following command as **root**:

```
# firewall-cmd --remove-lockdown-whitelist-context=context
```

- To query whether the context *context* is on the whitelist, 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 on the whitelist, enter the following command as **root**:

```
# firewall-cmd --list-lockdown-whitelist-uids
```

- To add a user ID *uid* to the whitelist, enter the following command as **root**:

```
# firewall-cmd --add-lockdown-whitelist-uid=uid
```

- To remove a user ID *uid* from the whitelist, enter the following command as **root**:

```
# firewall-cmd --remove-lockdown-whitelist-uid=uid
```

- To query whether the user ID *uid* is on the whitelist, 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 on the whitelist, enter the following command as **root**:

```
# firewall-cmd --list-lockdown-whitelist-users
```

- To add a user name *user* to the whitelist, enter the following command as **root**:

```
# firewall-cmd --add-lockdown-whitelist-user=user
```

- To remove a user name *user* from the whitelist, enter the following command as **root**:

```
# firewall-cmd --remove-lockdown-whitelist-user=user
```

- To query whether the user name *user* is on the whitelist, enter the following command:

```
$ firewall-cmd --query-lockdown-whitelist-user=user
```

Prints **yes** with exit status **0**, if true, prints **no** with exit status **1** otherwise.

36.17.3. Configuring lockdown whitelist options using configuration files

The default whitelist configuration file contains the **NetworkManager** context and the default context of **libvirt**. The user ID 0 is also on the list.

```
<?xml version="1.0" encoding="utf-8"?>
<whitelist>
  <selinux context="system_u:system_r:NetworkManager_t:s0"/>
  <selinux context="system_u:system_r:virtld_t:s0-s0:c0.c1023"/>
  <user id="0"/>
</whitelist>
```

Following is an example whitelist configuration file enabling all commands for the **firewall-cmd** utility, for a user called *user* whose user ID is **815**:

```
<?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 whitelisted 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.

36.18. LOG FOR DENIED PACKETS

With the **LogDenied** option in the **firewalld**, it is possible to add a simple logging mechanism for denied packets. These are the packets that are rejected or dropped. To change the setting of the logging, edit the **/etc/firewalld/firewalld.conf** file or use the command-line or GUI configuration tool.

If **LogDenied** is enabled, logging rules are added right before the reject and drop rules in the INPUT, FORWARD and OUTPUT chains for the default rules and also the final reject and drop rules in zones. The possible values for this setting are: **all**, **unicast**, **broadcast**, **multicast**, and **off**. The default setting is **off**. With the **unicast**, **broadcast**, and **multicast** setting, the **pkttype** match is used to match the link-layer packet type. With **all**, all packets are logged.

To list the actual **LogDenied** setting with **firewall-cmd**, use the following command as **root**:

```
# firewall-cmd --get-log-denied
off
```

To change the **LogDenied** setting, use the following command as **root**:

```
# firewall-cmd --set-log-denied=all
success
```

To change the **LogDenied** setting with the **firewalld** GUI configuration tool, start **firewall-config**, click the **Options** menu and select **Change Log Denied**. The **LogDenied** window appears. Select the new **LogDenied** setting from the menu and click OK.

36.19. RELATED INFORMATION

The following sources of information provide additional resources regarding **firewalld**.

Installed documentation

- **firewalld(1)** man page – describes command options for **firewalld**.
- **firewalld.conf(5)** man page – contains information to configure **firewalld**.
- **firewall-cmd(1)** man page – describes command options for the **firewalld** command-line client.
- **firewall-config(1)** man page – describes settings for the **firewall-config** tool.
- **firewall-offline-cmd(1)** man page – describes command options for the **firewalld** offline command-line client.
- **firewalld.icmptype(5)** man page – describes XML configuration files for **ICMP** filtering.
- **firewalld.ipset(5)** man page – describes XML configuration files for the **firewalld** IP sets.
- **firewalld.service(5)** man page – describes XML configuration files for **firewalld** service.
- **firewalld.zone(5)** man page – describes XML configuration files for **firewalld** zone configuration.

- **firewalld.direct(5)** man page – describes the **firewalld** direct interface configuration file.
- **firewalld.lockdown-whitelist(5)** man page – describes the **firewalld** lockdown whitelist configuration file.
- **firewalld.richlanguage(5)** man page – describes the **firewalld** rich language rule syntax.
- **firewalld.zones(5)** man page – general description of what zones are and how to configure them.
- **firewalld.dbus(5)** man page – describes the **D-Bus** interface of **firewalld**.

Online documentation

- <http://www.firewalld.org/> – **firewalld** home page.

CHAPTER 37. GETTING STARTED WITH NFTABLES

The **nftables** framework enables administrators to configure packet-filtering rules used by the Linux kernel firewall.

37.1. INTRODUCTION TO NFTABLES

The **nftables** framework provides packet classification facilities and it is the designated successor to the **iptables**, **ip6tables**, **arptables**, and **ebtables** tools. It offers numerous improvements in convenience, features, and performance over previous packet-filtering tools, most notably:

- 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 (**nfttrace**) and monitoring trace events (in the **nft** tool)
- more consistent and compact syntax, no protocol-specific extensions
- a Netlink API for third-party applications

Similarly to **iptables**, **nftables** use tables for storing chains. The chains contain individual rules for performing actions. The **nft** tool replaces all tools from the previous packet-filtering frameworks. The **libnftnl** library can be used for low-level interaction with **nftables** Netlink API over the **libmnl** library.

Effect of the modules on the **nftables** rules set can be observed using the **nft list rule set** 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.

Additional resources

- The **nft(8)** man page provides a comprehensive reference documentation for configuring and inspecting packet filtering with nftables using the **nft** command-line tool.

37.2. 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 to configure a firewall on workstations. The utility is easy to use and covers the typical use cases for this scenario.
- **nftables**: Use the **nftables** utility to set up complex firewalls, such as for a whole network.
- **iptables**: The **iptables** utility is deprecated in Red Hat Enterprise Linux 8. Use instead **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.

37.3. CONVERTING IPTABLES RULES TO NFTABLES RULES

Red Hat Enterprise Linux 8 provides the **iptables-translate** and **ip6tables-translate** tools to convert existing **iptables** or **ip6tables** rules into the equivalent ones for **nftables**.

Note that some extensions lack translation support. If such an extension exists, the tool prints the untranslated rule prefixed with the **#** sign. For example:

```
# iptables-translate -A INPUT -j CHECKSUM --checksum-fill
nft # -A INPUT -j CHECKSUM --checksum-fill
```

Additionally, users can use the **iptables-restore-translate** and **ip6tables-restore-translate** tools to translate a dump of rules. Note that before that, users can use the **iptables-save** or **ip6tables-save** commands to print a dump of current rules. For example:

```
# iptables-save >/tmp/iptables.dump
# iptables-restore-translate -f /tmp/iptables.dump

# Translated by iptables-restore-translate v1.8.0 on Wed Oct 17 17:00:13 2018
add table ip nat
...
```

For more information and a list of possible options and values, enter the **iptables-translate --help** command.

37.4. 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. You can either extend these files or write your scripts.

37.4.1. The required script header in nftables script

Similar to other scripts, **nftables** scripts require a shebang sequence in the first line of the script that sets the interpreter directive.

An **nftables** script must always start with the following line:

```
#!/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**.

37.4.2. 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:

```
#!/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:

```
#!/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
```

37.4.3. Running nftables scripts

To run an **nftables** script, the script must be executable. Only if the script is included in another script, it does not require to be executable. The procedure describes how to make a script executable and run the script.

Prerequisites

- The procedure of this section assumes that you stored an **nftables** script in the **/etc/nftables/example_firewall.nft** file.

Procedure

1. Steps that are required only once:

- a. Optionally, set the owner of the script to **root**:

```
# chown root /etc/nftables/example_firewall.nft
```

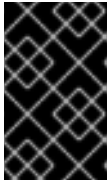
- b. Make the script executable for the owner:

```
# chmod u+x /etc/nftables/example_firewall.nft
```

2. Run the script:

```
# /etc/nftables/example_firewall.nft
```

If no output is displayed, the system executed the script successfully.



IMPORTANT

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

- For details about setting the owner of a file, see the **chown(1)** man page.
- For details about setting permissions of a file, see the **chmod(1)** man page.
- [Section 37.4.7, “Automatically loading nftables rules when the system boots”](#)

37.4.4. Using comments in nftables scripts

The **nftables** scripting environment interprets everything to the right of a **#** character as a comment.

Example 37.1. Comments in an nftables script

Comments can start at the beginning of a line, as well as next to a command:

```
...
# Flush the rule set
flush ruleset

add table inet example_table # Create a table
...
```

37.4.5. 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**:

```
define INET_DEV = enp1s0
```

You can use the variable in the script by writing the **\$** sign followed by the variable name:

```
...
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:

```
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

- For details about sets, see [Section 37.11, “Using sets in nftables commands”](#).
- For details about verdict maps, see [Section 37.12, “Using verdict maps in nftables commands”](#).

37.4.6. 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 37.2. Including files from the default search directory

To include a file from the default search directory:

```
include "example.nft"
```

Example 37.3. Including all *.nft files from a directory

To include all files ending in ***.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

- For further details, see the **Include files** section in the **nft(8)** man page.

37.4.7. 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. Enable the **nftables** service.

```
# systemctl enable nftables
```

3. Optionally, start the **nftables** service to load the firewall rules without rebooting the system:

```
# systemctl start nftables
```

Additional resources

- [Section 37.4.2, “Supported nftables script formats”](#)

37.5. DISPLAYING NFTABLES RULE SETS

Rule sets of **nftables** contain tables, chains, and rules. This section explains how to display these rule sets.

Procedure

1. To display all rule sets, enter:

```
# nft list ruleset
table inet example_table {
  chain example_chain {
    type filter hook input priority 0; policy accept;
```

```

    tcp dport http accept
    tcp dport ssh accept
  }
}

```



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.

37.6. 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

- For further details about address families, see the **Address families** section in the **nft(8)** man page.
- For details on other actions you can run on tables, see the **Tables** section in the **nft(8)** man page.

37.7. CREATING AN NFTABLES CHAIN

Chains are containers for rules. The following two rule types exists:

- **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.

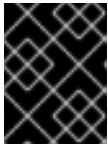
Prerequisites

- 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, you must escape the semicolons with a backslash.

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 0; policy accept;
  }
}
```

Additional resources

- For further details about address families, see the **Address families** section in the **nft(8)** man page.
- For details on other actions you can run on chains, see the **Chains** section in the **nft(8)** man page.

37.8. ADDING A RULE TO AN NFTABLES CHAIN

This section explains how to add a rule to an existing **nftables** chain. By default, the **nftables add rule** command appends a new rule to the end of the chain.

If you instead want to insert a rule at the beginning of chain, see [Section 37.9, “Inserting a rule into an 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 0; policy accept;
    ...
    tcp dport ssh accept
  }
}
```

Additional resources

- For further details about address families, see the **Address families** section in the **nft(8)** man page.
- For details on other actions you can run on rules, see the **Rules** section in the **nft(8)** man page.

37.9. INSERTING A RULE INTO AN NFTABLES CHAIN

This section explains how to insert a rule at the beginning of an existing **nftables** chain using the **nftables insert rule** command. If you instead want to add a rule to the end of a chain, see [Section 37.8, “Adding a rule to an 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 add 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 0; policy accept;
    tcp dport ssh accept
    ...
  }
}
```

Additional resources

- For further details about address families, see the **Address families** section in the **nft(8)** man page.
- For details on other actions you can run on rules, see the **Rules** section in the **nft(8)** man page.

37.10. CONFIGURING NAT USING NFTABLES

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

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

37.10.1. The different NAT types: masquerading, source NAT, and destination NAT

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 providers do not route reserved IP ranges, such as **10.0.0.0/8**. If you use reserved 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 route incoming traffic to a different host. For example, if your web server uses an IP address from a reserved 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.

37.10.2. 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
```

37.10.3. 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**:

```
# nft add rule nat postrouting oifname "ens3" snat to 192.0.2.1
```

Additional resources

- [Section 37.13.2, “Forwarding incoming packets on a specific local port to a different host”](#)

37.10.4. 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:

```
# 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 **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:

```
# nft add rule nat prerouting iifname 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

- [Section 37.10.1, “The different NAT types: masquerading, source NAT, and destination NAT”](#)

37.11. 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.

37.11.1. Using an 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 [Section 37.11.2, “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 0; policy accept;
    tcp dport { ssh, http, https } accept
  }
}
```

37.11.2. 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

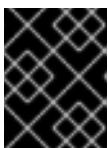
1. Create an empty set. The following examples create a set for IPv4 addresses:

- 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.

37.11.3. Related information

- For further details about sets, see the **Sets** section in the **nft(8)** man page.

37.12. 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.

37.12.1. Using literal maps in nftables

A literal 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 a literal map is that if you want to change the map, you must replace the rule. For a dynamic solution, use named verdict maps as described in [Section 37.12.2, “Using mutable verdict maps in nftables”](#).

The example describes how to use a literal 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 a literal map to **incoming_traffic**:

```
# nft add rule inet example_table incoming_traffic ip protocol vmap { tcp : jump tcp_packets,
udp : jump udp_packets }
```

The literal 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 0; 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.

37.12.2. Using mutable verdict maps in nftables

The **nftables** framework supports mutable verdict maps. You can use these maps in multiple rules within a table. Another benefit over literal maps is that you can update a mutable map without replacing the rules that use it.

When you create a mutable verdict map, you must specify the type of elements

- **ipv4_addr** for a map whose match part contains an IPv4 address, such as **192.0.2.1**.
- **ipv6_addr** for a map whose match part contains an IPv6 address, such as **2001:db8:1::1**.
- **ether_addr** for a map whose match part contains a media access control (MAC) address, such as **52:54:00:6b:66:42**.
- **inet_proto** for a map whose match part contains an internet protocol type, such as **tcp**.
- **inet_service** for a map whose match part contains an internet services name port number, such as **ssh** or **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 **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 mutable verdict 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 **example_table** that processes IPv4 packets:

```
# nft add table ip example_table
```

2. Create a chain. For example, to create a chain named **example_chain** in **example_table**:

```
# nft add chain ip example_table example_chain { type filter hook input priority 0 ; }
```



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:

```
# 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**:

```
# nft add rule example_table example_chain ip saddr vmap @example_map
```

5. Add IPv4 addresses and corresponding actions to **example_map**:

```
# 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:

```
# nft add element ip example_table example_map { 192.0.2.3 : accept }
```

7. Optionally, remove an entry from the map:

```
# nft delete element ip example_table example_map { 192.0.2.1 }
```

8. Optionally, display the rule set:

```
# 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 0; policy accept;
        ip saddr vmap @example_map
    }
}

```

37.12.3. Related information

- For further details about verdict maps, see the **Maps** section in the **nft(8)** man page.

37.13. 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.

37.13.1. 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.

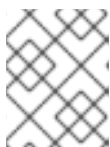
Procedure

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
```

37.13.2. 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.

Prerequisite

- 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:

```
# 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**:

```
# 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:

```
# nft add rule ip daddr 192.0.2.1 masquerade
```

5. Enable packet forwarding:

```
# echo "net.ipv4.ip_forward=1" > /etc/sysctl.d/95-IPv4-forwarding.conf
# sysctl -p /etc/sysctl.d/95-IPv4-forwarding.conf
```

37.14. 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. 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:

```
# nft add rule ip example_table example_chain tcp dport ssh meter example_meter { ip saddr
ct count over 2 } counter reject
```

2. Optionally, display the meter created in the previous step:

```
# nft list meter ip example_table example_meter
table ip example_table {
  meter example_meter {
    type ipv4_addr
    size 65535
    elements = { 192.0.2.1 : ct count over 2 , 192.0.2.2 : ct count over 2 }
  }
}
```

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.

37.15. BLOCKING IP ADDRESSES THAT ATTEMPT MORE THAN TEN NEW INCOMING TCP CONNECTIONS WITHIN ONE MINUTE

The **nftables** framework enables administrators to dynamically update sets. This section explains how you use this feature to temporarily block hosts that are establishing more than ten IPv4 TCP connections within one minute. After five minutes, **nftables** automatically removes the IP address from the blacklist.

Procedure

1. Create the **filter** table with the **ip** address family:

```
# nft add table ip filter
```

2. Add the **input** chain to the **filter** table:

```
# nft add chain ip filter input { type filter hook input priority 0 \; }
```

3. Add a set named **blacklist** to the **filter** table:

```
# nft add set ip filter blacklist { type ipv4_addr \; flags dynamic, timeout \; timeout 5m \; }
```

This command creates a dynamic set for IPv4 addresses. The **timeout 5m** parameter defines that **nftables** automatically removes entries after 5 minutes from the set.

4. Add a rule that automatically adds the source IP address of hosts that attempt to establish more than ten new TCP connections within one minute to the **blacklist** set:

```
# nft add rule ip filter input ip protocol tcp ct state new, untracked limit rate over 10/minute
add @blacklist { ip saddr }
```

5. Add a rule that drops all connections from IP addresses in the **blacklist** set:

```
# nft add rule ip filter input ip saddr @blacklist drop
```

Additional resources

- [Section 37.11.2, “Using named sets in nftables”](#)

37.16. DEBUGGING NFTABLES RULES

The **nftables** framework provides different options for administrators to debug rules and if packets match them. This section describes these options.

37.16.1. 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 a procedure that adds a counter to an existing rule, see [Section 37.16.2, “Adding a counter to an existing rule”](#).

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 0; policy accept;
    tcp dport ssh counter packets 6872 bytes 105448565 accept
  }
}
```

37.16.2. 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 a procedure to add a new rule with a counter, see [Section 37.16.1, “Creating a rule with a counter”](#).

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 {
  chain example_chain { # handle 1
    type filter hook input priority 0; policy accept;
    tcp dport ssh accept # handle 4
  }
}
```

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:

```
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 counter accept
```

3. To display the counter values:

```
# nft list ruleset
table inet example_table {
  chain example_chain {
    type filter hook input priority 0; policy accept;
    tcp dport ssh counter packets 6872 bytes 105448565 accept
  }
}
```

37.16.3. 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:

```
# nft --handle list chain inet example_table example_chain
table inet example_table {
  chain example_chain { # handle 1
    type filter hook input priority 0; policy accept;
    tcp dport ssh accept # handle 4
  }
}
```

2. Add the tracing feature by replacing the rule but with the **meta nfttrace set 1** parameters. The following example replaces the rule displayed in the previous step and enables tracing:

```
# nft replace rule inet example_table example_chain handle 4 tcp dport 22 meta nfttrace 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**:

```
# nft monitor | grep "inet example_table example_chain"
trace id 3c5eb15e inet example_table example_chain packet: iif "enp1s0" ether saddr
52:54:00:17:ff:e4 ether daddr 52:54:00:72:2f:6e ip saddr 192.0.2.1 ip daddr 192.0.2.2 ip dscp
cs0 ip ecn not-ect ip ttl 64 ip id 49710 ip protocol tcp ip length 60 tcp sport 56728 tcp dport
ssh tcp flags == syn tcp window 64240
trace id 3c5eb15e inet example_table example_chain rule tcp dport ssh nfttrace set 1 accept
(verdict accept)
...
```



WARNING

Depending on the number of rules with tracing enabled and the amount of matching traffic, the **nft monitor** command can display a lot of output. Use **grep** or other utilities to filter the output.

37.17. BACKING UP AND RESTORING NFTABLES RULE SETS

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.

37.17.1. Backing up nftables rule sets to a file

This section describes how to back up **nftables** rule sets to a file.

Procedure

1. To backup **nftables** rules:

- In **nft list ruleset** format:

```
# nft list ruleset > file.nft
```

- In JSON format:

```
# nft -j list ruleset > file.json
```

37.17.2. Restoring nftables rule sets from a file

This section describes how to restore **nftables** rule sets.

Procedure

1. To restore **nftables** rules:

- If the file to restore is in **nft list ruleset** format or contains **nft** commands:

```
# nft -f file.nft
```

- If the file to restore is in JSON format:

```
# nft -j -f file.json
```

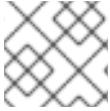
37.18. RELATED INFORMATION

- The [Using nftables in Red Hat Enterprise Linux 8](#) blog post provides an overview about using **nftables** features.
- The [What comes after iptables? Its successor, of course: nftables](#) article explains why **nftables** replaces **iptables**.
- The [Firewalld: The Future is nftables](#) article provides additional information on **nftables** as a default back end for **firewalld**.

CHAPTER 38. GETTING STARTED WITH DPDK

The Data Plane Development Kit (DPDK) provides libraries and network drivers to accelerate package processing in user space.

Administrators use DPDK, for example, in virtual machines to use Single Root I/O Virtualization (SR-IOV) to reduce latencies and increase I/O throughput.



NOTE

Red Hat does not support experimental DPDK APIs.

38.1. INSTALLING THE DPDK PACKAGE

This section describes how to install the **dpdk** package.

Prerequisites

- Red Hat Enterprise Linux is installed.
- A valid subscription is assigned to the host.

Procedure

1. Use the **yum** utility to install the **dpdk** package:

```
# yum install dpdk
```

38.2. RELATED INFORMATION

- For a list of network adapters that support SR-IOV on Red Hat Enterprise Linux 8, see [Network Adapter Fast Datapath Feature Support Matrix](#).

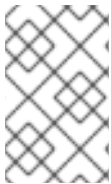
CHAPTER 39. NETWORK TRACING USING THE BPF COMPILER COLLECTION

This section explains what the BPF Compiler Collection (BCC) is, how you install the BCC, as well as how to perform different network tracing operations using the pre-created scripts provided by the **bcc-tools** package. All of these scripts support the **--ebpf** parameter to display the eBPF code the utility uploads to the kernel. You can use the code to learn more about writing eBPF scripts.

39.1. A BRIEF INTRODUCTION TO BCC

BPF Compiler Collection (BCC) is a library, which facilitates the creation of the extended Berkeley Packet Filter (eBPF) programs. The main utility of eBPF programs is analyzing OS performance and network performance without experiencing overhead or security issues.

BCC removes the need for users to know deep technical details of eBPF, and provides many out-of-the-box starting points, such as the **bcc-tools** package with pre-created eBPF programs.



NOTE

The eBPF programs are triggered on events, such as disk I/O, TCP connections, and process creations. It is unlikely that the programs should cause the kernel to crash, loop or become unresponsive because they run in a safe virtual machine in the kernel.

Additional resources

- For more information about BCC, see the `/usr/share/doc/bcc/README.md` file.

39.2. INSTALLING THE BCC-TOOLS PACKAGE

This section describes how to install the **bcc-tools** package, which also installs the BPF Compiler Collection (BCC) library as a dependency.

Prerequisites

- An active [Red Hat Enterprise Linux subscription](#)
- An [enabled repository](#) containing the **bcc-tools** package
- Introduction to **yum** [package manager](#)
- [Updated kernel](#)

Procedure

1. Install **bcc-tools**:

```
# yum install bcc-tools
```

Once installed, the tools are placed in the `/usr/share/bcc/tools/` directory.

2. Optionally, inspect the tools:

```
# ll /usr/share/bcc/tools/
```

```

...
-rwxr-xr-x. 1 root root 4198 Dec 14 17:53 dcsnoop
-rwxr-xr-x. 1 root root 3931 Dec 14 17:53 dcstat
-rwxr-xr-x. 1 root root 20040 Dec 14 17:53 deadlock_detector
-rw-r--r--. 1 root root 7105 Dec 14 17:53 deadlock_detector.c
drwxr-xr-x. 3 root root 8192 Mar 11 10:28 doc
-rwxr-xr-x. 1 root root 7588 Dec 14 17:53 execsnoop
-rwxr-xr-x. 1 root root 6373 Dec 14 17:53 ext4dist
-rwxr-xr-x. 1 root root 10401 Dec 14 17:53 ext4slower
...

```

The **doc** directory in the listing above contains documentation for each tool.

39.3. DISPLAYING TCP CONNECTIONS ADDED TO THE KERNEL'S ACCEPT QUEUE

After the kernel receives the **ACK** packet in a TCP 3-way handshake, the kernel moves the connection from the **SYN** queue to the **accept** queue after the connection's state changes to **ESTABLISHED**. Therefore, only successful TCP connections are visible in this queue.

The **tcpaccept** utility uses eBPF features to display all connections the kernel adds to the **accept** queue. The utility is lightweight because it traces the **accept()** function of the kernel instead of capturing packets and filtering them. For example, use **tcpaccept** for general troubleshooting to display new connections the server has accepted.

Procedure

1. Enter the following command to start the tracing the kernel **accept** queue:

```

# /usr/share/bcc/tools/tcpaccept
PID  COMM   IP RADDR   RPORT LADDR  LPORT
843  sshd    4 192.0.2.17 50598 192.0.2.1 22
1107 ns-slapd 4 198.51.100.6 38772 192.0.2.1 389
1107 ns-slapd 4 203.0.113.85 38774 192.0.2.1 389
...

```

Each time the kernel accepts a connection, **tcpaccept** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpaccept(8)** man page.
- For further details about **tcpaccept** and examples, see the **/usr/share/bcc/tools/doc/tcpaccept_example.txt** file.
- To display the eBPF script **tcpaccept8** uploads to the kernel, use the **/usr/share/bcc/tools/tcpaccept --ebpf** command.

39.4. TRACING OUTGOING TCP CONNECTION ATTEMPTS

The **tcpconnect** utility uses eBPF features to trace outgoing TCP connection attempts. The output of the utility also includes connections that failed.

The **tcpconnect** utility is lightweight because it traces, for example, the `connect()` function of the kernel instead of capturing packets and filtering them.

Procedure

1. Enter the following command to start the tracing process that displays all outgoing connections:

```
# /usr/share/bcc/tools/tcpconnect
PID  COMM      IP SADDR  DADDR      DPORT
31346 curl      4 192.0.2.1 198.51.100.16 80
31348 telnet   4 192.0.2.1 203.0.113.231 23
31361 isc-worker00 4 192.0.2.1 192.0.2.254 53
...
```

Each time the kernel processes an outgoing connection, **tcpconnect** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpconnect(8)** man page.
- For further details about **tcpconnect** and examples, see the `/usr/share/bcc/tools/doc/tcpconnect_example.txt` file.
- To display the eBPF script **tcpconnect(8)** uploads to the kernel, use the `/usr/share/bcc/tools/tcpconnect --ebpf` command.

39.5. MEASURING THE LATENCY OF OUTGOING TCP CONNECTIONS

The TCP connection latency is the time taken to establish a connection. This typically involves the kernel TCP/IP processing and network round trip time, and not the application runtime.

The **tcpconnl** utility uses eBPF features to measure the time between a sent **SYN** packet and the received response packet.

Procedure

1. Start measuring the latency of outgoing connections:

```
# /usr/share/bcc/tools/tcpconnl
PID  COMM      IP SADDR  DADDR      DPORT  LAT(ms)
32151 isc-worker00 4 192.0.2.1 192.0.2.254 53 0.60
32155 ssh      4 192.0.2.1 203.0.113.190 22 26.34
32319 curl     4 192.0.2.1 198.51.100.59 443 188.96
...
```

Each time the kernel processes an outgoing connection, **tcpconnl** displays the details of the connection after the kernel receives the response packet.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpconnl**(8) man page.
- For further details about **tcpconnl** and examples, see the `/usr/share/bcc/tools/doc/tcpconnl_example.txt` file.
- To display the eBPF script **tcpconnl**(8) uploads to the kernel, use the `/usr/share/bcc/tools/tcpconnl --ebpf` command.

39.6. DISPLAYING DETAILS ABOUT TCP PACKETS AND SEGMENTS THAT WERE DROPPED BY THE KERNEL

The **tcpdrop** utility enables administrators to display details about TCP packets and segments that were dropped by the kernel. Use this utility to debug high rates of dropped packets that can cause the remote system to send timer-based retransmits. High rates of dropped packets and segments can impact the performance of a server.

Instead of capturing and filtering packets, which is resource-intensive, the **tcpdrop** utility uses eBPF features to retrieve the information directly from the kernel.

Procedure

1. Enter the following command to start displaying details about dropped TCP packets and segments:

```
# /usr/share/bcc/tools/tcpdrop
TIME  PID  IP SADDR:SPORT  > DADDR:DPORT  STATE (FLAGS)
13:28:39 32253 4 192.0.2.85:51616 > 192.0.2.1:22 CLOSE_WAIT (FIN|ACK)
b'tcp_drop+0x1'
b'tcp_data_queue+0x2b9'
...

13:28:39 1    4 192.0.2.85:51616 > 192.0.2.1:22 CLOSE (ACK)
b'tcp_drop+0x1'
b'tcp_rcv_state_process+0xe2'
...
```

Each time the kernel drops TCP packets and segments, **tcpdrop** displays the details of the connection, including the kernel stack trace that led to the dropped package.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpdrop**(8) man page.
- For further details about **tcpdrop** and examples, see the `/usr/share/bcc/tools/doc/tcpdrop_example.txt` file.
- To display the eBPF script **tcpdrop**(8) uploads to the kernel, use the `/usr/share/bcc/tools/tcpdrop --ebpf` command.

39.7. TRACING TCP SESSIONS

The **tcplife** utility uses eBPF to trace TCP sessions that open and close, and prints a line of output to summarize each one. Administrators can use **tcplife** to identify connections and the amount of transferred traffic.

The example in this section describes how to display connections to port **22** (SSH) to retrieve the following information:

- The local process ID (PID)
- The local process name
- The local IP address and port number
- The remote IP address and port number
- The amount of received and transmitted traffic in KB.
- The time in milliseconds the connection was active

Procedure

1. Enter the following command to start the tracing of connections to the local port **22**:

```
/usr/share/bcc/tools/tcplife -L 22
PID COMM  LADDR  LPORT RADDR  RPORT TX_KB RX_KB  MS
19392 sshd  192.0.2.1 22 192.0.2.17 43892 53 52 6681.95
19431 sshd  192.0.2.1 22 192.0.2.245 43902 81 249381 7585.09
19487 sshd  192.0.2.1 22 192.0.2.121 43970 6998 7 16740.35
...
```

Each time a connection is closed, **tcplife** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcplife(8)** man page.
- For further details about **tcplife** and examples, see the `/usr/share/bcc/tools/doc/tcplife_example.txt` file.
- To display the eBPF script **tcplife(8)** uploads to the kernel, use the `/usr/share/bcc/tools/tcplife --ebpf` command.

39.8. TRACING TCP RETRANSMISSIONS

The **tcpretrans** utility displays details about TCP retransmissions, such as the local and remote IP address and port number, as well as the TCP state at the time of the retransmissions.

The utility uses eBPF features and, therefore, has a very low overhead.

Procedure

1. Use the following command to start displaying TCP retransmission details:

```
# /usr/share/bcc/tools/tcpretrans
TIME   PID IP LADDR:LPORT  T> RADDR:RPORT    STATE
00:23:02 0   4 192.0.2.1:22  R> 198.51.100.0:26788 ESTABLISHED
00:23:02 0   4 192.0.2.1:22  R> 198.51.100.0:26788 ESTABLISHED
00:45:43 0   4 192.0.2.1:22  R> 198.51.100.0:17634 ESTABLISHED
...
```

Each time the kernel calls the TCP retransmit function, **tcpretrans** displays the details of the connection.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpretrans(8)** man page.
- For further details about **tcpretrans** and examples, see the **/usr/share/bcc/tools/doc/tcpretrans_example.txt** file.
- To display the eBPF script **tcpretrans(8)** uploads to the kernel, use the **/usr/share/bcc/tools/tcpretrans --ebpf** command.

39.9. DISPLAYING TCP STATE CHANGE INFORMATION

During a TCP session, the TCP state changes. The **tcpstates** utility uses eBPF functions to trace these state changes, and prints details including the duration in each state. For example, use **tcpstates** to identify if connections spend too much time in the initialization state.

Procedure

1. Use the following command to start to start tracing TCP state changes:

```
# /usr/share/bcc/tools/tcpstates
SKADDR      C-PID C-COMM  LADDR  LPORT RADDR  RPORT OLDSTATE  ->
NEWSTATE  MS
ffff9cd377b3af80 0   swapper/1 0.0.0.0 22   0.0.0.0 0   LISTEN    -> SYN_RECV
0.000
ffff9cd377b3af80 0   swapper/1 192.0.2.1 22   192.0.2.45 53152 SYN_RECV  ->
ESTABLISHED 0.067
ffff9cd377b3af80 818  sssd_nss 192.0.2.1 22   192.0.2.45 53152 ESTABLISHED ->
CLOSE_WAIT 65636.773
ffff9cd377b3af80 1432 sshd     192.0.2.1 22   192.0.2.45 53152 CLOSE_WAIT ->
LAST_ACK 24.409
ffff9cd377b3af80 1267 pulseaudio 192.0.2.1 22   192.0.2.45 53152 LAST_ACK  ->
CLOSE 0.376
...
```

Each time a connection changes its state, **tcpstates** displays a new line with updated connection details.

If multiple connections change their state at the same time, use the socket address in the first column (**SKADDR**) to determine which entries belong to the same connection.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpstates(8)** man page.
- For further details about **tcpstates** and examples, see the **/usr/share/bcc/tools/doc/tcpstates_example.txt** file.
- To display the eBPF script **tcpstates(8)** uploads to the kernel, use the **/usr/share/bcc/tools/tcpstates --ebpf** command.

39.10. SUMMARIZING AND AGGREGATING TCP TRAFFIC SENT TO SPECIFIC SUBNETS

The **tcpsubnet** utility summarizes and aggregates IPv4 TCP traffic that the local host sends to subnets and displays the output on a fixed interval. The utility uses eBPF features to collect and summarize the data to reduce the overhead.

By default, **tcpsubnet** summarizes traffic for the following subnets:

- **127.0.0.1/32**
- **10.0.0.0/8**
- **172.16.0.0/12**
- **192.0.2.0/24/16**
- **0.0.0.0/0**

Note that the last subnet (**0.0.0.0/0**) is a catch-all option. The **tcpsubnet** utility counts all traffic for subnets different than the first four in this catch-all entry.

Follow the procedure to count the traffic for the **192.0.2.0/24** and **198.51.100.0/24** subnets. Traffic to other subnets will be tracked in the **0.0.0.0/0** catch-all subnet entry.

Procedure

1. Start monitoring the amount of traffic sent to the **192.0.2.0/24**, **198.51.100.0/24**, and other subnets:

```
# /usr/share/bcc/tools/tcpsubnet 192.0.2.0/24,198.51.100.0/24,0.0.0.0/0
Tracing... Output every 1 secs. Hit Ctrl-C to end
[02/21/20 10:04:50]
192.0.2.0/24      856
198.51.100.0/24  7467
[02/21/20 10:04:51]
192.0.2.0/24      1200
198.51.100.0/24  8763
0.0.0.0/0         673
...
```

This command displays the traffic in bytes for the specified subnets once per second.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcpsubnet(8)** man page.
- For further details about **tcpsubnet** and examples, see the `/usr/share/bcc/tools/doc/tcpsubnet.txt` file.
- To display the eBPF script **tcpsubnet(8)** uploads to the kernel, use the `/usr/share/bcc/tools/tcpsubnet --ebpf` command.

39.11. DISPLAYING THE NETWORK THROUGHPUT BY IP ADDRESS AND PORT

The **tcptop** utility displays TCP traffic the host sends and receives in kilobytes. The report automatically refreshes and contains only active TCP connections. The utility uses eBPF features and, therefore, has only a very low overhead.

Procedure

1. To monitor the sent and received traffic, enter:

```
# /usr/share/bcc/tools/tcptop
13:46:29 loadavg: 0.10 0.03 0.01 1/215 3875

PID  COMM      LADDR      RADDR      RX_KB  TX_KB
3853  3853      192.0.2.1:22 192.0.2.165:41838 32    102626
1285  sshd      192.0.2.1:22 192.0.2.45:39240 0      0
...
```

The output of the command includes only active TCP connections. If the local or remote system closes a connection, the connection is no longer visible in the output.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcptop(8)** man page.
- For further details about **tcptop** and examples, see the `/usr/share/bcc/tools/doc/tcptop.txt` file.
- To display the eBPF script **tcptop(8)** uploads to the kernel, use the `/usr/share/bcc/tools/tcptop --ebpf` command.

39.12. TRACING ESTABLISHED TCP CONNECTIONS

The **tcptracer** utility traces the kernel functions that connect, accept, and close TCP connections. The utility uses eBPF features and, therefore, has a very low overhead.

Procedure

1. Use the following command to start the tracing process:

```
# /usr/share/bcc/tools/tcptracer
```

```
Tracing TCP established connections. Ctrl-C to end.
T PID  COMM   IP SADDR  DADDR  SPORT DPORT
A 1088 ns-slapd 4 192.0.2.153 192.0.2.1 0 65535
A 845  sshd   4 192.0.2.1 192.0.2.67 22 42302
X 4502 sshd   4 192.0.2.1 192.0.2.67 22 42302
...
```

Each time the kernel connects, accepts, or closes a connection, **tcptracer** displays the details of the connections.

2. Press **Ctrl+C** to stop the tracing process.

Additional resources

- For further details, see the **tcptracer(8)** man page.
- For further details about **tcptracer** and examples, see the **/usr/share/bcc/tools/doc/tcptracer_example.txt** file.
- To display the eBPF script **tcptracer(8)** uploads to the kernel, use the **/usr/share/bcc/tools/tcptracer --ebpf** command.

39.13. ADDITIONAL RESOURCES

- For further information about BCC, see the **/usr/share/doc/bcc/README.md** file.