# IP Addresses and Services Configuration Guide for Cisco NCS 5500 Series Routers, IOS XR Release 6.0.x

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# Preface

This preface contains these sections:


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## Communications, Services, and Additional Information

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CHAPTER 1

# Implementing Network Stack IPv4 and IPv6


- Implementing Network Stack IPv4 and IPv6, on page 1
- Network Stack IPv4 and IPv6 Exceptions, on page 1
- IPv4 and IPv6 Functionality, on page 2
- IPv6 for Cisco IOS XR Software, on page 2
- How to Implement Network Stack IPv4 and IPv6, on page 2


## Implementing Network Stack IPv4 and IPv6

The Network Stack IPv4 and IPv6 features are used to configure and monitor Internet Protocol Version 4 (IPv4) and Internet Protocol Version 6 (IPv6).

**Restrictions**

In any Cisco IOS XR software release with IPv6 support, multiple IPv6 global addresses can be configured on an interface. However, multiple IPv6 link-local addresses on an interface are not supported.

## Network Stack IPv4 and IPv6 Exceptions

The Network Stack feature in the Cisco IOS XR software has the following exceptions:

- In Cisco IOS XR software, the **clear ipv6 neighbors** and **show ipv6 neighbors** commands include the **location** *node-id* keyword. If a location is specified, only the neighbor entries in the specified location are displayed.
- The **ipv6 nd scavenge-timeout** command sets the lifetime for neighbor entries in the stale state. When the scavenge-timer for a neighbor entry expires, the entry is cleared.
- In Cisco IOS XR software, the **show ipv4 interface** and **show ipv6 interface** commands include the **location** *node-id* keyword. If a location is specified, only the interface entries in the specified location are displayed.
- Cisco IOS XR software allows conflicting IP address entries at the time of configuration. If an IP address conflict exists between two interfaces that are active, Cisco IOS XR software brings down the interface according to the configured conflict policy, the default policy being to bring down the higher interface instance.

For example, if HundredGigE 0/0/0/1 conflicts with HundredGigE 0/0/0/2, then the IPv4 protocol on HundredGigE 0/0/0/2, is brought down and IPv4 remains active on HundredGigE 0/0/0/1.

# IPv4 and IPv6 Functionality

When Cisco IOS XR software is configured with both an IPv4 and an IPv6 address, the interface can send and receive data on both IPv4 and IPv6 networks.

The architecture of IPv6 has been designed to allow existing IPv4 users to make the transition easily to IPv6 while providing services such as end-to-end security, quality of service (QoS), and globally unique addresses. The larger IPv6 address space allows networks to scale and provide global reachability. The simplified IPv6 packet header format handles packets more efficiently. IPv6 prefix aggregation, simplified network renumbering, and IPv6 site multihoming capabilities provide an IPv6 addressing hierarchy that allows for more efficient routing. IPv6 supports widely deployed routing protocols such as Open Shortest Path First (OSPF), and multiprotocol Border Gateway Protocol (BGP).

The IPv6 neighbor discovery (nd) process uses Internet Control Message Protocol (ICMP) messages and solicited-node multicast addresses to determine the link-layer address of a neighbor on the same network (local link), verify the reachability of a neighbor, and keep track of neighboring routers.

# IPv6 for Cisco IOS XR Software

IPv6, formerly named IPng (next generation) is the latest version of the Internet Protocol (IP). IP is a packet-based protocol used to exchange data, voice, and video traffic over digital networks. IPv6 was proposed when it became clear that the 32-bit addressing scheme of IP version 4 (IPv4) was inadequate to meet the demands of Internet growth. After extensive discussion, it was decided to base IPng on IP but add a much larger address space and improvements such as a simplified main header and extension headers. IPv6 is described initially in RFC 2460, I*nternet Protocol, Version 6 (IPv6) Specification* issued by the Internet Engineering Task Force (IETF). Further RFCs describe the architecture and services supported by IPv6.

# How to Implement Network Stack IPv4 and IPv6

This section contains the following procedures:

## Configuring IPv4 Addressing

A basic and required task for configuring IP is to assign IPv4 addresses to network interfaces. Doing so enables the interfaces and allows communication with hosts on those interfaces using IPv4. An IP address identifies a location to which IP datagrams can be sent. An interface can have one primary IP address and multiple secondary addresses. Packets generated by the software always use the primary IPv4 address. Therefore, all networking devices on a segment should share the same primary network number.

Associated with this task are decisions about subnetting and masking the IP addresses. A mask identifies the bits that denote the network number in an IP address. When you use the mask to subnet a network, the mask is then referred to as a *subnet mask*.

**Note** Cisco supports only network masks that use contiguous bits that are flush left against the network field.

### Configuration Example

An IPv4 address of 192.168.1.27 and a network mask of "/8" is assigned to the **interface HundredGigE 0/0/0/1**.

**Note** The network mask can be a four-part dotted decimal address. For example, 255.0.0.0 indicates that each bit equal to 1 means the corresponding address bit belongs to the network address. The network mask can be indicated as a slash (/) and a number- a prefix length. The prefix length is a decimal value that indicates how many of the high-order contiguous bits of the address comprise the prefix (the network portion of the address). A slash must precede the decimal value, and there is no space between the IP address and the slash.

```
Router#configure HundredGigE0/0/0/1
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv4 address 192.168.1.27/8
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 192.168.1.27 255.0.0.0
!
```

### Verification

Verify that the HundredGigE interface is active and IPv4 is enabled.

```
Router# show ipv4 interface HundredGigE0/0/0/1

interface HundredGigE0/0/0/1 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is 192.168.1.27/8
  MTU is 1514 (1500 is available to IP)
  Helper address is not set
  Multicast reserved groups joined: 224.0.0.2 224.0.0.1
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  access list is not set
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000
```

### Associated Commands

- ipv4 address
- show ipv4 interface

# Configuring IPv6 Addressing

IPv6 addresses are configured to individual router interfaces in order to enable the forwarding of IPv6 traffic globally on the router. By default, IPv6 addresses are not configured.

**Note** The *ipv6-prefix* argument in the **ipv6 address** command must be in the form documented in RFC 2373 in which the address is specified in hexadecimal using 16-bit values between colons.

The **/prefix-length** argument in the **ipv6 address** command is a decimal value that indicates how many of the high-order contiguous bits of the address comprise the prefix (the network portion of the address) A slash must precede the decimal value.

The *ipv6-address* argument in the **ipv6 address link-local** command must be in the form documented in RFC 2373 where the address is specified in hexadecimal using 16-bit values between colons.

## IPv6 Multicast Groups

An IPv6 address must be configured on an interface for the interface to forward IPv6 traffic. Configuring a global IPv6 address on an interface automatically configures a link-local address and activates IPv6 for that interface.

Additionally, the configured interface automatically joins the following required multicast groups for that link:

- Solicited-node multicast group FF02:0:0:0:0:1:FF00::/104 for each unicast address assigned to the interface
- All-nodes link-local multicast group FF02::1
- All-routers link-local multicast group FF02::2

**Note** The solicited-node multicast address is used in the neighbor discovery process.

### Configuration Example

An IPv6 address of 2001:0DB8:0:1::1/64 is assigned to the `interface HundredGigE 0/0/0/1`:

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv6 address 2001:0DB8:0:1::1/64
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 192.168.1.27 255.0.0.0
 ipv4 address 1.0.0.1 255.255.255.0 secondary
 ipv4 address 2.0.0.1 255.255.255.0 secondary
 ipv6 address 2001:db8:0:1::1/64
!
```

### Verification

Verify that the HundredGigE interface is active and IPv6 is enabled.

```
Router#show ipv6 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv6 protocol is Up, Vrfid is default (0x60000000)
  IPv6 is enabled, link-local address is fe80::c672:95ff:fea6:1c75
  Global unicast address(es):
    2001:db8:0:1::1, subnet is 2001:db8:0:1::/64
  Joined group address(es): ff02::1:ff00:1 ff02::1:ffa6:1c75 ff02::2
      ff02::1
  MTU is 1514 (1500 is available to IPv6)
  ICMP redirects are disabled
  ICMP unreachables are enabled
  ND DAD is enabled, number of DAD attempts 1
  ND reachable time is 0 milliseconds
  ND cache entry limit is 1000000000
  ND advertised retransmit interval is 0 milliseconds
  Hosts use stateless autoconfig for addresses.
  Outgoing access list is not set
  Inbound  access list is not set
  Table Id is 0xe0800000
  Complete protocol adjacency: 0
  Complete glean adjacency: 0
  Incomplete protocol adjacency: 0
  Incomplete glean adjacency: 0
  Dropped protocol request: 0
  Dropped glean request: 0
```

### Associated Commands

- ipv6 address
- interface
- show ipv6 interface

### Configuration Example

An IPv6 address of 2001:0DB8:0:1::/64 is assigned to the **interface HundredGigE 0/0/0/1**. The **eui-64** keyword configures site-local and global IPv6 addresses with an interface identifier (ID) in the low-order 64 bits of the IPv6 address. Only the 64-bit network prefix for the address needs to be specified; the last 64 bits are automatically computed from the interface ID.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv6 address 2001:0DB8:0:1::/64 eui-64
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 192.168.1.27 255.0.0.0
 ipv4 address 1.0.0.1 255.255.255.0 secondary
 ipv4 address 2.0.0.1 255.255.255.0 secondary
 ipv6 address 2001:db8:0:1::/64 eui-64
!
```

### Verification

Verify that the HundredGigE interface is active and IPv6 is enabled.

```
Router#show ipv6 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv6 protocol is Up, Vrfid is default (0x60000000)
  IPv6 is enabled, link-local address is fe80::c672:95ff:fea6:1c75
  Global unicast address(es):
    2001:db8:0:1:c672:95ff:fea6:1c75, subnet is 2001:db8:0:1::/64
  Joined group address(es): ff02::1:ffa6:1c75 ff02::2 ff02::1
  MTU is 1514 (1500 is available to IPv6)
  ICMP redirects are disabled
  ICMP unreachables are enabled
  ND DAD is enabled, number of DAD attempts 1
  ND reachable time is 0 milliseconds
  ND cache entry limit is 1000000000
  ND advertised retransmit interval is 0 milliseconds
  Hosts use stateless autoconfig for addresses.
  Outgoing access list is not set
  Inbound  access list is not set
  Table Id is 0xe0800000
  Complete protocol adjacency: 0
  Complete glean adjacency: 0
  Incomplete protocol adjacency: 0
  Incomplete glean adjacency: 0
  Dropped protocol request: 0
  Dropped glean request: 0
```

### Associated Commands

- ipv6 address
- interface
- show ipv6 interface

### Configuration Example

An IPv6 address of FE80::260:3EFF:FE11:6770 is assigned to the **interface HundredGigE 0/0/0/1**. The link-local keyword configures a link-local address on the interface that is used instead of the link-local address that is automatically configured when IPv6 is enabled on the interface.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv6 address FE80::260:3EFF:FE11:6770 link-local
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv6 address fe80::260:3eff:fe11:6770 link-local
!
```

### Verification

Verify that the HundredGigE interface is active and IPv6 is enabled with link-local address.

```
Router#show ipv6 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv6 protocol is Up, Vrfid is default (0x60000000)
  IPv6 is enabled, link-local address is fe80::260:3eff:fe11:6770
```

```
  Global unicast address(es):
    2001:db8:0:1:260:3eff:fe11:6770, subnet is 2001:db8:0:1::/64
  Joined group address(es): ff02::1:ff11:6770 ff02::2 ff02::1
  MTU is 1514 (1500 is available to IPv6)
  ICMP redirects are disabled
  ICMP unreachables are enabled
  ND DAD is enabled, number of DAD attempts 1
  ND reachable time is 0 milliseconds
  ND cache entry limit is 1000000000
  ND advertised retransmit interval is 0 milliseconds
  Hosts use stateless autoconfig for addresses.
  Outgoing access list is not set
  Inbound  access list is not set
  Table Id is 0xe0800000
  Complete protocol adjacency: 0
  Complete glean adjacency: 0
  Incomplete protocol adjacency: 0
  Incomplete glean adjacency: 0
  Dropped protocol request: 0
  Dropped glean request: 0
```

### Associated Commands

- ipv6 address
- interface
- show ipv6 interface

### Configuration Example

Enable IPv6 processing on the **interface HundredGigE 0/0/0/1**; that has not been configured with an explicit IPv6 address.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv6 enable
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1interface HundredGigE0/0/0/1
ipv6 enable
!
```

### Verification

Verify that the HundredGigE interface is active and IPv6 is enabled.

```
Router#show ipv6 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv6 protocol is Up, Vrfid is default (0x60000000)
  IPv6 is enabled, link-local address is fe80::c672:95ff:fea6:1c75
  No global unicast address is configured
  Joined group address(es): ff02::1:ffa6:1c75 ff02::2 ff02::1
  MTU is 1514 (1500 is available to IPv6)
  ICMP redirects are disabled
  ICMP unreachables are enabled
  ND DAD is enabled, number of DAD attempts 1
  ND reachable time is 0 milliseconds
  ND cache entry limit is 1000000000
  ND advertised retransmit interval is 0 milliseconds
```

```
Hosts use stateless autoconfig for addresses.
Outgoing access list is not set
Inbound  access list is not set
Table Id is 0xe0800000
Complete protocol adjacency: 0
Complete glean adjacency: 0
Incomplete protocol adjacency: 0
Incomplete glean adjacency: 0
Dropped protocol request: 0
Dropped glean request: 0
```

### Associated Commands

- ipv6 enable
- interface
- show ipv6 interface

# Assigning Multiple IP Addresses to Network Interfaces

The Cisco IOS XR software supports multiple IP addresses (secondary addresses) per interface. You can specify an unlimited number of secondary addresses. Secondary IP addresses can be used in a variety of situations. The following are the most common applications:

- There might not be enough host addresses for a particular network segment. For example, suppose your subnetting allows up to 254 hosts per logical subnet, but on one physical subnet you must have 300 host addresses. Using secondary IP addresses on the routers or access servers allows you to have two logical subnets using one physical subnet.
- Many older networks were built using Level 2 bridges, and were not subnetted. The judicious use of secondary addresses can aid in the transition to a subnetted, router-based network. Routers on an older, bridged segment can easily be made aware that many subnets are on that segment.
- Two subnets of a single network might otherwise be separated by another network. You can create a single network from subnets that are physically separated by another network by using a secondary address. In these instances, the first network is *extended*, or layered on top of the second network. Note that a subnet cannot appear on more than one active interface of the router at a time.

**Note** If any router on a network segment uses a secondary IPv4 address, all other routers on that same segment must also use a secondary address from the same network or subnet.

**Caution** Inconsistent use of secondary addresses on a network segment can quickly cause routing loops.

### Configuration Example

A secondary IPv4 address of 192.168.1.27 is assigned to the Hundredgige interface-0/0/0/1.

Note: For IPv6, an interface can have multiple IPv6 addresses without specifying the **secondary** keyword.

```
Router# configure
Router(config)# interface HundredGigE 0/0/0/1
Router(config-if)# ipv4 address 192.168.1.27 255.255.255.0 secondary
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 192.168.1.27 255.255.255.0 secondary
!
```

### Verification

```
Router#show ipv4 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is unassigned
  Secondary address 192.168.1.27/24
  MTU is 1514 (1500 is available to IP)
  Helper address is not set
  Multicast reserved groups joined: 224.0.0.2 224.0.0.1
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  access list is not set
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000
```

### Associated Commands

- ipv4 address
- show ipv4 interface

## Configuring IPv4 and IPv6 Protocol Stacks

This task configures an interface in a Cisco networking device to support both the IPv4 and IPv6 protocol stacks.

When an interface in a Cisco networking device is configured with both an IPv4 and an IPv6 address, the interface forwards both IPv4 and IPv6 traffic—the interface can send and receive data on both IPv4 and IPv6 networks.

### Configuration Example

An IPv4 address of 192.168.99.1 and an IPv6 address of 2001:0DB8:c18:1::3/64 is configured on the **`interface HundredGigE 0/0/0/1`**.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv4 address 192.168.99.1 255.255.255.0
Router(config-if)#ipv6 address 2001:0DB8:c18:1::3/64
Router(config-if)#commit
```

### Running Configuration

```
Router# show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 192.168.99.1 255.255.255.0
 ipv6 address 2001:db8:c18:1::3/64
!
```

### Verification

Verify that the HundredGigE interface is active and IPv4 and IPv6 are enabled.

```
Router#show ipv4 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is 192.168.99.1/24
  MTU is 1514 (1500 is available to IP)
  Helper address is not set
  Multicast reserved groups joined: 224.0.0.2 224.0.0.1
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  access list is not set
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000

Router#show ipv6 interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is Up, ipv6 protocol is Up, Vrfid is default (0x60000000)
  IPv6 is enabled, link-local address is fe80::c672:95ff:fea6:1c75
  Global unicast address(es):
    2001:db8:c18:1::3, subnet is 2001:db8:c18:1::/64
  Joined group address(es): ff02::1:ff00:3 ff02::1:ffa6:1c75 ff02::2
      ff02::1
  MTU is 1514 (1500 is available to IPv6)
  ICMP redirects are disabled
  ICMP unreachables are enabled
  ND DAD is enabled, number of DAD attempts 1
  ND reachable time is 0 milliseconds
  ND cache entry limit is 1000000000
  ND advertised retransmit interval is 0 milliseconds
  Hosts use stateless autoconfig for addresses.
  Outgoing access list is not set
  Inbound  access list is not set
  Table Id is 0xe0800000
  Complete protocol adjacency: 0
  Complete glean adjacency: 0
  Incomplete protocol adjacency: 0
  Incomplete glean adjacency: 0
  Dropped protocol request: 0
  Dropped glean request: 0
```

### Associated Commands

- ipv4 address
- ipv6 address
- show ipv4 interface
- show ipv6 interface

# Enabling IPv4 Processing on an Unnumbered Interface

This section describes the process of enabling an IPv4 point-to-point interface without assigning an explicit IP address to the interface. Whenever the unnumbered interface generates a packet (for example, for a routing update), it uses the address of the interface you specified as the source address of the IP packet. It also uses the specified interface address in determining which routing processes are sending updates over the unnumbered interface. Restrictions are as follows:

- Interfaces using High-Level Data Link Control (HDLC), PPP, and Frame Relay encapsulations can be unnumbered. Serial interfaces using Frame Relay encapsulation can also be unnumbered, but the interface must be a point-to-point sub-interface.
- You cannot use the **ping** EXEC command to determine whether the interface is up, because the interface has no IP address. The Simple Network Management Protocol (SNMP) can be used to remotely monitor interface status.
- You cannot support IP security options on an unnumbered interface.

If you are configuring Intermediate System-to-Intermediate System (IS-IS) across a serial line, you should configure the serial interfaces as unnumbered, which allows you to conform with RFC 1195, which states that IP addresses are not required on each interface.

### Configuration Example

Enables an IPv4 point-to-point interface without assigning an explicit IP address to the interface.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv4 unnumbered loopback 0
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 point-to-point
 ipv4 unnumbered Loopback0
!
```

### Verification

```
Router#show interface HundredGigE0/0/0/1
HundredGigE0/0/0/1 is up, line protocol is up
  Interface state transitions: 5
  Hardware is Hundredgige, address is 00e2.2a33.445b (bia 00e2.2a33.445b)
  Layer 1 Transport Mode is LAN
  Internet address is 10.0.0.2/32
  MTU 1514 bytes, BW 10000000 Kbit (Max: 10000000 Kbit)
     reliability 255/255, txload 194/255, rxload 0/255
  Encapsulation ARPA,
  Full-duplex, 10000Mb/s, link type is force-up
  output flow control is off, input flow control is off
  Carrier delay (up) is 10 msec
  loopback not set,
  Last link flapped 01:38:49
  ARP type ARPA, ARP timeout 04:00:00
  Last input 00:00:00, output 00:00:00
  Last clearing of "show interface" counters 02:34:16
  5 minute input rate 0 bits/sec, 0 packets/sec
```

```
  5 minute output rate 7647051000 bits/sec, 12254894 packets/sec
     1061401410 packets input, 82789675614 bytes, 0 total input drops
     0 drops for unrecognized upper-level protocol
     Received 5 broadcast packets, 19429 multicast packets
              0 runts, 0 giants, 0 throttles, 0 parity
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     76895885948 packets output, 6192569128048 bytes, 0 total output drops
     Output 7 broadcast packets, 18916 multicast packets
     0 output errors, 0 underruns, 0 applique, 0 resets
     0 output buffer failures, 0 output buffers swapped out
     2 carrier transitions

Router #show run int lo 0
interface Loopback0
 ipv4 address 10.0.0.2 255.255.255.255
```

### Associated Commands

- ipv4 unnumbered
- show interfaces

# IPv4 ICMP Rate Limiting

The IPv4 ICMP rate limiting feature limits the rate that IPv4 ICMP destination unreachable messages are generated. The Cisco IOS XR software maintains two timers: one for general destination unreachable messages and one for DF destination unreachable messages. Both share the same time limits and defaults. If the DF keyword is not configured, the icmp ipv4 rate-limit unreachable command sets the time values for DF destination unreachable messages. If the DF keyword is configured, its time values remain independent from those of general destination unreachable messages.

### Configuration Example

Limits the rate that IPv4 ICMP destination unreachable messages are generated every 1000 millisecond.

The **DF** keyword, which is optional limits the rate at which ICMP destination unreachable messages are sent when code 4 fragmentation is needed and Don't Fragment (DF) is set, as specified in the IP header of the ICMP destination unreachable message.

```
Router#configure
Router(config)#icmp ipv4 rate-limit unreachable 1000
Router(config)#icmp ipv4 rate-limit unreachable DF 1000
Router(config)#commit
```

### Running Configuration

```
Router#show running-config | in icmp
Building configuration...
icmp ipv4 rate-limit unreachable DF 1000
icmp ipv4 rate-limit unreachable 1000
```

### Verification

```
Router#show ipv4 interface HundredGigE0/0/0/2
HundredGigE0/0/0/2 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is 192.85.1.1/24
  MTU is 1514 (1500 is available to IP)
```

```
  Helper address is not set
  Multicast reserved groups joined: 224.0.0.2 224.0.0.1 224.0.0.2
      224.0.0.5 224.0.0.6
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  common access list is not set, access list is not set
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000
```

The number of ICMP unreachable messages that were we sent or received can be identified using the **show ipv4 traffic** command.

```
Router# show ipv4 traffic
ICMP statistics:
  Sent: 0 admin unreachable, 5 network unreachable
        0 host unreachable, 0 protocol unreachable
        0 port unreachable, 0 fragment unreachable
        0 time to live exceeded, 0 reassembly ttl exceeded
        0 echo request, 0 echo reply
        0 mask request, 0 mask reply
        0 parameter error, 0 redirects
        5 total
  Rcvd: 0 admin unreachable, 0 network unreachable
        0 host unreachable, 0 protocol unreachable
        0 port unreachable, 0 fragment unreachable
        0 time to live exceeded, 0 reassembly ttl exceeded
        0 echo request, 0 echo reply
        0 mask request, 0 mask reply
        0 redirect, 0 parameter error
        0 source quench, 0 timestamp, 0 timestamp reply
        0 router advertisement, 0 router solicitation
        0 total, 0 checksum errors, 0 unknown
```

### Associated Commands

- icmp ipv4 rate-limit unreachable
- show ipv4 traffic

# IPv6 ICMP Rate Limiting

The IPv6 ICMP rate limiting feature implements a token bucket algorithm for limiting the rate at which IPv6 ICMP error messages are sent out on the network. The initial implementation of IPv6 ICMP rate limiting defined a fixed interval between error messages, but some applications, such as traceroute, often require replies to a group of requests sent in rapid succession. The fixed interval between error messages is not flexible enough to work with applications such as traceroute and can cause the application to fail. Implementing a token bucket scheme allows a number of tokens-representing the ability to send one error message each-to be stored in a virtual bucket. The maximum number of tokens allowed in the bucket can be specified, and for every error message to be sent, one token is removed from the bucket. If a series of error messages is generated, error messages can be sent until the bucket is empty. When the bucket is empty of tokens, IPv6 ICMP error messages are not sent until a new token is placed in the bucket. The token bucket algorithm does not increase the average rate limiting time interval, and it is more flexible than the fixed time interval scheme.

### Configuration Example

Configure the interval for 50 milliseconds and the bucket size for 20 tokens, for IPv6 ICMP error messages.

- The milliseconds argument specifies the interval between tokens being added to the bucket.
- The optional bucketsize argument defines the maximum number of tokens stored in the bucket.

```
Router#configure
Router(config)#ipv6 icmp error-interval 50 20
Router(config)#commit
```

### Running Configuration

```
Router#show running-config
Building configuration...
!! IOS XR Configuration version = 6.0.0.26I
!! Last configuration change at Mon Dec 14 22:07:35 2015 by root
!
hostname test-83
logging console debugging
username root
 group root-lr
 group cisco-support
 secret 5 $1$d2NC$RbAdqdU7kw/kEJoMP/IJG1
!
cdp
ipv6 icmp error-interval 50 20
icmp ipv4 rate-limit unreachable DF 1000
icmp ipv4 rate-limit unreachable 1000
ipv4 conflict-policy static
```

### Associated Commands

- ipv6 icmp error-interval

# Selecting Flexible Source IP

You can select flexible source IP address in the Internet Control Message Protocol (ICMP) response packet to respond to a failure.

### Configuration Example

Enables RFC compliance for source address selection.

```
Router#configure
Router(config)#icmp ipv4 source rfc
Router(config)#commit
```

### Running Configuration

```
Router#show running-config | in source rfc
Building configuration...
icmp ipv4 source rfc
```

### Associated Commands

# Configuring IPARM Conflict Resolution

This task sets the IP Address Repository Manager (IPARM) address conflict resolution parameters:

- Static Policy Resolution
- Longest Prefix Address Conflict Resolution
- Highest IP Address Conflict Resolution
- Route-Tag Support for Connected Routes

## Static Policy Resolution

The static policy resolution configuration prevents new address configurations from affecting interfaces that are currently running.

### Configuration Example

Sets the conflict policy to static, that is, prevents new interface addresses from affecting the currently running interface.

```
Router#configure
Router(config)#ipv4 conflict-policy static
*/For IPv6, use the ipv6 conflict-policy static command/*
Router(config)#commit
```

### Running Configuration

```
Router#show running-config | in ipv4 config
Building configuration...
!! IOS XR Configuration version = 6.0.0.26I
!! Last configuration change at Mon Dec 14 21:57:27 2015 by root
!
hostname sample-83
logging console debugging
username root
 group root-lr
 group test
 secret 5 $1$d2NC$RbAdqdU7kw/eKJpMo/GJI1
!
cdp
ipv4 conflict-policy static
interface Loopback0
 ipv4 address 1.1.1.1 255.255.255.255
!
…..
```

### Verification

```
Router#show arm ipv4 conflicts
F Forced down
| Down interface & addr              Up interface & addr VRF

F Te0/0/0/19 192.85.1.2/24   HundredGigE0/0/0/1  192.85.1.1/24 default

Forced down interface         Up interface                  VRF
```

### Associated Commands

- ipv4 conflict-policy
- ipv6 conflict-policy

## Longest Prefix Address Conflict Resolution

This conflict resolution policy attempts to give highest precedence to the IP address that has the longest prefix length, that is, all addresses within the conflict-set that do not conflict with the longest prefix address of the currently running interface are allowed to run as well.

### Configuration Example

Configures longest prefix address conflict resolution.

```
Router# configure
Router(config)# ipv4 conflict-policy longest-prefix
*/For IPv6, use the ipv6 conflict-policy command*/
Router(config)# commit
```

### Running Configuration

```
Router# show running-config | in longest-prefix
Building configuration...
ipv4 conflict-policy longest-prefix
```

### Verification

```
Router#show arm ipv4 conflicts
F Forced down
| Down interface & addr              Up interface & addr VRF

F Te0/0/0/19 192.85.1.2/24   HundredGigE0/0/0/1  192.85.1.1/24 default

Forced down interface         Up interface                  VRF
```

## Highest IP Address Conflict Resolution

This conflict resolution policy attempts to give highest precedence to the IP address that has the highest value, that is, the IP address with the highest value gets precedence.

### Configuration

Configures highest IP address conflict resolution.

```
Router# configure
Router(config)#ipv4 conflict-policy highest-ip
*/For IPv6, use the ipv6 conflict-policy highest-ip command/*
Router(config)#commit
```

### Running Configuration

```
Router#show running-config | in highest-ip
Building configuration...
ipv4 conflict-policy highest-ip
```

### Verification

```
Router#show arm ipv4 conflicts
F Forced down
| Down interface & addr              Up interface & addr VRF

F Te0/0/0/19 192.85.1.2/24   HundredGigE0/0/0/1  192.85.1.1/24 default

Forced down interface        Up interface                 VRF
```

## Route-Tag Support for Connected Routes

The Route-Tag Support for Connected Routes feature attaches a tag with all IPv4 and IPv6 addresses of an interface. The tag is propagated from the IPv4 and IPv6 management agents (MA) to the IPv4 and IPv6 address repository managers (ARM) to routing protocols, thus enabling the user to control the redistribution of connected routes by looking at the route tags, by using routing policy language (RPL) scripts. This prevents the redistribution of some interfaces, by checking for route tags in a route policy. The route tag feature is already available for static routes and connected routes (interfaces) wherein the route tags are matched to policies and redistribution can be prevented.

### Configuration Example

Specifies an IPv4 address 10.0.54.2/30 that has a route tag of 20 to the **interface HundredGigE 0/0/0/1**.

```
Router#configure
Router(config)#interface HundredGigE 0/0/0/1
Router(config-if)#ipv4 address 10.0.54.2/30 route-tag 1899
Router(config)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/1
interface HundredGigE0/0/0/1
 ipv4 address 10.0.54.2/30 route-tag 1899
!
```

### Verification

Verify the parameters of the route.

```
Router#show route 10.0.54.2
Routing entry for 10.0.54.2/32
  Known via "local", distance 0, metric 0 (connected)
  Tag 1899
Routing Descriptor Blocks
    directly connected, via HundredGigE0/0/0/1
      Route metric is 0
  No advertising protos.
```

### Associated Commands

- route-tag

# Larger IPv6 Address Space

The primary motivation for IPv6 is the need to meet the anticipated future demand for globally unique IP addresses. Applications such as mobile Internet-enabled devices (such as personal digital assistants [PDAs], telephones, and cars), home-area networks (HANs), and wireless data services are driving the demand for globally unique IP addresses. IPv6 quadruples the number of network address bits from 32 bits (in IPv4) to 128 bits, which provides more than enough globally unique IP addresses for every networked device on the planet. By being globally unique, IPv6 addresses inherently enable global reachability and end-to-end security for networked devices, functionality that is crucial to the applications and services that are driving the demand for the addresses. Additionally, the flexibility of the IPv6 address space reduces the need for private addresses and the use of Network Address Translation (NAT); therefore, IPv6 enables new application protocols that do not require special processing by border routers at the edge of networks.

# IPv6 Address Formats

IPv6 addresses are represented as a series of 16-bit hexadecimal fields separated by colons (:) in the format: x:x:x:x:x:x:x:x. Following are two examples of IPv6 addresses:

2001:0DB8:7654:3210:FEDC:BA98:7654:3210

2001:0DB8:0:0:8:800:200C:417A

It is common for IPv6 addresses to contain successive hexadecimal fields of zeros. To make IPv6 addresses less cumbersome, two colons (::) can be used to compress successive hexadecimal fields of zeros at the beginning, middle, or end of an IPv6 address. (The colons represent successive hexadecimal fields of zeros.) Table 1: Compressed IPv6 Address Formats, on page 18 lists compressed IPv6 address formats.

A double colon may be used as part of the *ipv6-address* argument when consecutive 16-bit values are denoted as zero. You can configure multiple IPv6 addresses per interfaces, but only one link-local address.

**Note** Two colons (::) can be used only once in an IPv6 address to represent the longest successive hexadecimal fields of zeros.

The hexadecimal letters in IPv6 addresses are not case-sensitive.

***Table 1: Compressed IPv6 Address Formats***

| IPv6 Address Type | Preferred Format | Compressed Format |
|---|---|---|
| Unicast | 2001:0:0:0:0DB8:800:200C:417A | 1080::0DB8:800:200C:417A |
| Multicast | FF01:0:0:0:0:0:0:101 | FF01::101 |
| Loopback | 0:0:0:0:0:0:0:1 | ::1 |
| Unspecified | 0:0:0:0:0:0:0:0 | :: |

The loopback address listed in Table 1: Compressed IPv6 Address Formats, on page 18 may be used by a node to send an IPv6 packet to itself. The loopback address in IPv6 functions the same as the loopback address in IPv4 (127.0.0.1).

**Note** The IPv6 loopback address cannot be assigned to a physical interface. A packet that has the IPv6 loopback address as its source or destination address must remain within the node that created the packet. IPv6 routers do not forward packets that have the IPv6 loopback address as their source or destination address.

The unspecified address listed in Table 1: Compressed IPv6 Address Formats, on page 18 indicates the absence of an IPv6 address. For example, a newly initialized node on an IPv6 network may use the unspecified address as the source address in its packets until it receives its IPv6 address.

**Note** The IPv6 unspecified address cannot be assigned to an interface. The unspecified IPv6 addresses must not be used as destination addresses in IPv6 packets or the IPv6 routing header.

An IPv6 address prefix, in the format *ipv6-prefix/prefix-length* , can be used to represent bit-wise contiguous blocks of the entire address space. The *ipv6-prefix* argument must be in the form documented in RFC 2373, in which the address is specified in hexadecimal using 16-bit values between colons. The prefix length is a decimal value that indicates how many of the high-order contiguous bits of the address compose the prefix (the network portion of the address). For example, 2001:0DB8:8086:6502::/32 is a valid IPv6 prefix.

# IPv6 Address Type: Unicast

An IPv6 unicast address is an identifier for a single interface, on a single node. A packet that is sent to a unicast address is delivered to the interface identified by that address. Cisco IOS XR software supports the following IPv6 unicast address types:

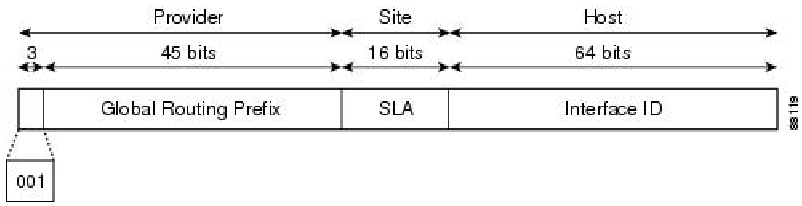
- Global aggregatable address
- Site-local address (proposal to remove by IETF)
- Link-local address
- IPv4-compatible IPv6 address

## Aggregatable Global Address

An aggregatable global address is an IPv6 address from the aggregatable global unicast prefix. The structure of aggregatable global unicast addresses enables strict aggregation of routing prefixes that limits the number of routing table entries in the global routing table. Aggregatable global addresses are used on links that are aggregated upward through organizations, and eventually to the Internet service providers (ISPs).

Aggregatable global IPv6 addresses are defined by a global routing prefix, a subnet ID, and an interface ID. Except for addresses that start with binary 000, all global unicast addresses have a 64-bit interface ID. The current global unicast address allocation uses the range of addresses that start with binary value 001 (2000::/3). This figure below shows the structure of an aggregatable global address.

*Figure 1: Aggregatable Global Address Format*




Addresses with a prefix of 2000::/3 (001) through E000::/3 (111) are required to have 64-bit interface identifiers in the extended universal identifier (EUI)-64 format. The Internet Assigned Numbers Authority (IANA) allocates the IPv6 address space in the range of 2000::/16 to regional registries.

The aggregatable global address typically consists of a 48-bit global routing prefix and a 16-bit subnet ID or Site-Level Aggregator (SLA). In the IPv6 aggregatable global unicast address format document (RFC 2374), the global routing prefix included two other hierarchically structured fields named Top-Level Aggregator (TLA) and Next-Level Aggregator (NLA).The IETF decided to remove the TLS and NLA fields from the RFCs, because these fields are policy-based. Some existing IPv6 networks deployed before the change might still be using networks based on the older architecture.

A 16-bit subnet field called the subnet ID could be used by individual organizations to create their own local addressing hierarchy and to identify subnets. A subnet ID is similar to a subnet in IPv4, except that an organization with an IPv6 subnet ID can support up to 65,535 individual subnets.

An interface ID is used to identify interfaces on a link. The interface ID must be unique to the link. It may also be unique over a broader scope. In many cases, an interface ID is the same as or based on the link-layer address of an interface. Interface IDs used in aggregatable global unicast and other IPv6 address types must be 64 bits long and constructed in the modified EUI-64 format.

Interface IDs are constructed in the modified EUI-64 format in one of the following ways:

- For all IEEE 802 interface types (for example, Ethernet interfaces and FDDI interfaces), the first three octets (24 bits) are taken from the Organizationally Unique Identifier (OUI) of the 48-bit link-layer address (MAC address) of the interface, the fourth and fifth octets (16 bits) are a fixed hexadecimal value of FFFE, and the last three octets (24 bits) are taken from the last three octets of the MAC address. The construction of the interface ID is completed by setting the Universal/Local (U/L) bit—the seventh bit of the first octet—to a value of 0 or 1. A value of 0 indicates a locally administered identifier; a value of 1 indicates a globally unique IPv6 interface identifier.
- For tunnel interface types that are used with IPv6 overlay tunnels, the interface ID is the IPv4 address assigned to the tunnel interface with all zeros in the high-order 32 bits of the identifier.

**Note** For interfaces using Point-to-Point Protocol (PPP), given that the interfaces at both ends of the connection might have the same MAC address, the interface identifiers used at both ends of the connection are negotiated (picked randomly and, if necessary, reconstructed) until both identifiers are unique. The first MAC address in the router is used to construct the identifier for interfaces using PPP.

If no IEEE 802 interface types are in the router, link-local IPv6 addresses are generated on the interfaces in the router in the following sequence:

1. The router is queried for MAC addresses (from the pool of MAC addresses in the router).

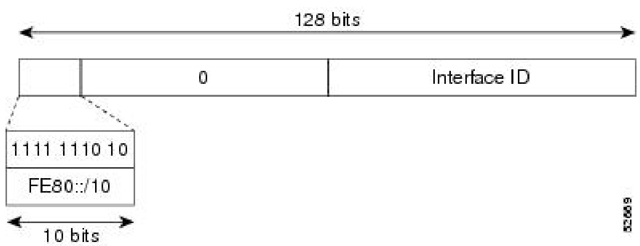
2. If no MAC address is available, the serial number of the Route Processor (RP) or line card (LC) is used to form the link-local address.

## Link-Local Address

A link-local address is an IPv6 unicast address that can be automatically configured on any interface using the link-local prefix FE80::/10 (1111 1110 10) and the interface identifier in the modified EUI-64 format. Link-local addresses are used in the neighbor discovery protocol and the stateless autoconfiguration process. Nodes on a local link can use link-local addresses to communicate; the nodes do not need site-local or globally unique addresses to communicate. This figure below shows the structure of a link-local address.

IPv6 routers must not forward packets that have link-local source or destination addresses to other links.

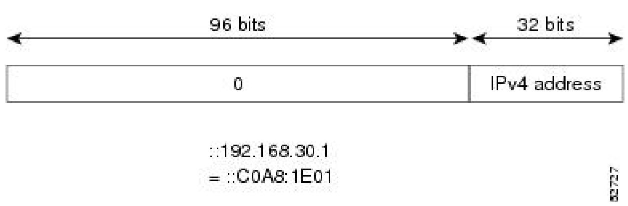
*Figure 2: Link-Local Address Format*




## IPv4-Compatible IPv6 Address

An IPv4-compatible IPv6 address is an IPv6 unicast address that has zeros in the high-order 96 bits of the address and an IPv4 address in the low-order 32 bits of the address. The format of an IPv4-compatible IPv6 address is 0:0:0:0:0:0:A.B.C.D or ::A.B.C.D. The entire 128-bit IPv4-compatible IPv6 address is used as the IPv6 address of a node and the IPv4 address embedded in the low-order 32 bits is used as the IPv4 address of the node. IPv4-compatible IPv6 addresses are assigned to nodes that support both the IPv4 and IPv6 protocol stacks and are used in automatic tunnels. This figure below shows the structure of an IPv4-compatible IPv6 address and a few acceptable formats for the address.

*Figure 3: IPv4-Compatible IPv6 Address Format*




# Simplified IPv6 Packet Header

The basic IPv4 packet header has 12 fields with a total size of 20 octets (160 bits). The 12 fields may be followed by an Options field, which is followed by a data portion that is usually the transport-layer packet. The variable length of the Options field adds to the total size of the IPv4 packet header. The shaded fields of the IPv4 packet header are not included in the IPv6 packet header.

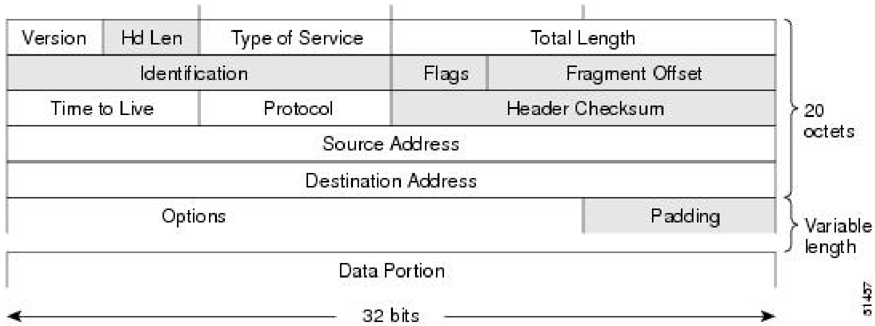



*Figure 4: IPv4 Packet Header Format*

The basic IPv6 packet header has 8 fields with a total size of 40 octets (320 bits). Fields were removed from the IPv6 header because, in IPv6, fragmentation is not handled by routers and checksums at the network layer are not used. Instead, fragmentation in IPv6 is handled by the source of a packet and checksums at the data link layer and transport layer are used. (In IPv4, the User Datagram Protocol (UDP) transport layer uses an optional checksum. In IPv6, use of the UDP checksum is required to check the integrity of the inner packet.) Additionally, the basic IPv6 packet header and Options field are aligned to 64 bits, which can facilitate the processing of IPv6 packets.

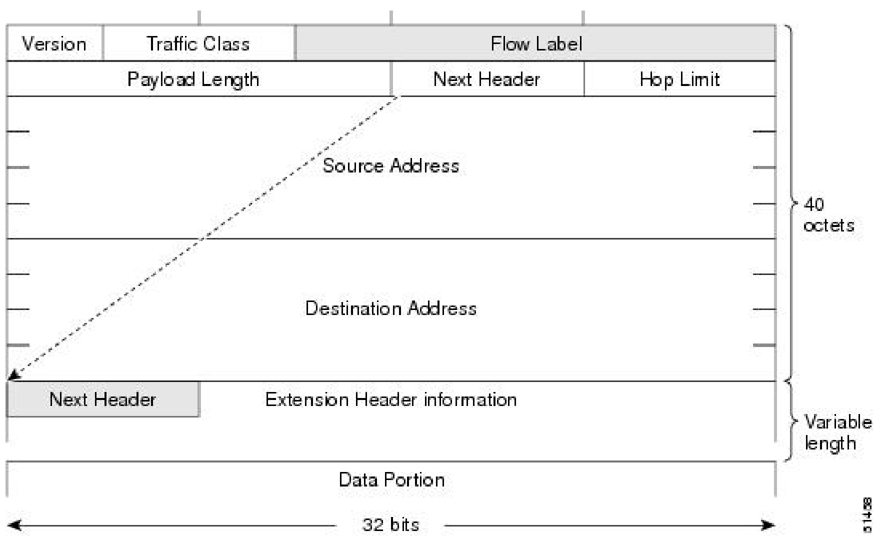



*Figure 5: IPv6 Packet Header Format*

This table lists the fields in the basic IPv6 packet header.

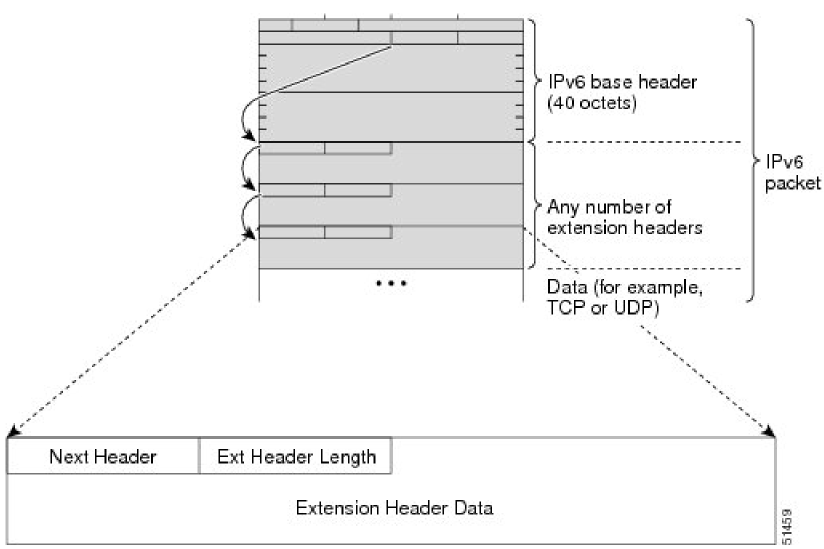
*Table 2: Basic IPv6 Packet Header Fields*

| Field | Description |
|---|---|
| Version | Similar to the Version field in the IPv4 packet header, except that the field lists number 6 for IPv6 instead of number 4 for IPv4. |
| Traffic Class | Similar to the Type of Service field in the IPv4 packet header. The Traffic Class field tags packets with a traffic class that is used in differentiated services. |

| Field | Description |
|---|---|
| Flow Label | A new field in the IPv6 packet header. The Flow Label field tags packets with a specific flow that differentiates the packets at the network layer. |
| Payload Length | Similar to the Total Length field in the IPv4 packet header. The Payload Length field indicates the total length of the data portion of the packet. |
| Next Header | Similar to the Protocol field in the IPv4 packet header. The value of the Next Header field determines the type of information following the basic IPv6 header. The type of information following the basic IPv6 header can be a transport-layer packet, for example, a TCP or UDP packet, or an Extension Header. |
| Hop Limit | Similar to the Time to Live field in the IPv4 packet header. The value of the Hop Limit field specifies the maximum number of routers that an IPv6 packet can pass through before the packet is considered invalid. Each router decrements the value by one. Because no checksum is in the IPv6 header, the router can decrement the value without needing to recalculate the checksum, which saves processing resources. |
| Source Address | Similar to the Source Address field in the IPv4 packet header, except that the field contains a 128-bit source address for IPv6 instead of a 32-bit source address for IPv4. |
| Destination Address | Similar to the Destination Address field in the IPv4 packet header, except that the field contains a 128-bit destination address for IPv6 instead of a 32-bit destination address for IPv4. |

Following the eight fields of the basic IPv6 packet header are optional extension headers and the data portion of the packet. If present, each extension header is aligned to 64 bits. There is no fixed number of extension headers in an IPv6 packet. Together, the extension headers form a chain of headers. Each extension header is identified by the Next Header field of the previous header. Typically, the final extension header has a Next Header field of a transport-layer protocol, such as TCP or UDP. This figure below shows the IPv6 extension header format.

*Figure 6: IPv6 Extension Header Format*




This table lists the extension header types and their Next Header field values.

*Table 3: IPv6 Extension Header Types*

| Header Type | Next Header Value | Description |
|---|---|---|
| Hop-by-hop options header | 0 | This header is processed by all hops in the path of a packet. When present, the hop-by-hop options header always follows immediately after the basic IPv6 packet header. |
| Destination options header | 60 | The destination options header can follow any hop-by-hop options header, in which case the destination options header is processed at the final destination and also at each visited address specified by a routing header. Alternatively, the destination options header can follow any Encapsulating Security Payload (ESP) header, in which case the destination options header is processed only at the final destination. |
| Routing header | 43 | The routing header is used for source routing. |
| Fragment header | 44 | The fragment header is used when a source must fragment a packet that is larger than the maximum transmission unit (MTU) for the path between itself and a destination. The Fragment header is used in each fragmented packet. |
| Authentication header<br>and<br>ESP header | 51<br><br>50 | The Authentication header and the ESP header are used within IP Security Protocol (IPSec) to provide authentication, integrity, and confidentiality of a packet. These headers are identical for both IPv4 and IPv6. |
| Upper-layer header | 6 (TCP)<br>17 (UDP) | The upper-layer (transport) headers are the typical headers used inside a packet to transport the data. The two main transport protocols are TCP and UDP. |
| Mobility header | To be done by IANA | Extension headers used by mobile nodes, correspondent nodes, and home agents in all messaging related to the creation and management of bindings. |

# Path MTU Discovery for IPv6

As in IPv4, path MTU discovery in IPv6 allows a host to dynamically discover and adjust to differences in the MTU size of every link along a given data path. In IPv6, however, fragmentation is handled by the source of a packet when the path MTU of one link along a given data path is not large enough to accommodate the size of the packets. Having IPv6 hosts handle packet fragmentation saves IPv6 router processing resources and helps IPv6 networks run more efficiently.

In IPv4, the minimum link MTU is 68 octets, which means that the MTU size of every link along a given data path must support an MTU size of at least 68 octets. In IPv6, the minimum link MTU is 1280 octets. We recommend using an MTU value of 1500 octets for IPv6 links.

**Note** Path MTU discovery is supported only for applications using TCP.

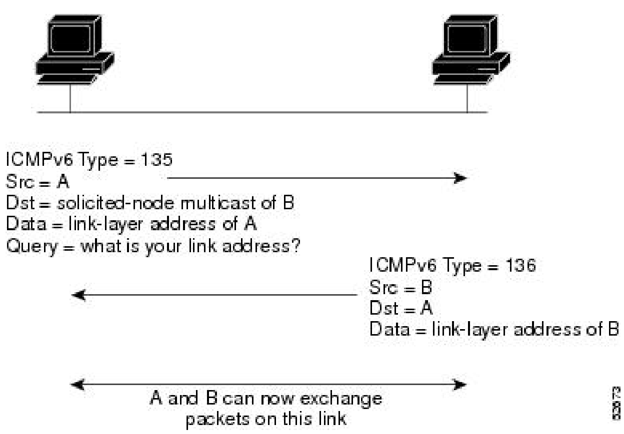
# IPv6 Neighbor Discovery

The IPv6 neighbor discovery process uses ICMP messages and solicited-node multicast addresses to determine the link-layer address of a neighbor on the same network (local link), verify the reachability of a neighbor, and keep track of neighboring routers.

## IPv6 Neighbor Solicitation Message

A value of 135 in the Type field of the ICMP packet header identifies a neighbor solicitation message. Neighbor solicitation messages are sent on the local link when a node wants to determine the link-layer address of another node on the same local link. When a node wants to determine the link-layer address of another node, the source address in a neighbor solicitation message is the IPv6 address of the node sending the neighbor solicitation message. The destination address in the neighbor solicitation message is the solicited-node multicast address that corresponds to the IPv6 address of the destination node. The neighbor solicitation message also includes the link-layer address of the source node.

*Figure 7: IPv6 Neighbor Discovery—Neighbor Solicitation Message*




After receiving the neighbor solicitation message, the destination node replies by sending a neighbor advertisement message, which has a value of 136 in the Type field of the ICMP packet header, on the local link. The source address in the neighbor advertisement message is the IPv6 address of the node (more specifically, the IPv6 address of the node interface) sending the neighbor advertisement message. The destination address in the neighbor advertisement message is the IPv6 address of the node that sent the neighbor solicitation message. The data portion of the neighbor advertisement message includes the link-layer address of the node sending the neighbor advertisement message.

After the source node receives the neighbor advertisement, the source node and destination node can communicate.

Neighbor solicitation messages are also used to verify the reachability of a neighbor after the link-layer address of a neighbor is identified. When a node wants to verifying the reachability of a neighbor, the destination address in a neighbor solicitation message is the unicast address of the neighbor.

Neighbor advertisement messages are also sent when there is a change in the link-layer address of a node on a local link. When there is such a change, the destination address for the neighbor advertisement is the all-nodes multicast address.

Neighbor solicitation messages are also used to verify the reachability of a neighbor after the link-layer address of a neighbor is identified. Neighbor unreachability detection identifies the failure of a neighbor or the failure of the forward path to the neighbor, and is used for all paths between hosts and neighboring nodes (hosts or routers). Neighbor unreachability detection is performed for neighbors to which only unicast packets are being sent and is not performed for neighbors to which multicast packets are being sent.

A neighbor is considered reachable when a positive acknowledgment is returned from the neighbor (indicating that packets previously sent to the neighbor have been received and processed). A positive acknowledgment—from an upper-layer protocol (such as TCP)—indicates that a connection is making forward progress (reaching its destination) or that a neighbor advertisement message in response to a neighbor solicitation message has been received. If packets are reaching the peer, they are also reaching the next-hop neighbor of the source. Therefore, forward progress is also a confirmation that the next-hop neighbor is reachable.

For destinations that are not on the local link, forward progress implies that the first-hop router is reachable. When acknowledgments from an upper-layer protocol are not available, a node probes the neighbor using unicast neighbor solicitation messages to verify that the forward path is still working. The return of a solicited neighbor advertisement message from the neighbor is a positive acknowledgment that the forward path is still working. (Neighbor advertisement messages that have the solicited flag set to a value of 1 are sent only in response to a neighbor solicitation message.) Unsolicited messages confirm only the one-way path from the source to the destination node; solicited neighbor advertisement messages indicate that a path is working in both directions.

**Note** A neighbor advertisement message that has the solicited flag set to a value of 0 must not be considered as a positive acknowledgment that the forward path is still working.

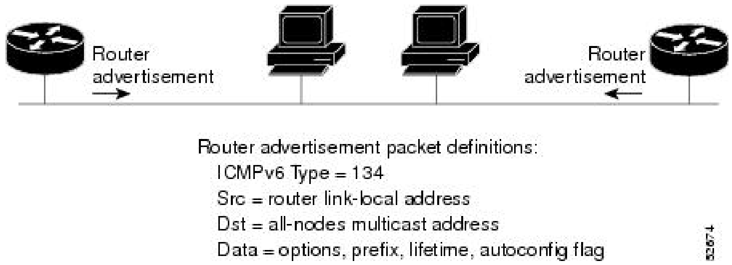
Neighbor solicitation messages are also used in the stateless autoconfiguration process to verify the uniqueness of unicast IPv6 addresses before the addresses are assigned to an interface. Duplicate address detection is performed first on a new, link-local IPv6 address before the address is assigned to an interface. (The new address remains in a tentative state while duplicate address detection is performed.) Specifically, a node sends a neighbor solicitation message with an unspecified source address and a tentative link-local address in the body of the message. If another node is already using that address, the node returns a neighbor advertisement message that contains the tentative link-local address. If another node is simultaneously verifying the uniqueness of the same address, that node also returns a neighbor solicitation message. If no neighbor advertisement messages are received in response to the neighbor solicitation message and no neighbor solicitation messages are received from other nodes that are attempting to verify the same tentative address, the node that sent the original neighbor solicitation message considers the tentative link-local address to be unique and assigns the address to the interface.

Every IPv6 unicast address (global or link-local) must be checked for uniqueness on the link; however, until the uniqueness of the link-local address is verified, duplicate address detection is not performed on any other IPv6 addresses associated with the link-local address. The Cisco implementation of duplicate address detection in the Cisco IOS XR software does not check the uniqueness of anycast or global addresses that are generated from 64-bit interface identifiers.

## IPv6 Router Advertisement Message

Router advertisement (RA) messages, which have a value of 134 in the Type field of the ICMP packet header, are periodically sent out each configured interface of an IPv6 router. The router advertisement messages are sent to the all-nodes multicast address.

*Figure 8: IPv6 Neighbor Discovery—Router Advertisement Message*




Router advertisement messages typically include the following information:

- One or more onlink IPv6 prefixes that nodes on the local link can use to automatically configure their IPv6 addresses
- Lifetime information for each prefix included in the advertisement
- Sets of flags that indicate the type of autoconfiguration (stateless or statefull) that can be completed
- Default router information (whether the router sending the advertisement should be used as a default router and, if so, the amount of time, in seconds, that the router should be used as a default router)
- Additional information for hosts, such as the hop limit and MTU a host should use in packets that it originates

Router advertisements are also sent in response to router solicitation messages. Router solicitation messages, which have a value of 133 in the Type field of the ICMP packet header, are sent by hosts at system startup so that the host can immediately autoconfigure without needing to wait for the next scheduled router advertisement message. Given that router solicitation messages are usually sent by hosts at system startup (the host does not have a configured unicast address), the source address in router solicitation messages is usually the unspecified IPv6 address (0:0:0:0:0:0:0:0). If the host has a configured unicast address, the unicast address of the interface sending the router solicitation message is used as the source address in the message. The destination address in router solicitation messages is the all-routers multicast address with a scope of the link. When a router advertisement is sent in response to a router solicitation, the destination address in the router advertisement message is the unicast address of the source of the router solicitation message.

The following router advertisement message parameters can be configured:

- The time interval between periodic router advertisement messages
- The “router lifetime” value, which indicates the usefulness of a router as the default router (for use by all nodes on a given link)
- The network prefixes in use on a given link
- The time interval between neighbor solicitation message retransmissions (on a given link)
- The amount of time a node considers a neighbor reachable (for use by all nodes on a given link)

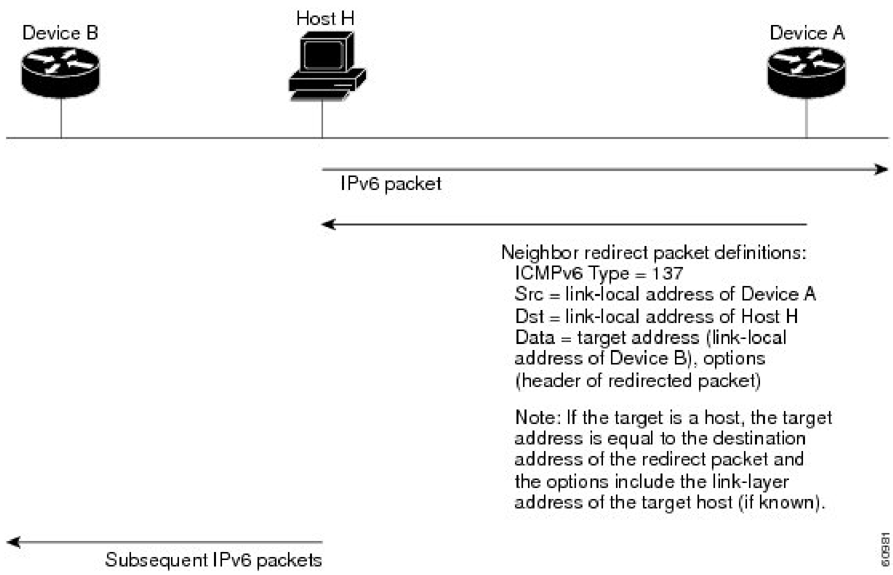
The configured parameters are specific to an interface. The sending of router advertisement messages (with default values) is automatically enabled on Ethernet and FDDI interfaces. For other interface types, the sending of router advertisement messages must be manually configured by using the **no ipv6 nd suppress-ra** command in interface configuration mode. The sending of router advertisement messages can be disabled on individual interfaces by using the **ipv6 nd suppress-ra** command in interface configuration mode.

**Note** For stateless autoconfiguration to work properly, the advertised prefix length in router advertisement messages must always be 64 bits.

## IPv6 Neighbor Redirect Message

A value of 137 in the Type field of the ICMP packet header identifies an IPv6 neighbor redirect message. Routers send neighbor redirect messages to inform hosts of better first-hop nodes on the path to a destination.

*Figure 9: IPv6 Neighbor Discovery—Neighbor Redirect Message*




**Note** A router must be able to determine the link-local address for each of its neighboring routers to ensure that the target address (the final destination) in a redirect message identifies the neighbor router by its link-local address. For static routing, the address of the next-hop router should be specified using the link-local address of the router; for dynamic routing, all IPv6 routing protocols must exchange the link-local addresses of neighboring routers.

After forwarding a packet, a router should send a redirect message to the source of the packet under the following circumstances:

- The destination address of the packet is not a multicast address.
- The packet was not addressed to the router.
- The packet is about to be sent out the interface on which it was received.
- The router determines that a better first-hop node for the packet resides on the same link as the source of the packet.
- The source address of the packet is a global IPv6 address of a neighbor on the same link, or a link-local address.

Use the **ipv6 icmp error-interval** global configuration command to limit the rate at which the router generates all IPv6 ICMP error messages, including neighbor redirect messages, which ultimately reduces link-layer congestion.

**Note** A router must not update its routing tables after receiving a neighbor redirect message, and hosts must not originate neighbor redirect messages.

# Address Repository Manager

IPv4 and IPv6 Address Repository Manager (IPARM) enforces the uniqueness of global IP addresses configured in the system, and provides global IP address information dissemination to processes on route processors (RPs) and line cards (LCs) using the IP address consumer application program interfaces (APIs), which includes unnumbered interface information.

## Address Conflict Resolution

There are two parts to conflict resolution; the conflict database and the conflict set definition.

### Conflict Database

IPARM maintains a global conflict database. IP addresses that conflict with each other are maintained in lists called conflict sets. These conflict sets make up the global conflict database.

A set of IP addresses are said to be part of a conflict set if at least one prefix in the set conflicts with every other IP address belonging to the same set. For example, the following four addresses are part of a single conflict set.

address 1: 10.1.1.1/16

address 2: 10.2.1.1/16

address 3: 10.3.1.1/16

address 4: 10.4.1.1/8

When a conflicting IP address is added to a conflict set, an algorithm runs through the set to determine the highest precedence address within the set.

This conflict policy algorithm is deterministic, that is, the user can tell which addresses on the interface are enabled or disabled. The address on the interface that is enabled is declared as the highest precedence ip address for that conflict set.

The conflict policy algorithm determines the highest precedence ip address within the set.

CHAPTER 2

# Configuring ARP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## Configuring ARP

Address resolution is the process of mapping network addresses to Media Access Control (MAC) addresses, which is typically done dynamically by the system using the ARP protocol, but can also be done by Static ARP entry configuration. This process is accomplished using the Address Resolution Protocol (ARP).

ARP is used to associate IP addresses with media or MAC addresses. Taking an IP address as input, ARP determines the associated media address. After a media or MAC address is determined, the IP address or media address association is stored in an ARP cache for rapid retrieval. Then the IP datagram is encapsulated in a link-layer frame and sent over the network.

For more details on ARP, see Information About Configuring ARP, on page 36

### ARP and Proxy ARP

Two forms of address resolution are supported by Cisco IOS XR software: Address Resolution Protocol (ARP) and proxy ARP, as defined in RFC 826 and RFC 1027, respectively. Cisco IOS XR software also supports a form of ARP called local proxy ARP.

For more details on Proxy ARP and Local Proxy ARP, see Proxy ARP and Local Proxy ARP, on page 32

**Restrictions**

The following restrictions apply to configuring ARP :

- Reverse Address Resolution Protocol (RARP) is not supported.
- ARP throttling, which is the rate limiting of ARP packets in Forwarding Information Base (FIB), is not supported.

## ARP Cache Entries

ARP establishes correspondences between network addresses (an IP address, for example) and Ethernet hardware addresses. A record of each correspondence is kept in a cache for a predetermined amount of time and then discarded.

You can also add a static (permanent) entry to the ARP cache that persists until explicitly removed.

## Defining a Static ARP Cache Entry

ARP and other address resolution protocols provide a dynamic mapping between IP addresses and media addresses. Because most hosts support dynamic address resolution, generally you need not specify static ARP entries. If you must define them, you can do so globally. Performing this task installs a permanent entry in the ARP cache. Cisco IOS XR software uses this entry to translate 32-bit IP addresses into 48-bit hardware addresses.

Optionally, you can specify that the software responds to ARP requests as if the software was identified by the specified IP address, by making an alias entry in the ARP cache.

### Configuration Example

A cache entry is created to establish connection between an IP address **203.0.1.2** and the MAC address **0010.9400.000c**. Additionally, the cache entry is created as an alias entry such that the interface to which the entry is attached will respond to ARP request packets for this network layer address with the data link layer address in the entry.

```
Router#config
Router(config)#arp 203.0.1.2 0010.9400.000c arPA
Router(config)#commit
```

### Running Configuration

```
Router#show run arp 203.0.1.2 0010.9400.000c arpA
arp vrf default 203.0.1.2 0010.9400.000c ARPA
```

### Verification

Verify that the State is static for proper functioning:

```
Router#show arp location 0/0/CPU0
Address         Age        Hardware Addr   State      Type  Interface
203.0.1.1       -          ea28.5f0b.8024  Interface  ARPA  HundredGigE0/0/0/9
203.0.1.2       -          0010.9400.000c  Static ARPA  HundredGigE0/0/0/9
```

# Proxy ARP and Local Proxy ARP

When proxy ARP is disabled, the networking device responds to ARP requests received on an interface only if one of the following conditions is met:

- The target IP address in the ARP request is the same as the interface IP address on which the request is received.
- The target IP address in the ARP request has a statically configured ARP alias.

When proxy ARP is enabled, the networking device also responds to ARP requests that meet all the following conditions:

- The target IP address is not on the same physical network (LAN) on which the request is received.
- The networking device has one or more routes to the target IP address.
- All of the routes to the target IP address go through interfaces other than the one on which the request is received.

When local proxy ARP is enabled, the networking device responds to ARP requests that meet all the following conditions:

- The target IP address in the ARP request, the IP address of the ARP source, and the IP address of the interface on which the ARP request is received are on the same Layer 3 network.
- The next hop for the target IP address is through the same interface as the request is received.

Typically, local proxy ARP is used to resolve MAC addresses to IP addresses in the same Layer 3 network. Local proxy ARP supports all types of interfaces supported by ARP and unnumbered interfaces.

# Enabling Proxy ARP

Cisco IOS XR software uses proxy ARP (as defined in RFC 1027) to help hosts with no knowledge of routing determine the media addresses of hosts on other networks or subnets. For example, if the router receives an ARP request for a host that is not on the same interface as the ARP request sender, and if the router has all of its routes to that host through other interfaces, then it generates a proxy ARP reply packet giving its own local data-link address. The host that sent the ARP request then sends its packets to the router, which forwards them to the intended host. Proxy ARP is disabled by default; this task describes how to enable proxy ARP if it has been disabled.

### Configuration Example

Proxy ARP is enabled on the HundredGigE interface-0/0/0/0:

```
Router#configure
Router(config)#interface HundredGigE0/0/0/0
Router(config-if)#proxy-arp
Router(config-if)#commit
```

### Running Configuration

```
Router# show running-config interface HundredGigE0/0/0/0
interface HundredGigE0/0/0/0
 mtu 4000
 ipv4 address 1.0.0.1 255.255.255.0
 proxy-arp
!
!
```

### Verification

Verify that proxy ARP is configured and enabled:

```
Router#show arp idb interface HundredGigE0/0/0/0 location 0/0/CPU0
  interface HundredGigE0/0/0/0 (0x08000038):
  IPv4 address 1.0.0.1, Vrf ID 0x60000000
  VRF Name default
  Dynamic learning: Enable
  Dynamic entry timeout: 14400 secs
  Purge delay: off
  IPv4 caps added (state up)
  MPLS caps not added
  Interface not virtual, not client fwd ref,
  Proxy arp is configured, is enabled
  Local Proxy arp not configured
  Packet IO layer is NetIO
  Srg Role : DEFAULT
```

```
  Idb Flag : 262332
  IDB is Complete
```

## Enabling Local Proxy ARP

Local proxy ARP is used to resolve MAC addresses to IP addresses in the same Layer 3 network such as, private VLANs that are Layer 2-separated. Local proxy ARP supports all types of interfaces supported by ARP and unnumbered interfaces.

### Configuration Example

Local proxy ARP is enabled on the HundredGigE interface-0/0/0/0

```
Router#configure
Router(config)#interface HundredGigE0/0/0/0
Router(config-if)#local-proxy-arp
Router(config-if)#commit
```

### Running Configuration

```
Router#show running-config interface HundredGigE0/0/0/0
 interface HundredGigE0/0/0/0
ipv4 address 1.0.0.1 255.255.255.0
local-proxy-arp
!
```

### Verification

Verify that local proxy ARP is configured:

```
Router#show arp idb interface HundredGigE0/0/0/0 location 0/0/CPU0
HundredGigE0/0/0/0 (0x08000038):
  IPv4 address 1.0.0.1, Vrf ID 0x60000000
  VRF Name default
  Dynamic learning: Enable
  Dynamic entry timeout: 14400 secs
  Purge delay: off
  IPv4 caps added (state up)
  MPLS caps not added
  Interface not virtual, not client fwd ref,
  Proxy arp not configured, not enabled
  Local Proxy arp is configured
  Packet IO layer is NetIO
  Srg Role : DEFAULT
  Idb Flag : 264332
  IDB is Complete
```

### Associated Commands

- local-proxy-arp
- show arp idb

# Configure Learning of Local ARP Entries

You can configure an interface or a sub-interface to learn only the ARP entries from its local subnet.

Use the following procedure to configure local ARP learning on an interface.

1. Enter the interface configuration mode.

```
Router(config)# interface GigabitEthernet 0/0/0/1
```

2. Configure the IPv4/IPv6 address for the interface.

```
Router(config-if)# ipv4 address 12.1.3.4 255.255.255.0
```

3. Configure local ARP learning on the interface.

```
Router(config-if)# arp learning local
```

4. Enable the interface and commit your configuration.

```
Router(config-if)# no shut
Router(config-if)# commit
RP/0/0/CPU0:Dec 12 13:41:16.580 : ifmgr[397]: %PKT_INFRA-LINK-3-UPDOWN : interface
GigabitEthernet 0/0/0/1, changed state to Down
RP/0/0/CPU0:Dec 12 13:41:16.683 : ifmgr[397]: %PKT_INFRA-LINK-3-UPDOWN : interface
GigabitEthernet 0/0/0/1 changed state to Up
```

5. Confirm your configuration.

```
Router(config-if)# show running-configuration
..
Building configuration...
!! IOS XR Configuration 0.0.0
!! Last configuration change at Mon Dec 12 13:41:16 2016
!interface GigabitEthernet 0/0/0/1
 ipv4 address 12.1.3.4 255.255.255.0
 arp learning local
!
```

6. Verify if local ARP learning is working as configured on the interface.

```
Router(config-if)# do show arp idb gigabitEthernet 0/0/0/1 location 0/0/CPU0
Thu Dec 15 10:00:11.733 IST

GigabitEthernet 0/0/0/1 (0x00000040):
  IPv4 address 12.1.3.4, Vrf ID 0x60000000
  VRF Name default
  Dynamic learning: Local
  Dynamic entry timeout: 14400 secs
  Purge delay: off
  IPv4 caps added (state up)
  MPLS caps not added
  Interface not virtual, not client fwd ref,
  Proxy arp not configured, not enabled
  Local Proxy arp not configured
  Packet IO layer is NetIO
  Srg Role : DEFAULT
  Idb Flag : 2146444
  IDB is Complete
```

7. (Optional) You can monitor the ARP traffic on the interface.

```
Router(config-if)# do show arp idb gigabitEthernet 0/0/0/1 location 0/0/CPU0
Thu Dec 15 10:13:28.964 IST

ARP statistics:
  Recv: 0 requests, 0 replies
  Sent: 0 requests, 1 replies (0 proxy, 0 local proxy, 1 gratuitous)
  Subscriber Interface:
         0 requests recv, 0 replies sent, 0 gratuitous replies sent
  Resolve requests rcvd: 0
  Resolve requests dropped: 0
```

```
  Errors: 0 out of memory, 0 no buffers, 0 out of sunbet

ARP cache:
  Total ARP entries in cache: 1
  Dynamic: 0, Interface: 1, Standby: 0
  Alias: 0,   Static: 0,    DHCP: 0

  IP Packet drop count for GigabitEthernet0_0_0_1: 0
```

# Information About Configuring ARP

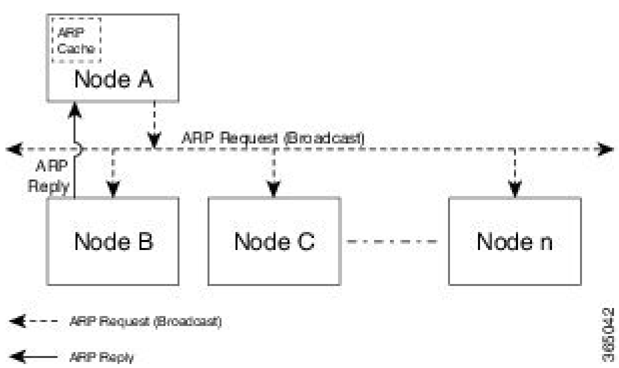
## Addressing Resolution Overview

A device in the IP can have both a local address (which uniquely identifies the device on its local segment or LAN) and a network address (which identifies the network to which the device belongs). The local address is more properly known as a *data link address*, because it is contained in the data link layer (Layer 2 of the OSI model) part of the packet header and is read by data-link devices (bridges and all device interfaces, for example). The more technically inclined person will refer to local addresses as *MAC addresses*, because the MAC sublayer within the data link layer processes addresses for the layer.

To communicate with a device on Ethernet, for example, Cisco IOS XR software first must determine the 48-bit MAC or local data-link address of that device. The process of determining the local data-link address from an IP address is called address resolution.

## Address Resolution on a Single LAN

The following process describes address resolution when the source and destination devices are attached to the same LAN:

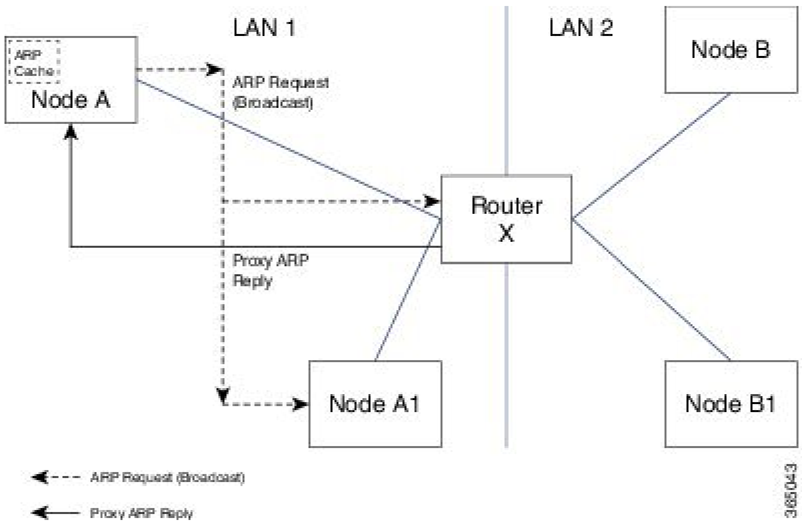



1. End System A (Node A) broadcasts an ARP request onto the LAN, attempting to learn the MAC address of End System B (Node B).
2. The broadcast is received and processed by all devices on the LAN, including End System B.
3. Only End System B replies to the ARP request. It sends an ARP reply containing its MAC address to End System A (Node A).
4. End System A (Node A) receives the reply and saves the MAC address of End System B in its ARP cache. (The ARP cache is where network addresses are associated with MAC addresses.)

5. Whenever End System A (Node A) needs to communicate with End System B, it checks the ARP cache, finds the MAC address of System B, and sends the frame directly, without needing to first use an ARP request.

# Address Resolution When Interconnected by a Router

The following process describes address resolution when the source and destination devices are attached to different LANs that are interconnected by a router (only if proxy-arp is turned on):




1. End System Y (Node A) broadcasts an ARP request onto the LAN, attempting to learn the MAC address of End System Z (Node B).
2. The broadcast is received and processed by all devices on the LAN, including Router X.
3. Router X checks its routing table and finds that End System Z (Node B) is located on a different LAN.
4. Router X therefore acts as a proxy for End System Z (Node B). It replies to the ARP request from End System Y (Node A), sending an ARP reply containing its own MAC address as if it belonged to End System Z (Node B).
5. End System Y (Node A) receives the ARP reply and saves the MAC address of Router X in its ARP cache, in the entry for End System Z (Node B).
6. When End System Y (Node A) needs to communicate with End System Z (Node B), it checks the ARP cache, finds the MAC address of Router X, and sends the frame directly, without using ARP requests.
7. Router X receives the traffic from End System Y (Node A) and forwards it to End System Z (Node B) on the other LAN.

CHAPTER 3

# Implementing Host Services and Applications


- Implementing Host Services and Applications, on page 39
- Network Connectivity Tools, on page 39
- Domain Services, on page 43
- File Transfer Services, on page 45
- Cisco inetd, on page 48
- Telnet, on page 49
- Syslog source-interface, on page 49


## Implementing Host Services and Applications

Cisco IOS XR software Host Services and Applications features on the router are used primarily for checking network connectivity and the route a packet follows to reach a destination, mapping a hostname to an IP address or an IP address to a hostname, and transferring files between routers and UNIX workstations.

## Network Connectivity Tools

Network connectivity tools enable you to check device connectivity by running traceroutes and pinging devices on the network:

### Ping

The **ping** command is a common method for troubleshooting the accessibility of devices. It uses two Internet Control Message Protocol (ICMP) query messages, ICMP echo requests, and ICMP echo replies to determine whether a remote host is active. The **ping** command also measures the amount of time it takes to receive the echo reply.

The **ping** command first sends an echo request packet to an address, and then it waits for a reply. The ping is successful only if the echo request gets to the destination, and the destination is able to get an echo reply (hostname is alive) back to the source of the ping within a predefined time interval.

The bulk option has been introduced to check reachability to multiple destinations. The destinations are directly input through the CLI. This option is supported for ipv4 destinations only.

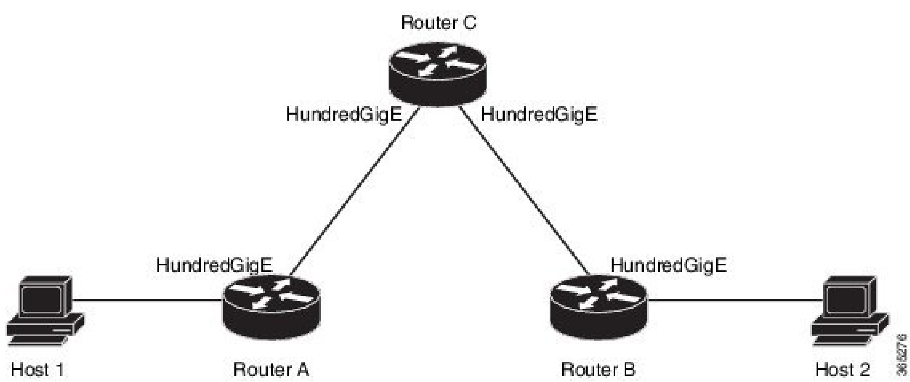
# Checking Network Connectivity

As an aid to diagnosing basic network connectivity, many network protocols support an echo protocol. The protocol involves sending a special datagram to the destination host, then waiting for a reply datagram from that host. Results from this echo protocol can help in evaluating the path-to-host reliability, delays over the path, and whether the host can be reached or is functioning.

## Configuration for Checking Network Connectivity

The following configuration shows an extended **ping** command sourced from the Router A HundredGigEinterface and destined for the Router B HundredGigE interface. If this ping succeeds, it is an indication that there is no routing problem. Router A knows how to get to the HundredGigEinterface of Router B, and Router B knows how to get to the HundredGigE interface of Router A. Also, both hosts have their default gateways set correctly.

If the extended **ping** command from Router A fails, it means that there is a routing problem. There could be a routing problem on any of the three routers: Router A could be missing a route to the subnet of Router B's interface, or to the subnet between Router C and Router B; Router B could be missing a route to the subnet of Router A's subnet, or to the subnet between Router C and Router A; and Router C could be missing a route to the subnet of Router A's or Router B's Ethernet segments. You should correct any routing problems, and then Host 1 should try to ping Host 2. If Host 1 still cannot ping Host 2, then both hosts' default gateways should be checked. The connectivity between the HundredGigE interface of Router A and the HundredGigE interface of Router B is checked with the extended **ping** command.




With a normal ping from Router A to Router B's HundredGigE interface, the source address of the ping packet would be the address of the outgoing interface; that is the address of the HundredGigE interface, (10.0.0.2). When Router B replies to the ping packet, it replies to the source address (that is, 10.0.0.2). This way, only the connectivity between the HundredGigE interface of Router A (10.0.0.2) and the 10gige interface of Router B (10.0.0.1) is tested.

To test the connectivity between Router A's HundredGigE interface (10.0.0.2) and Router B's interface (10.0.0.1 .), we use the extended **ping** command. With extended **ping**, we get the option to specify the source address of the **ping** packet.

## Configuration Example

In this use case, the extended **ping** command verifies the IP connectivity between the two IP addresses Router A (10.0.0.2) and Router B (10.0.0.1) .

```
Router# ping 10.0.0.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
```

```
!!!!!
Success rate is 100 percent (5/5)
Router#!!!!!

*/If you do not enter a hostname or an IP address on the same line as the ping command,
the system prompts you to specify the target IP address and several other command parameters.

After specifying the target IP address, you can specify alternate values for the
remaining parameters or accept the displayed default for each parameter /*

Router# ping
Protocol [ipv4]:
Target IP address: 10.0.0.1
Repeat count [5]: 5
Datagram size [100]: 1000
Timeout in seconds [2]: 1
Interval in milliseconds [10]: 1
Extended commands? [no]: no
Sweep range of sizes? [no]:
Type escape sequence to abort.
Sending 5, 1000-byte ICMP Echos to 10.0.0.1, timeout is 1 seconds:
!!!!!
Success rate is 100 percent (5/5)
Router#!!!!!
```

### Associated Commands

- ping

## Checking Network Connectivity for Multiple Destinations

The bulk option enables you to check reachability to multiple destinations. The destinations are directly input through the CLI. This option is supported for ipv4 destinations only.

### Configuration Example

Check reachability and network connectivity to multiple hosts on IP networks with the following IP addresses:

- 1: 1.1.1.1
- 2: 2.2.2.2
- 3: 3.3.3.3

```
Router# ping bulk ipv4 input cli batch
*/You must hit the Enter button and then specify one destination address per line*/
Please enter input via CLI with one destination per line and when done Ctrl-D/(exit) to
initiate pings:
1: 1.1.1.1
2: 2.2.2.2
3: 3.3.3.3
4:
Starting pings...
Target IP address: 1.1.1.1
Repeat count [5]: 5
Datagram size [100]: 1
% A decimal number between 36 and 18024.
Datagram size [100]: 1
% A decimal number between 36 and 18024.
Datagram size [100]: 1000
Timeout in seconds [2]: 1
```

```
Interval in milliseconds [10]: 10
Extended commands? [no]: no
Sweep range of sizes? [no]: q
% Please answer 'yes' or 'no'.
Sweep range of sizes? [no]: q
% Please answer 'yes' or 'no'.
Sweep range of sizes? [no]:
Type escape sequence to abort.
Sending 5, 1000-byte ICMP Echos to 1.1.1.1, vrf is default, timeout is 1 seconds:
!!!!!
Success rate is 100 percent (5/5),
Target IP address: 2.2.2.2
Repeat count [5]:
Datagram size [100]: q
% A decimal number between 36 and 18024.
Datagram size [100]:
Timeout in seconds [2]:
Interval in milliseconds [10]:
Extended commands? [no]:
Sweep range of sizes? [no]:
Sending 5, 100-byte ICMP Echos to 1.1.1.1, vrf is default, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5),
Target IP address:  3.3.3.3
Repeat count [5]: 4
Datagram size [100]: 100
Timeout in seconds [2]: 1
Interval in milliseconds [10]: 10
Extended commands? [no]: no
Sweep range of sizes? [no]: no
Sending 4, 100-byte ICMP Echos to 1.1.1.1, vrf is default, timeout is 1 seconds:
!!!!!
Success rate is 100 percent (4/5),
```

### Associated Commands

- ping bulk ipv4

# Traceroute

Where the **ping** command can be used to verify connectivity between devices, the **traceroute** command can be used to discover the paths packets take to a remote destination and where routing breaks down.

The **traceroute** command records the source of each ICMP "time-exceeded" message to provide a trace of the path that the packet took to reach the destination. You can use the IP **traceroute** command to identify the path that packets take through the network on a hop-by-hop basis. The command output displays all network layer (Layer 3) devices, such as routers, that the traffic passes through on the way to the destination.

The **traceroute** command uses the Time To Live (TTL) field in the IP header to cause routers and servers to generate specific return messages. The **traceroute** command sends a User Datagram Protocol (UDP) datagram to the destination host with the TTL field set to 1. If a router finds a TTL value of 1 or 0, it drops the datagram and sends back an ICMP time-exceeded message to the sender. The traceroute facility determines the address of the first hop by examining the source address field of the ICMP time-exceeded message.

To identify the next hop, the **traceroute** command sends a UDP packet with a TTL value of 2. The first router decrements the TTL field by 1 and sends the datagram to the next router. The second router sees a TTL value of 1, discards the datagram, and returns the time-exceeded message to the source. This process continues until the TTL increments to a value large enough for the datagram to reach the destination host (or until the maximum TTL is reached).

To determine when a datagram reaches its destination, the **traceroute** command sets the UDP destination port in the datagram to a very large value that the destination host is unlikely to be using. When a host receives a datagram with an unrecognized port number, it sends an ICMP port unreachable error to the source. This message indicates to the traceroute facility that it has reached the destination.

## Checking Packet Routes

The **traceroute** command allows you to trace the routes that packets actually take when traveling to their destinations.

### Configuration Example

Trace the route from 10.0.0.2 to 20.1.1.1:

```
Router# traceroute 20.1.1.1
Type escape sequence to abort.
Tracing the route to 20.1.1.1
 1  10.0.0.1 39 msec  *  3 msec

*/If you do not enter a hostname or an IP address on the same line as the traceroute
command, the system prompts you to specify the target IP address and several other
command parameters. After specifying the target IP address, you can specify alternate
values for the remaining parameters or accept the displayed default for each
parameter/*

Router #traceroute
Protocol [ipv4]:
Target IP address: 20.1.1.1
Source address: 10.0.0.2
Numeric display? [no]:
Timeout in seconds [3]:
Probe count [3]:
Minimum Time to Live [1]:
Maximum Time to Live [30]:
Port Number [33434]:
Loose, Strict, Record, Timestamp, Verbose[none]:

Type escape sequence to abort.
Tracing the route to 20.1.1.1
 1  10.0.0.1 3 msec  *  3 msec
```

### Associated Commands

- traceroute

# Domain Services

Cisco IOS XR software domain services acts as a Berkeley Standard Distribution (BSD) domain resolver. The domain services maintains a local cache of hostname-to-address mappings for use by applications, such as Telnet, and commands, such as **ping** and **traceroute** . The local cache speeds the conversion of host names to addresses. Two types of entries exist in the local cache: static and dynamic. Entries configured using the **domain ipv4 host** or **domain ipv6 host** command are added as static entries, while entries received from the name server are added as dynamic entries.

The name server is used by the World Wide Web (WWW) for translating names of network nodes into addresses. The name server maintains a distributed database that maps hostnames to IP addresses through the

DNS protocol from a DNS server. One or more name servers can be specified using the **domain name-server** command.

When an application needs the IP address of a host or the hostname of an IP address, a remote-procedure call (RPC) is made to the domain services. The domain service looks up the IP address or hostname in the cache, and if the entry is not found, the domain service sends a DNS query to the name server.

You can specify a default domain name that Cisco IOS XR software uses to complete domain name requests. You can also specify either a single domain or a list of domain names. Any IP hostname that does not contain a domain name has the domain name you specify appended to it before being added to the host table. To specify a domain name or names, use either the **domain name** or **domain list** command.

# Configuring Domain Services

DNS-based hostname-to-address translation is enabled by default. If hostname-to-address translation has been disabled using the **domain lookup disable** command, re-enable the translation using the **no domain lookup disable** command.

### Configuration Example

Define a static hostname-to-address mapping. Associate (or map) the IPv4 addresses (192.168.7.18 and 10.2.0.2 192.168.7.33) with two hosts. The host names are host1 and host2.

```
Defining the Domain Host
==================================
Router# configure
Router(config)#domain ipv4 host host1 192.168.7.18
Router(config)#domain ipv4 host host2 10.2.0.2 192.168.7.33
Router(config)#commit

Defining the Domain Name
==========================
*/Define cisco.com as the default domain name/*
Router#configure
Router(config)#domain name cisco.com
Router(config)#commit

Specifying the Addresses of the Name Servers
=============================================
*/Specify host 192.168.1.111 as the primary name server
and host 192.168.1.2 as the secondary server/*
Router#configure
Router(config)#domain name-server 192.168.1.111
Router(config)#domain name-server 192.168.1.2
Router(config)#commit
```

### Verification

```
Router#show hosts
Default domain is cisco.com
Name/address lookup uses domain service
Name servers: 192.168.1.111, 192.168.1.2

Host                       Flags     Age(hr) Type Address(es)
host2                     (perm, OK)    0      IP  10.2.0.2
                                                   192.168.7.33
host1                     (perm, OK)    0      IP  192.168.7.18
```

### Associated Commands

- domain name
- domain list
- domain name-server
- domain ipv4 host
- domain ipv6 host

# File Transfer Services

File Transfer Protocol (FTP), Trivial File Transfer Protocol (TFTP), remote copy protocol (rcp) rcp clients, and Secure Copy Protocol (SCP) are implemented as file systems or resource managers. For example, path names beginning with tftp:// are handled by the TFTP resource manager.

The file system interface uses URLs to specify the location of a file. URLs commonly specify files or locations on the WWW. However, on Cisco routers, URLs also specify the location of files on the router or remote file servers.

When a router crashes, it can be useful to obtain a copy of the entire memory contents of the router (called a core dump) for your technical support representative to use to identify the cause of the crash. SCP, FTP, TFTP, rcp can be used to save the core dump to a remote server.

# FTP

File Transfer Protocol (FTP) is part of the TCP/IP protocol stack, which is used for transferring files between network nodes. FTP is defined in RFC 959.

## Configuring a Router to Use FTP Connections

You can configure the router to use FTP connections for transferring files between systems on the network. You can set the following FTP characteristics:

- Passive-mode FTP
- Password
- IP address

### Configuration Example

Enable the router to use FTP connections. Configure the software to use passive FTP connections, a password for anonymous users, and also specify the source IP address for FTP connections.

```
Router#configure
Router(config)#ftp client passive

Router(config)#ftp client anonymous-password xxxx
Router(config)#ftp client source-interface HundredGigE 0/0/0/0
Router(config)#commit
```

### Running Configuration

```
Router#show running-config ftp client passive
ftp client passive

Router#show running-config ftp client anonymous-password xxxx
ftp client anonymous-password xxxx
Router#show running-config ftp client source-interface HundredGigE 0/0/0/0
ftp client source-interface HundredGigE 0/0/0/0
```

### Associated Commands

- ftp client passive
- ftp client anonymous-password
- ftp client source-interface

# TFTP

Trivial File Transfer Protocol (TFTP) is a simplified version of FTP that allows files to be transferred from one computer to another over a network, usually without the use of client authentication (for example, username and password).

## TFTP Server

It is expensive and inefficient to have a machine that acts only as a server on every network segment. However, when you do not have a server on every segment, your network operations can incur substantial time delays across network segments. You can configure a router to serve as a TFTP server to reduce costs and time delays in your network while you use your router for its regular functions.

Typically, a router that you configure as a TFTP server enables the router to serve requests from client routers. This includes services such as providing client routers with system image or router configuration files from its flash memory. You can also configure the router to respond to other types of service requests.

## Configuring a Router as a TFTP Server

The server and client router must be able to reach each other before the TFTP function can be implemented. Verify this connection by testing the connection between the server and client router (in either direction) using the **ping** command.

This task allows you to configure the router as a TFTP server so other devices acting as TFTP clients are able to read and write files from and to the router under a specific directory, such as slot0:, /tmp, and so on (TFTP home directory).

**Note** For security reasons, the TFTP server requires that a file must already exist for a write request to succeed.

The server and client router must be able to reach each other before the TFTP function can be implemented. Verify this connection by testing the connection between the server and client router (in either direction) using the **ping** command.

### Configuration Example

Configure the router (home directory disk0:) as the TFTP server.

```
Router#configure
Router(config)#tftp ipv4 server homedir disk0
Router(config)#commit
```

### Running Configuration

```
Router#show running-config tftp ipv4 server homedir disk0:
tftp vrf default ipv4 server homedir disk0:
```

### Verification

```
Router#show cinetd services
Vrf Name Family Service     Proto Port ACL  max_cnt  curr_cnt wait  Program Client Option

default  v4     tftp    udp   69      unlimited 0       wait   tftpd   sysdb disk0:

default  v4       telnet      tcp   23      10         0       nowait telnetd sysdb
```

### Associated Commands

## Configuring a Router to Use TFTP Connections

### Configuration Example

Configure the router to use TFTP connections and set the IP address of the HundredGigE 0/0/0/0 as the source address for TFTP connections:

```
Router#configure
Router(config)#tftp client source-interface HundredGigE 0/0/0/0
Router(config)#commit
```

### Running Configuration

```
Router#show running-config tftp client source-interface HundredGigE 0/0/0/0
tftp client source-interface HundredGigE 0/0/0/0
```

### Verification

```
Router#show cinetd services
Vrf Name Family  Service  Proto Port ACL max_cnt  curr_cnt  wait   Program Client Option

default  v4     tftp udp    69      unlimited  0       wait   tftpd    sysdb disk0:

default  v4      telnet   tcp    23      10         0       nowait telnetd  sysdb
```

### Associated Commands

- tftp client source-interface type
- show cinetd services

# SCP

Secure Copy Protocol (SCP) is a file transfer protocol which provides a secure and authenticated method for transferring files. SCP relies on SSHv2 to transfer files from a remote location to a local location or from local location to a remote location.

Cisco IOS XR software supports SCP server and client operations. If a device receives an SCP request, the SSH server process spawns the SCP server process which interacts with the client. For each incoming SCP subsystem request, a new SCP server instance is spawned. If a device sends a file transfer request to a destination device, it acts as the client.

When a device starts an SSH connection to a remote host for file transfer, the remote device can either respond to the request in Source Mode or Sink Mode. In Source Mode, the device is the file source. It reads the file from its local directory and transfers the file to the intended destination. In Sink Mode, the device is the destination for the file to be transferred.

Using SCP, you can copy a file from the local device to a destination device or from a destination device to the local device.

Using SCP, you can only transfer individual files. You cannot transfer a file from a destination device to another destination device.

## Transferring Files Using SCP

Secure Copy Protocol (SCP) allows you to transfer files between source and destination devices. You can transfer one file at a time. If the destination is a server, SSH server process must be running.

### Configuration Example

Transfers the file "test123.txt" from the local directory to the remote directory.

```
Router#scp /harddisk:/test123.txt xyz@1.75.55.1:/auto/remote/test123.txt
Connecting to 1.75.55.1...
Password:
Router#commit
```

### Verification

Verify if the file "test123.txt" is copied:

```
xyz-lnx-v1:/auto/remote> ls -altr test123.txt
-rw-r--r-- 1 xyz eng 0 Nov 23 09:46 test123.txt
```

### Associated Commands

- scp

# Cisco inetd

Cisco Internet services process daemon (Cinetd) is a multithreaded server process that is started by the system manager after the system has booted. Cinetd listens for Internet services such as Telnet service, TFTP service, and so on. Whether Cinetd listens for a specific service depends on the router configuration. For example, when the **tftp server** command is entered, Cinetd starts listening for the TFTP service. When a request arrives, Cinetd runs the server program associated with the service.

# Telnet

Enabling Telnet allows inbound Telnet connections into a networking device.

### Configuration Example

Enable telnet and limit the number of simultaneous users that can access the router to 10.

```
Router# configure
Router(config)# telnet ipv4 server max-servers 10
Router(config)# commit
```

### Verification

```
Router# show cinetd services
Vrf Name  Family    Service   Proto Port ACL max_cnt  curr_cnt  wait   Program Client Option

default   v4         tftp      udp  69       unlimited  0         wait   tftpd   sysdb
disk0:
default   v4     telnet  tcp  23         10  0        nowait telnetd sysdb
```

### Associated Commands

# Syslog source-interface

You can configure the logging source interface to identify the syslog traffic, originating in a VRF from a particular router, as coming from a single device.

### Configuration Example

Enable a source interface for the remote syslog server. Configure interface loopback 2 to be the logging source interface for the default vrf.

```
Router#configure
Router(config)#logging source-interface Loopback2

Router(config)#commit
```

### Running Configuration

```
Router#show running-config logging
/*Logging configuration after changing the source into loopback2 interface.
logging console debugging
logging monitor debugging
logging facility local4
logging 123.100.100.189 vrf default severity info port default
logging source-interface Loopback2
```

### Associated Commands

- logging source-interface
- show running-configuration logging

CHAPTER 4

# Implementing Access Lists and Prefix Lists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# Understanding Access Lists

Access lists perform packet filtering to control which packets move through the network and where. Such controls help to limit network traffic and restrict the access of users and devices to the network. Access lists have many uses, and therefore many commands accept a reference to an access list in their command syntax. Access lists can be used to do the following:

An access control list (ACL) consists of one or more access control entries (ACE) that collectively define the network traffic profile. This profile can then be referenced by Cisco IOS XR software features such as traffic filtering, route filtering, QoS classification, and access control. There are 2 types of ACLs:

- Standard ACLs- Verifies only the source IP address of the packets. Traffic is controlled by the comparison of the address or prefix configured in the ACL, with the source address found in the packet.
- Extended ACLs- Verifies more than just the source address of the packets. Attributes such as destination address, specific IP protocols, UDP or TCP port numbers, DSCP, and so on are validated. Traffic is controlled by a comparison of the attributes stated in the ACL with those in the incoming or outgoing packets.

Cisco IOS XR does not differentiate between standard and extended access lists. Standard access list support is provided for backward compatibility.

### Purpose of IP Access Lists

- Filter incoming or outgoing packets on an interface.
- Filter packets for mirroring.
- Redirect traffic as required.

- Restrict the contents of routing updates.
- Limit debug output based on an address or protocol.
- Control vty access.
- Identify or classify traffic for advanced features, such as congestion avoidance, congestion management, and priority and custom queueing.

### How an IP Access List Works

An access list is a sequential list consisting of permit and deny statements that apply to IP addresses and possibly upper-layer IP protocols. The access list has a name by which it is referenced. Many software commands accept an access list as part of their syntax.

An access list can be configured and named, but it is not in effect until the access list is referenced by a command that accepts an access list. Multiple commands can reference the same access list. An access list can control traffic arriving at the router or leaving the router, but not traffic originating at the router.

Source address and destination addresses are two of the most typical fields in an IP packet on which to base an access list. Specify source addresses to control packets from certain networking devices or hosts. Specify destination addresses to control packets being sent to certain networking devices or hosts.

You can also filter packets on the basis of transport layer information, such as whether the packet is a TCP, UDP, ICMP, or IGMP packet.

### ACL Workflow

The following image illustrates the workflow of an ACL.

### IP Access List Process and Rules

Use the following process and rules when configuring an IP access list:

- The software tests the source or destination address or the protocol of each packet being filtered against the conditions in the access list, one condition (permit or deny statement) at a time.
- If a packet does not match an access list statement, the packet is then tested against the next statement in the list.
- If a packet and an access list statement match, the remaining statements in the list are skipped and the packet is permitted or denied as specified in the matched statement. The first entry that the packet matches determines whether the software permits or denies the packet. That is, after the first match, no subsequent entries are considered.
- If the access list denies the address or protocol, the software discards the packet and returns an Internet Control Message Protocol (ICMP) Host Unreachable message. ICMP is configurable in the Cisco IOS XR software.
- If no conditions match, the software drops the packet because each access list ends with an unwritten or implicit deny statement. That is, if the packet has not been permitted or denied by the time it was tested against each statement, it is denied.
- The access list should contain at least one permit statement or else all packets are denied.

- Because the software stops testing conditions after the first match, the order of the conditions is critical. The same permit or deny statements specified in a different order could result in a packet being passed under one circumstance and denied in another circumstance.
- Only one access list per interface, per protocol, per direction is allowed.
- Inbound access lists process packets arriving at the router. Incoming packets are processed before being routed to an outbound interface. An inbound access list is efficient because it saves the overhead of routing lookups if the packet is to be discarded because it is denied by the filtering tests. If the packet is permitted by the tests, it is then processed for routing. For inbound lists, permit means continue to process the packet after receiving it on an inbound interface; **deny** means discard the packet.
- Outbound access lists process packets before they leave the router. Incoming packets are routed to the outbound interface and then processed through the outbound access list. For outbound lists, permit means send it to the output buffer; deny means discard the packet.
- An access list can not be removed if that access list is being applied by an access group in use. To remove an access list, remove the access group that is referencing the access list and then remove the access list.
- Before removing an interface, which is configured with an ACL that denies certain traffic, you must remove the ACL and commit your configuration. If this is not done, then some packets are leaked through the interface as soon as the **no interface <interface-name>** command is configured and committed.
- An access list must exist before you can use the **ipv4 | ipv6 access group** command.

### ACL Filtering by Wildcard Mask and Implicit Wildcard Mask

Address filtering uses wildcard masking to indicate whether the software checks or ignores corresponding IP address bits when comparing the address bits in an access-list entry to a packet being submitted to the access list. By carefully setting wildcard masks, an administrator can select a single or several IP addresses for permit or deny tests.

Wildcard masking for IP address bits uses the number 1 and the number 0 to specify how the software treats the corresponding IP address bits. A wildcard mask is sometimes referred to as an *inverted mask*, because a 1 and 0 mean the opposite of what they mean in a subnet (network) mask.

- A wildcard mask bit 0 means *check* the corresponding bit value.
- A wildcard mask bit 1 means *ignore* that corresponding bit value.

You do not have to supply a wildcard mask with a source or destination address in an access list statement. If you use the **host** keyword, the software assumes a wildcard mask of 0.0.0.0.

Unlike subnet masks, which require contiguous bits indicating network and subnet to be ones, wildcard masks allow noncontiguous bits in the mask.

You can also use CIDR format (/x) in place of wildcard bits. For example, the IPv4 address 1.2.3.4 0.255.255.255 corresponds to 1.2.3.4/8 and for IPv6 address 2001:db8:abcd:0012:0000:0000:0000:0000 corresponds to 2001:db8:abcd:0012::0/64.

### Restrictions for Configuring Access Lists

You must be aware of the following restrictions for configuring access lists.

- IPv4 and IPv6 ACLs are not supported for loopback and interflex interfaces.

- If the TCAM utilization is high and large ACLs are modified, then an error may occur. During such instances, remove the ACL from the interface and reconfigure the ACL. Later, reapply the ACL to the interface.
- Filtering of MPLS packets through interface ACL is not supported.
- ICMP type and code such as ECHO, ECHO-REPLY, MASK-REPLY, MASK-REQUEST, and so on are not supported.
- From Release 6.0.2 onward, modifying an ACL when it is attached to the interface is supported.

### Including Comments in Access Lists

You can include comments (remarks) about entries in any named IP access list using the remark access list configuration command. The remarks make the access list easier for the network administrator to understand and scan. Each remark line is limited to 255 characters.

The remark can go before or after a **permit** or **deny** statement. You should be consistent about where you put the remark so it is clear which remark describes which **permit** or **deny** statement. For example, it would be confusing to have some remarks before the associated **permit** or **deny** statements and some remarks after the associated statements. Remarks can be sequenced.

Remember to apply the access list to an interface or terminal line after the access list is created.

# Configuring IPv4 ACLs

This section describes the basic configuration of IPv4 ingress and egress ACLs.

### Notes and Restrictions for Configuring IPv4 Ingress ACLs

IPv4 ingress ACLs are characterized by the following behavior.

- Ingress IPv4 ACLs are supported on all interfaces except management interfaces.
- ACL-based Forwarding (ABF) is supported only in the ingress direction.
- The total number of ACLs allowed by default per NPU is 31.
- The number of attached ACEs allowed per line card is 4000.
- Packet Length (using the **pkt-length** keyword) is supported only for ingress IPv4 ACLs. The **pkt-length** filtering values can only be specified in increments of 16 bytes by default.
- ACL logging with input interface (using the **log-input** keyword) is not supported.

### Notes and Restrictions for Configuring IPv4 Egress ACLs

IPv4 egress ACLs are characterized by the following behavior.

- Egress IPv4 ACLs are supported on main physical interfaces and bundle interfaces.

**Note** Egress ACLs are not directly supported on sub-interfaces. However, If you configure an egress ACL on a main interface that has sub-interfaces, the ACL action is also applied to the sub-interface traffic. This egress ACL behavior holds true even if the sub-interfaces are configured after the ACL is applied to the main interface.

- ACL is not supported on Management interface on egress direction.
- The number of attached ACEs allowed per line card is 4000.
- ACL logging (using the **log** command) and ACL logging with input interface (using the **log-input** command) is not supported.

### Configuring an Ingress IPv4 ACL on a Gigabit Ethernet Interface

Use the following configuration to configure an ingress IPv4 ACL on a GigE interface.

```
/* Configure a GigE interface with an IPv4 address */
Router(config)# interface gigabitEthernet 0/0/0/0
Router(config-if)# ipv4 address 10.1.1.1 255.255.255.0
Router(config-if)# no shut
Router(config-if)# commit
Thu Jan 25 10:07:54.700 IST
Router(config-if)# exit

/* Verify if the interface is up */
Router(config)# do show ipv4 interface brief
Thu Jan 25 10:08:49.087 IST

Interface                      IP-Address      Status          Protocol Vrf-Name
GigabitEthernet0/0/0/0         10.1.1.1        Up              Up       default

/* Configure an IPv4 ingress ACL */
Router(config)# ipv4 access-list V4-ACL-INGRESS
Router(config-ipv4-acl)# 10 permit tcp 10.2.1.1 0.0.0.255 any
Router(config-ipv4-acl)# 20 deny udp any any
Router(config-ipv4-acl)# 30 permit ipv4 10.2.0.0 0.255.255.255 any
Router(config-ipv4-acl)# commit
Thu Jan 25 10:16:11.473 IST

/* Verify the ingress ACL creation */
Router(config)# do show access-lists ipv4
Thu Jan 25 10:25:19.896 IST
...
ipv4 access-list V4-ACL-INGRESS
 10 permit tcp 10.2.1.0 0.0.0.255 any
 20 deny udp any any
 30 permit ipv4 10.0.0.0 0.255.255.255 any


/* Apply the ingress ACL to the GigE interface */
Router(config)# interface GigabitEthernet0/0/0/0
Router(config-if)# ipv4 access-group V4-ACL-INGRESS ingress
Router(config-if)# commit
Thu Jan 25 10:28:19.671 IST
Router(config-if)# exit
```

```
/* Verify if the ingress ACL has been successfully applied to the interface */
Router(config)# do show ipv4 interface
Thu Jan 25 10:29:44.944 IST
GigabitEthernet0/0/0/0 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is 10.1.1.1/24
  MTU is 1514 (1500 is available to IP)
  Helper address is not set
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  common access list is not set, access list is V4-ACL-INGRESS
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000
```

You have successfully configured an IPv4 ingress ACL on a Gigabit Ethernet interface.

### Configuring an Egress IPv4 ACL on a Gigabit Ethernet Interface

Use the following configuration to configure an egress IPv4 ACL on a GigE interface.

```
/* Configure a GigE interface with an IPv4 address */
Router(config)# interface gigabitEthernet 0/0/0/0
Router(config-if)# ipv4 address 20.1.1.1 255.255.255.0
Router(config-if)# no shut
Router(config-if)# commit
Thu Jan 25 10:08:38.767 IST
Router(config-if)# exit

/* Verify if the interface is up */
Router(config)# do show ipv4 interface brief
Thu Jan 25 10:08:49.087 IST

Interface                      IP-Address      Status          Protocol Vrf-Name
GigabitEthernet0/0/0/0         10.1.1.1        Up              Up       default
GigabitEthernet0/0/0/0         20.1.1.1        Up              Up       default

/* Configure an IPv4 egress ACL */
Router(config)# ipv4 access-list V4-ACL-EGRESS
Router(config-ipv4-acl)# 10 permit ipv4 10.2.0.0 0.255.255.255 20.2.0.0 0.255.255.255
Router(config-ipv4-acl)# 20 deny ipv4 any any
Router(config-ipv4-acl)# commit
Thu Jan 25 10:25:04.655 IST

/* Verify the egress ACL creation */
Router(config)# do show access-lists ipv4
Thu Jan 25 10:25:19.896 IST
ipv4 access-list V4-ACL-EGRESS
 10 permit ipv4 10.0.0.0 0.255.255.255 20.0.0.0 0.255.255.255
 20 deny ipv4 any any
...

/* Apply the egress ACL to the GigE interface */
Router(config)# interface gigabitEthernet 0/0/0/1
Router(config-if)# ipv4 access-group V4-ACL-EGRESS egress
Router(config-if)# commit
Thu Jan 25 10:28:45.937 IST
Router(config-if)# exit

/* Verify if the egress ACL has been successfully applied to the interface */
```

```
Router(config)# do show ipv4 interface
Thu Jan 25 10:29:44.944 IST
GigabitEthernet 0/0/0/1 is Up, ipv4 protocol is Up
  Vrf is default (vrfid 0x60000000)
  Internet address is 20.1.1.1/24
  MTU is 1514 (1500 is available to IP)
  Helper address is not set
  Directed broadcast forwarding is disabled
  Outgoing access list is V4-ACL-EGRESS
  Inbound  common access list is not set, access list is not set
  Proxy ARP is disabled
  ICMP redirects are never sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  Table Id is 0xe0000000
...
```

You have successfully configured an IPv4 egress ACL on a Gigabit Ethernet interface.

# Modifying ACLs

This section describes a sample configuration for modification of ACLs.

```
*/ Create an Access List*/
Router(config)#ipv4 access-list acl_1

*/Add entries (ACEs) to the ACL*/
Router(config-ipv4-acl)#10 permit ip host 10.3.3.3 host 172.16.5.34
Router(config-ipv4-acl)#20 permit icmp any any
Router(config-ipv4-acl)#30 permit tcp any host 10.3.3.3
Router(config-ipv4-acl)#end

*/Verify the entries of the ACL*/:
Router#show access-lists ipv4 acl_1
ipv4 access-list acl_1
10 permit ip host 10.3.3.3 host 172.16.5.34
20 permit icmp any any
30 permit tcp any host 10.3.3.3

*/Add new entries, one with a sequence number "15" and another without a sequence number
to the ACL. Delete an entry with the sequence number "30":*/
Router(config)#ipv4 access-list acl_1
Router(config-ipv4-acl)# 15 permit 10.5.5.5 0.0.0.255
Router(config-ipv4-acl)# no 30
Router(config-ipv4-acl)# permit 10.4.4.4 0.0.0.255
Router(config-ipv4-acl)# commit


*/When an entry is added without a sequence number, it is automatically given a sequence
number
that puts it at the end of the access list. Because the default increment is 10, the entry
 will have a sequence
number 10 higher than the last entry in the existing access list*/

*/Verify the entries of the ACL:*/
Router(config)#show access-lists ipv4 acl_1
ipv4 access-list acl_1
 10 permit ipv4 host 10.3.3.3 host 172.16.5.34

15 permit 10.5.5.5 0.0.0.255---*/newly added ACE (with the sequence number)*/
```

```
20 permit icmp any any
30 permit ipv4 10.4.4.0 0.0.0.255 any ---*/newly added ACE (without the sequence number)*/

*/The entry with the sequence number 30, that is, "30 permit tcp any host 10.3.3.3" is
deleted from the ACL*/
```

You have successfully modified ACLs in operation.

# Configuring ACLs with Fragment Control

The non-fragmented packets and the initial fragments of a packet were processed by IP extended access lists (if you apply this access list), but non-initial fragments were permitted, by default. However, now, the IP Extended Access Lists with Fragment Control feature allows more granularity of control over non-initial fragments of a packet. Using this feature, you can specify whether the system examines non-initial IP fragments of packets when applying an IP extended access list.

As non-initial fragments contain only Layer 3 information, these access-list entries containing only Layer 3 information, can now be applied to non-initial fragments also. The fragment has all the information the system requires to filter, so the access-list entry is applied to the fragments of a packet.

This feature adds the optional **fragments** keyword to the following IP access list commands: **deny** and **permit** . By specifying the **fragments** keyword in an access-list entry, that particular access-list entry applies only to non-initial fragments of packets; the fragment is either permitted or denied accordingly.

The behavior of access-list entries regarding the presence or absence of the **fragments** keyword can be summarized as follows:

| If the Access-List Entry has... | Then... |
|---|---|
| ...no **fragments** keyword and all of the access-list entry information matches | For an access-list entry containing only Layer 3 information:<br>• The entry is applied to non-fragmented packets, initial fragments, and non-initial fragments.<br><br>For an access-list entry containing Layer 3 and Layer 4 information:<br>• The entry is applied to non-fragmented packets and initial fragments.<br>    • If the entry matches and is a **permit** statement, the packet or fragment is permitted.<br>    • If the entry matches and is a **deny** statement, the packet or fragment is denied.<br>• The entry is also applied to non-initial fragments in the following manner. Because non-initial fragments contain only Layer 3 information, only the Layer 3 portion of an access-list entry can be applied. If the Layer 3 portion of the access-list entry matches, and<br>    • If the entry is a **permit** statement, the non-initial fragment is permitted.<br>    • If the entry is a **deny** statement, the next access-list entry is processed.<br><br>**Note** The deny statements are handled differently for non-initial fragments versus non-fragmented or initial fragments. |
| ...the **fragments** keyword and all of the access-list entry information matches | The access-list entry is applied only to non-initial fragments.<br><br>**Note** The **fragments** keyword cannot be configured for an access-list entry that contains any Layer 4 information. |

You should not add the **fragments** keyword to every access-list entry, because the first fragment of the IP packet is considered a non-fragment and is treated independently of the subsequent fragments. Because an initial fragment will not match an access list permit or deny entry that contains the **fragments** keyword, the packet is compared to the next access list entry until it is either permitted or denied by an access list entry that does not contain the **fragments** keyword. Therefore, you may need two access list entries for every deny entry. The first deny entry of the pair will not include the **fragments** keyword, and applies to the initial fragment. The second deny entry of the pair will include the **fragments** keyword and applies to the subsequent fragments. In the cases where there are multiple **deny** access list entries for the same host but with different Layer 4 ports, a single deny access-list entry with the **fragments** keyword for that host is all that has to be added. Thus all the fragments of a packet are handled in the same manner by the access list.

Packet fragments of IP datagrams are considered individual packets and each fragment counts individually as a packet in access-list accounting and access-list violation counts.

**Note** The **fragments** keyword cannot solve all cases involving access lists and IP fragments.

**Note** Within the scope of ACL processing, Layer 3 information refers to fields located within the IPv4 header; for example, source, destination, protocol. Layer 4 information refers to other data contained beyond the IPv4 header; for example, source and destination ports for TCP or UDP, flags for TCP, type and code for ICMP.

# Understanding IP Access List Logging Messages

Cisco IOS XR software can provide logging messages about packets permitted or denied by a standard IP access list. That is, any packet that matches the access list causes an informational logging message about the packet to be sent to the console. The level of messages logged to the console is controlled by the **logging console** command in global configuration mode.

The first packet that triggers the access list causes an immediate logging message, and subsequent packets are collected over 5-minute intervals before they are displayed or logged. The logging message includes the access list number, whether the packet was permitted or denied, the source IP address of the packet, and the number of packets from that source permitted or denied in the prior 5-minute interval.

However, you can use the { **ipv4 | ipv6** } **access-list log-update threshold** command to set the number of packets that, when they match an access list (and are permitted or denied), cause the system to generate a log message. You might do this to receive log messages more frequently than at 5-minute intervals.

**Caution** If you set the *update-number* argument to 1, a log message is sent right away, rather than caching it; every packet that matches an access list causes a log message. A setting of 1 is not recommended because the volume of log messages could overwhelm the system.

Even if you use the { **ipv4 | ipv6} access-list log-update threshold** command, the 5-minute timer remains in effect, so each cache is emptied at the end of 5 minutes, regardless of the number of messages in each cache. Regardless of when the log message is sent, the cache is flushed and the count reset to 0 for that message the same way it is when a threshold is not specified.

**Note** The logging facility might drop some logging message packets if there are too many to be handled or if more than one logging message is handled in 1 second. This behavior prevents the router from using excessive CPU cycles because of too many logging packets. Therefore, the logging facility should not be used as a billing tool or as an accurate source of the number of matches to an access list.

# Understanding Prefix Lists

Prefix lists are used in route maps and route filtering operations and can be used as an alternative to access lists in many Border Gateway Protocol (BGP) route filtering commands. A prefix is a portion of an IP address, starting from the far left bit of the far left octet. By specifying exactly how many bits of an address belong to a prefix, you can then use prefixes to aggregate addresses and perform some function on them, such as redistribution (filter routing updates).

### BGP Filtering Using Prefix Lists

Prefix lists can be used as an alternative to access lists in many BGP route filtering commands. It is configured under the Global configurations of the BGP protocol. The advantages of using prefix lists are as follows:

- Significant performance improvement in loading and route lookup of large lists.
- Incremental updates are supported.
- More user friendly CLI. The CLI for using access lists to filter BGP updates is difficult to understand and use because it uses the packet filtering format.
- Greater flexibility.

Before using a prefix list in a command, you must set up a prefix list, and you may want to assign sequence numbers to the entries in the prefix list.

### How the System Filters Traffic by Prefix List

Filtering by prefix list involves matching the prefixes of routes with those listed in the prefix list. When there is a match, the route is used. More specifically, whether a prefix is permitted or denied is based upon the following rules:

- An empty prefix list permits all prefixes.
- An implicit deny is assumed if a given prefix does not match any entries of a prefix list.
- When multiple entries of a prefix list match a given prefix, the longest, most specific match is chosen.

Sequence numbers are generated automatically unless you disable this automatic generation. If you disable the automatic generation of sequence numbers, you must specify the sequence number for each entry using the *sequence-number* argument of the **permit** and **deny** commands in IPv4 or IPv6 prefix list configuration command. Use the **no** form of the **permit** or **deny** command with the *sequence-number* argument to remove a prefix-list entry.

The **show** commands include the sequence numbers in their output.

# Configuring Prefix Lists

### Configuration Example

Creates a prefix-list "pfx_2" with a remark "Deny all routes with a prefix of 10/8". This prefix-list denies all prefixes matching /24 in 128.0.0.0/8.

```
Router#configure
Router(config)#ipv4 prefix-list pfx_2
/* Use the ipv6 access-list command to create an IPv6 access list */

Router(config-ipv4_pfx)#10 remark Deny all routes with a prefix of 10/8
Router(config-ipv4_pfx)#20 deny 128.0.0.0/8 eq 24
/* Repeat the above step as necessary. Use the no sequence-number command to delete an
entry. */

Router(config-ipv4_pfx)#commit
```

### Running Configuration

```
Router#show running-config ipv4 prefix-list pfx_2
ipv4 prefix-list pfx_2
 10 remark Deny all routes with a prefix of 10/8
 20 deny 128.0.0.0/8 eq 24
!
```

### Verification

Verify that the permit and remark settings are according to the set configuration.

```
Router# show prefix-list pfx_2
ipv4 prefix-list pfx_2
 10 remark Deny all routes with a prefix of 10/8
 20 deny 128.0.0.0/8 eq 24
RP/0/RP0/CPU0:ios#
```

### Associated Commands

- ipv4 prefix-list
- ipv6 prefix-list
- show prefix-list ipv4
- show prefix-list ipv6

# Sequencing Prefix List Entries and Revising the Prefix List

### Configuration Example

Assigns sequence numbers to entries in a named prefix list and how to add or delete an entry to or from a prefix list. It is assumed a user wants to revise a prefix list. Resequencing a prefix list is optional.

```
Router#config
Router(config)#ipv4 prefix-list cl_1
/* Use the ipv6 prefix-list command to create an IPv6 prefix-list */

Router(config)#10 permit 172.16.0.0 0.0.255.255
/* Repeat the above step as necessary adding statements by sequence number where you planned;
 use the no sequence-number command to delete an entry */

Router(config)#commit
end
Router#resequence prefix-list ipv4 cl_1 20 15
/* Use the resequence prefix-list ipv6 to resequence IPv6 prefix list */
```

### Running Configuration

```
/*Before resequencing/*
Router#show running-config ipv4 prefix-list cl_1
ipv4 prefix-list cl_1
 10 permit 172.16.0.0/16
!
/* After resequencing using the resequence prefix-list ipv4 cl_1 20 15 command: */
Router#show running-config ipv4 prefix-list cl_1
```

```
ipv4 prefix-list cl_1
 35 permit 172.16.0.0/16
!
```

### Verification

Verify that the prefix list has been resequenced:

```
Router#show prefix-list cl_1
ipv4 prefix-list cl_1
 35 permit 172.16.0.0/16
```

### Associated Commands

- resequence prefix-list ipv4
- resequence prefix-list ipv6
- ipv4 prefix-list
- ipv6 prefix-list
- show prefix-lists ipv4
- show prefix-lists ipv6

CHAPTER 5

# Implementing Cisco Express Forwarding


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# Implementing Cisco Express Forwarding

Cisco Express Forwarding (CEF) is an advanced, Layer 3 IP switching technology. CEF optimizes network performance and scalability for networks with large and dynamic traffic patterns, such as the Internet, on networks characterized by intensive web-based applications, or interactive sessions. CEF is an inherent feature and the users need not perform any configuration to enable it. If required, the users can change the default route purge delay and static routes. Cisco NCS 5500 Series Routers supports only single stage forwarding.

### Components

Cisco IOS XR software CEF always operates in CEF mode with two distinct components:

- Forwarding Information Base (FIB) database: The protocol-dependent FIB process maintains the forwarding tables for IPv4 and IPv6 unicast in the route processor and line card (LC). The FIB on each node processes Routing Information Base (RIB) updates, performing route resolution and maintaining FIB tables independently in the route processor and line card (LC). FIB tables on each node can be slightly different.
- Adjacency table—a protocol-independent adjacency information base (AIB)

CEF is a primary IP packet-forwarding database for Cisco IOS XR software. CEF is responsible for the following functions:

- Software switching path
- Maintaining forwarding table and adjacency tables (which are maintained by the AIB) for software and hardware forwarding engines

The following features are supported for CEF on Cisco IOS XR software:

- Bundle interface support
- Multipath support
- Route consistency
- High availability features such as packaging, restartability, and Out of Resource (OOR) handling
- OSPFv2 SPF prefix prioritization

- BGP attributes download

**CEF Benefits**

- Improved performance—CEF is less CPU-intensive than fast-switching route caching. More CPU processing power can be dedicated to Layer 3 services such as quality of service (QoS) and encryption.
- Scalability—CEF offers full switching capacity at each line card.
- Resilience—CEF offers an unprecedented level of switching consistency and stability in large dynamic networks. In dynamic networks, fast-switched cache entries are frequently invalidated due to routing changes. These changes can cause traffic to be process switched using the routing table, rather than fast switched using the route cache. Because the Forwarding Information Base (FIB) lookup table contains all known routes that exist in the routing table, it eliminates route cache maintenance and the fast-switch or process-switch forwarding scenario. CEF can switch traffic more efficiently than typical demand caching schemes.

The following CEF forwarding tables are maintained in Cisco IOS XR software:

- IPv4 CEF database—Stores IPv4 Unicast routes for forwarding IPv4 unicast packets
- IPv6 CEF database—Stores IPv6 Unicast routes for forwarding IPv6 unicast packets
- MPLS LFD database—Stores MPLS Label table for forwarding MPLS packets

# Verifying CEF

To view the details of the IPv4 or IPv6 CEF tables, use the following commands:

- show cef {*ipv4 address* | *ipv6 address*} hardware egress

Displays the IPv4 or IPv6 CEF table. The next hop and forwarding interface are displayed for each prefix. The output of the **show cef** command varies by location.

```
Router# show cef 203.0.1.2 hardware egress
  203.0.1.2/32, version 0, internal 0x1020001 0x0 (ptr 0x8d7db7f0) [1], 0x0 (0x8daeedf0),
0x0 (0x0)
 Updated Nov 20 13:33:23.557
 local adjacency 203.0.1.2
 Prefix Len 32, traffic index 0, Adjacency-prefix, precedence n/a, priority 15
   via 203.0.1.2/32, HundredGigE0/0/0/9, 3 dependencies, weight 0, class 0 [flags 0x0]
    path-idx 0 NHID 0x0 [0x8cfc81a0 0x0]
    next hop 203.0.1.2/32
    local adjacency
```

- show cef {ipv4 | ipv6} summary

Displays a summary of the IPv4 or IPv6 CEF table.

```
Router#show cef ipv4 summary
Fri Nov 20 13:50:45.239 UTC

Router ID is 216.1.1.1

IP CEF with switching (Table Version 0) for node0_RP0_CPU0

  Load balancing: L4
  Tableid 0xe0000000 (0x8cf5b368), Vrfid 0x60000000, Vrid 0x20000000, Flags 0x1019
  Vrfname default, Refcount 4129
```

```
  56 routes, 0 protected, 0 reresolve, 0 unresolved (0 old, 0 new), 7616 bytes
  13 rib, 0 lsd, 0:27 aib, 1 internal, 10 interface, 4 special, 1 default routes
  56 load sharing elements, 24304 bytes, 1 references
  1 shared load sharing elements, 432 bytes
  55 exclusive load sharing elements, 23872 bytes
  0 route delete cache elements
  13 local route bufs received, 1 remote route bufs received,  0 mix bufs received
  13 local routes, 0 remote routes
  13 total local route updates processed
  0 total remote route updates processed
  0 pkts pre-routed to cust card
  0 pkts pre-routed to rp card
  0 pkts received from core card
  0 CEF route update drops, 0 revisions of existing leaves
  0 CEF route update drops due to version mis-match
  Resolution Timer: 15s
  0 prefixes modified in place
  0 deleted stale prefixes
  0 prefixes with label imposition, 0 prefixes with label information
  0 LISP EID prefixes, 0 merged, via 0 rlocs
 28 next hops
  1 incomplete next hop

 0 PD backwalks on LDIs with backup path
```

- show cef { ipv4 address | ipv6 address } detail

Displays the details of the IPv4 or IPv6 CEF table.

```
Router#show cef 203.0.1.2 detail
203.0.1.2/32, version 0, internal 0x1020001 0x0 (ptr 0x8d7db7f0) [1], 0x0 (0x8daeedf0), 0x0
 (0x0)
 Updated Nov 20 13:33:23.556
 local adjacency 203.0.1.2
 Prefix Len 32, traffic index 0, Adjacency-prefix, precedence n/a, priority 15
  gateway array (0x8d84beb0) reference count 1, flags 0x0, source aib (10), 0 backups
                [2 type 3 flags 0x8401 (0x8d99a598) ext 0x0 (0x0)]
  LW-LDI[type=3, refc=1, ptr=0x8daeedf0, sh-ldi=0x8d99a598]
  gateway array update type-time 1 Nov 20 13:33:23.556
 LDI Update time Nov 20 13:33:23.556
 LW-LDI-TS Nov 20 13:33:23.556
   via 203.0.1.2/32, HundredGigE0/0/0/9, 3 dependencies, weight 0, class 0 [flags 0x0]
    path-idx 0 NHID 0x0 [0x8cfc81a0 0x0]
    next hop 203.0.1.2/32
    local adjacency
        Load distribution: 0 (refcount 2)

    Hash  OK  Interface                 Address
    0     Y   HundredGigE0/0/0/9        203.0.1.2
```

- show adjacency detail

Displays detailed adjacency information, including Layer 2 information for each interface. The output of the show adjacency command varies by location.

```
Router#show adjacency detail

-------------------------------------------------------------------------------
0/5/CPU0
-------------------------------------------------------------------------------
Interface                  Address                  Version  Refcount Protocol
Hu0/5/0/12                 (interface)                   13        1(    0)
```

```
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/30         (interface)              31        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/19         (interface)              20        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/16         (interface)              17        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/23         (interface)              24        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/22         (interface)              23        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/1          (interface)               2        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/6          (interface)               7        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/10         (interface)              11        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/31         (interface)              32        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/28         (interface)              29        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/35         (interface)              36        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4

                 Hu0/5/0/32         (interface)              33        1(     0)
                                   (interface entry)
                                   mtu: 1500, flags 1 4
```

```
Hu0/5/0/15                  (interface)                16        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/34                  (interface)                35        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/2                   (interface)                 3        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/26                  (interface)                27        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/0/0/9                   203.0.1.2                  50        2(    0) mpls
                           00109400000cea285f0b80248847
                           mtu: 8986, flags 1 0


Hu0/0/0/9                   203.0.1.2                  49        2(    0) ipv4
                           00109400000cea285f0b80240800
                           mtu: 8986, flags 1 0


Hu0/5/0/29                  (interface)                30        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/33                  (interface)                34        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/20                  (interface)                21        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/24                  (interface)                25        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/0                   (interface)                 1        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/4                   (interface)                 5        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4


Hu0/5/0/8                   (interface)                 9        1(    0)
                           (interface entry)
                           mtu: 1500, flags 1 4
```

```
Hu0/5/0/3                  (interface)                   4        1(    0)
                          (interface entry)
                          mtu: 1500, flags 1 4

Hu0/5/0/27                 (interface)                  28        1(    0)
                          (interface entry)
                          mtu: 1500, flags 1 4

Hu0/5/0/7                  (interface)                   8        1(    0)
                          (interface entry)
                          mtu: 1500, flags 1 4

Hu0/5/0/14                 (interface)                  15        1(    0)
                          (interface entry)
                          mtu: 1500, flags 1 4

Hu0/5/0/11                 (interface)                  12        1(    0)
                          (interface entry)
                          mtu: 1500, flags 1 4

Hu0/5/0/18                 (interface)                  19        1(    0)
                          (interface entry)
```

# Per-Flow Load Balancing

The system inherently supports the 7-tuple hash algorithm. Load balancing describes the functionality in a router that distributes packets across multiple links based on Layer 3 (network layer) and Layer 4 (transport layer) routing information. If the router discovers multiple paths to a destination, the routing table is updated with multiple entries for that destination.

Per-flow load balancing performs these functions:

- Incoming data traffic is evenly distributed over multiple equal-cost connections.
- Incoming data traffic is evenly distributed over multiple equal-cost connections member links within a bundle interface.
- Layer 2 bundle and Layer 3 (network layer) load balancing decisions are taken on IPv4, IPv6, and MPLS flows . If it is an IPv4 or an IPv6 payload, then a 7-tuple hashing is done. If it is an MPLS payload with three or less labels, then the hardware parses the payload underneath and identifies whether the payload packet has an IPv4 or an IPv6 header. If it is an IPv4 or IPv6 header, then a 4-tuple hashing is performed based on the IP source, IP destination, router ID, and label stack; otherwise, an MPLS label based hashing is performed. In case of MPLS label-based hashing, the top 4 labels are used in hash computation.
- A 7-tuple hash algorithm provides more granular load balancing and used for load balancing over multiple equal-cost Layer 3 (network layer) paths. The Layer 3 (network layer) path is on a physical interface or on a bundle interface. In addition, load balancing over member links can occur within a Layer 2 bundle interface.
- The 7-tuple load-balance hash calculation contains:
  - Source IP address
  - Destination IP address

- IP Protocol type
- Router ID
- Source port
- Destination port
- Input interface

### Per-Destination Load Balancing

Per destination load balancing is used for packets that transit over a recursive MPLS path (for example, learned through BGP 3107). Per-destination load balancing means the router distributes the packets based on the destination of the route. Given two paths to the same network, all packets for destination1 on that network go over the first path, all packets for destination2 on that network go over the second path, and so on. This preserves packet order, with potential unequal usage of the links. If one host receives the majority of the traffic all packets use one link, which leaves bandwidth on other links unused. A larger number of destination addresses leads to more equally used links.

# Configuring Static Route

Routers forward packets using either route information from route table entries that you manually configure or the route information that is calculated using dynamic routing algorithms. Static routes, which define explicit paths between two routers, cannot be automatically updated; you must manually reconfigure static routes when network changes occur. Static routes use less bandwidth than dynamic routes. Use static routes where network traffic is predictable and where the network design is simple. You should not use static routes in large, constantly changing networks because static routes cannot react to network changes. Most networks use dynamic routes to communicate between routers but might have one or two static routes configured for special cases. Static routes are also useful for specifying a gateway of last resort (a default router to which all unroutable packets are sent).

### Configuration Example

Create a static route between Router A and B over a HundredGigE interface. The destination IP address is 203.0.1.2/32 and the next hop address is 1.0.0.2.


```
Router(config)#router static address-family ipv4 unicast
Router(config-static-afi)#203.0.1.2/32 HundredGigE 0/0/0/9 1.0.0.2
Router(config-static-afi)#commit
```

### Running Configuration

```
Router#show running-config router static address-family ipv4 unicast
router static
 address-family ipv4 unicast
 203.0.1.2/32 HundredGigE 0/0/0/9 1.0.0.2
 !
!
```

### Verification

Verify that the Next Hop Flags fields indicate COMPLETE for accurate functioning of the configuration.

```
Router#show cef  203.0.1.2/32 hardware egress detail location 0/RP0/CPU0
203.0.1.2/32, version 0, internal 0x1020001 0x0 (ptr 0x8d7db7f0) [1], 0x0 (0x8daeedf0), 0x0
 (0x0)
 Updated Nov 20 13:33:23.557
 local adjacency 203.0.1.2
 Prefix Len 32, traffic index 0, Adjacency-prefix, precedence n/a, priority 15
   via 203.0.1.2/32, HundredGigE0/0/0/9, 3 dependencies, weight 0, class 0 [flags 0x0]
    path-idx 0 NHID 0x0 [0x8cfc81a0 0x0]
    next hop 1.0.0.2
    local adjacency
```

### Associated Commands

- router static
- show cef

# BGP Attributes Download

The BGP Attributes Download feature enables you to display the installed BGP attributes in CEF.

- The **show cef bgp-attribute** command displays the installed BGP attributes in CEF.
- The **show cef bgp-attribute** *attribute-id* command and the **show cef bgp-attribute** *local-attribute-id* command are used to view the specific BGP attributes by attribute ID and local attribute ID.

### Verification

```
Router# show cef bgp-attribute
Router ID is 216.1.1.1

IP CEF with switching (Table Version 0) for node0_RP0_CPU0

  Load balancing: L4
  Tableid 0xe0000000 (0x8cf5b368), Vrfid 0x60000000, Vrid 0x20000000, Flags 0x1019
  Vrfname default, Refcount 4129
  56 routes, 0 protected, 0 reresolve, 0 unresolved (0 old, 0 new), 7616 bytes
  13 rib, 0 lsd, 0:27 aib, 1 internal, 10 interface, 4 special, 1 default routes
  56 load sharing elements, 24304 bytes, 1 references
  1 shared load sharing elements, 432 bytes
  55 exclusive load sharing elements, 23872 bytes
  0 route delete cache elements
  13 local route bufs received, 1 remote route bufs received,  0 mix bufs received
  13 local routes, 0 remote routes
  13 total local route updates processed
  0 total remote route updates processed
  0 pkts pre-routed to cust card
  0 pkts pre-routed to rp card
  0 pkts received from core card
  0 CEF route update drops, 0 revisions of existing leaves
  0 CEF route update drops due to version mis-match
  Resolution Timer: 15s
  0 prefixes modified in place
  0 deleted stale prefixes
  0 prefixes with label imposition, 0 prefixes with label information
  0 LISP EID prefixes, 0 merged, via 0 rlocs
```

```
 28 next hops
  1 incomplete next hop

 0 PD backwalks on LDIs with backup path


VRF: default
_____________
Table ID: 0xe0000000. Total number of entries: 0
OOR state: GREEN. Number of OOR attributes: 0
```

### Associated Commands

- show cef bgp-attribute

CHAPTER 6

# Implementing LPTS


- LPTS Overview, on page 75
- LPTS Policers, on page 75


## LPTS Overview

Local Packet Transport Services (LPTS) maintains tables describing all packet flows destined for the secure domain router (SDR), making sure that packets are delivered to their intended destinations.

LPTS uses two components to accomplish this task: the port arbitrator and flow managers. The port arbitrator and flow managers are processes that maintain the tables that describe packet flows for a logical router, known as the Internal Forwarding Information Base (IFIB). The IFIB is used to route received packets to the correct Route Processor for processing.

LPTS interfaces internally with all applications that receive packets from outside the router. LPTS functions without any need for customer configuration. However, the policer values can be customized if required. The LPTS show commands are provided that allow customers to monitor the activity and performance of LPTS flow managers and the port arbitrator.

## LPTS Policers

In Cisco IOS XR, the control packets, which are destined to the Route Processor (RP), are policed using a set of ingress policers in the incoming ports. These policers are programmed statically during bootup by LPTS components. The policers are applied based on the flow type of the incoming control traffic. The flow type is determined by looking at the packet headers. The policer rates for these static ingress policers are defined in a configuration file, which are programmed on the route processor during bootup. You can change the policer values based on the flow types of these set of ingress policers. You are able to configure the rate per policer per node.

**Note**

- You can get the default policer values and the current rates of the flow types from the output of the following show command:

```
show lpts pifib hardware police
```

### Configuration Example

Configure the LPTS policer for the OSPF and BGP flowtypes with the following values globally for all nodes:

- ospf unicast default rate 3000
- bgp default rate 4000

```
Router#configure
Router(config)#lpts pifib hardware police
Router(config-pifib-policer-global)#flow ospf unicast default rate 3000
Router(config-pifib-policer-global)#flow bgp default rate 4000
Router (config-pifib-policer-global)#commit
```

### Running Configuration

```
lpts pifib hardware police
flow ospf unicast default rate 3000
flow bgp default rate 4000
!
```

### Verification

```
Router#show run lpts pifib hardware police
lpts pifib hardware police
flow ospf unicast default rate 3000
flow bgp default rate 4000
```

### Configuration Example

Configure the LPTS policer for the OSPF and BGP flow types with the following values on an individual node - 0/0/CPU0:

- ospf unicast default rate 3000
- flow bgp default rate 4000

```
Router#configure
Router(config)#lpts pifib hardware police location 0/0/CPU0
Router(config-pifib-policer-per-node)#flow ospf unicast default rate 3000
Router(config-pifib-policer-per-node)#flow bgp default rate 4000
Router(config-pifib-policer-per-node)#commit
```

### Running Configuration

```
lpts pifib hardware police location 0/0/CPU0
flow ospf unicast default rate 3000
flow bgp default rate 4000
```

### Verification

The **show lpts pifib hardware police location 0/0/CPU0** command displays pre-Internal Forwarding Information Base (IFIB) information for the designated node.

```
Router#show lpts pifib hardware police location 0/0/CPU0
------------------------------------------------------------
                Node 0/0/CPU0:
-------------------------------------------------------------
 Burst = 100ms for all flow types
-------------------------------------------------------------
FlowType               Policer Type    Cur. Rate Burst     npu
```

```
---------------------- ------- ------- --------- --------- ---------
OSPF-uc-default        32106   np      3000      1000      0
BGP-default            32118   np      4000      1250      0
```

### Verification

The **show controllers npu stats traps-all instance all location 0/0/CPU0** command displays packets that are locally processed and packets that are dropped by the CPU.

```
Router# show controllers npu stats traps-all instance all location 0/0/CPU0

Trap Type                                    NPU  Trap TrapStats  Policer Packet    Packet

                                             ID    ID     ID             Accepted  Dropped
==========================================================================================
RxTrapMimSaMove(CFM_DOWM_MEP_DMM)             0    6     0x6         32037   0          0

RxTrapMimSaUnknown(RCY_CFM_DOWN_MEP_DMM)      0    7     0x7         32037   0          0

RxTrapAuthSaLookupFail (IPMC default)         0    8     0x8         32033   0          0

RxTrapSaMulticast                             0    11    0xb         32018   0          0

RxTrapArpMyIp                                 0    13    0xd         32001   0          0

RxTrapArp                                     0    14    0xe         32001   11         0

RxTrapDhcpv4Server                            0    18    0x12        32022   0          0

RxTrapDhcpv4Client                            0    19    0x13        32022   0          0

RxTrapDhcpv6Server                            0    20    0x14        32022   0          0

RxTrapDhcpv6Client                            0    21    0x15        32022   0          0

RxTrapL2Cache_LACP                            0    23    0x17        32003   0          0

RxTrapL2Cache_LLDP1                           0    24    0x18        32004   0          0

RxTrapL2Cache_LLDP2                           0    25    0x19        32004   1205548    0

RxTrapL2Cache_LLDP3                           0    26    0x1a        32004   0          0

RxTrapL2Cache_ELMI                            0    27    0x1b        32005   0          0

RxTrapL2Cache_BPDU                            0    28    0x1c        32027   0          0

RxTrapL2Cache_BUNDLE_BPDU                     0    29    0x1d        32027   0          0

RxTrapL2Cache_CDP                             0    30    0x1e        32002   0          0

RxTrapHeaderSizeErr                           0    32    0x20        32018   0          0

RxTrapIpCompMcInvalidIp                       0    35    0x23        32018   0          0

RxTrapMyMacAndIpDisabled                      0    36    0x24        32018   0          0

RxTrapMyMacAndMplsDisable                     0    37    0x25        32018   0          0

RxTrapArpReply                                0    38    0x26        32001   2693       0

RxTrapFibDrop                                 0    41    0x29        32018   0          0

RxTrapMTU                                     0    42    0x2a        32020   0          0
```

| | | | | | | |
|---|---|---|---|---|---|---|
| RxTrapMiscDrop | 0 | 43 | 0x2b | 32018 | 0 | 0 |
| RxTrapL2AclDeny | 0 | 44 | 0x2c | 32034 | 0 | 0 |
| Rx_UNKNOWN_PACKET | 0 | 46 | 0x2e | 32018 | 0 | 0 |
| RxTrapL3AclDeny | 0 | 47 | 0x2f | 32034 | 0 | 0 |
| RxTrapOamY1731MplsTp(OAM_SWOFF_DN_CCM) | 0 | 57 | 0x39 | 32029 | 0 | 0 |
| RxTrapOamY1731Pwe(OAM_SWOFF_DN_CCM) | 0 | 58 | 0x3a | 32030 | 0 | 0 |
| RxTrapOamLevel | 0 | 64 | 0x40 | 32023 | 0 | 0 |
| RxTrapRedirectToCpuOamPacket | 0 | 65 | 0x41 | 32025 | 0 | 0 |
| RxTrapOamPassive | 0 | 66 | 0x42 | 32024 | 0 | 0 |
| RxTrap1588 | 0 | 67 | 0x43 | 32038 | 0 | 0 |
| RxTrapExternalLookupError | 0 | 72 | 0x48 | 32018 | 0 | 0 |
| RxTrapArplookupFail | 0 | 73 | 0x49 | 32001 | 0 | 0 |
| RxTrapUcLooseRpfFail | 0 | 84 | 0x54 | 32035 | 0 | 0 |
| RxTrapMplsControlWordTrap | 0 | 88 | 0x58 | 32015 | 0 | 0 |
| RxTrapMplsControlWordDrop | 0 | 89 | 0x59 | 32015 | 0 | 0 |
| RxTrapMplsUnknownLabel | 0 | 90 | 0x5a | 32018 | 0 | 0 |
| RxTrapIpv4VersionError | 0 | 98 | 0x62 | 32018 | 0 | 0 |
| RxTrapIpv4ChecksumError | 0 | 99 | 0x63 | 32018 | 0 | 0 |
| RxTrapIpv4HeaderLengthError | 0 | 100 | 0x64 | 32018 | 0 | 0 |
| RxTrapIpv4TotalLengthError | 0 | 101 | 0x65 | 32018 | 0 | 0 |
| RxTrapIpv4Ttl0 | 0 | 102 | 0x66 | 32008 | 0 | 0 |
| RxTrapIpv4Ttl1 | 0 | 104 | 0x68 | 32008 | 0 | 0 |
| RxTrapIpv4DipZero | 0 | 106 | 0x6a | 32018 | 0 | 0 |
| RxTrapIpv4SipIsMc | 0 | 107 | 0x6b | 32018 | 0 | 0 |
| RxTrapIpv6VersionError | 0 | 109 | 0x6d | 32018 | 0 | 0 |
| RxTrapIpv6HopCount0 | 0 | 110 | 0x6e | 32011 | 0 | 0 |
| RxTrapIpv6LoopbackAddress | 0 | 113 | 0x71 | 32018 | 0 | 0 |
| RxTrapIpv6MulticastSource | 0 | 114 | 0x72 | 32018 | 0 | 0 |
| RxTrapIpv6NextHeaderNull | 0 | 115 | 0x73 | 32010 | 0 | 0 |
| RxTrapIpv6Ipv4CompatibleDestination | 0 | 121 | 0x79 | 32018 | 0 | 0 |
| RxTrapMplsTtl1 | 0 | 125 | 0x7d | 32012 | 316278 | 2249 |
| RxTrapUcStrictRpfFail | 0 | 137 | 0x89 | 32035 | 0 | 0 |

```
RxTrapMcExplicitRpfFail                     0    138  0x8a       32033   0          0
RxTrapOamp(OAM_BDL_DN_NON_CCM)              0    141  0x8d       32031   0          0
RxTrapOamEthUpAccelerated(OAM_BDL_UP_NON_CCM) 0  145  0x91       32032   0          0
RxTrapReceive                               0    150  0x96       32017   125266112  0
RxTrapUserDefine_FIB_IPV4_NULL0             0    151  0x97       32018   0          0
RxTrapUserDefine_FIB_IPV6_NULL0             0    152  0x98       32018   0          0
RxTrapUserDefine_FIB_IPV4_GLEAN             0    153  0x99       32016   0          0
RxTrapUserDefine_FIB_IPV6_GLEAN             0    154  0x9a       32016   0          0
RxTrapUserDefine_IPV4_OPTIONS               0    155  0x9b       32006   0          0
RxTrapUserDefine_IPV4_RSVP_OPTIONS          0    156  0x9c       32007   0          0
RxTrapUserDefine                            0    157  0x9d       32026   0          0
RxTrapUserDefine_BFD                        0    163  0xa3       32028   0          0
RxTrapMC                                    0    181  0xb5       32033   0          0
RxNetflowSnoopTrap0                         0    182  0xb6       32018   0          0
RxNetflowSnoopTrap1                         0    183  0xb7       32018   0          0
RxTrapMimSaMove(CFM_DOWM_MEP_DMM)           1    6    0x6        32037   0          0
RxTrapMimSaUnknown(RCY_CFM_DOWN_MEP_DMM)    1    7    0x7        32037   0          0
RxTrapAuthSaLookupFail (IPMC default)       1    8    0x8        32033   0          0
RxTrapSaMulticast                           1    11   0xb        32018   0          0
RxTrapArpMyIp                               1    13   0xd        32001   0          0
```

### Associated Commands

- lpts pifib hardware police
- flow ospf
- flow bgp
- show lpts pifib hardware police

CHAPTER 7

# Configuring Transports


- Information About Configuring NSR, TCP, UDP Transports, on page 81


# Information About Configuring NSR, TCP, UDP Transports

To configure NSR, TCP, UDP, and RAW transports, you must understand the following concepts:

## NSR Overview

Nonstop Routing (NSR) is provided for Open Shortest Path First (OSPF), Border Gateway Protocol (BGP), and Label Distribution Protocol (LDP) protocols for the following events:

- Route Processor (RP) failover
- Process restart for either OSPF, LDP, or TCP
- Online insertion removal (OIR)

In the case of the RP failover, NSR is achieved by for both TCP and the applications (OSPF, BGP, or LDP).

NSR is a method to achieve High Availability (HA) of the routing protocols. TCP connections and the routing protocol sessions are migrated from the active RP to standby RP after the RP failover without letting the peers know about the failover. Currently, the sessions terminate and the protocols running on the standby RP reestablish the sessions after the standby RP goes active. Graceful Restart (GR) extensions are used in place of NSR to prevent traffic loss during an RP failover but GR has several drawbacks.

You can use the **nsr process-failures switchover** command to let the RP failover be used as a recovery action when the active TCP or active LDP restarts. When standby TCP or LDP restarts, only the NSR capability is lost till the standby instances come up and the sessions are resynchronized but the sessions do not go down. In the case of the process failure of an active OSPF, a fault-management policy is used. For more information, refer to Implementing OSPF on Routing Configuration Guide for Cisco NCS 5500 Series Routers .

## TCP Overview

TCP is a connection-oriented protocol that specifies the format of data and acknowledgments that two computer systems exchange to transfer data. TCP also specifies the procedures the computers use to ensure that the data arrives correctly. TCP allows multiple applications on a system to communicate concurrently, because it handles all demultiplexing of the incoming traffic among the application programs.

# UDP Overview

The User Datagram Protocol (UDP) is a connectionless transport-layer protocol that belongs to the IP family. UDP is the transport protocol for several well-known application-layer protocols, including Network File System (NFS), Simple Network Management Protocol (SNMP), Domain Name System (DNS), and TFTP.

Any IP protocol other than TCP and UDP is known as a RAW protocol.

For most sites, the default settings for the TCP, UDP, and RAW transports need not be changed.

# Configuring Failover as a Recovery Action for NSR

When the active TCP or the NSR client of the active TCP terminates or restarts, the TCP sessions go down. To continue to provide NSR, failover is configured as a recovery action. If failover is configured, a switchover is initiated if the active TCP or an active application (for example, LDP, OSPF, and so forth) restarts or terminates.

For information on how to configure MPLS Label Distribution Protocol (LDP) for NSR, refer to the MPLS Configuration Guide for Cisco NCS 5500 Series Routers .

For information on how to configure NSR on a per-process level for each process, refer to the Routing Configuration Guide for Cisco NCS 5500 Series Routers .

### Configuration Example

Configure failover as a recovery action for active instances to switch over to a standby to maintain nonstop routing.

```
Router#configure
Router(config)#nsr process-failures switchover
Router(config)#commit
```

### Running Configuration

```
Router#show running-configuration nsr process-failures switchover
nsr process-failures switchover
```

### Associated Commands

- nsr process-failures switchover