



Configure IP-in-IP Tunnels

This chapter provides conceptual and configuration information for IP-in-IP tunnels.

Table 1: Feature History for Configure Tunnels

Release 7.0.11	This feature was introduced.
Release 7.0.14	Support for the following feature was introduced in Configure Tunnels: • Extended ACL must match on the outer header for IP-in-IP Decapsulation.

Table 2: Feature History Table

Feature Name	Release Information	Feature Description
IPv4 packets with IPv6 outer header	Release 7.5.3	With this release, decapsulation of IPv4 and IPv6 tunnels with IPv6 outer headers are supported. This feature helps the administrators to take advantage of the benefits of IPv6, such as improved routing and security, without having to upgrade their entire network to IPv6.

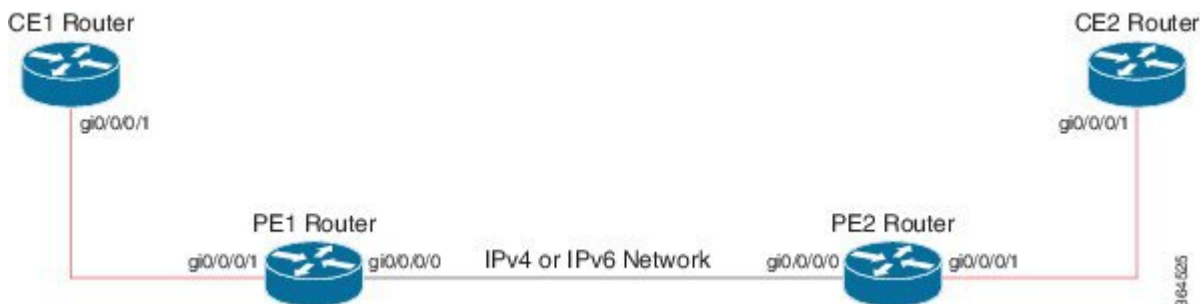
Overview of IP-in-IP Tunnels

Tunneling provides a mechanism to transport packets of one protocol within another protocol. IP-in-IP tunneling refers to the encapsulation and decapsulation of an IP packet as a payload in another IP packet. Cisco 8000 Series Routers support IP-in-IP decapsulation with all possible combinations of IPv4 and IPv6; that is, IPv4 over IPv4, IPv6 over IPv4, IPv4 over IPv6, and IPv6 over IPv6. For example, an IPv4 over IPv6 refers to an IPv4 packet as a payload encapsulated within an IPv6 packet and routed across an IPv6 network to reach the destination IPv4 network, where it is decapsulated.

IP-in-IP tunneling can be used to connect remote networks securely or provide virtual private network (VPN) services.

The following example provides configurations for an IPv4 or IPv6 tunnel, with the transport VRF as the default VRF for the following simplified network topology.

Figure 1: IP-in-IP Tunnel Network Topology



Guidelines and Restrictions for Configure IP-in-IP Tunnels

- The feature does not support decapsulation tunnels on subinterfaces.
- Only the default Virtual Routing and Forwarding (VRF) instance is supported.
- IPv6 link local addresses are not supported.
- Regular tunnels cannot use a configured IP address as the tunnel source; only a non-existent IP address can be used.
- Configuring multiple interfaces with the same IP address is not supported.
- Each line card can have different number of Network Processor (NP) slices.
- The maximum IPv4 and IPv6 IP-in-IP decapsulation tunnels supported is 64 per slice.

Configuration Example for IPv4 Tunnel

PE1 Router Configuration	PE2 Router Configuration
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<pre> interface GigabitEthernet0/0/0/0 !! Link between PE1-PE2 ipv4 address 100.1.1.1/24 ! interface GigabitEthernet0/0/0/1 !! Link between CE1-PE1 ipv4 address 20.1.1.1/24 ipv6 address 20::1/64 ! interface tunnel-ip 1 ipv4 address 10.1.1.1/24 ipv6 address 10::1/64 tunnel mode ipv4 tunnel source GigabitEthernet0/0/0/0 tunnel destination 100.1.1.2 ! router static address-family ipv4 unicast 30.1.1.0/24 tunnel-ip1 address-family ipv6 unicast 30::0/64 tunnel-ip1 ! ! ! </pre>	<pre> interface GigabitEthernet0/0/0/0 !! Link between PE1-PE2 ipv4 address 100.1.1.2/24 ! interface GigabitEthernet0/0/0/1 !! Link between PE2-CE2 ipv4 address 30.1.1.1/24 ipv6 address 30::1/64 ! interface tunnel-ip 1 ipv4 address 10.1.1.2/24 ipv6 address 10::2/64 tunnel mode ipv4 tunnel source GigabitEthernet0/0/0/0 tunnel destination 100.1.1.1 ! router static address-family ipv4 unicast 20.1.1.0/24 tunnel-ip1 address-family ipv6 unicast 20::0/64 tunnel-ip1 ! ! ! </pre>
CE1 Router Configuration	CE2 Router Configuration
<pre> interface GigabitEthernet0/0/0/1 !! Link between CE1-PE1 ipv4 address 20.1.1.2 255.255.255.0 ipv6 address 20::2/64 ! router static address-family ipv4 unicast 30.1.1.0/24 20.1.1.1 address-family ipv6 unicast 30::0/64 20::1 ! ! ! </pre>	<pre> interface GigabitEthernet0/0/0/1 !! Link between CE2-PE2 ipv4 address 30.1.1.2 255.255.255.0 ipv6 address 30::2/64 ! router static address-family ipv4 unicast 20.1.1.0/24 30.1.1.1 address-family ipv6 unicast 20::0/64 30::1 ! ! ! </pre>

Configuration Example for IPv6 Tunnel

PE1 Router Configuration	PE2 Router Configuration
---------------------------------	---------------------------------

<pre> interface GigabitEthernet0/0/0/0 !! Link between PE1-PE2 ipv6 address 100::1/64 ! interface GigabitEthernet0/0/0/1 !! Link between CE1-PE1 vrf RED ipv4 address 20.1.1.1/24 ipv6 address 20::1/64 ! interface tunnel-ip 1 vrf RED ipv4 address 10.1.1.1/24 ipv6 address 10::1/64 tunnel mode ipv6 tunnel source GigabitEthernet0/0/0/0 tunnel destination 100::2 ! vrf RED address-family ipv6 unicast import route-target 2:1 ! export route-target 2:1 ! address-family ipv4 unicast import route-target 2:1 ! export route-target 2:1 ! router static vrf RED address-family ipv4 unicast 30.1.1.0/24 tunnel-ip1 address-family ipv6 unicast 30::0/64 tunnel-ip1 ! ! ! </pre>	<pre> interface GigabitEthernet0/0/0/0 !! Link between PE1-PE2 ipv6 address 100::2/64 ! interface GigabitEthernet0/0/0/1 !! Link between PE2-CE2 vrf RED ipv4 address 30.1.1.1/24 ipv6 address 30::1/64 ! interface tunnel-ip 1 vrf RED ipv4 address 10.1.1.2/24 ipv6 address 10::2/64 tunnel mode ipv6 tunnel source GigabitEthernet0/0/0/0 tunnel destination 100::1 ! vrf RED address-family ipv6 unicast import route-target 2:1 ! export route-target 2:1 ! address-family ipv4 unicast import route-target 2:1 ! export route-target 2:1 ! router static vrf RED address-family ipv4 unicast 20.1.1.0/24 tunnel-ip1 address-family ipv6 unicast 20::0/64 tunnel-ip1 ! ! ! </pre>
CE1 Router Configuration	CE2 Router Configuration
<pre> interface GigabitEthernet0/0/0/1 !! Link between CE1-PE1 ipv4 address 20.1.1.2 255.255.255.0 ipv6 address 20::2/64 ! router static address-family ipv4 unicast 30.1.1.0/24 20.1.1.1 address-family ipv6 unicast 30::0/64 20::1 ! ! ! </pre>	<pre> interface GigabitEthernet0/0/0/1 !! Link between CE2-PE2 ipv4 address 30.1.1.2 255.255.255.0 ipv6 address 30::2/64 ! router static address-family ipv4 unicast 20.1.1.0/24 30.1.1.1 address-family ipv6 unicast 20::0/64 30::1 ! ! ! </pre>

- [IP-in-IP Decapsulation, on page 5](#)
- [ECMP Hashing Support for Load Balancing, on page 13](#)

IP-in-IP Decapsulation

IP-in-IP encapsulation involves the insertion of an outer IP header over the existing IP header. The source and destination address in the outer IP header point to the endpoints of the IP-in-IP tunnel. The stack of IP headers is used to direct the packet over a predetermined path to the destination, provided the network administrator knows the loopback addresses of the routers transporting the packet. This tunneling mechanism can be used for determining availability and latency for most network architectures. It is to be noted that the entire path from source to the destination does not have to be included in the headers, but a segment of the network can be chosen for directing the packets.

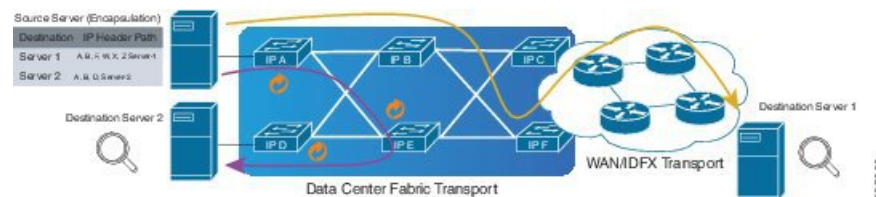
In IP-in-IP encapsulation and decapsulation has two types of packets. The original IP packets that are encapsulated are called Inner packets and the IP header stack added while encapsulation are called the Outer packets.



Note The router only supports decapsulation and no encapsulation. Encapsulation is done by remote routers.

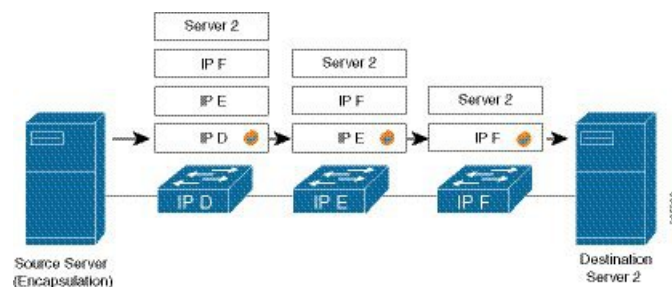
The following topology describes a use case where IP-in-IP encapsulation and decapsulation are used for different segments of the network from source to destination. The IP-in-IP tunnel consists of multiple routers that are used to decapsulate and direct the packet through the data center fabric network.

Figure 2: IP-in-IP Decapsulation Through a Data Center Network



The following illustration shows how the stacked IPv4 headers are decapsulated as they traverse through the decapsulating routers.

Figure 3: IP Header Decapsulation



Stacked IP Header in an Encapsulated Packet

The encapsulated packet has an outer IPv4 header that is stacked over the original IPv4 header, as shown in the following illustration.

Figure 4: Encapsulated Packet

Frame	
EthernetII	
Preamble (hex)	fb555555555555d5
Destination MAC	62:19:88:64:E2:68
Source MAC	00:10:94:00:00:02
EtherType (hex)	<auto> Internet IP
IPv4 Header	
Version (int)	<auto> 4
Header length (int)	<auto> 5
ToS/DiffServ	tos (0x00)
Total length (int)	<auto> calculated
Identification (int)	0
Control Flags	
Reserved (bit)	0
DF Bit (bit)	0
MF Bit (bit)	0
Fragment Offset (int)	0
Time to live (int)	255
Protocol (int)	<auto> IP
Checksum (int)	<auto> 33492
Source	192.xx.xx.xx
Destination	127.0.0.1
Header Options	
Gateway	192.0.2.10
IPv4 Header	
Version (int)	<auto> 4
Header length (int)	<auto> 5
ToS/DiffServ	tos (0x00)
Total length (int)	<auto> calculated
Identification (int)	0
Control Flags	
Reserved (bit)	0

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Configuration

You can use the following sample configuration in the routers to decapsulate the packet as it traverses the IP-in-IP tunnel:

```
Router(config)# interface loopback 0
Router(config-if)# ipv4 address 127.0.0.1/32
Router(config-if)# no shutdown
Router(config-if)# interface tunnel-ip 10
```

```
Router(config-if)# ipv4 unnumbered loopback 1
Router(config-if)# tunnel mode ipv4 decap
Router(config-if)# tunnel source loopback 0
```

- **tunnel-ip**: configures an IP-in-IP tunnel interface.
- **ipv4 unnumbered loopback address**: enables ipv4 packet processing without an explicit address, except for loopback address.
- **tunnel mode ipv4 decap**: enables IP-in-IP decapsulation.
- **tunnel source**: indicates the source address for the IP-in-IP decap tunnel with respect to the router interface.



Note You can configure the tunnel destination only if you want to decapsulate packets from a particular destination. If no tunnel destination is configured, then all the ip-in-ip ingress packets on the configured interface are decapsulated.

Running Configuration

```
Router# show running-config interface tunnel-ip 10
...
interface tunnel-ip 10
ipv4 unnumbered loopback 1
tunnel mode ipv4 decap
```

Extended ACL to Match the Outer Header for IP-in-IP Decapsulation

Starting with Cisco IOS XR Software Release 7.0.14, extended ACL has to match on the outer header for IP-in-IP Decapsulation. Extended ACL support reduces mirrored traffic throughput. This match is based only on the IPv4 protocol, and extended ACL is applied to the received outermost IP header, even if the outer header is locally terminated.

Sample configuration:

```
Router#show running-config interface bundle-Ether 50.5
Tue May 26 12:11:49.017 UTC
interface Bundle-Ether50.5
ipv4 address 101.1.5.1 255.255.255.0
encapsulation dot1q 5
ipv4 access-group ExtACL_IPinIP ingress
ipv4 access-group any_dscpegg egress
!

Router#show access-lists ipv4 ExtACL_IPinIP hardware ingress location$
Tue May 26 12:11:55.940 UTC
ipv4 access-list ExtACL_IPinIP
10 permit ipv4 192.168.0.0 0.0.255.255 any ttl gt 150
11 deny ipv4 172.16.0.0 0.0.255.255 any fragments
12 permit ipv4 any any
```

Decapsulation using tunnel source direct

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
Decapsulation using tunnel source direct	Release 7.5.3	Tunnel source direct allows you to decapsulate the tunnels on any L3 interface on the router. You can use the tunnel source direct configuration command to choose the specific IP Equal-Cost Multipath (ECMP) links for troubleshooting, when there are multiple IP links between two devices.

To debug faults in various large networks, you may have to capture and analyze the network traffic at a packet level. In datacenter networks, administrators face problems with the volume of traffic and diversity of faults. To troubleshoot faults in a timely manner, DCN administrators must identify affected packets inside large volumes of traffic. They must track them across multiple network components, analyze traffic traces for fault patterns, and test or confirm potential causes.

In some networks, IP-in-IP decapsulation is currently used in network management, to verify ECMP availability and to measure the latency of each path within a datacenter.

The Network Management System (NMS) sends IP-in-IP (IPv4 or IPv6) packets with a stack (multiple) of predefined IPv4 or IPv6 headers (device IP addresses). The destination device at each hop removes the outside header, performs a lookup on the next header, and forwards the packets if a route exists.

Using the **tunnel source direct** command, you can choose the specific IP Equal-Cost Multipath (ECMP) links for troubleshooting, when there are multiple IP links between two devices.



Tip You can programmatically configure and manage the Ethernet interfaces using `openconfig-ethernet-if.yang` and `openconfig-interfaces.yang` OpenConfig data models. To get started with using data models, see the *Programmability Configuration Guide for Cisco 8000 Series Routers*.

Guidelines and Limitations

The following guidelines are applicable to this feature.

- The **tunnel source direct** command is only compatible with 'tunnel mode decap' for IP-in-IP decapsulation.
- The source-direct tunnel is always operationally `up` unless it is administratively shut down. The directly connected interfaces are identified using the **show ip route direct** command.
- All Layer 3 interfaces that are configured on the device are supported.
- Platform can accept and program only certain number of IP addresses. The number of IP addresses depends on the make of the platform linecard (LC). Each LC can have different number of Network Processor (NP) slices and interfaces.

- Only one source-direct tunnel per address-family is supported for configuration.
- Regular decapsulation tunnels which have specific source address, are supported. However, the tunnel's specific source address must not be part of any interface.

The following functionalities are not supported for the **tunnel source direct** option.

- GRE tunneling mode.
- VRF (only default VRF is supported).
- ACL and QoS on the tunnels.
- Tunnel encapsulation.
- Tunnel NetIO DLL: Decapsulation is not supported if the packet is punted to slow path.

Configure Decapsulation Using Tunnel Source Direct

Configuration

The **tunnel source direct** configures IP-in-IP tunnel decapsulation on any directly connected IP addresses. This option is now supported only when the IP-in-IP decapsulation is used to source route the packets through the network.

This example shows how to configure IP-in-IP tunnel decapsulation on directly connected IP addresses:

```
Router# configure terminal
Router(config)#interface Tunnel4
Router(config)#tunnel mode ipv4 decap
Router(config)#tunnel source direct
Router(config)#no shutdown
```

This example shows how to configure IP-in-IP tunnel decapsulation on IPv6 enabled networks:

```
Router# configure terminal
Router(config)#interface Tunnel6
Router(config)#tunnel mode ipv6 decap
Router(config)#tunnel source direct
Router(config)#no shutdown
```

Verifying the Configuration

The following example shows how to verify IP-in-IP tunnel decapsulation with **tunnel source direct** option:

```
Router#show running-config interface tunnel 1
interface Tunnel1
  tunnel mode ipv6ipv6 decapsulate-any
  tunnel source direct
  no shutdown

Router#show interface tunnel 1
Tunnel1 is up    Admin State: up
MTU 1460 bytes, BW 9 Kbit
Tunnel protocol/transport IPv6/DECAPANY/IPv6
Tunnel source - direct
Tx      0 packets output, 0 bytes    Rx      0 packets input, 0 bytes
```

Configure Tunnel Destination with an Object Group

Table 4: Feature History Table

Feature Name	Release Information	Description
Configure Tunnel Destination with an Object Group	Release 7.5.4	You can now assign an object group as the destination for an IP-in-IP decapsulation tunnel. With this functionality, you could configure an IPv4 or IPv6 object group consisting of multiple IPv4 or IPv6 addresses as the destination for the tunnel instead of a single IPv4 or IPv6 address. Using an object group instead of a singular IP address. This helps reduce the configuration complexity in the router by replacing the multiple tunnels with one destination with a single decapsulation tunnel that supports a diverse range of destinations The feature introduces these changes: • CLI: New tunnel destination command. • YANG Data Model: New object-group option supported in Cisco-IOS-XR-um-ipv4-tunnel-cfg.yang Cisco native model (see GitHub).

In IP-in-IP Decapsulation, the router accepts a packet on a tunneled interface only when the tunnel IP address matches the source IP address of the incoming packets. With this implementation, the user needs to configure separate interface tunnels for each IP address that the router needs to receive the traffic packets. This limitation often leads to configuration overload on the router.

You can eliminate the configuration overload on the router by assigning an object group as the tunnel destination for IPv4 and IPv6 traffic types. That is, the router matches the source IP address of the incoming packet against the object group available as the tunnel destination. The decapsulation tunnel accepts the incoming traffic packets when there's a match between the packet source and the object group. Otherwise, the router drops the packets.

Restrictions

The following restrictions are applicable to the tunnel destination with an object group feature:

- GRE tunnels don't support configuring object groups as the tunnel destination.

- The router supports configuring tunnel destination with an object group only when the tunnel source is tunnel source direct.
- You can configure the object group as tunnel destination only on default VRF.
- Configuring object groups as the tunnel destination isn't applicable to tunnel encapsulation.
- Subinterfaces don't support configuring object groups as the tunnel destination.
- Configuring object groups as the tunnel destination feature is mutually exclusive with ACL and QoS features.
- The tunnel destination feature supports only IPv4 and IPv6 object groups.
- The router does not support changing tunnel configuration after its creation. Configure the tunnel source direct and tunnel destination with an object group while creating the tunnel only.

Prerequisites

- Define an object group including the network elements for the tunnel destination.
- Enable the tunnel source direct feature. For more information, see [Decapsulation using tunnel source direct, on page 8](#).

Configuration example

This section provides an example for configuring the tunnel destination with an object group.

IPv4 configuration

```
Router# configure
/* Configure the IPv4 object group */
Router(config)# object-group network ipv4 Test_IPv4
Router(config-object-group-ipv4)# 192.0.2.0/24
Router(config-object-group-ipv4)# 198.51.100.0/24
Router(config-object-group-ipv4)# 203.0.113.0/24
Router(config-object-group-ipv4)# commit
Router(config-object-group-ipv4)# exit

/* Enters the tunnel configuration mode */
Router(config)# interface tunnel-ip 1

/* Configures the tunnel mode */
Router(config-if)# tunnel mode ipv4 decap

/* Configures the tunnel to accept all packets with destination address matching the IP
addresses on the router */
Router(config-if)# tunnel source direct

/* Configures the destination of the tunnel as the defined object-group */
Router(config-if)# tunnel destination object-group ipv4 Test_IPv4

Router(config-if)# no shutdown
Router(config-if)# commit
Router(config-if)# exit
```

IPv6 configuration

```
Router# configure
/* Configure the IPv6 object group */
Router(config)# object-group network ipv6 Test_IPv6
```

```

Router(config-object-group-ipv6)# 2001:DB8::/32
Router(config-object-group-ipv6)# 2001:DB8::/48
Router(config-object-group-ipv6)# commit
Router(config-object-group-ipv6)# exit

/* Enters the tunnel configuration mode */
Router(config)# interface tunnel-ip 2

/* Configures the tunnel mode */
Router(config-if)# tunnel mode ipv6 decap

/* Configures the tunnel to accept all packets with destination address matching the IP
addresses on the router */
Router(config-if)# tunnel source direct

/* Configures the destination of the tunnel as the defined object-group */
Router(config-if)# tunnel destination object-group ipv6 Test_IPv6

Router(config-if)# no shutdown
Router(config-if)# commit
Router(config-if)# exit

```

Running Configuration

```

Router# show running-config object-group
object-group network ipv4 Test_IPv4
  192.0.2.0/24
  198.51.100.0/24
  203.0.113.0/24
!
object-group network ipv6 Test_IPv6
  2001:DB8::/32
  2001:DB8::/48
!

Router#show running-config interface tunnel-ip 1
interface tunnel-ip1
  tunnel mode ipv4 decap
  tunnel source direct
  tunnel destination object-group ipv4 Test_IPv4
!

Router#show running-config interface tunnel-ip 2
Fri Nov 29 11:26:54.716 UTC
interface tunnel-ip2
  tunnel mode ipv6 decap
  tunnel source direct
  tunnel destination object-group ipv6 Test_IPv6
!

```

Verification

```

Router# show tunnel ip ea database

----- node0_0_CPU0 -----
tunnel ifhandle 0x80022cc
tunnel source 161.115.1.2
tunnel destination address group Test_IPv4
tunnel transport vrf table id 0xe0000000
tunnel mode gre ipv4, encap
tunnel bandwidth 100 kbps
tunnel platform id 0x0
tunnel flags 0x40003400
IntfStateUp
BcStateUp
Ipv4Caps

```

```

Encap
tunnel mtu 1500
tunnel tos 0
tunnel ttl 255
tunnel adjacency flags 0x1
tunnel o/p interface handle 0x0
tunnel key 0x0, entropy length 0 (mask 0xffffffff)
tunnel QT next 0x0
tunnel platform data (nil)
Platform:
Handle: (nil)
Decap ID: 0
Decap RIF: 0
Decap Recycle Encap ID: 0x00000000
Encap RIF: 0
Encap Recycle Encap ID: 0x00000000
Encap IPv4 Encap ID: 0x4001381b
Encap IPv6 Encap ID: 0x00000000
Encap MPLS Encap ID: 0x00000000
DecFEC DecRcyLIF DecStatsId EncRcyLIF

```

ECMP Hashing Support for Load Balancing

The system inherently supports the n-tuple hash algorithm. The first inner header in the n-tuple hashing includes the source port and the destination port of UDP / TCP protocol headers.

The load balancing performs these functions:

- Incoming data traffic is distributed over multiple equal-cost connections.
- Incoming data traffic is 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, and IPv6. If it is an IPv4 or an IPv6 payload, then an n-tuple hashing is done.
- An n-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.
- The n-tuple load-balance hash calculation contains:
 - Source IP address
 - Destination IP address
 - IP Protocol type
 - Router ID
 - Source port
 - Destination port
 - Input interface
 - Flow-label (for IPv6 only)

