Implementing IPv6 over MPLS

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Multiprotocol Label Switching (MPLS) is deployed by many service providers in their IPv4 networks. Service providers want to introduce IPv6 services to their customers, but changes to their existing IPv4 infrastructure can be expensive and the cost benefit for a small amount of IPv6 traffic does not make economic sense. Several integration scenarios have been developed to leverage an existing IPv4 MPLS infrastructure and add IPv6 services without requiring any changes to the network backbone. This document describes how to implement IPv6 over MPLS.

Finding Feature Information

Your software release may not support all the features documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. To find information about the features documented in this module, and to see a list of the releases in which each feature is supported, see the "Feature Information for Implementing IPv6 over MPLS" section on page 18.

Use Cisco Feature Navigator to find information about platform support and Cisco IOS and Catalyst OS software image support. To access Cisco Feature Navigator, go to http://www.cisco.com/go/cfn. An account on Cisco.com is not required.

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Prerequisites for Implementing IPv6 over MPLS

- This module assumes that you are familiar with IPv4. Refer to the publications referenced in the "Related Documents" section for IPv4 configuration and command reference information.
- Before the IPv6 Provider Edge Router over MPLS (6PE) feature can be implemented, MPLS must be running over the core IPv4 network. If Cisco routers are used, Cisco Express Forwarding or distributed Cisco Express Forwarding must be enabled for both IPv4 and IPv6 protocols. This module assumes that you are familiar with MPLS.

Information About Implementing IPv6 over MPLS

To configure IPv6 over MPLS, you need to understand the following concepts:

Benefits of Deploying IPv6 over MPLS Backbones

IPv6 over MPLS backbones enables isolated IPv6 domains to communicate with each other over an MPLS IPv4 core network. This implementation requires only a few backbone infrastructure upgrades and no reconfiguration of core routers because forwarding is based on labels rather than the IP header itself, providing a very cost-effective strategy for the deployment of IPv6.

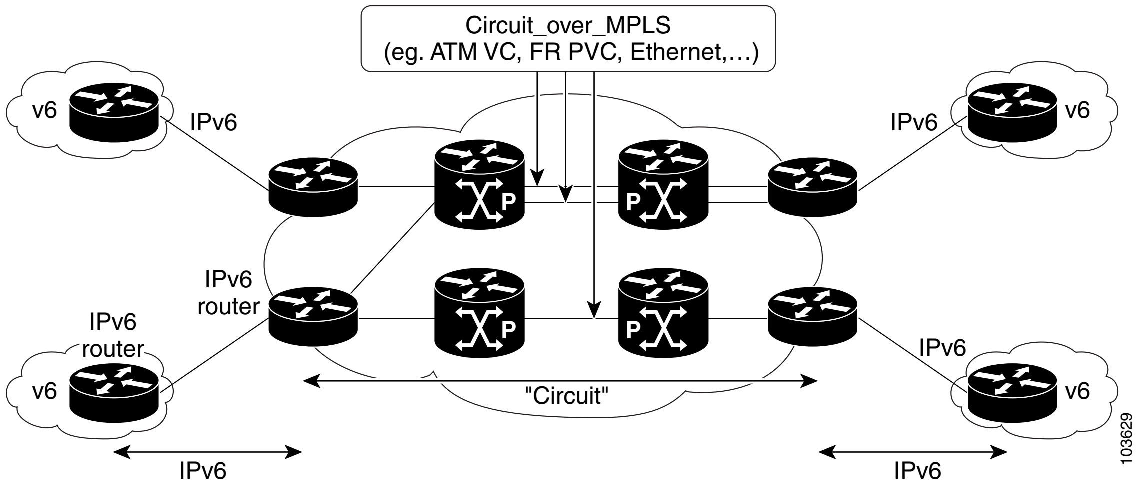
Additionally, the inherent Virtual Private Network (VPN) and MPLS traffic engineering (MPLS-TE) services available within an MPLS environment allow IPv6 networks to be combined into IPv4 VPNs or extranets over an infrastructure supporting IPv4 VPNs and MPLS-TE.

IPv6 over a Circuit Transport over MPLS

Using any circuit transport for deploying IPv6 over MPLS networks has no impact on the operation or infrastructure of MPLS, and requires no configuration changes to the core or provider edge routers. Communication between the remote IPv6 domains runs native IPv6 protocols over a dedicated link, where the underlying mechanisms are fully transparent to IPv6. The IPv6 traffic is tunneled using the Any Transport over MPLS (MPLS/AToM) or Ethernet over MPLS (EoMPLS) feature with the routers connected through an ATM OC-3 or Ethernet interface, respectively.

Figure 21 shows the configuration for IPv6 over any circuit transport over MPLS.

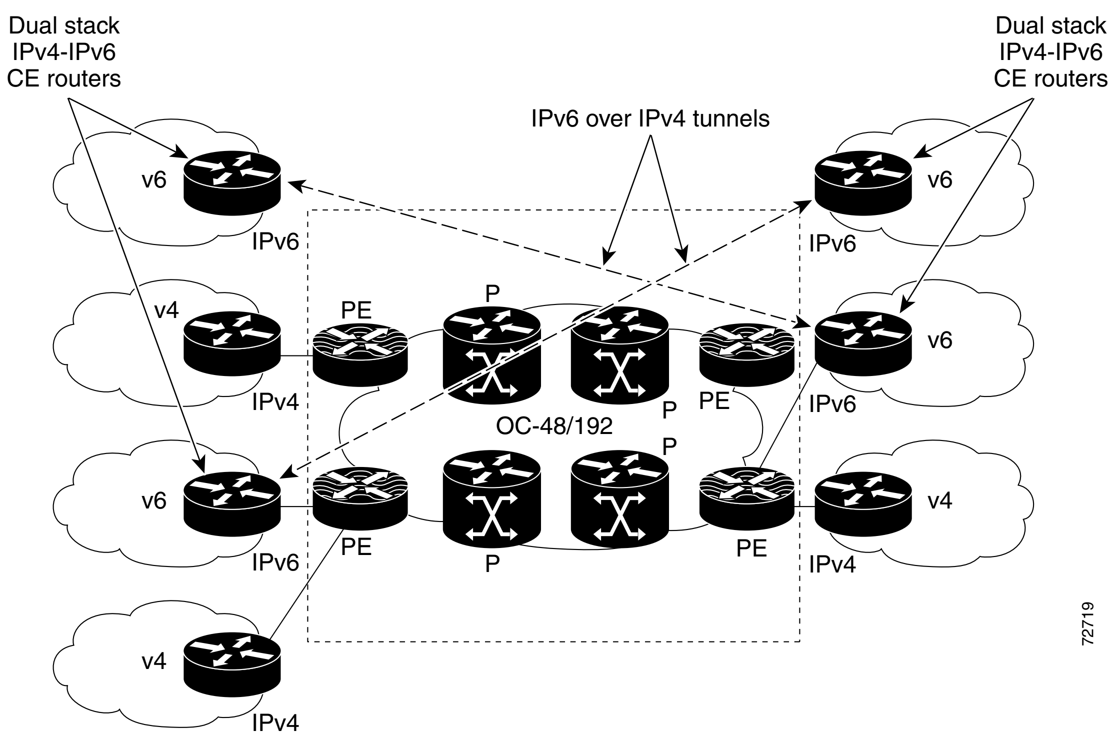
Figure 21 IPv6 over a Circuit Transport over MPLS



IPv6 Using Tunnels on the Customer Edge Routers

Using tunnels on the customer edge (CE) routers is the simplest way of deploying IPv6 over MPLS networks with no impact on the operation or infrastructure of MPLS, and no configuration changes to the core or provider edge routers. Communication between the remote IPv6 domains uses standard tunneling mechanisms and requires the CE routers to be configured to run dual IPv4 and IPv6 protocol stacks. Figure 22 shows the configuration using tunnels on the CE routers.

Figure 22 IPv6 Using Tunnels on the CE Routers



Refer to *Implementing Tunneling for IPv6* for configuration information on manually configured tunnels, automatic tunnels, and 6to4 tunnels.

Limitations on using tunnels involve the manual configuring of a mesh of tunnels on the CE routers, creating scaling issues for large networks.

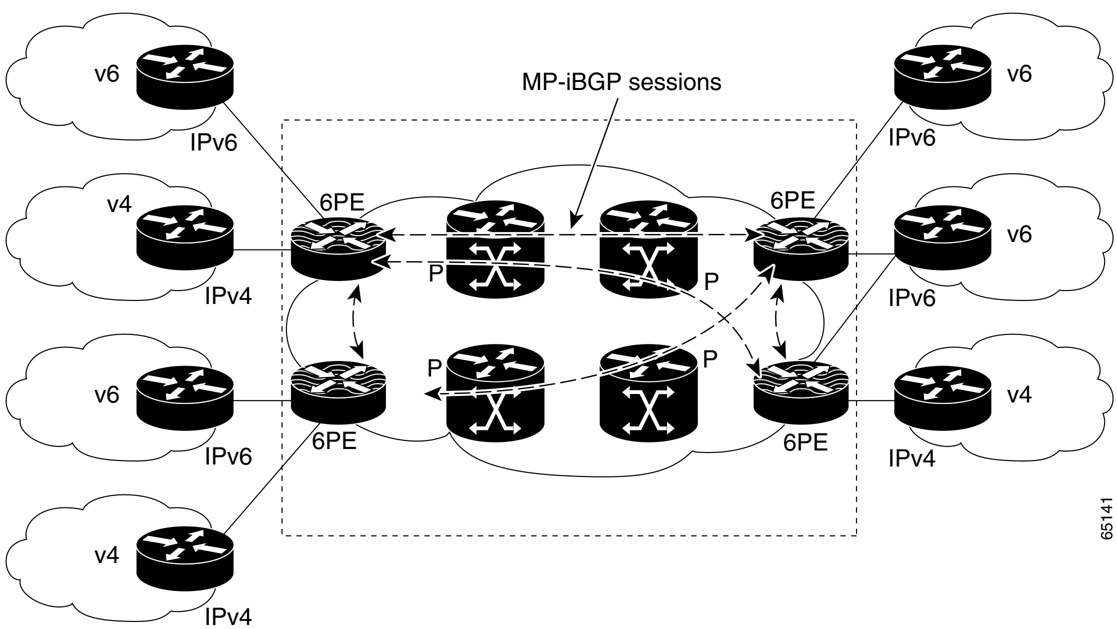
IPv6 on the Provider Edge Routers (6PE)

The Cisco implementation of IPv6 provider edge router over MPLS is called 6PE, and it enables IPv6 sites to communicate with each other over an MPLS IPv4 core network using MPLS label switched paths (LSPs). This feature relies on multiprotocol Border Gateway Protocol (BGP) extensions in the IPv4 network configuration on the provider edge (PE) router to exchange IPv6 reachability information in addition to an MPLS label for each IPv6 address prefix to be advertised. Edge routers are configured to be dual stack running both IPv4 and IPv6, and use the IPv4 mapped IPv6 address for IPv6 prefix reachability exchange.

A hierarchy of labels is imposed on the 6PE ingress router to keep the IPv6 traffic transparent to all the core routers. The top label provides connectivity inside the IPv4 MPLS core network and the label is distributed by Label Distribution Protocol (LDP), Tag Distribution Protocol (TDP), or Resource Reservation Protocol (RSVP). TDP and LDP can both be used for label distribution, but RSVP is used only in the context of MPLS-TE label exchange. The bottom label, automatically assigned to the IPv6 prefix of the destination, is distributed by multiprotocol BGP and used at each 6PE egress router for IPv6 forwarding.

In Figure 23 the 6PE routers are configured as dual stack routers able to route both IPv4 and IPv6 traffic. Each 6PE router is configured to run LDP, TDP, or RSVP (if traffic engineering is configured) to bind the IPv4 labels. The 6PE routers use multiprotocol BGP to exchange reachability information with the other 6PE devices within the MPLS domain, and to distribute aggregate IPv6 labels between them. All 6PE and core routers—P routers in Figure 3—within the MPLS domain share a common IPv4 Interior Gateway Protocol (IGP) such as Open Shortest Path First (OSPF) or Integrated Intermediate System-to-Intermediate System (IS-IS).

Figure 23 6PE Router Topology



The interfaces on the 6PE routers connecting to the CE router can be configured to forward IPv6 traffic, IPv4 traffic, or both types of traffic depending on the customer requirements. 6PE routers advertise IPv6 reachability information learned from their 6PE peers over the MPLS cloud. Service providers can delegate an IPv6 prefix from their registered IPv6 prefixes over the 6PE infrastructure; otherwise, there is no impact on the CE router.

The P routers in the core of the network are not aware that they are switching IPv6 packets. Core routers are configured to support MPLS and the same IPv4 IGP as the PE routers to establish internal reachability inside the MPLS cloud. Core routers also use LDP, TDP, or RSVP for binding IPv4 labels. Implementing the Cisco 6PE feature does not have any impact on the MPLS core devices.

Within the MPLS network, IPv6 traffic is forwarded using label switching, making the IPv6 traffic transparent to the core of the MPLS network. No IPv6 over IPv4 tunnels or Layer 2 encapsulation methods are required.

6PE Multipath

Internal and external Border Gateway Protocol (BGP) multipath for IPv6 allows the IPv6 router to load balance between several paths (for example, same neighboring autonomous system [AS] or sub-AS, or the same metric) to reach its destination. The 6PE multipath feature uses multiprotocol internal BGP (MP-iBGP) to distribute IPv6 routes over the MPLS IPv4 core network and to attach an MPLS label to each route.

When MP-iBGP multipath is enabled on the 6PE router, all labeled paths are installed in the forwarding table with MPLS information (label stack) when MPLS information is available. This functionality enables 6PE to perform load balancing.

How to Implement IPv6 over MPLS

The following sections explain how to configure IPv6 over MPLS:

Deploying IPv6 over a Circuit Transport over MPLS

To deploy IPv6 over a circuit transport over MPLS, the IPv6 routers must be configured for IPv6 connectivity. Refer to *Implementing IPv6 Addressing and Basic Connectivity* for details on basic IPv6 configuration. The MPLS router configuration requires AToM configuration or EoMPLS configuration.

Deploying IPv6 on the Provider Edge Routers (6PE)

To implement IPv6 on provider edge routers two tasks must be completed. The first task is to specify the interface from which locally generated packets take their source IPv6 address. The second task is to bind and advertise aggregate labels.

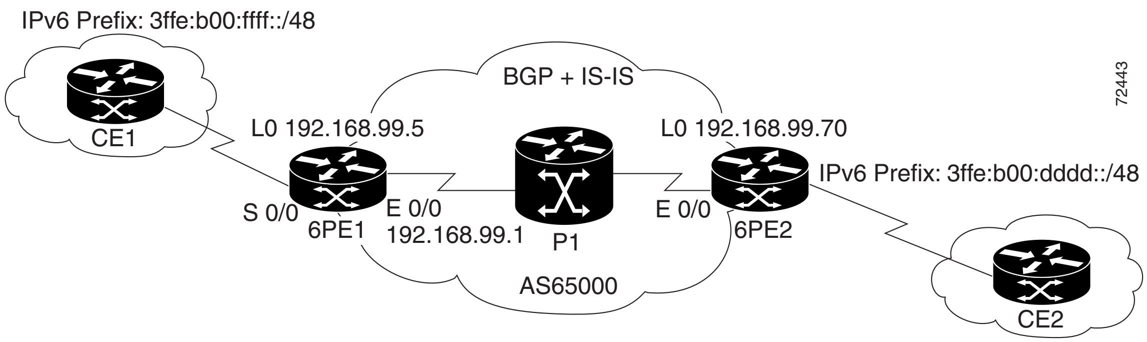
Each 6PE router—6PE1 and 6PE2 in Figure 24—is assumed to be running IPv4 routing and Cisco Express Forwarding.

6PE Network Configuration

Two configuration tasks using the network shown in Figure 24 are required at the 6PE1 router to enable the 6PE feature.

The customer edge router—CE1 in Figure 24—is configured to forward its IPv6 traffic to the 6PE1 router. The P1 router in the core of the network is assumed to be running MPLS, a label distribution protocol, an IPv4 IGP, and Cisco Express Forwarding or distributed Cisco Express Forwarding, and does not require any new configuration to enable the 6PE feature. Although new configuration tasks are not required for the CE1 and P1 routers, configuration examples are shown for reference in the "Configuration Examples for IPv6 over MPLS" section on page 13.

Figure 24 6PE Configuration Example



Prerequisites

- The 6PE routers—the 6PE1 and 6PE2 routers in Figure 24—must be members of the core IPv4 network. The 6PE router interfaces attached to the core network must be running MPLS, the same label distribution protocol, and the same IPv4 IGP, as in the core network.
- The 6PE routers must also be configured to be dual stack to run both IPv4 and IPv6.

Restrictions

Note As of Cisco IOS Release 12.2(22)S, the following restrictions do not apply to Cisco IOS 12.2 S releases.

The following restrictions apply when implementing the IPv6 Provider Edge Router over MPLS (6PE) feature:

- Core MPLS routers are supporting MPLS and IPv4 only, so they cannot forward or create any IPv6 Internet Control Message Protocol (ICMP) messages.
- Load balancing ability is not provided by Cisco 6PE between an MPLS path and an IPv6 path. If both are available, the MPLS path is always preferred. Load balancing between two MPLS paths is possible.
- BGP multipath is not supported for Cisco 6PE routes. If two BGP peers advertise the same prefix with an equal cost, Cisco 6PE will use the last route to cross the MPLS core.
- 6PE feature is not supported over tunnels other than RSVP-TE tunnels.

Specifying the Source Address Interface on a 6PE Router

This task explains how to specify the interface from which locally generated packets take their source IPv6 address. This task is the first of two tasks that must be completed to deploy 6PE. See the "Binding and Advertising the 6PE Label to Advertise Prefixes" task for details about the second task required to implement 6PE.

SUMMARY STEPS

1. **enable**
2. **configure terminal**
3. **ipv6 unicast-routing**
4. **ipv6 cef**
5. **interface** *type number*
6. **ipv6 address** {*ipv6-address/prefix-length* | *prefix-name sub-bits/prefix-length*}

DETAILED STEPS

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**ipv6 unicast-routing** **Example:** `Router(config)# ipv6 unicast-routing`	Enables the forwarding of IPv6 unicast datagrams.
Step 4	**ipv6 cef** **Example:** `Router(config)# ipv6 cef`	Enables IPv6 Cisco Express Forwarding.
Step 5	**interface** *type number* **Example:** `Router(config)# interface Serial 0/0`	Specifies an interface type and number and enters interface configuration mode. • In the context of this feature, the interface to be configured is the interface communicating with the CE router.
Step 6	**ipv6 address** {*ipv6-address/prefix-length* | *prefix-name sub-bits/prefix-length*} **Example:** `Router(config-if)# ipv6 address 2001:0DB8:FFFF::2/64`	Configures an IPv6 address based on an IPv6 general prefix and enable IPv6 processing on an interface.

Binding and Advertising the 6PE Label to Advertise Prefixes

This task explains how to enable the binding and advertising of aggregate labels when advertising IPv6 prefixes to a specified BGP neighbor.

SUMMARY STEPS

1. **enable**
2. **configure terminal**
3. **router bgp** *as-number*
4. **no bgp default ipv4-unicast**
5. **neighbor** {*ip-address* | *ipv6-address* | *peer-group-name*} **remote-as** *as-number*
6. **neighbor** {*ip-address* | *ipv6-address* | *peer-group-name*} **update-source** *interface-type interface-number*
7. **address-family ipv6** [**unicast**]
8. **neighbor** {*ip-address* | *peer-group-name* | *ipv6-address*} **activate**
9. **neighbor** {*ip-address* | *ipv6-address*} **send-label**

DETAILED STEPS

	Command or Action	Purpose

Step 1	`enable`
	
	Example:
	`Router> enable`
		Enables privileged EXEC mode.
		• Enter your password if prompted.

Step 2	`configure terminal`
	
	Example:
	`Router# configure terminal`
		Enters global configuration mode.

Step 3	`router bgp` *as-number* **Example:** `Router(config)# router bgp 65000`	Enters router configuration mode for the specified routing process.

Step 4	`no bgp default ipv4-unicast`
	
	Example:
	`Router(config-router)# no bgp default ipv4-unicast`
		Disables the IPv4 unicast address family for the BGP routing process specified in the previous step.
		Note Routing information for the IPv4 unicast address family is advertised by default for each BGP routing session configured with the **neighbor remote-as** command unless you configure the **no bgp default ipv4-unicast** command before configuring the **neighbor remote-as** command.

	Command or Action	Purpose
Step 5	**neighbor** {*ip-address* | *ipv6-address* | *peer-group-name*} **remote-as** *as-number* **Example:** `Router(config-router)# neighbor 192.168.99.70 remote-as 65000`	Adds the IP address of the neighbor in the specified autonomous system to the BGP neighbor table of the local router.
Step 6	**neighbor** {*ip-address* | *ipv6-address* | *peer-group-name*} **update-source** *interface-type interface-number* **Example:** `Router(config-router)# neighbor 192.168.99.70 update-source Loopback 0`	Specifies the interface whose IPv4 address is to be used as the source address for the peering. • In the context of this task, the interface must have an IPv4 address with a 32-bit mask configured. Use of a loopback interface is recommended. This address is used to determine the IPv6 next hop by the peer 6PE.
Step 7	**address-family ipv6** [**unicast**] **Example:** `Router(config-router)# address-family ipv6`	Specifies the IPv6 address family and enters address family configuration mode. • The **unicast** keyword specifies the IPv6 unicast address family. By default, the router is placed in configuration mode for the IPv6 unicast address family if the **unicast** keyword is not specified with the **address-family ipv6** command.
Step 8	**neighbor** {*ip-address* | *peer-group-name* | *ipv6-address*} **activate** **Example:** `Router(config-router-af)# neighbor 192.168.99.70 activate`	Enables the neighbor to exchange prefixes for the IPv6 address family with the local router.
Step 9	**neighbor** {*ip-address* | *ipv6-address*} **send-label** **Example:** `Router(config-router-af)# neighbor 192.168.99.70 send-label`	Advertises the capability of the router to send MPLS labels with BGP routes. • In IPv6 address family configuration mode this command enables binding and advertisement of aggregate labels when advertising IPv6 prefixes in BGP.

Configuring iBGP Multipath Load Sharing

This task describes how to configure iBGP multipath load sharing and control the maximum number of parallel iBGP routes that can be installed in a routing table.

SUMMARY STEPS

1. **enable**
2. **configure terminal**
3. **router bgp** *as-number*
4. **maximum-paths ibgp** *number-of-paths*

DETAILED STEPS

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**router bgp** *as-number* **Example:** `Router(config)# router bgp 65000`	Enters router configuration mode for the specified routing process.
Step 4	**maximum-paths ibgp** *number-of-paths* **Example:** Router(config-router)# maximum-paths ibgp 3	Controls the maximum number of parallel iBGP routes that can be installed in a routing table.

Verifying 6PE Configuration and Operation

When 6PE is running the following components can be monitored:

- Multiprotocol BGP
- MPLS
- Cisco Express Forwarding for IPv6
- IPv6 routing table

This optional task explains how to display information about the various components to verify the configuration and operation of 6PE.

SUMMARY STEPS

1. **show bgp ipv6** {**unicast** | **multicast**} [*ipv6-prefix*/*prefix-length*] [**longer-prefixes**] [**labels**]
2. **show bgp ipv6** {**unicast** | **multicast**} **neighbors** [*ipv6-address*] [**received-routes** | **routes** | **flap-statistics** | **advertised-routes** | **paths** *regular-expression* | **dampened-routes**]
3. **show mpls forwarding-table** [*network* {*mask* | *length*} | **labels** *label* [**-***label*] | **interface** *interface* | **next-hop** *address* | **lsp-tunnel** [*tunnel-id*]] [**vrf** *vrf-name*] [**detail**]
4. **show ipv6 cef** [*ipv6-prefix/prefix-length*] | [*interface-type interface-number*] [**longer-prefixes** | **similar-prefixes** | **detail** | **internal** | **platform** | **epoch** | **source**]]
5. **show ipv6 route** [*ipv6-address* | *ipv6-prefix*/*prefix-length* | *protocol* | *interface-type interface-number*]

DETAILED STEPS

	Command or Action	Purpose
Step 1	**show bgp ipv6** {**unicast** | **multicast**} [*ipv6-prefix***/***prefix-length*] [**longer-prefixes**] [**labels**] **Example:** `Router> show bgp ipv6 unicast 2001:0DB8:DDDD::/48`	(Optional) Displays entries in the IPv6 BGP routing table. • In this example, information about the IPv6 route for the prefix 2001:0DB8:DDDD::/48 is displayed.
Step 2	**show bgp ipv6** {**unicast** | **multicast**} **neighbors** [*ipv6-address*] [**received-routes** | **routes** | **flap-statistics** | **advertised-routes** | **paths** *regular-expression* | **dampened-routes**] **Example:** `Router> show bgp ipv6 neighbors unicast 192.168.99.70`	(Optional) Displays information about IPv6 BGP connections to neighbors. • In this example, information including the IPv6 label capability is displayed for the BGP peer at 192.168.99.70.
Step 3	**show mpls forwarding-table** [*network* {*mask* | *length*} | **labels** *label* [**-***label*] | **interface** *interface* | **nexthop** *address* | **lsp-tunnel** [*tunnel-id*]] [**vrf** *vrf-name*] [**detail**] **Example:** `Router> show mpls forwarding-table`	(Optional) Displays the contents of the MPLS Forwarding Information Base (FIB). • In this example, information linking the MPLS label with IPv6 prefixes is displayed where the labels are shown as aggregate and the prefix is shown as IPv6.
Step 4	**show ipv6 cef** [*ipv6-prefix***/***prefix-length*] | [*interface-type interface-number*] [**longer-prefixes** | **similar-prefixes** | **detail** | **internal** | **platform** | **epoch** | **source**]] **Example:** `Router> show ipv6 cef 2001:0DB8:DDDD::/64`	(Optional) Displays FIB entries based on IPv6 address information. • In this example, label information from the Cisco Express Forwarding table for prefix 2001:0DB8:DDDD::/64 is displayed.
Step 5	**show ipv6 route** [*ipv6-address* | *ipv6-prefix***/***prefix-length* | *protocol* | *interface-type interface-number*] **Example:** `Router> show ipv6 route`	(Optional) Displays the current contents of the IPv6 routing table.

Output Examples

This section provides the following output examples:

- Sample Output from the show bgp ipv6 Command, page 12
- Sample Output from the show bgp ipv6 neighbors Command, page 12
- Sample Output from the show mpls forwarding-table Command, page 12
- Sample Output from the show bgp ipv6 Command, page 13
- Sample Output from the show ipv6 cef Command, page 13
- Sample Output from the show ipv6 route Command, page 13

Sample Output from the show bgp ipv6 Command

In the following example, output information about an IPv6 route is displayed using the **show bgp ipv6** command with an IPv6 prefix:

```
Router# show bgp ipv6 2001:0DB8:DDDD::/48

BGP routing table entry for 2001:0DB8:DDDD::/48, version 15
Paths: (1 available, best #1, table Global-IPv6-Table)
  Not advertised to any peer
  Local
    ::FFFF:192.168.99.70 (metric 20) from 192.168.99.70 (192.168.99.70)
      Origin IGP, localpref 100, valid, internal, best
```

Sample Output from the show bgp ipv6 neighbors Command

In the following example, output information about a BGP peer including the "IPv6 label" capability is displayed using the **show bgp ipv6 neighbors** command with an IP address:

```
Router# show bgp ipv6 neighbors 192.168.99.70

BGP neighbor is 192.168.99.70, remote AS 65000, internal link
  BGP version 4, remote router ID 192.168.99.70
  BGP state = Established, up for 00:05:17
  Last read 00:00:09, hold time is 0, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received
    Address family IPv6 Unicast: advertised and received
    ipv6 MPLS Label capability: advertised and received
  Received 54 messages, 0 notifications, 0 in queue
  Sent 55 messages, 1 notifications, 0 in queue
  Default minimum time between advertisement runs is 5 seconds

 For address family: IPv6 Unicast
  BGP table version 21880, neighbor version 21880
  Index 1, Offset 0, Mask 0x2
  Route refresh request: received 0, sent 0
  77 accepted prefixes consume 4928 bytes
  Prefix advertised 4303, suppressed 0, withdrawn 1328
  Number of NLRIs in the update sent: max 1, min 0
```

Sample Output from the show mpls forwarding-table Command

In the following example, output information linking the MPLS label with prefixes is displayed using the **show mpls forwarding-table** command. If the 6PE feature is configured, the labels are aggregated because there are several prefixes for one local label, and the prefix column contains "IPv6" instead of a target prefix.

```
Router# show mpls forwarding-table

Local Outgoing      Prefix             Bytes tag Outgoing       Next Hop
tag   tag or VC     or Tunnel Id       switched  interface
16    Aggregate     IPv6               0
17    Aggregate     IPv6               0
18    Aggregate     IPv6               0
19    Pop tag       192.168.99.64/30   0         Se0/0         point2point
20    Pop tag       192.168.99.70/32   0         Se0/0         point2point
21    Pop tag       192.168.99.200/32  0         Se0/0         point2point
22    Aggregate     IPv6               5424
23    Aggregate     IPv6               3576
24    Aggregate     IPv6               2600
```

Sample Output from the show bgp ipv6 Command

In the following example, output information about the top of the stack label with label switching information is displayed using the **show bgp ipv6** command with the **labels** keyword:

```
Router# show bgp ipv6 labels

Network              Next Hop              In tag/Out tag
2001:0DB8:DDDD::/64  ::FFFF:192.168.99.70  notag/20
```

Sample Output from the show ipv6 cef Command

In the following example, output information about labels from the Cisco Express Forwarding table is displayed using the **show ipv6 cef** command with an IPv6 prefix:

```
Router# show ipv6 cef 2001:0DB8:DDDD::/64

2001:0DB8:DDDD::/64
      nexthop ::FFFF:192.168.99.70
      fast tag rewrite with Se0/0, point2point, tags imposed {19 20}
```

Sample Output from the show ipv6 route Command

In the following example, output information from the IPv6 routing table is displayed using the **show ipv6 route** command. The output shows the IPv6 MPLS virtual interface as the output interface of IPv6 routes forwarded across the MPLS cloud. In this example using the routers in Figure 24, the output is from the 6PE1 router.

The 6PE2 router has advertised the IPv6 prefix of 2001:0DB8:dddd::/48 configured for the CE2 router and the next-hop address is the IPv4-compatible IPv6 address ::ffff:192.168.99.70, where 192.168.99.70 is the IPv4 address of the 6PE2 router.

```
Router# show ipv6 route

IPv6 Routing Table - 10 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
B 2001:0DB8:DDDD::/64 [200/0]
  via ::FFFF:192.168.99.70, IPv6-mpls
B 2001:0DB8:DDDD::/64 [200/0]
  via ::FFFF:192.168.99.70, IPv6-mpls
L 2001:0DB8:FFFF::1/128 [0/0]
  via ::, Ethernet0/0
C 2001:0DB8:FFFF::/64 [0/0]
  via ::, Ethernet0/0
S 2001:0DB8:FFFF::/48 [1/0]
  via 2001:0DB8:B00:FFFF::2, Ethernet0/0
```

Configuration Examples for IPv6 over MPLS

The following examples show 6PE configuration examples for three of the routers shown in Figure 24 and used in the "Specifying the Source Address Interface on a 6PE Router" and "Binding and Advertising the 6PE Label to Advertise Prefixes" sections.

- Customer Edge Router: Example, page 14
- Provider Edge Router: Example, page 14
- Core Router: Example, page 15

Customer Edge Router: Example

In the following example, serial interface 0/0 of the customer edge router—CE1 in Figure 24—is connected to the service provider and is assigned an IPv6 address. IPv6 is enabled and a default static route is installed using the IPv6 address of serial interface 0/0 of the 6PE1 router.

```
ip cef
!
ipv6 unicast-routing
!
interface Serial 0/0
 description to_6PE1_router
 no ip address
 ipv6 address 2001:0DB8:FFFF::2/64
!
ipv6 route ::/0 Serial 0/0 FE80::210:XXXX:FEE1:1001
```

Provider Edge Router: Example

The 6PE router—Router 6PE1 in Figure 24—is configured for both IPv4 and IPv6 traffic. Ethernet interface 0/0 is configured with an IPv4 address and is connected to a router in the core of the network—router P1 in Figure 24. Integrated IS-IS and TDP configurations on this router are similar to the P1 router.

Router 6PE1 exchanges IPv6 routing information with another 6PE router—Router 6PE2 in Figure 24—using internal BGP (iBGP) established over an IPv4 connection so that all the **neighbor** commands use the IPv4 address of the 6PE2 router. All the BGP peers are within autonomous system 65000, so synchronization with IGP is turned off for IPv4. In IPv6 address family configuration mode, synchronization is disabled by default.

IPv6 and Cisco Express Forwarding for IPv6 are enabled, the 6PE2 neighbor is activated, and aggregate label binding and advertisement is enabled for IPv6 prefixes using the **neighbor send-label** command. Connected and static IPV6 routes are redistributed using BGP. If IPv6 packets are generated in the local router, the IPv6 address for MPLS processing will be the address of loopback interface 0.

In the following example, serial interface 0/0 connects to the customer and the IPv6 prefix delegated to the customer is 2001:0DB8:ffff::/48, which is determined from the service provider IPv6 prefix. A static route is configured to route IPv6 packets between the 6PE route and the CE router.

```
ip cef
ipv6 cef
ipv6 unicast-routing
!
mpls ipv6 source-interface Loopback0
tag-switching tdp router-id Loopback0
!
interface Loopback0
 ip address 192.168.99.5 255.255.255.255
 ipv6 address 2001:0DB8:1000:1::1/64
!
interface Ethernet0/0
 description to_P_router
 ip address 192.168.99.1 255.255.255.252
 ip router isis
 tag-switching ip
!
interface Serial0/0
 description to_CE_router
 no ip address
```

```
 ipv6 address 2001:0DB8:FFFF::1/64
!
router isis
 passive-interface Loopback0
 net 49.0001.1921.6809.9005.00
!
router bgp 65000
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 192.168.99.70 remote-as 65000
 neighbor 192.168.99.70 description to_6PE2
 neighbor 192.168.99.70 update-source Loopback0
 !
 address-family ipv6
 neighbor 192.168.99.70 activate
 neighbor 192.168.99.70 send-label
 network 2001:0DB8:FFFF::/48
 exit-address-family
!
ipv6 route 2001:0DB8:FFFF::/48 Ethernet0/0 2001:0DB8:FFFF::2
```

Core Router: Example

In the following example, the router in the core of the network—Router P in Figure 24—is running MPLS, IS-IS, and IPv4 only. The Ethernet interfaces are configured with IPv4 address and are connected to the 6PE routers. IS-IS is the IGP for this network and the P1 and 6PE routers are in the same IS-IS area 49.0001. TDP and tag switching are enabled on both the Ethernet interfaces. Cisco Express Forwarding is enabled in global configuration mode.

```
ip cef
!
tag-switching tdp router-id Loopback0
!
interface Loopback0
 ip address 192.168.99.200 255.255.255.255
!
interface Ethernet0/0
 description to_6PE1
 ip address 192.168.99.2 255.255.255.252
 ip router isis
 tag-switching ip
!
interface Ethernet0/1
 description to_6PE2
 ip address 192.168.99.66 255.255.255.252
 ip router isis
 tag-switching ip

router isis
 passive-interface Loopback0
 net 49.0001.1921.6809.9200.00
```

Where to Go Next

If you want to further customize your MPLS network, refer to the *Cisco IOS IP Switching Configuration Guide*.

Additional References

The following sections provide references related to the Implementing IPv6 over MPLS feature.

Related Documents

Related Topic	Document Title
IPv6 using tunnels on the CE routers	"Implementing Tunneling for IPv6," *Cisco IOS IPv6 Configuration Guide*
IPv6 supported feature list	"Start Here: Cisco IOS Software Release Specifics for IPv6 Features," *Cisco IOS IPv6 Configuration Guide*
IPv6 commands: complete command syntax, command mode, defaults, usage guidelines, and examples	*Cisco IOS IPv6 Command Reference*
MPLS configuration tasks	"Multiprotocol Label Switching Overview," *Cisco IOS Multiprotocol Label Switching Configuration Guide*
MPLS commands: complete command syntax, command mode, defaults, usage guidelines, and examples	*Cisco IOS Multiprotocol Label Switching Command Reference*

Standards

Standards	Title
Draft-ietf-ngtrans-bgp-tunnel-04.txt	*Connecting IPv6 Islands Across IPv4 Clouds with BGP*

MIBs

MIBs	MIBs Link
No new or modified MIBs are supported, and support for existing MIBs has not been modified.	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: http://www.cisco.com/go/mibs

RFCs

RFCs	Title
No new or modified RFCs are supported by this feature, and support for existing RFCs has not been modified by this feature.	—

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/techsupport

Feature Information for Implementing IPv6 over MPLS

Table 8 lists the features in this module and provides links to specific configuration information. Only features that were introduced or modified in Cisco IOS Release 12.3(14)T or a later release appear in the table.

For information on a feature in this technology that is not documented here, see the *Start Here: Cisco IOS Software Release Specifies for IPv6 Features* roadmap.

Not all commands may be available in your Cisco IOS software release. For release information about a specific command, see the command reference documentation.

Use Cisco Feature Navigator to find information about platform support and software image support. Cisco Feature Navigator enables you to determine which Cisco IOS and Catalyst OS software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to http://www.cisco.com/go/cfn. An account on Cisco.com is not required.

Note Table 8 lists only the Cisco IOS software release that introduced support for a given feature in a given Cisco IOS software release train. Unless noted otherwise, subsequent releases of that Cisco IOS software release train also support that feature.

Table 8 Feature Information for Implementing IPv6 over MPLS

Feature Name	Releases	Feature Information
IPv6 over a circuit transport over MPLS	12.0(22)S 12.2(14)S 12.2(28)SB 12.2(15)T 12.3 12.3(2)T 12.4 12.4(2)T	In this feature, communication between the remote IPv6 domains runs native IPv6 protocols over a dedicated link, where the underlying mechanisms are fully transparent to IPv6. The following sections provide information about this feature: • IPv6 over a Circuit Transport over MPLS, page 2 • Deploying IPv6 over a Circuit Transport over MPLS, page 5
IPv6 using tunnels over the customer edge routers	12.0(22)S 12.2(14)S 12.2(28)SB 12.2(15)T 12.3 12.3(2)T 12.4 12.4(2)T	Using tunnels on the CE routers is the simplest way of deploying IPv6 over MPLS networks with no impact on the operation or infrastructure of MPLS. The following sections provide information about this feature: • IPv6 Using Tunnels on the Customer Edge Routers, page 3

Table 8 Feature Information for Implementing IPv6 over MPLS (continued)

Feature Name	Releases	Feature Information
IPv6 switching: provider edge router over MPLS (6PE)	12.0(22)S 12.2(14)S 12.2(28)SB 12.2(33)SRA 12.2(15)T 12.3 12.3(2)T 12.4 12.4(2)T	The Cisco implementation of IPv6 provider edge router over MPLS enables IPv6 sites to communicate with each other over an MPLS IPv4 core network using MPLS LSPs. The following sections provide information about this feature: • IPv6 on the Provider Edge Routers (6PE), page 4 • Deploying IPv6 on the Provider Edge Routers (6PE), page 5 • Specifying the Source Address Interface on a 6PE Router, page 7 • Binding and Advertising the 6PE Label to Advertise Prefixes, page 8 • Configuration Examples for IPv6 over MPLS, page 13
6PE multipath	12.2(25)S 12.2(28)SB 12.2(33)SRA 12.4(6)T	The 6PE multipath feature uses multiprotocol internal BGP (MP-iBGP) to distribute IPv6 routes over the MPLS IPv4 core network and to attach an MPLS label to each route. The following sections provide information about this feature: • 6PE Multipath, page 5 • Configuring iBGP Multipath Load Sharing, page 9