



Configuring Multiprotocol Label Switching

This chapter describes how to configure your network to perform Multiprotocol Label Switching (MPLS). For a complete description of the MPLS commands, see the chapter “MPLS Commands” in the *Cisco IOS Switching Services Command Reference*. For documentation of other commands that appear in this chapter, you can use the command reference master index or search online.

This chapter contains the following sections:

- Configuring MPLS Levels of Control
- Configuring MPLS Traffic Engineering
- Configuring MPLS Traffic Engineering Paths
- Configuring MPLS Virtual Private Networks
- Configuring MPLS CoS Backbone Support
- Configuring MPLS CoS
- Configuring the Label Switch Controller
- MPLS Configuration Examples

Configuring MPLS Levels of Control

This section describes three sample cases where MPLS is configured on Cisco 7500/7200 series routers. These cases show the levels of control possible in selecting how MPLS is deployed in a network.

Table 16 lists the cases, including the steps to perform MPLS and their corresponding Cisco IOS CLI commands.

Table 16 MPLS—Levels of Control

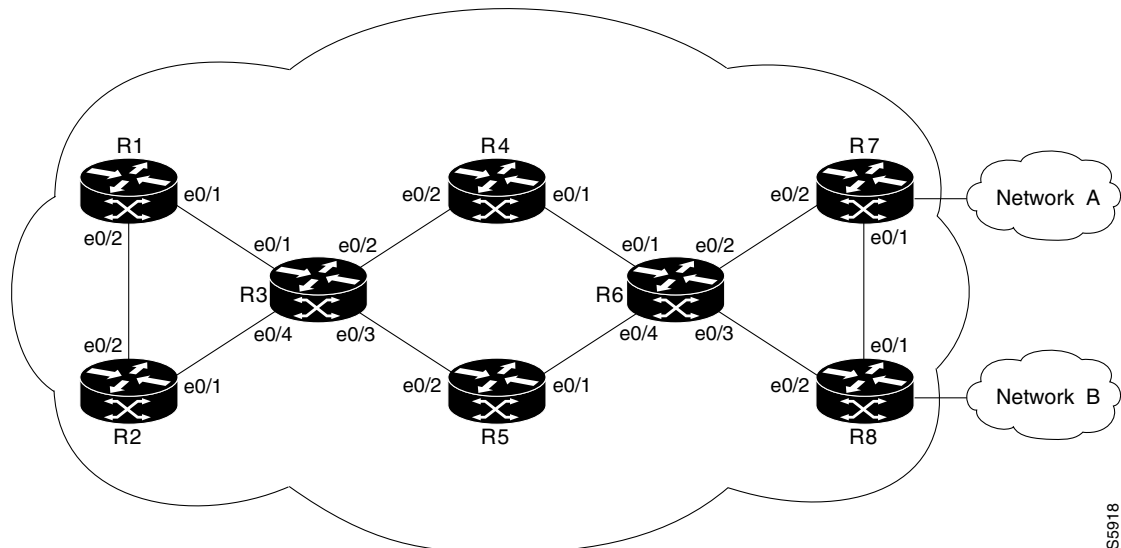
Levels of Control Examples	Describes
Example 1—Enable MPLS Incrementally in a Network	The steps necessary for incrementally deploying MPLS through a network, assuming that packets to all destination prefixes should be label switched.
Example 2—Route Labeled Packets to Network A Only	The mechanism by which MPLS can be restricted, such that packets are label switched to only a subset of destinations.
Example 3—Limit Label Distribution on a MPLS Network	The mechanisms for further controlling the distribution of labels within a network.

For more information about the Cisco IOS CLI commands, see the chapter “MPLS Commands” in the *Cisco IOS Switching Services Command Reference*.

Figure 21 shows a router-only MPLS network with Ethernet interfaces. The following sections outline the procedures for configuring MPLS and displaying MPLS information in a network based on the topology shown in Figure 21.

**Note**

Ethernet interfaces are shown in Figure 21, but any of the interfaces that are supported could be used instead. ATM interfaces operating as TC-ATM interfaces are the exception to this statement.

Figure 21 A Router-Only MPLS Network with Ethernet Interfaces

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Example 1—Enable MPLS Incrementally in a Network

In the first case, assume that you want to deploy MPLS incrementally throughout a network of routers, but that you do not want to restrict which destination prefixes are label switched. For a description of the commands listed in these cases, see the chapter “MPLS Commands” in the *Cisco IOS Switching Services Command Reference*.

To enable MPLS incrementally in a network, use the following steps and enter the commands in router configuration mode (see Figure 21):

	Command	Purpose
Step 1	<pre>At R1: Router# configuration terminal Router(config)# ip cef distributed Router(config)# tag-switching advertise-tags Router(config)# interface e0/1 Router(config-if)# tag-switching ip Router(config-if)# exit At R3: Router# configuration terminal Router(config)# ip cef distributed Router(config)# tag-switching advertise-tags Router(config)# interface e0/1 Router(config-if)# tag-switching ip</pre>	<p>Enables MPLS between R1 and R3.</p> <p>In order to configure distributed VIP MPLS, you must configure distributed CEF switching. Enter the ip cef distributed command on all routers.</p>
Step 2	<pre>At R3: Router(config)# interface e0/2 Router(config-if)# tag-switching ip Router(config-if)# exit At R4: Router# configuration terminal Router(config)# ip cef distributed Router(config)# tag-switching advertise-tags Router(config)# interface e0/2 Router(config-if)# tag-switching ip Router(config-if)# exit</pre>	<p>Enables MPLS between R3 and R4.</p>

After you perform these steps, R1 applies labels to packets that are forwarded through interface e0/1, with a next hop to R3.

You can enable MPLS throughout the rest of the network by repeating steps 1 and 2 as appropriate on other routers until all routers and interfaces are enabled for MPLS. See the example in the “Enabling MPLS Incrementally in a Network Example” section.

Example 2—Route Labeled Packets to Network A Only

In the second case, assume that you want to enable MPLS for a subset of destination prefixes. This option might be used to test MPLS across a large network. In this case, you would configure the system so that only a small number of destinations is label switched (for example, internal test networks) without the majority of traffic being affected.

Use the following commands at each router in the network in router configuration mode (see Figure 21):

	Command	Purpose
Step 1	Router(config)# access-list 1 permit A	Limits label distribution by using an access list. (Enter the actual network address and netmask in place of permit A. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)
Step 2	Router(config)# tag-switching advertise-tags for 1	Instructs the router to advertise for network A only to all adjacent label switch routers. Any labels for other destination networks that the router may have distributed before this step are withdrawn.

Example 3—Limit Label Distribution on a MPLS Network

The third case demonstrates the full control which is available to you in determining the destination prefixes and paths for which MPLS is enabled.

Configure the routers so that packets addressed to network A are labeled, all other packets are unlabeled, and only links R1-R3, R3-R4, R4-R6, and R6-R7 carry labeled packets addressed to A. For example, suppose the normally routed path for packets arriving at R1 addressed to network A or network B is R1, R3, R5, R6, R7. A packet addressed to A would flow labeled on links R1-R3 and R6-R7, and unlabeled on links R3-R5 and R5-R6. A packet addressed to B would follow the same path, but would be unlabeled on all links.

Assume that at the outset the routers are configured so that packets addressed to network A are labeled and all other packets are unlabeled (as at the completion of Case 2).

Use the **tag-switching advertise-tags** command and access lists to limit label distribution. Specifically, you need to configure routers R2, R5, and R8 to distribute no labels to other routers. This ensures that no other routers send labeled packets to any of those three. You also need to configure routers R1, R3, R4, R6, and R7 to distribute labels only for network A and to distribute them only to the appropriate adjacent router; that is, R3 distributes its label for network A only to R1, R4 only to R3, and so on.

To limit label distribution on a MPLS network, use the following commands in router configuration mode:

	Command	Purpose
Step 1	Router(config)# no tag-switching advertise-tags	Configures R2 to distribute no labels.
Step 2	Router(config)# no tag-switching advertise-tags	Configures R5 to distribute no labels.
Step 3	Router(config)# no tag-switching advertise-tags	Configures R8 to distribute no labels.

	Command	Purpose
Step 4	<pre>Router(config)# access-list 2 permit R1 Router(config)# no tag-switching advertise-tags for 1 Router(config)# tag-switching advertise-tags for 1 to 2 Router(config)# exit</pre>	<p>Configures R3 by defining an access list and by instructing the router to distribute labels for the networks permitted by access list 1 (created as part of Case 2) to the routers permitted by access list 2.</p> <p>The access list 2 permit R1 command permits R1 and denies all other routers.</p> <p>(Enter the actual network address and netmask in place of permit R1. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)</p>
Step 5	<pre>Router(config)# access-list 1 permit A Router(config)# access-list 2 permit R1 Router(config)# tag-switching advertise-tags for 1 to 2 Router(config)# exit</pre>	<p>Configures R3.</p> <p>(Enter the actual network address and netmask in place of permit R1. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)</p>
Step 6	<pre>Router(config)# access-list 1 permit A Router(config)# access-list 2 permit R3 Router(config)# tag-switching advertise-tags for 1 to 2 Router(config)# exit</pre>	<p>Configures R4.</p> <p>(Enter the actual network address and netmask in place of permit R1. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)</p>
Step 7	<pre>Router(config)# access-list 1 permit A Router(config)# access-list 2 permit R4 Router(config)# tag-switching advertise-tags for 1 to 2 Router(config)# exit</pre>	<p>Configures R6.</p> <p>(Enter the actual network address and netmask in place of permit R1. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)</p>
Step 8	<pre>Router(config)# access-list 1 permit A Router(config)# access-list 2 permit R6 Router(config)# tag-switching advertise-tags for 1 to 2 Router(config)# exit</pre>	<p>Configures R7.</p> <p>(Enter the actual network address and netmask in place of permit R1. For example, access-list 1 permit 192.5.34.0 0.0.0.255.)</p>

Configuring MPLS Traffic Engineering

Perform the following tasks before enabling MPLS traffic engineering:

- Configure MPLS tunnels
- Enable Cisco Express Forwarding (CEF)
- Enable IS-IS

Perform the tasks in the following sections to configure MPLS traffic engineering:

- Configuring a Device to Support Tunnels
- Configuring an Interface to Support RSVP-based Tunnel Signalling and IGP Flooding
- Configuring an MPLS Traffic Engineering Tunnel
- Configuring IS-IS for MPLS Traffic Engineering

Configuring a Device to Support Tunnels

To configure a device to support tunnels, use the following commands in configuration mode:

	Command	Purpose
Step 1	Router(config)# ip cef	Enables standard CEF operation. For information about CEF configuration and command syntax, see the <i>Cisco IOS Switching Services Configuration Guide</i> and <i>Cisco IOS Switching Services Command Reference</i> .
Step 2	Router(config)# mpls traffic-eng tunnels	Enables the MPLS traffic engineering tunnel feature on a device.

Configuring an Interface to Support RSVP-based Tunnel Signalling and IGP Flooding

To configure an interface to support RSVP-based tunnel signalling and IGP flooding, use the following commands in interface configuration mode:



Note

You need to enable the tunnel feature and specify the amount of reservable RSVP bandwidth if you have an interface that supports MPLS traffic engineering.

	Command	Purpose
Step 1	Router(config-if)# mpls traffic-eng tunnels	Enables the MPLS traffic engineering tunnel feature on an interface.
Step 2	Router(config-if)# ip rsvp bandwidth <i>bandwidth</i>	Enables RSVP for IP on an interface and specify amount of bandwidth to be reserved. For a description of IP RSVP command syntax, see the <i>Cisco IOS Quality of Service Command Reference</i> .

Configuring an MPLS Traffic Engineering Tunnel

To configure an MPLS traffic engineering tunnel, use the following commands in interface configuration mode. This tunnel has two path setup options—a preferred explicit path and a backup dynamic path.

	Command	Purpose
Step 1	Router(config)# interface tunnel1	Configures an interface type and enter interface configuration mode.
Step 2	Router(config-if)# tunnel destination A.B.C.D	Specifies the destination for a tunnel.
Step 3	Router(config-if)# tunnel mode mpls traffic-eng	Sets encapsulation mode of the tunnel to MPLS traffic engineering.
Step 4	Router(config-if)# tunnel mpls traffic-eng bandwidth bandwidth	Configures bandwidth for the MPLS traffic engineering tunnel.
Step 5	Router(config-if)# tunnel mpls traffic-eng path-option 1 explicit name test	Configures a named IP explicit path.
Step 6	Router(config-if)# tunnel mpls traffic-eng path-option 2 dynamic	Configures a backup path to be dynamically calculated from the traffic engineering topology database.

Configuring IS-IS for MPLS Traffic Engineering

To configure IS-IS for MPLS Traffic engineering, use the following IS-IS traffic engineering commands in interface configuration mode. For a description of IS-IS commands (excluding the IS-IS traffic engineering commands), see the *Cisco IOS IP and IP Routing Configuration Guide*.

	Command	Purpose
Step 1	Router(config)# router isis	Enables IS-IS routing and specify an IS-IS process for IP, which places you in router configuration mode.
Step 2	Router(config-router)# mpls traffic-eng level 1	Turns on MPLS traffic engineering for IS-IS level 1.
Step 3	Router(config-router)# mpls traffic-eng router-id loopback0	Specifies the traffic engineering router identifier for the node to be the IP address associated with interface loopback0.
Step 4	Router(config-router)# metric-style wide	Configures a router to generate and accept only new-style TLVs.

Configuring MPLS Traffic Engineering Paths

To configure an MPLS traffic engineering tunnel that an IGP can use, use the following commands in interface configuration mode:

	Command	Purpose
Step 1	Router(config-if)# interface tunnel1	Configures an interface type and enters interface configuration mode.
Step 2	Router(config-router)# tunnel mpls traffic-eng autoroute announce	Causes the IGP to use the tunnel in its enhanced SPF calculation.

Configuring MPLS Virtual Private Networks

Perform the tasks in the following sections to configure and verify VPNs:

- Defining VPNs
- Configuring BGP Routing Sessions
- Configuring PE to PE Routing Sessions
- Configuring BGP PE to CE Routing Sessions
- Configuring RIP PE to CE Routing Sessions
- Configuring Static Route PE to CE Routing Sessions
- Verifying VPN Operation

Defining VPNs

To define VPN routing instances, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config)# ip vrf vrf-name	Enters VRF configuration mode and define the VPN routing instance by assigning a VRF name.
Step 2	Router(config-vrf)# rd route-distinguisher	Creates routing and forwarding tables.
Step 3	Router(config-vrf)# route-target {import export both} route-target-ext-community	Creates a list of import and/or export route target communities for the specified VRF.
Step 4	Router(config-vrf)# import map route-map	(Optional) Associates the specified import route map with the VRF.
Step 5	Router(config-vrf)# export map route-map	(Optional) Associates the specified export route map with the VRF.
Step 6	Router(config-if)# ip vrf forwarding vrf-name	Associates a VRF with an interface or subinterface.

Configuring BGP Routing Sessions

To configure BGP routing sessions in a provider network, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config)# router bgp <i>autonomous-system</i>	Configures the BGP routing process with the autonomous system number passed along to other BGP routers.
Step 2	Router(config-router)# neighbor { <i>ip-address</i> <i>peer-group-name</i> } remote-as <i>number</i>	Specifies a neighbor's IP address or BGP peer group identifying it to the local autonomous system.
Step 3	Router(config-router)# neighbor ip-address activate	Activates the advertisement of the IPv4 address family.


Configuring PE to PE Routing Sessions

To configure PE to PE routing sessions in a provider network, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config-router)# address-family vpnv4 [unicast multicast]	Defines IBGP parameters for VPNv4 NLRI exchange.
Step 2	Router(config-router-af)# neighbor address remote-as as-number	Defines an IBGP session to exchange VPNv4 NRIs.
Step 3	Router(config-router-af)# neighbor address activate	Activates the advertisement of the IPv4 address family.

Configuring BGP PE to CE Routing Sessions


To configure BGP PE to CE routing sessions, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config-router)# address-family ipv4 [unicast] vrf <i>vrf-name</i>	Defines EBGP parameters for PE to CE routing sessions.
		 <p>Note The default is Off for auto-summary and synchronization in the VRF address-family submode.</p>

	Command	Purpose
Step 2	Router(config-router-af)# neighbor <i>address remote-as as-number</i>	Defines an EBGP session between PE and CE routers.
Step 3	Router(config-router-af)# neighbor <i>address activate</i>	Activates the advertisement of the IPv4 address family.


Configuring RIP PE to CE Routing Sessions

To configure RIP PE to CE routing sessions, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config)# router rip	Enables RIP.
Step 2	Router(config-router-af)# address-family ipv4 [unicast] vrf <i>vrf-name</i>	Defines RIP parameters for PE to CE routing sessions.  Note The default is Off for auto-summary and synchronization in the VRF address-family submode.
Step 3	Router(config-router-af)# network <i>prefix</i>	Enables RIP on the PE to CE link.

Configuring Static Route PE to CE Routing Sessions

To configure static route PE to CE routing sessions, use the following commands in router configuration mode on the PE router:

	Command	Purpose
Step 1	Router(config)# ip route vrf <i>vrf-name</i>	Defines static route parameters for every PE to CE session.
Step 2	Router(config-router)# address-family ipv4 [unicast] vrf <i>vrf-name</i>	Defines static route parameters for every BGP PE to CE routing session.  Note The default is Off for auto-summary and synchronization in the VRF address-family submode.
Step 3	Router(config-router-af)# redistribute static	Redistributes VRF static routes into the VRF BGP table.
Step 4	Router(config-router-af)# redistribute static connected	Redistributes directly connected networks into the VRF BGP table.

Verifying VPN Operation

To verify VPN operation by displaying routing information on the PE routers, use any of the following **show** commands in any order:

Command	Purpose
Router# show ip vrf	Displays the set of defined VRFs and interfaces.
Router# show ip vrf [{ brief detail interfaces }] <i>vrf-name</i>	Displays information about defined VRFs and associated interfaces.
Router# show ip route vrf <i>vrf-name</i>	Displays the IP routing table for a VRF.
Router# show ip protocols vrf <i>vrf-name</i>	Displays the routing protocol information for a VRF.
Router# show ip cef vrf <i>vrf-name</i>	Displays the CEF forwarding table associated with a VRF.
Router# show ip interface <i>interface-number</i>	Displays the VRF table associated with an interface.
Router# show ip bgp vpnv4 all [tags]	Displays information about all BGP VPN-IPv4 prefixes.
Router# show tag-switching forwarding vrf <i>vrf-name</i> [<i>prefix mask/length</i>] [detail]	Displays label forwarding entries that correspond to VRF routes advertised by this router.

Configuring MPLS CoS Backbone Support

Several different methods exist for supporting CoS across an MPLS backbone, the choice depending on whether the core has label switch routers (LSRs) or ATM LSRs. In each case, however, the CoS building blocks are the same: CAR, WRED, and WFQ.

Three configurations are described below:

- LSRs used at the core of the network backbone
- ATM LSRs used at the core of the network backbone
- ATM switches without the MPLS feature enabled

LSRs

LSRs at the core of the MPLS backbone are usually either Cisco 7200 and Cisco 7500 series routers running MPLS software. Packets are processed as follows:

1. IP packets enter into the edge of the MPLS network.
2. The edge LSRs invoke CAR to classify the IP packets and possibly set IP precedence. Alternatively, IP packets can be received with their IP precedence already set.
3. For each packet, the router performs a lookup on the IP address to determine the next-hop LSR.
4. The appropriate label is placed on the packet with the IP precedence bits copied into every label entry in the MPLS header.
5. The labeled packet is then forwarded to the appropriate output interface for processing.

6. The packets are differentiated by class. This is done according to drop probability (WRED) or according to bandwidth and delay (WFQ). In either case, LSRs enforce the defined differentiation by continuing to employ WRED or WFQ on each hop.

ATM LSRs

ATM LSRs at the core implement the multiple label virtual circuit model (LVC). In the multiple LVC model, one label is assigned for each service class for each destination. The operation of the edge LSR is the same as that described previously for the LSR case, except that the output is an ATM interface. WRED is used to define service classes and determine discard policy during congestion.

In the multiple LVC model, however, class-based WFQ is used to define the amount of bandwidth available to each service class. Packets are scheduled by class during congestion. The ATM LSRs participate in the differentiation of classes with WFQ and intelligently drop packets when congestion occurs. The mechanism for this discard activity is weighted early packet discard (WEPD).

ATM Switches

When the core network uses ATM switches and the edge of the network uses MPLS-enabled edge LSRs, the edge LSRs are interconnected through a mesh of ATM Forum PVCs (CBR, VBR, or UBR) over the ATM core switches. The edge LSRs invoke WFQ on a per-VC basis to provide differentiation based on the delay of each MPLS CoS multiplexed onto the ATM Forum PVC. Optionally, WRED can also be used on a per-VC basis to manage drop priority between classes when congestion occurs on the edge LSR.

Table 17 lists the MPLS CoS features supported on packet interfaces.

Table 17 *MPLS CoS Features Supported on Packet Interfaces*

MPLS CoS Packet Feature	Cisco 7500 Series	Cisco 7200 Series	Cisco 4x00 Series	Cisco 36x0 Series	Cisco 2600 Series
Per-interface WRED	X	X	X	X	Untested
Per-interface, per-flow WFQ	X	X	X	X	Untested
Per-interface, per-class WFQ	X	X	X	X	Untested

Table 18 lists the MPLS CoS features supported on ATM interfaces.

Table 18 *MPLS CoS Features Supported on ATM Interfaces*

MPLS CoS ATM Forum PVCs Feature	Cisco 7500 Series	Cisco 7200 Series	Cisco 4x00 Series	Cisco 36x0 Series	Cisco 2600 Series
Per-VC WRED	X ¹	X ¹	—	—	—
Per-VC WRED and per VC, per-class WFQ	—	X ¹	—	—	—
MPLS CoS Multi-VC or LBR Feature					

Table 18 MPLS CoS Features Supported on ATM Interfaces

Per-interface WRED	X ²	X ²	—	—	—
Per-interface, per-class WFQ	X ²	X ²	—	—	—

1. This feature is only available on the PA-A3.
2. This feature is only available on the PA-A1.

Table 19 lists the MPLS CoS features supported on ATM switches.

Table 19 MPLS CoS Features Supported on ATM Switches

MPLS CoS ATM Forum PVCs Feature	BPX 8650 Series	MGX 8800 Series	LightStream 1010 ATM Switch ¹	Catalyst 8540 MSR ¹
MPLS CoS ATM Forum PVCs	X	X	X	X
MPLS CoS Multi-VC or LBR—per-class WFQ	X	—	—	—

1. This can be used for the core only.

Configuring MPLS CoS

Perform the tasks in the following sections to configure the MPLS CoS feature:

- Configuring PVC Mode in a Non-MPLS-Enabled Core
- Configuring Multi-VC Mode in a MPLS-Enabled Core
- Configuring Multi-VCs Using the Cos-Map Function
- Configuring DWFQ and Changing Queue Weights on an Outgoing Interface
- Verifying CoS Operation

Configuring PVC Mode in a Non-MPLS-Enabled Core

To configure a PVC in a non-MPLS-enabled core, use the following commands in router configuration mode:

	Command	Purpose
Step 1	Router(config)# interface <i>type number</i> point-to-point	Configures a point-to-point ATM subinterface.
Step 2	Router(config-subif)# ip unnumbered Loopback0	Assigns IP address to the subinterface.
Step 3	Router(config-subif)# pvc 4/40	Creates a PVC on the subinterface.
Step 4	Router(config-if-atm-vc)# random-detect attach groupname	Activates (D)WRED on the interface.
Step 5	Router(config-if-atm-vc)# encapsulation aal5snap	Sets encapsulation type for the PVC.

	Command	Purpose
Step 6	Router(config-subif)# exit	Exits from PVC mode and enters subinterface mode.
Step 7	Router(config-subif)# tag-switching ip	Enables MPLS IP on the point-to-point interface.

Configuring Multi-VC Mode in a MPLS-Enabled Core

To configure multi-VC mode in an MPLS-enabled core, use the following commands in router configuration mode:



Note

The default for the multi-VC mode creates four VCs for each MPLS destination.

	Command	Purpose
Step 1	Router(config)# interface <i>type number</i> tag-switching	Configures an ATM MPLS subinterface.
Step 2	Router(config-subif)# ip unnumbered Loopback0	Assigns IP address to the subinterface.
Step 3	Router(config-subif)# tag-switching atm multi-vc	Enables ATM multi-VC mode on the subinterface.
Step 4	Router(config-subif)# tag-switching ip	Enables MPLS on the ATM subinterface.

Configuring Multi-VCs Using the Cos-Map Function

If you do not choose to use the default for configuring label VCs, you can configure fewer label VCs by using the CoS map function. To use the CoS map function, use the following commands in router configuration mode:

	Command	Purpose
Step 1	Router(config)# tag-switching cos-map <i>cos-map number</i>	Creates a CoS map.
Step 2	Router(config-tag-cos-map)# class 1 premium	<p>Enters the cos-map submenu and maps premium and standard classes to label VCs.</p> <p>This CoS map assigns class 1 traffic to share the same label VC as class 2 traffic. The numbers you assign to the CoS map range from 0 to 3.</p> <p>The defaults are:</p> <ul style="list-style-type: none"> • class 0 is available • class 1 is standard • class 2 is premium • class 3 is control
Step 3	Router(config-tag-cos-map)# exit	Exits the MPLS CoS map submenu.

	Command	Purpose
Step 4	Router(config)# access-list <i>access-list-number</i> permit <i>destination</i>	Creates an access list. The access list acts on traffic going to the specified destination address.
Step 5	Router(config)# tag-switching prefix-map <i>prefix-map</i> access-list <i>access-list</i> cos-map <i>cos-map</i>	Configures the router to use a specified CoS map when a MPLS destination prefix matches the specified access list.

Configuring DWFQ and Changing Queue Weights on an Outgoing Interface

To configure distributed fair queueing and change queue weights on an interface, use the following commands in interface configuration mode after specifying the interface:

	Command	Purpose
Step 1	Router(config)# interface <i>type number</i>	Specifies the interface type and number.
Step 2	Router(config-if)# fair-queue tos	Configures an interface to use fair queueing
Step 3	Router(config)# fair-queue tos <i>class weight</i>	Changes the class weight on the specified interface.

Verifying CoS Operation

To verify the operation of MPLS CoS, use the following commands in configuration mode:

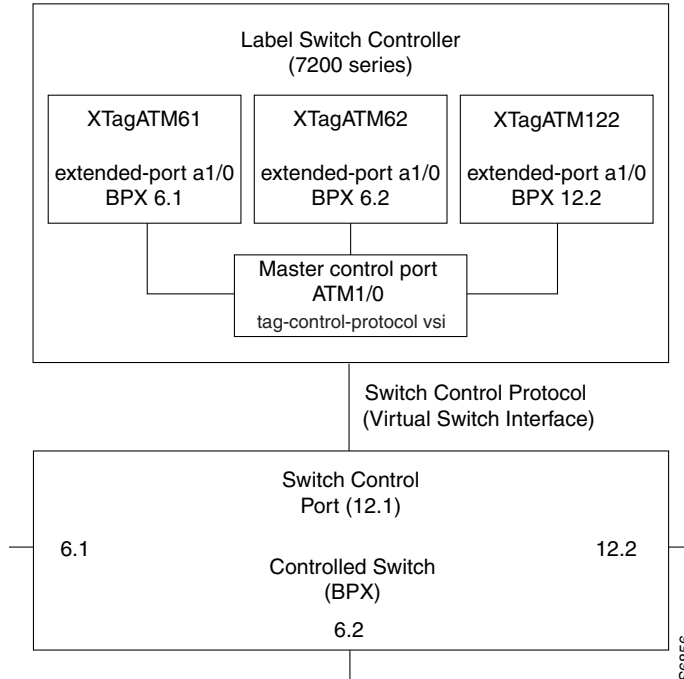
	Command	Purpose
Step 1	Router# show tag-switching interfaces <i>interfaces</i>	Displays detailed information about label switching interfaces.
Step 2	Router# show tag-switching cos-map	Displays the CoS map used to assign VCs.
Step 3	Router# show tag-switching prefix-map	Displays the prefix map used to assign a CoS map to network prefixes.

Configuring the Label Switch Controller

On the Label Switch Controller (LSC), the TC-ATM ports on the controlled switch are represented as a new IOS interface type called extended Label ATM (XmplsATM). XmplsATM interfaces are associated with particular physical interfaces on the controlled switch through the **extended-port** interface configuration command.

Figure 22 illustrates a configuration in which a LSC is controlling three ports on a BPX—6.1, 6.2, and 12.2. These corresponding XmplsATM interfaces have been created on the LSC and associated with the corresponding ATM ports using the **extended-port** interface configuration command. Note that an additional port on the BPX (12.1) acts as the switch control port, and an ATM interface (ATM1/0) on the LSC acts as the master control port.

Figure 22 shows a typical LSC configuration where the LSC and BPX together function as an ATM-LSR.

Figure 22 Typical LSC/BPX Configuration

LSC as Label Edge Device

The LSC can function simultaneously as a controller for an ATM switch and as a label edge device. Traffic can be forwarded between a router interface and a TC-ATM interface on the controlled switch as well as between two TC-ATM interfaces on the controlled switch. The LSC can perform the imposition and removal of labels and can serve as the head or tail of a label-switched path (LSP) tunnel. However, when acting as a label edge device, the LSC is limited by the capabilities of its control link with the switch as follows:

- Total throughput between all other router interfaces and switch interfaces is limited by the bandwidth of the control link (that is, OC-3, 155 Mb per second).
- Label space for LSC-terminated VCs is limited by the number of VCs supported on the control link.

Support for ATM Forum Protocols

The LSC may be connected to a network running ATM Forum protocols while simultaneously performing its LSC function. However, the connection to the ATM-Forum network must be through a separate ATM interface, that is, not through the master control port.

Configuring MPLS on a LSC-Controlled BPX Port

To configure MPLS on a port of the BPX that is being controlled by the LSC, use the following commands in configuration mode. The assumption is that the BPX is connected to the LSC through ATM1/0; the goal is to configure MPLS on slot 6, port 1 of the BPX.

	Command	Purpose
Step 1	Router(config)# interface atm1/0 Router(config-if)# tag-control-protocol vsi	Enables the VSI protocol on the control interface (ATM1/0).
Step 2	Router(config-if)# interface XTagATM61 Router(config-if)# extended-port atm1/0 bpx 6.1	Creates an extended label ATM (XmplsATM) virtual interface and bind it to BPX port 6.1.
Step 3	Router(config-if)# ip address 192.103.210.5 255.255.255.0 Router(config-if)# tag-switching ip Router(config-if)# exit	Configures MPLS on the extended label ATM interface. (extended label ATM interfaces differ from ordinary ATM interfaces in that MPLS is configured on the primary interface of an extended label ATM interface, whereas it is configured on a MPLS subinterface of an ordinary ATM interface.)
Step 4	Router(config)# ip cef switch	Enables Cisco Express Forwarding (CEF) switching.

MPLS Configuration Examples

This section provides sample configurations. It contains the following sections:

- Enabling MPLS Incrementally in a Network Example
- Enabling MPLS for a Subset of Destination Prefixes Example
- Selecting the Destination Prefixes and Paths Example
- Displaying MPLS LDP Binding Information Example
- Displaying MPLS Forwarding Table Information Example
- Displaying MPLS Interface Information Example
- Displaying MPLS LDP Neighbor Information Example
- Enabling LSP Tunnel Signalling Example
- Configuring a LSP Tunnel Example
- Displaying the LSP Tunnel Information Example
- Configuring an MPLS Traffic Engineering Tunnel Example
- Configuring MPLS Virtual Private Networks Example
- Configuring MPLS on a LSC-Controlled BPX Port Example
- Implementing MPLS CoS Example

Enabling MPLS Incrementally in a Network Example

The following example shows you how to configure MPLS incrementally throughout a network of routers. You enable MPLS first between one pair of routers (in this case, R1 and R3 shown in Figure 21) and add routers step by step until every router in the network is label switch enabled.

```

router-1# configuration terminal
router-1(config)# ip cef distributed
router-1(config)# tag-switching ip
router-1(config)# interface e0/1
router-1(config-if)# tag-switching ip
router-1(config-if)# exit
router-1(config)#
router-3# configuration terminal
router-3(config)# ip cef distributed
router-3(config)# tag-switching ip
router-3(config)# interface e0/1
router-3(config-if)# tag-switching ip
router-3(config-if)# exit
router-3(config)#

```

Enabling MPLS for a Subset of Destination Prefixes Example

The following example shows the commands you enter at each of the routers to enable MPLS for only a subset of destination prefixes (see Figure 21).

```

Router(config)# access-list-1 permit A
Router(config)# tag-switching advertise-tags for 1

```

Selecting the Destination Prefixes and Paths Example

The following example shows the commands you enter to configure the routers to select the destination prefixes and paths for which MPLS is enabled. When you configure R2, R5, and R8 to distribute no labels to other routers, you ensure that no routers send them labeled packets. You also need to configure routers R1, R3, R4, R6, and R7 to distribute labels only for network A and only to the applicable adjacent router. This configuration ensures that R3 distributes its label for network A only to R1, R4 only to R3, R6 only to R4, and R7 only to R6 (see Figure 21).

```

router-2(config)# no tag-switching advertise-tags
router-5(config)# no tag-switching advertise-tags
router-8(config)# no tag-switching advertise-tags
router-1(config)# access-list permit R1
router-1(config)# no tag-switching advertise-tags for 1
router-1(config)# tag-switching advertise-tags for 1 to 2
router-1(config)# exit

router-3# access-list 1 permit A
router-3# access-list 2 permit R1
router-3# tag-switching advertise-tags for 1 to 2
router-3# exit

router-4# access-list 1 permit A
router-4# access-list 2 permit R3
router-4# tag-switching advertise-tags for 1 to 2
router-4# exit

```

```

router-6# access-list 1 permit A
router-6# access-list 2 permit R4
router-6# tag-switching advertise-tags for 1 to 2
router-6# exit
router-7# access-list 1 permit A
router-7# access-list 2 permit R6
router-7# tag-switching advertise-tags for 1 to 2
router-7# exit

```

Displaying MPLS LDP Binding Information Example

The following example shows how to use the **show tag-switching tdp bindings** command to display the contents of the Label Information Base (LIB). The display can show the entire database or can be limited to a subset of entries, based on prefix, input or output label values or ranges, and/or the neighbor advertising the label.



Note

This command displays downstream mode bindings. For label VC bindings, see the **show tag-switching atm-tdp bindings** command.

```
Router# show tag-switching tdp bindings
```

Matching entries:

```

tib entry: 10.92.0.0/16, rev 28
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 10.102.0.0/16, rev 29
    local binding: tag: 26
    remote binding: tsr: 172.27.32.29:0, tag: 26
tib entry: 10.105.0.0/16, rev 30
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 10.205.0.0/16, rev 31
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 10.211.0.7/32, rev 32
    local binding: tag: 27
    remote binding: tsr: 172.27.32.29:0, tag: 28
tib entry: 10.220.0.7/32, rev 33
    local binding: tag: 28
    remote binding: tsr: 172.27.32.29:0, tag: 29
tib entry: 99.101.0.0/16, rev 35
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 100.101.0.0/16, rev 36
    local binding: tag: 29
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 171.69.204.0/24, rev 37
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 172.27.32.0/22, rev 38
    local binding: tag: imp-null(1)
    remote binding: tsr: 172.27.32.29:0, tag: imp-null(1)
tib entry: 210.10.0.0/16, rev 39
    local binding: tag: imp-null(1)
tib entry: 210.10.0.8/32, rev 40
    remote binding: tsr: 172.27.32.29:0, tag: 27

```

Displaying MPLS Forwarding Table Information Example

The following example shows how to use the **show tag-switching forwarding-table** command to display the contents of the Label Forwarding Information Base (LFIB). The LFIB lists the labels, output interface information, prefix or tunnel associated with the entry, and number of bytes received with each incoming label. A request can show the entire LFIB or can be limited to a subset of entries. A request can also be restricted to selected entries in any of the following ways:

- Single entry associated with a given incoming label
- Entries associated with a given output interface
- Entries associated with a given next hop
- Single entry associated with a given destination
- Single entry associated with a given tunnel having the current node as an intermediate hop

```
Router# show tag-switching forwarding-table
```

Local tag	Outgoing tag or VC	Prefix or Tunnel Id	Bytes switched	tag Outgoing interface	Next Hop
26	Untagged	10.253.0.0/16	0	Et4/0/0	172.27.32.4
28	1/33	10.15.0.0/16	0	AT0/0.1	point2point
29	Pop tag 1/36	10.91.0.0/16	0	Hs5/0	point2point
		10.91.0.0/16	0	AT0/0.1	point2point
30	32	10.250.0.97/32	0	Et4/0/2	10.92.0.7
		10.250.0.97/32	0	Hs5/0	point2point
34	26	10.77.0.0/24	0	Et4/0/2	10.92.0.7
		10.77.0.0/24	0	Hs5/0	point2point
35	Untagged [T]	10.100.100.101/32	0	Tu301	point2point
36	Pop tag 1/37	168.1.0.0/16	0	Hs5/0	point2point
		168.1.0.0/16	0	AT0/0.1	point2point

```
[T] Forwarding through a TSP tunnel.
View additional tagging info with the 'detail' option
```

Displaying MPLS Interface Information Example

The following example shows how to use the **show tag-switching interfaces** command to show information about the requested interface or about all interfaces on which MPLS is enabled. The per-interface information includes the interface name and indications as to whether IP MPLS is enabled and operational.

```
Router# show tag-switching interfaces
```

Interface	IP	Tunnel	Operational
Hssi3/0	Yes	Yes	No
ATM4/0.1	Yes	Yes	Yes (ATM tagging)
Ethernet5/0/0	No	Yes	Yes
Ethernet5/0/1	Yes	No	Yes
Ethernet5/0/2	Yes	No	No
Ethernet5/0/3	Yes	No	Yes
Ethernet5/1/1	Yes	No	No

The following shows sample output from the **show tag-switching interfaces** command when you specify **detail**:

```
Router# show tag-switching interface detail

Interface Hssi3/0:
  IP tagging enabled
  TSP Tunnel tagging enabled
  Tagging not operational
  MTU = 4470
Interface ATM4/0.1:
  IP tagging enabled
  TSP Tunnel tagging enabled
  Tagging operational
  MTU = 4470
  ATM tagging: Tag VPI = 1, Control VC = 0/32
Interface Ethernet5/0/0:
  IP tagging not enabled
  TSP Tunnel tagging enabled
  Tagging operational
  MTU = 1500
Interface Ethernet5/0/1:
  IP tagging enabled
  TSP Tunnel tagging not enabled
  Tagging operational
  MTU = 1500
Interface Ethernet5/0/2:
  IP tagging enabled
  TSP Tunnel tagging not enabled
  Tagging not operational
  MTU = 1500
Interface Ethernet5/0/3:
  IP tagging enabled
  TSP Tunnel tagging not enabled
  Tagging operational
  MTU = 1500
```

Displaying MPLS LDP Neighbor Information Example

The following example shows how to use the **show tag-switching tdp neighbors** command to display the status of Label Distribution Protocol (LDP) sessions. The neighbor information branch can have information about all LDP neighbors or can be limited to the neighbor with a specific IP address or, LDP identifier, or to LDP neighbors known to be accessible over a specific interface.

```
Router# show tag-switching tdp neighbors

Peer TDP Ident: 10.220.0.7:1; Local TDP Ident 172.27.32.29:1
  TCP connection: 10.220.0.7.711 - 172.27.32.29.11029
  State: Oper; PIEs sent/rcvd: 17477/17487; Downstream on demand
Up time: 01:03:00
TDP discovery sources:
  ATM0/0.1
Peer TDP Ident: 210.10.0.8:0; Local TDP Ident 172.27.32.29:0
  TCP connection: 210.10.0.8.11004 - 172.27.32.29.711
  State: Oper; PIEs sent/rcvd: 14656/14675; Downstream;
Up time: 2d5h
TDP discovery sources:
  Ethernet4/0/1
  Ethernet4/0/2
  POS6/0/0
Addresses bound to peer TDP Ident:
  99.101.0.8      172.27.32.28   10.105.0.8     10.92.0.8
  10.205.0.8     210.10.0.8
```

Enabling LSP Tunnel Signalling Example

The following example shows how to configure support for label-switched path (LSP) tunnel signalling along a path and on each interface crossed by one or more tunnels:

```
Router(config)# ip cef distributed
Router(config)# tag-switching tsp-tunnels
Router(config)# interface e0/1
Router(config-if)# tag-switching tsp-tunnels
Router(config-if)# interface e0/2
Router(config-if)# tag-switching tsp-tunnels
Router(config-if)# exit
```

Configuring a LSP Tunnel Example

The following example shows how to set the encapsulation of the tunnel to MPLS and how to define hops in the path for the LSP.

Follow these steps to configure a two-hop tunnel, hop 0 being the headend router. For hops 1 and 2, you specify the IP addresses of the incoming interfaces for the tunnel. The tunnel interface number is arbitrary, but must be less than 65,535.

```
Router(config)# interface tunnel 2003
Router(config-if)# tunnel mode tag-switching
Router(config-if)# tunnel tsp-hop 1 10.10.0.12
Router(config-if)# tunnel tsp-hop 2 10.50.0.24 lasthop
Router(config-if)# exit
```

To shorten the previous path, delete the hop by entering the following commands:

```
Router(config)# interface tunnel 2003
Router(config-if)# no tunnel tsp-hop 2
Router(config-if)# tunnel tsp-hop 1 10.10.0.12 lasthop
Router(config-if)# exit
```

Displaying the LSP Tunnel Information Example

The following example shows how to use the **show tag-switching tsp tunnels** command to display information about the configuration and status of selected tunnels.

```
Router# show tag-switching tsp-tunnels

Signalling Summary:
    TSP Tunnels Process:      running
    RSVP Process:            running
    Forwarding:               enabled

TUNNEL ID DESTINATION      STATUS      CONNECTION
10.106.0.6.200310.2.0.12up  up
```

Configuring an MPLS Traffic Engineering Tunnel Example

The following example shows how to configure a dynamic tunnel and how to add a second tunnel to the same destination with an explicit path. Note that this example specifies point-to-point outgoing IP addresses. Before you configure MPLS traffic engineering tunnels, you must enter the following global, IS-IS, and interface commands on the router.

```
configure terminal
ip cef
mpls traffic-eng tunnels
interface loopback 0
ip address 11.11.11.11 255.255.255.255
ip router isis

interface s1/0
ip address 131.0.0.1 255.255.0.0
ip router isis
mpls traffic-eng tunnels
    ip rsvp bandwidth 1000
    mpls traffic-eng administrative-weight 10

router isis
net 47.0000.0011.0011.00
is-type level-1
metric-style wide
    mpls traffic-eng router-id Loopback0
    mpls traffic-eng level-1
```

This example includes the commands for configuring a dynamic tunnel from Router 1 to Router 5.

```
configure terminal
interface tunnel1
 ip unnumbered loopback 0
 tunnel destination 17.17.17.17
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng bandwidth 100
 tunnel mpls traffic-eng priority 1 1
 tunnel mpls traffic-eng path-option 1 dynamic
```

To verify that the tunnel is up and traffic is routed through the tunnel, enter these commands:

```
show mpls traffic-eng tunnel
show ip route 17.17.17.17
show mpls traffic-eng autoroute
ping 17.17.17.17
show interface tunnel1 accounting
show interface s1/0 accounting
```

To create an explicit path, enter these commands:

```
configure terminal
ip explicit-path identifier 1
 next-address 131.0.0.1
 next-address 135.0.0.1
 next-address 136.0.0.1
 next-address 133.0.0.1
```

To add a second tunnel to the same destination with an explicit path, enter these commands:

```
configure terminal
interface tunnel2
 ip unnumbered loopback 0
 tunnel destination 17.17.17.17
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng bandwidth 100
 tunnel mpls traffic-eng priority 1 1
 tunnel mpls traffic-eng path-option 1 explicit identifier 1
```

To verify that the tunnel is up and traffic is routed through the tunnel, enter these commands:

```
show mpls traffic-eng tunnel
show ip route 17.17.17.17
show mpls traffic-eng autoroute
ping 17.17.17.17
show interface tunnel1 accounting
show interface s1/0 accounting
```

Configuring MPLS Virtual Private Networks Example

The following example provides a sample configuration file from a PE router.

```
ip cef distributed           ! CEF switching is pre-requisite for label Switching
frame-relay switching
!
ip vrf vrf1                 ! Define VPN Routing instance vrf1
  rd 100:1
  route-target both 100:1   ! Configure import and export route-targets for vrf1
!
ip vrf vrf2                 ! Define VPN Routing instance vrf2
  rd 100:2
  route-target both 100:2   ! Configure import and export route-targets for vrf2
  route-target import 100:1 ! Configure an additional import route-target for vrf2
  import map vrf2_import    ! Configure import route-map for vrf2
!
interface lo0
  ip address 10.13.0.13 255.255.255.255
!
interface atm9/0/0          ! Backbone link to another Provider router
!
interface atm9/0/0.1 tag-switching
  ip unnumbered loopback0
no ip directed-broadcast
tag-switching atm vpi 2-5
tag-switching ip

interface atm5/0
no ip address
no ip directed-broadcast
atm clock INTERNAL
no atm ilmi-keepalive

interface Ethernet1/0
ip address 3.3.3.5 255.255.0.0
no ip directed-broadcast
no ip mroute-cache
no keepalive
```

```

interface Ethernet5/0/1    ! Set up Ethernet interface as VRF link to a CE router
 ip vrf forwarding vrf1
 ip address 10.20.0.13 255.255.255.0
 !
interface hssi 10/1/0

 hssi internal-clock
 encaps fr
 frame-relay intf-type dce
 frame-relay lmi-type ansi
 !
interface hssi 10/1/0.16 point-to-point
 ip vrf forwarding vrf2
 ip address 10.20.1.13 255.255.255.0
 frame-relay interface-dlci 16 ! Set up Frame Relay PVC subinterface as link to another
 !                               ! CE router

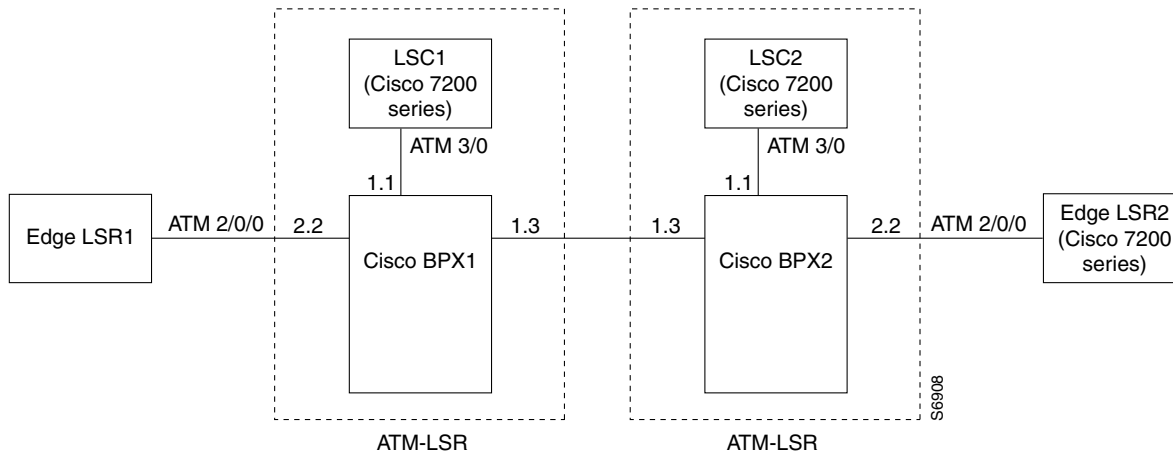
router bgp 1                ! Configure BGP sessions
 no synchronization
 no bgp default ipv4-activate    ! Deactivate default IPv4 advertisements
 neighbor 10.15.0.15 remote-as 1  ! Define IBGP session with another PE
 neighbor 10.15.0.15 update-source lo0
 !
 address-family vpnv4 unicast    ! Activate PE exchange of VPNv4 NLRI
  neighbor 10.15.0.15 activate
  exit-address-family
 !
 address-family ipv4 unicast vrf vrf1    ! Define BGP PE-CE session for vrf1
  redistribute static
  redistribute connected
  neighbor 10.20.0.60 remote-as 65535
  neighbor 10.20.0.60 activate
  no auto-summary
  exit-address-family
 !
 address-family ipv4 unicast vrf vrf2    ! Define BGP PE-CE session for vrf2
  redistribute static
  redistribute connected
  neighbor 10.20.1.11 remote-as 65535
  neighbor 10.20.1.11 update-source h10/1/0.16
  neighbor 10.20.1.11 activate
  no auto-summary
  exit-address-family
 !
 ! Define a VRF static route
 ip route vrf vrf1 12.0.0.0 255.0.0.0 e5/0/1 10.20.0.60
 !
 route-map vrf2_import permit 10        ! Define import route-map for vrf2.
 ...

```

Configuring MPLS on a LSC-Controlled BPX Port Example

In this example, the network topology includes ATM-LSRs in a MPLS network (see Figure 23). The following subsections provide configurations for two LSCs (Cisco 7200 routers), two BPX Service Nodes, and two edge LSRs (Cisco 7500 routers).

Figure 23 ATM-LSR Network Configuration Example



LSC1 Configuration

```
7200 TSC1:
  ip cef switch
  !
  interface ATM3/0
  no ip address
tag-control-protocol vsi
!
interface XTagATM13
  extended-port ATM3/0 bpx 1.3
  !
  ip address 142.4.133.13 255.255.0.0
  tag-switching ip
  !
  interface XTagATM22
  extended-port ATM3/0 bpx 2.2
  !
  ip address 142.6.133.22 255.255.0.0
  tag-switching ip
  !
```

BPX1 and BPX2 Configuration

```
BPX1 and BPX2:
  uptrk 1.1
  cnfrsrc 1.1 256 0 1 e 0 2000 1 255 0 353000
  uptrk 1.3
  cnfrsrc 1.3 256 0 1 e 0 2000 1 255 0 353000
  uptrk 2.2
  cnfrsrc 2.2 256 0 1 e 0 2000 1 255 0 353000
  addshelf 1.1 v 1 1
```

LSC2 Configuration

```
7200 TSC2:
  ip cef switch
  !
  interface ATM3/0
  no ip address
  tag-control-protocol vsi slaves 2
  !
  interface XTagATM13
  extended-port ATM3/0 bpx 1.3
  !
  ip address 142.4.143.13 255.255.0.0
  tag-switching ip
  !
  interface XTagATM22
  extended-port ATM3/0 bpx 2.2
  !
  ip address 142.2.143.22 255.255.0.0
  tag-switching ip
  !
```

Edge LSR1 Configuration

```
7500 TSR1:
  ip cef distributed switch
  !
  interface ATM2/0/0
  no ip address
  !
  interface ATM2/0/0.5 tag-switching
  ip address 142.6.132.2 255.255.0.0
  tag-switching ip
  !
```

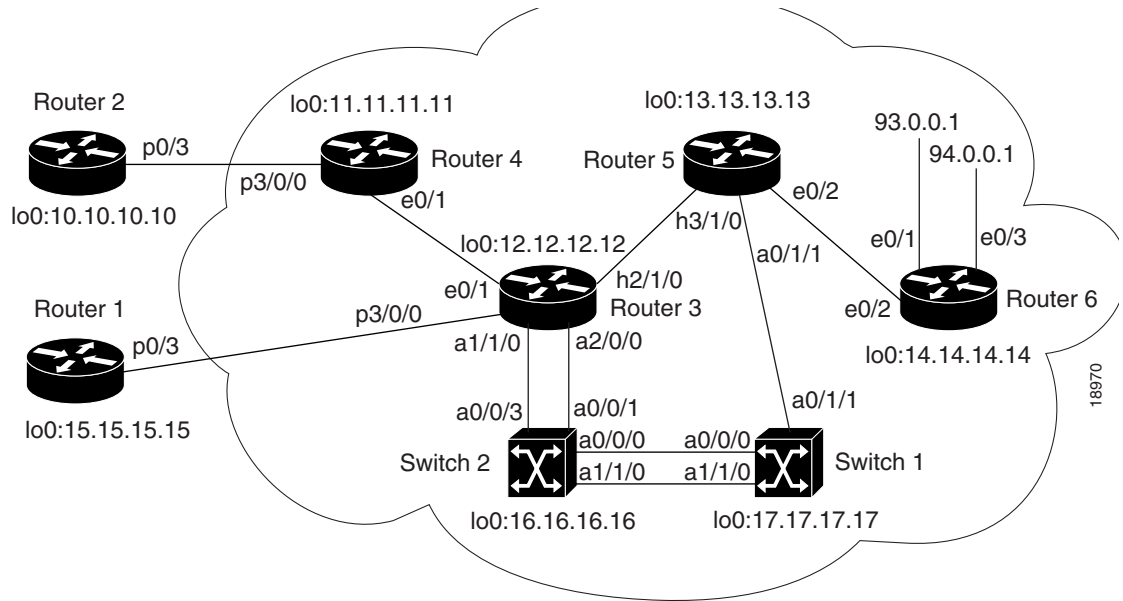
Edge LSR2 Configuration

```
7500 TSR2:
  ip cef distributed switch
  !
  interface ATM2/0/0
  no ip address
  !
  interface ATM2/0/0.9 tag-switching
  ip address 142.2.142.2 255.255.0.0
  tag-switching ip
  !
```

Implementing MPLS CoS Example

Figure 24 illustrates a sample MPLS topology that implements the MPLS CoS feature. The following sections contain the configuration commands entered on Routers R1 to R6 and on Switches 1 and 2 included in this figure.

Figure 24 Sample MPLS Topology Implementing CoS



Configuring Cisco Express Forwarding

The following configuration commands enable Cisco express forwarding (CEF). CEF switching is a prerequisite for the MPLS feature and must be running on all routers in the network.

```
ip cef distributed
tag-switching ip
!
```

Running IP on Router 2

The following commands enable IP routing on Router 2. All routers must have IP enabled.

**Note**

Router 2 is not part of the MPLS network.

```
!  
ip routing  
!  
hostname R2  
!  
interface Loopback0  
 ip address 10.10.10.10 255.255.255.255  
!  
interface POS0/3  
 ip unnumbered Loopback0  
crc 16  
 clock source internal  
!  
router ospf 100  
 network 10.0.0.0 0.255.255.255 area 100  
!
```

Running IP on Router 1

The following commands enable IP routing on Router 1.

**Note**

Router 1 is not part of the MPLS network.

```
ip routing  
!  
hostname R1  
!  
interface Loopback0  
 ip address 15.15.15.15 255.255.255.255  
!  
interface POS0/3  
 ip unnumbered Loopback0  
crc 16  
 clock source internal  
!  
router ospf 100  
 network 15.0.0.0 0.255.255.255 area 100
```

Running MPLS on Router 4

Router 4 is a label edge router. CEF and the MPLS feature must be enabled on this router. Committed Access Rate (CAR) is also configured on Router 4 on interface POS3/0/0 (see the following section on configuring CAR).

```
!  
hostname R4  
!  
ip routing  
tag-switching ip  
tag-switching advertise-tags  
!  
ip cef distributed  
!  
interface Loopback0  
 ip address 11.11.11.11 255.255.255.255  
!  
interface Ethernet0/1  
 ip address 90.0.0.1 255.0.0.0  
tag-switching ip  
!
```

Configuring CAR

Lines 3 and 4 of the following sample configuration contain the CAR rate policies. Line 3 sets the committed information rate (CIR) at 155,000,000 bits and the normal burst/maximum burst size at 200,000/800,000 bytes. The conform action (action to take on packets) sets the IP precedence and transmits the packets that conform to the rate limit. The exceed action sets the IP precedence and transmits the packets when the packets exceed the rate limit.

```
!  
interface POS3/0/0  
 ip unnumbered Loopback0  
rate-limit input 155000000 2000000 8000000 conform-action set-prec-transmit 5  
exceed-action set-prec-transmit 1  
 ip route-cache distributed  
!  
router ospf 100  
 network 11.0.0.0 0.255.255.255 area 100  
 network 90.0.0.0 0.255.255.255 area 100
```

Running MPLS on Router 3

Router 3 is running MPLS. CEF and the MPLS feature must be enabled on this router. Router 3 contains interfaces that are configured for WRED, multi-VC, per VC WRED, WFQ, and CAR. The following sections contain these sample configurations.

```
!  
hostname R3  
!  
ip cef distributed  
!  
interface Loopback0  
 ip address 12.12.12.12 255.255.255.255  
!  
interface Ethernet0/1  
 ip address 90.0.0.2 255.0.0.0  
tag-switching ip
```

Configuring Point-to-Point WRED

The following commands configure WRED on an ATM interface. In this example, the commands refer to a PA-A1 port adapter.

```
!
interface ATM1/1/0
ip route-cache distributed
  atm clock INTERNAL
  random-detect
!
```

Configuring an Interface for Multi-VC Mode

The following commands configure interface ATM1/1/0 for multi-VC mode. In this example, the commands refer to a PA-A1 port adapter.

```
!
interface ATM1/1/0.1 tag-switching
  ip unnumbered Loopback0
tag-switching atm multi-vc
tag-switching ip
!
```

Configuring WRED and Multi-VC Mode on a PA-A3 Port-Adapter Interface

The commands to configure a PA-A3 port adapter differ slightly from the commands to configure a PA-A1 port adapter as shown previously.

On an PA-A3 port-adapter interface, (D)WRED is supported only per-VC, not per-interface.

To configure a PA-A3 port adapter, enter the following commands:

```
!
interface ATM1/1/0
ip route-cache distributed
atm clock INTERNAL
!
interface ATM 1/1/0.1 tag-switching
ip unnumbered Loopback0
tag-switching multi-vc
tag-switching random detect attach groupname
!
```

Configuring Per VC WRED

The following commands configure per VC WRED on a PA-A3 port adapter only.



Note

The PA-A1 port adapter does not support the per-VC WRED drop mechanism.

```
!interface ATM2/0/0
  no ip address
  ip route-cache distributed

interface ATM2/0/0.1 point-to-point
  ip unnumbered Loopback0
  no ip directed-broadcast
  pvc 10/100
    random-detect
    encapsulation aal5snap
  exit
!
tag-switching ip
```

Configuring WRED and WFQ

Lines 5 and 6 of the following sample configuration contain the commands for configuring WRED and WFQ on interface Hssi2/1/0.

```
!
interface Hssi2/1/0
  ip address 91.0.0.1 255.0.0.0
  ip route-cache distributed
  tag-switching ip
    random-detect
  fair queue tos
  hssi internal-clock
!
```

Configuring CAR

Lines 3 and 4 of the following sample configuration contain the CAR rate policies. Line 3 sets the committed information rate (CIR) at 155,000,000 bits and the normal burst/maximum burst size at 200,000/800,000 bytes. The conform action (action to take on packets) sets the IP precedence and transmits the packets that conform to the rate limit. The exceed action sets the IP precedence and transmits the packets when the packets exceed the rate limit.

```
!
interface POS3/0/0
  ip unnumbered Loopback0
  rate-limit input 155000000 2000000 8000000 conform-action set-prec-transmit 2
  exceed-action set-prec-transmit 2
  ip route-cache distributed
!
router ospf 100
  network 12.0.0.0 0.255.255.255 area 100
  network 90.0.0.0 0.255.255.255 area 100
  network 91.0.0.0 0.255.255.255 area 100
!
ip route 93.0.0.0 255.0.0.0 Hssi2/1/0 91.0.0.2
!
```

Running MPLS on Router 5

Router 5 is running the MPLS feature. CEF and the MPLS feature must be enabled on this router. Router 5 has also been configured to create an ATM subinterface in multi-VC mode and to create a PVC on a Point-to-Point subinterface. The sections that follow contain these sample configurations.

```
!  
hostname R5  
!  
ip cef distributed  
!  
interface Loopback0  
  ip address 13.13.13.13 255.255.255.255  
!  
interface Ethernet0/2  
  ip address 92.0.0.1 255.0.0.0  
  tag-switching ip
```

Configuring an ATM Interface Example

The following commands create an ATM interface.

```
!  
interface ATM1/0/0  
  no ip address  
  ip route-cache distributed  
  atm clock INTERNAL  
!
```

Configuring an ATM MPLS Subinterface in Multi-VC Mode Example

The following commands create an MPLS subinterface in multi-VC mode.

```
!  
interface ATM1/0/0.1 tag-switching  
  ip unnumbered Loopback0  
  tag-switching atm multi-vc  
  tag-switching ip  
!
```

Configuring a PVC on Point-to-Point Subinterface

The following commands create a PVC on a point-to-point subinterface (interface ATM1/0/0.2).

```
!  
interface ATM1/0/0.2 point-to-point  
 ip unnumbered Loopback0  
pvc 10/100  
 random-detect  
 encapsulation aal5snap  
 exit  
!  
 tag-switching ip  
!  
interface Hssi3/0  
 ip address 91.0.0.2 255.0.0.0  
 tag-switching ip  
 hssi internal-clock  
!  
router ospf 100  
 network 13.0.0.0 0.255.255.255 area 100  
 network 91.0.0.0 0.255.255.255 area 100  
 network 92.0.0.0 0.255.255.255 area 100  
!
```

Running MPLS on Router 6

Router 6 is running the MPLS feature. CEF and the MPLS feature must be enabled on this router.

```
!  
hostname R6  
!  
ip cef distributed  
!  
interface Loopback0  
 ip address 14.14.14.14 255.255.255.255  
!  
interface Ethernet0/1  
 ip address 93.0.0.1 255.0.0.0  
 tag-switching ip  
!  
interface Ethernet0/2  
 ip address 92.0.0.2 255.0.0.0  
 tag-switching ip  
!  
interface Ethernet0/3  
 ip address 94.0.0.1 255.0.0.0  
 tag-switching ip  
!  
router ospf 100  
 network 14.0.0.0 0.255.255.255 area 100  
 network 92.0.0.0 0.255.255.255 area 100  
 network 93.0.0.0 0.255.255.255 area 100  
 network 94.0.0.0 0.255.255.255 area 100  
!
```

Configuring ATM Switch 2

Switch 2 is configured for MPLS and creates an ATM Forum PVC.

```
!  
hostname S2  
!  
interface Loopback0  
 ip address 16.16.16.16 255.255.255.255  
!  
interface ATM0/0/0  
 ip unnumbered Loopback0  
 tag-switching ip  
!  
interface ATM0/0/1  
 ip unnumbered Loopback0  
 tag-switching ip  
 atm pvc 10 100 interface ATM0/0/0 10 100  
  
interface ATM0/0/2  
 no ip address  
 no ip directed-broadcast  
!  
interface ATM0/0/3  
 ip unnumbered Loopback0  
 tag-switching ip  
!  
interface ATM1/1/0  
 ip unnumbered Loopback0  
 tag-switching ip  
!  
router ospf 100  
 network 16.0.0.0 0.255.255.255 area 100  
!
```

Configuring ATM Switch 1

Switch 1 is configured to create an ATM Forum PVC.

```
!  
hostname S1  
!  
interface Loopback0  
 ip address 17.17.17.17 255.255.255.255  
!  
interface ATM0/0/0  
 ip unnumbered Loopback0  
 tag-switching ip  
!
```

Configuring Label VCs and an ATM Forum PVC

Line 3 of the following sample configuration contains the configuration command for an ATM Forum PVC.

```
!  
interface ATM0/1/1  
 ip unnumbered Loopback0  
 atm pvc 10 100 interface ATM0/0/0 10 100  
 tag-switching ip  
!  
interface ATM1/1/0  
 ip unnumbered Loopback0  
 tag-switching ip  
!  
router ospf 100  
 network 17.0.0.0 0.255.255.255 area 100  
!
```