MPLS Traffic Engineering – DiffServ Aware (DS-TE)

Feature History

Release	Modification
12.0(11) ST	This feature was introduced.
12.0(14) ST	Support for the Cisco Series 7500(VIP) platform was added. Support for the IS-IS Interior Gateway Protocol was added.
12.0(14) ST-1	Support was added for guaranteed bandwidth service directed to many destination prefixes (for example, guaranteed bandwidth service destined to an autonomous system or to a BGP community).
12.2(14)S	This feature was integrated into Cisco IOS Release 12.2(14)S.
12.2(18)S	This feature was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This feature was integrated into Cisco IOS Release 12.2(18)SXD.

This document describes extensions made to Multiprotocol Label Switching Traffic Engineering (MPLS TE) that make it DiffServ aware. Specifically, the bandwidth reservable on each link for constraint-based routing (CBR) purposes can now be managed through two bandwidth pools: a *global pool* and a *sub-pool*. The sub-pool can be limited to a smaller portion of the link bandwidth. Tunnels using the sub-pool bandwidth can then be used in conjunction with MPLS Quality of Service (QoS) mechanisms to deliver guaranteed bandwidth services end-to-end across the network.

The document contains the following sections:

Feature Overview

MPLS traffic engineering allows constraint-based routing of IP traffic. One of the constraints satisfied by CBR is the availability of required bandwidth over a selected path. DiffServ-aware Traffic Engineering extends MPLS traffic engineering to enable you to perform constraint-based routing of "guaranteed" traffic, which satisfies a more restrictive bandwidth constraint than that satisfied by CBR for regular traffic. The more restrictive bandwidth is termed a *sub-pool*, while the regular TE tunnel bandwidth is called the *global pool*. (The sub-pool is a portion of the global pool.) This ability to satisfy a more restrictive bandwidth constraint translates into an ability to achieve higher QoS performance (in terms of delay, jitter, or loss) for the guaranteed traffic.

For example, DS-TE can be used to ensure that traffic is routed over the network so that, on every link, there is never more than 40 percent (or any assigned percentage) of the link capacity of guaranteed traffic (for example, voice), while there can be up to 100 percent of the link capacity of regular traffic. Assuming QoS mechanisms are also used on every link to queue guaranteed traffic separately from regular traffic, it then becomes possible to enforce separate "overbooking" ratios for guaranteed and regular traffic. (In fact, for the guaranteed traffic it becomes possible to enforce no overbooking at all—or even an underbooking—so that very high QoS can be achieved end-to-end for that traffic, even while for the regular traffic a significant overbooking continues to be enforced.)

Also, through the ability to enforce a maximum percentage of guaranteed traffic on any link, the network administrator can directly control the end-to-end QoS performance parameters without having to rely on over-engineering or on expected shortest path routing behavior. This is essential for transport of applications that have very high QoS requirements (such as real-time voice, virtual IP leased line, and bandwidth trading), where over-engineering cannot be assumed everywhere in the network.

DS-TE involves extending OSPF (Open Shortest Path First) routing protocol, so that the available sub-pool bandwidth at each preemption level is advertised in addition to the available global pool bandwidth at each preemption level. And DS-TE modifies constraint-based routing to take this more complex advertised information into account during path computation.

Benefits

DiffServ-aware Traffic Engineering enables service providers to perform separate admission control and separate route computation for discrete subsets of traffic (for example, voice and data traffic).

Therefore, by combining DS-TE with other Cisco IOS features such as QoS, the service provider can:

- Develop QoS services for end customers based on *signaled* rather than *provisioned* QoS
- Build the higher-revenue generating "strict-commitment" QoS services, without overprovisioning
- Offer virtual IP leased-line, Layer 2 service emulation, and point-to-point guaranteed bandwidth services including voice-trunking
- Enjoy the scalability properties offered by MPLS

Related Features and Technologies

The DS-TE feature is related to OSPF, IS-IS, RSVP (Resource Reservation Protocol), QoS, and MPLS traffic engineering. Cisco documentation for all of these features is listed in the next section.

Related Documents

For OSPF:

- "Configuring OSPF" in *Cisco IOS IP Configuration Guide,* Release 12.2
- "OSPF Commands" in *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols,* Release 12.2

For IS-IS:

- "Configuring Integrated IS-IS" in *Cisco IOS IP Configuration Guide,* Release 12.2
- "Integrated IS-IS Commands" in *Cisco IOS IP Command Reference, Volume 2 of 3: Routing Protocols,* Release 12.2

For RSVP:

- "Configuring RSVP" in *Cisco IOS Quality of Service Solutions Configuration Guide,* Release 12.2
- *Cisco IOS Quality of Service Solutions Command Reference*, Release 12.2

For QoS:

- *Cisco IOS Quality of Service Solutions Configuration Guide,* Release 12.2
- *Cisco IOS Quality of Service Solutions Command Reference,* Release 12.2

For MPLS Traffic Engineering:

- "Multiprotocol Label Switching" in *Cisco IOS Switching Services Configuration Guide,* Release 12.2
- *Cisco IOS Switching Services Command Reference,* Release 12.2

Supported Platforms and Interfaces

This release supports DS-TE together with QoS on the Cisco IOS 7500 series router (VIP) over the POS (Packet over SONET) interface.

Finding Support Information for Platforms and Cisco IOS Software Images

Use Cisco Feature Navigator to find information about platform support and Cisco IOS software image support. Access Cisco Feature Navigator at http://www.cisco.com/go/fn. You must have an account on Cisco.com. If you do not have an account or have forgotten your username or password, click **Cancel** at the login dialog box and follow the instructions that appear.

Supported Standards, MIBs, and RFCs

Standards

Standardization of DiffServ-aware MPLS Traffic Engineering is still in progress in the IETF (Internet Engineering Task Force). At the time of publication of this feature guide, DS-TE is documented in the following IETF drafts:

- *Requirements for Support of Diff-Serv-aware MPLS Traffic Engineering* by F. Le Faucheur, T. Nadeau, A. Chiu, W. Townsend, D. Skalecki & M. Tatham
  http://search.ietf.org/internet-drafts/draft-ietf-tewg-diff-te-reqts-05.txt
- *Protocol Extensions for Support of Diff-Serv-aware MPLS Traffic Engineering* by F. Le Faucheur, T. Nadeau, J. Boyle, K. Kompella, W. Townsend & D. Skalecki
  http://search.ietf.org/internet-drafts/draft-ietf-tewg-diff-te-proto-01.txt

As the IETF work is still in progress, details are still under definition and subject to change, so DS-TE should be considered as a pre-standard implementation of IETF DiffServ-aware MPLS Traffic Engineering. However, it is in line with the requirements described in the first document above. The concept of "Class-Type" defined in that IETF draft corresponds to the concept of bandwidth pool implemented by DS-TE. And because DS-TE supports two bandwidth pools (global pool and sub-pool), DS-TE should be seen as supporting two Class-Types (Class-Type 0 and Class-Type 1).

MIBs

No new or modified MIBs are supported by this release.

To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL:

http://tools.cisco.com/ITDIT/MIBS/servlet/index

If Cisco MIB Locator does not support the MIB information that you need, you can also obtain a list of supported MIBs and download MIBs from the Cisco MIBs page at the following URL:

http://www.cisco.com/public/sw-center/netmgmt/cmtk/mibs.shtml

To access Cisco MIB Locator, you must have an account on Cisco.com. If you have forgotten or lost your account information, send a blank e-mail to cco-locksmith@cisco.com. An automatic check will verify that your e-mail address is registered with Cisco.com. If the check is successful, account details with a new random password will be e-mailed to you. Qualified users can establish an account on Cisco.com by following the directions found at this URL:

http://www.cisco.com/register

RFCs

No new or modified RFCs are supported by this feature.

Prerequisites

Your network must support the following Cisco IOS features in order to support guaranteed bandwidth services based on DiffServ-aware Traffic Engineering:

- MPLS
- IP Cisco Express Forwarding (CEF)
- OSPF or IS-IS
- RSVP-TE
- QoS

Configuration Tasks

This section lists the minimum set of commands you need to implement the DiffServ-aware Traffic Engineering feature—in other words, to establish a tunnel that reserves bandwidth from the sub-pool.

The "Configuration Examples" section on page 9 presents these same commands in context and shows how, by combining them with QoS commands, you can build guaranteed bandwidth services.

Modified Commands

DS-TE commands were developed from the existing command set that configures MPLS traffic engineering. The only difference introduced to create DS-TE was the expansion of two commands:

- **ip rsvp bandwidth** was expanded to configure the size of the sub-pool on every link.
- **tunnel mpls traffic-eng bandwidth** was expanded to enable a TE tunnel to reserve bandwidth from the sub-pool.

ip rsvp bandwidth command

The old command was

```
ip rsvp bandwidth x y
```

where x = the size of the only possible pool, and y = the size of a single traffic flow (ignored by traffic engineering)

Now the extended command is

```
ip rsvp bandwidth interface-kbps single-flow-kbps [sub-pool kbps]
```

where *x* = the size of the global pool, and *z* = the size of the sub-pool.

(Remember, the sub-pool's bandwidth is less than—because it is part of—the global pool's bandwidth.)

tunnel mpls traffic-eng bandwidth command

The old command was

```
tunnel mpls traffic-eng bandwidth b
```

where b = the amount of bandwidth this tunnel requires.

Now you specify from which pool (global or sub) the tunnel's bandwidth is to come. You can enter

```
tunnel mpls traffic-eng bandwidth sub-pool b
```

This indicates that the tunnel should use bandwidth from the sub-pool. Alternatively, you can enter

```
tunnel mpls traffic-eng bandwidth b
```

This indicates that the tunnel should use bandwidth from the global pool (the default).

Configuration Procedure

To establish a sub-pool TE tunnel, you must enter configurations at three levels:

- Device (router or switch router)
- Physical interface
- Tunnel interface

On the first two levels, you activate traffic engineering; on the third level—the tunnel interface—you establish the sub-pool tunnel. Therefore, it is only at the tunnel headend device that you need to configure all three levels. At the tunnel midpoints and tail, it is sufficient to configure the first two levels.

Level 1: Configuring the Device

At this level, you tell the device (switch router) to use accelerated packet-forwarding (known as Cisco Express Forwarding or CEF), Multiprotocol Label Switching (MPLS), traffic-engineering tunneling, and the OSPF routing algorithm. This level is often called global configuration mode because the configuration is applied globally, to the entire device, rather than to a specific interface or routing instance. (These commands have not been modified from earlier releases of Cisco IOS.)

Enter the following commands:

	Command	Purpose
Step 1	`Router(config)# ip cef`	Enables CEF, which accelerates the flow of packets through the device.
Step 2	`Router(config)# mpls traffic-eng tunnels`	Enables MPLS, and specifically its traffic engineering tunnel capability.
Step 3	`Router(config)# router ospf`	Invokes the OSPF routing process for IP and puts the device into router configuration mode. Go to Steps 9 and 10.
Step 4	`Router(config-router)# mpls traffic-eng router-id loopback0`	Specifies that the traffic engineering router identifier is the IP address associated with the *loopback0* interface.
Step 5	`Router(config-router)# mpls traffic-eng area` *num*	Turns on MPLS traffic engineering for a particular OSPF area.

Level 2: Configuring the Physical Interface

Having configured the device, you now must configure the interface on that device through which the tunnel will run. To do that, you first put the router into interface configuration mode.

You then enable RSVP. RSVP is used to signal (set up) a traffic engineering tunnel, and to tell devices along the tunnel path to reserve a specific amount of bandwidth for the traffic that will flow through that tunnel. This command establishes the maximum size of the sub-pool.

Finally, you enable the MPLS traffic engineering tunnel feature on this physical interface.

To accomplish these tasks, enter the following commands:

	Command	Purpose
Step 1	`Router(config)# interface interface-id`	Moves configuration to the interface level, directing subsequent configuration commands to the specific interface identified by the *interface-id*.
Step 2	`Router(config-if)# ip rsvp bandwidth interface-kbps sub-pool kbps`	Enables RSVP on this interface and limits the amount of bandwidth RSVP can reserve on this interface. The sum of bandwidth used by all tunnels on this interface cannot exceed *interface-kbps,* and the sum of bandwidth used by all sub-pool tunnels cannot exceed sub-pool *kbps*.
Step 3	`Router(config-if)# mpls traffic-eng tunnels`	Enables the MPLS traffic engineering tunnel feature on this interface.

Level 3: Configuring the Tunnel Interface

Now you create a set of attributes for the tunnel itself; those attributes are configured on the tunnel interface (not to be confused with the physical interface just configured above).

The only command which was modified at this level for DS-TE is **tunnel mpls traffic-eng bandwidth**.

Enter the following commands:

	Command	Purpose
Step 1	`Router(config)# interface tunnel1`	Creates a tunnel interface (named in this example **tunnel1**) and enters interface configuration mode.
Step 2	`Router(config-if)# tunnel destination A.B.C.D`	Specifies the IP address of the tunnel tail device.
Step 3	`Router(config-if)# tunnel mode mpls traffic-eng`	Sets the tunnel's encapsulation mode to MPLS traffic engineering.
Step 4	`Router(config-if)# tunnel mpls traffic-eng bandwidth {sub-pool | [global]} bandwidth`	Configures the tunnel's bandwidth and assigns it either to the sub-pool or the global pool.
Step 5	`Router(config-if)# tunnel mpls traffic-eng priority`	Sets the priority to be used when system determines which existing tunnels are eligible to be preempted.
Step 6	`Router(config-if)# tunnel mpls traffic-eng path-option`	Configures the paths (hops) a tunnel should use. The user can enter an explicit path (can specify the IP addresses of the hops) or can specify a dynamic path (the router figures out the best set of hops).

Verifying the Configurations

To view the complete configuration you have entered, use the **show running-config** EXEC command and check its output for correctness.

To check *just one tunnel's* configuration, enter **show interfaces tunnel** followed by the tunnel interface number. To see that tunnel's RSVP bandwidth and flow, enter **show ip rsvp interface** followed by the name or number of the physical interface.

Here is an example of the information displayed by these two commands.

```
GSR1# show interfaces tunnel 4

Tunnel4 is up, line protocol is down
  Hardware is Routing Tunnel
  MTU 1500 bytes, BW 9 Kbit, DLY 500000 usec, rely 255/255, load 1/255
  Encapsulation TUNNEL, loopback not set, keepalive set (10 sec)
  Tunnel source 0.0.0.0, destination 0.0.0.0
  Tunnel protocol/transport GRE/IP, key disabled, sequencing disabled
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Output queue 0/0, 0 drops; input queue 0/75, 0 drops
  Five minute input rate 0 bits/sec, 0 packets/sec
  Five minute output rate 0 bits/sec, 0 packets/sec
    0 packets input, 0 bytes, 0 no buffer
    Received 0 broadcasts, 0 runts, 0 giants
    0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
    0 packets output, 0 bytes, 0 underruns
    0 output errors, 0 collisions, 0 interface resets, 0 restarts

GSR1# show ip rsvp interface pos4/0

interface    allocated  i/f max  flow max sub max
PO4/0        300K       466500K  466500K  0M
```

To view *all tunnels at once* on the router you have configured, enter **show mpls traffic-eng tunnels brief**. The information displayed when tunnels are functioning properly looks like this.

```
GSR1# show mpls traffic-eng tunnels brief

Signalling Summary:
    LSP Tunnels Process:           running
    RSVP Process:                  running
    Forwarding:                    enabled
    Periodic reoptimization:       every 3600 seconds, next in 3029 seconds
TUNNEL NAME DESTINATION      UP IF     DOWN IF   STATE/PROT
GSR1_t0 192.168.1.13     -         SR3/0     up/up
GSR1_t1 192.168.1.13     -         SR3/0     up/up
GSR1_t2 192.168.1.13     -         PO4/0     up/up
Displayed 3 (of 3) heads, 0 (of 0) midpoints, 0 (of 0) tails
```

When one or more tunnels is not functioning properly, the display could instead look like this. (In the following example, tunnels t0 and t1 are down, as indicated in the far right column).

```
GSR1# show mpls traffic-eng tunnels brief

Signalling Summary:
    LSP Tunnels Process:           running
    RSVP Process:                  running
    Forwarding:                    enabled
    Periodic reoptimization:       every 3600 seconds, next in 2279 seconds
```

```
TUNNEL NAME DESTINATION      UP IF     DOWN IF   STATE/PROT
GSR1_t0 192.168.1.13     -          SR3/0     up/down
GSR1_t1 192.168.1.13     -          SR3/0     up/down
GSR1_t2 192.168.1.13     -          PO4/0     up/up
Displayed 3 (of 3) heads, 0 (of 0) midpoints, 0 (of 0) tails
```

To find out *why* a tunnel is down, insert its name into this same command, after adding the **name** keyword and omitting the **brief** keyword. For example:

```
GSR1# show mpls traffic-eng tunnels name GSR1_t0

Name:GSR1_t0                             (Tunnel0) Destination:192.168.1.13
  Status:
    Admin:up         Oper:down Path: not valid       Signalling:connected
```

If, as in this example, the Path is displayed as **not valid**, use the **show mpls traffic-eng topology** command to make sure the router has received the needed updates.

Additionally, you can use any of the following **show** commands to inspect particular aspects of the network, router, or interface concerned:

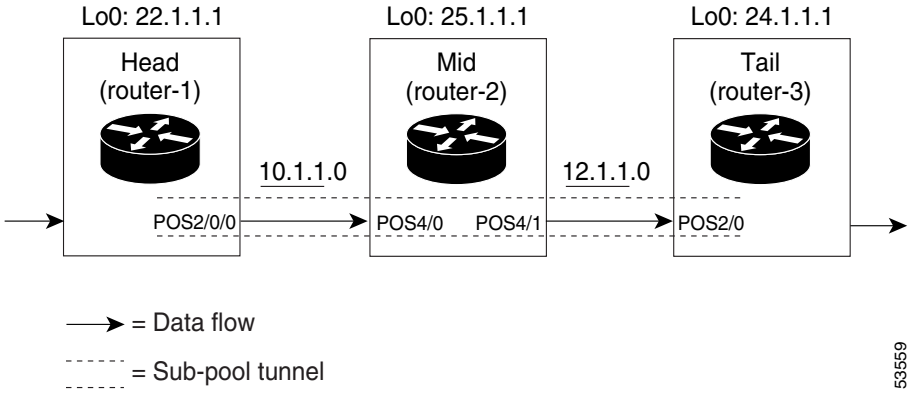
To see information about...		
this level	**and this item ...**	**Use this command**
Network	Advertised bandwidth allocation information	**show mpls traffic-eng link-management advertisements**
	Preemptions along the tunnel path	**debug mpls traffic-eng link-management preemption**
	Available TE link bandwidth on all head routers	**show mpls traffic-eng topology**
Router	Status of all tunnels currently signalled by the router	**show mpls traffic-eng link-management admission-control**
	Tunnels configured on midpoint routers	**show mpls traffic-eng link-management summary**
Physical interface	Detailed information on current bandwidth pools	**show mpls traffic-eng link-management bandwidth-allocation** [*interface-name*]
	TE RSVP bookkeeping	**show mpls traffic-eng link-management interfaces**
	Entire configuration of one interface	**show run interface**

Configuration Examples

First this section presents the DS-TE configurations needed to create the sub-pool tunnel. Then it presents the more comprehensive design for building end-to-end guaranteed bandwidth service, which involves configuring QoS as well.

As shown in Figure 1, the tunnel configuration involves at least three devices—tunnel head, midpoint, and tail. On each of those devices one or two network interfaces must be configured for traffic ingress and egress.

Figure 1 Sample Tunnel Topology



Tunnel Head

At the device level:

```
Router-1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.

Router-1(config)# ip cef distributed
Router-1(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-1(config)# router isis                          router ospf 100
    Router-1(config-router)# net                       redistribute connected
    49.0000.1000.0000.0010.00
    Router-1(config-router)# metric-style wide         network 10.1.1.0 0.0.0.255 area
                                                       0
    Router-1(config-router)# is-type level-1           network 22.1.1.1 0.0.0.0 area 0
    Router-1(config-router)# mpls traffic-eng level-1  mpls traffic-eng area 0
    Router-1(config-router)# passive-interface
    Loopback0

   Router-1(config-router)# mpls traffic-eng router-id Loopback0
   Router-1(config-router)# exit
```

Now resume the common command set.

```
Router-1(config)# interface Loopback0
```

At the virtual interface level:

```
Router-1(config-if)# ip address 22.1.1.1 255.255.255.255
Router-1(config-if)# no ip directed-broadcast
Router-1(config-if)# exit
```

At the device level:

```
Router-1(config)# interface POS2/0/0
```

At the physical interface level (egress):

```
Router-1(config-if)# ip address 10.1.1.1 255.255.255.0
Router-1(config-if)# mpls traffic-eng tunnels
Router-1(config-if)# ip rsvp bandwidth 130000 130000 sub-pool 80000
```

If using IS-IS instead of OSPF:

```
Router-1(config-if)# ip router isis
```

In all cases:

```
Router-1(config-if)# exit
```

At the device level:

```
Router-1(config)# interface Tunnel1
```

At the tunnel interface level:

```
Router-1(config-if)# bandwidth 110000
Router-1(config-if)# ip unnumbered Loopback0
Router-1(config-if)# tunnel destination 24.1.1.1
Router-1(config-if)# tunnel mode mpls traffic-eng
Router-1(config-if)# tunnel mpls traffic-eng priority 0 0
Router-1(config-if)# tunnel mpls traffic-eng bandwidth sub-pool 30000
Router-1(config-if)# tunnel mpls traffic-eng path-option 1 dynamic
Router-1(config)#
```

Midpoint Devices

At the device level:

```
Router-2# configure terminal
    Router-2(config)# ip cef distributed
    Router-2(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-2(config)# router isis
    Router-2(config-router)# net
    49.0000.1000.0000.0012.00
    Router-2(config-router)# metric-style wide
    Router-2(config-router)# is-type level-1
    Router-2(config-router)# mpls traffic-eng
    level-1
    Router-2(config-router)# passive-interface
    Loopback0
```

```
router ospf 100
redistribute connected

    network 11.1.1.0 0.0.0.255 area 0
    network 12.1.1.0 0.0.0.255 area 0
    network 25.1.1.1 0.0.0.0 area 0

    mpls traffic-eng area 0
```

```
    router-2(config-router)# mpls traffic-eng router-id Loopback0
    router-2(config-router)# exit
```

Now resume the common command set.

```
Router-2(config)# interface Loopback0
```

At the virtual interface level:

```
Router-2(config-if)# ip address 25.1.1.1 255.255.255.255
Router-2(config-if)# no ip directed-broadcast
Router-2(config-if)# exit
```

At the device level:

```
router-1(config)# interface POS4/0
    Router-1(config-if)# ip address 11.1.1.2 255.255.255.0
    Router-1(config-if)# mpls traffic-eng tunnels
    Router-1(config-if)# ip rsvp bandwidth 130000 130000 sub-pool 80000
```

If you are using IS-IS instead of OSPF:

```
Router-1(config-if)# ip router isis
```

In all cases:

```
Router-1(config-if)# exit
```

At the device level:

```
router-1(config)# interface POS4/1
    Router-1(config-if)# ip address 12.1.1.2 255.255.255.0
    Router-1(config-if)# mpls traffic-eng tunnels
    Router-1(config-if)# ip rsvp bandwidth 130000 130000 sub-pool 80000
```

If you are using IS-IS instead of OSPF:

```
Router-1(config-if)# ip router isis
```

In all cases:

```
Router-1(config-if)# exit
```

Note that there is no configuring of tunnel interfaces at the mid-point devices, only network interfaces and the device globally.

Tail-End Device

At the device level:

```
Router-3# configure terminal
Router-3(config)# ip cef distributed
Router-3(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

`Router-3(config)# router isis`	`router ospf 100`
`Router-3(config-router)# net 49.0000.1000.0000.0013.00`	`redistribute connected`
`Router-3(config-router)# metric-style wide`	`network 12.1.1.0 0.0.0.255 area 0`
`Router-3(config-router)# is-type level-1`	`network 24.1.1.1 0.0.0.0 area 0`
`Router-3(config-router)# mpls traffic-eng level-1`	`mpls traffic-eng area 0`
`Router-3(config-router)# passive-interface Loopback0`	

```
Router-3(config-router)# mpls traffic-eng router-id Loopback0
Router-3(config-router)# exit
```

Now resume the common command set.

```
Router-3(config)# interface Loopback0
```

At the virtual interface level:

```
Router-3(config-if)# ip address 24.1.1.1 255.255.255.255
Router-3(config-if)# no ip directed-broadcast
```

If you are using IS-IS instead of OSPF:

```
Router-3(config-if)# ip router isis
```

In all cases:

```
Router-3(config-if)# exit
```

At the device level:

```
Router(config)# interface POS4/0
 Router-1(config-if)# ip address 12.1.1.3 255.255.255.0
 Router-1(config-if)# mpls traffic-eng tunnels
 Router-1(config-if)# ip rsvp bandwidth 130000 130000 sub-pool 80000
```

If you are using IS-IS instead of OSPF:

```
Router-1(config-if)# ip router isis
```

In all cases:

```
Router-1(config-if)# exit
```

Guaranteed Bandwidth Service Configuration

Having configured two bandwidth pools, you now can

- Use one pool, the sub-pool, for tunnels that carry traffic requiring strict bandwidth guarantees or delay guarantees.
- Use the other pool, the global pool, for tunnels that carry traffic requiring only Differentiated Service.

Having a separate pool for traffic requiring strict guarantees allows you to limit the amount of such traffic admitted on any given link. Often it is possible to achieve strict QoS guarantees only if the amount of guaranteed traffic is limited to a portion of the total link bandwidth.

Having a separate pool for other traffic (best-effort or DiffServ traffic) allows you to have a separate limit for the amount of such traffic admitted on any given link. This is useful because it allows you to fill up links with best-effort/DiffServ traffic, thereby achieving a greater utilization of those links.

Providing Strict QoS Guarantees Using DS-TE Sub-pool Tunnels

A tunnel using sub-pool bandwidth can satisfy the stricter requirements if you do all of the following:

1. Select a queue—or in DiffServ terminology, select a PHB (per-hop behavior)—to be used exclusively by the strict guarantee traffic. This will be called the “GB queue.”

If delay/jitter guarantees are sought, the DiffServ Expedited Forwarding queue (EF PHB) is used. You must configure the bandwidth of the queue to be at least equal to the bandwidth of the sub-pool.

If only bandwidth guarantees are sought, the DiffServ Assured Forwarding PHB (AF PHB) is used.

2. Ensure that the guaranteed traffic sent through the sub-pool tunnel is placed in the GB queue *at the outbound interface of every tunnel hop*, and that no other traffic is placed in this queue.

   You do this by marking the traffic that enters the tunnel with a unique value in the mpls exp bits field, and steering only traffic with that marking into the GB queue.

3. Ensure that this GB queue is never oversubscribed; that is, see that no more traffic is sent into the sub-pool tunnel than the GB queue can handle.

   You do this by rate-limiting the guaranteed traffic before it enters the sub-pool tunnel. The aggregate rate of all traffic entering the sub-pool tunnel should be less than or equal to the bandwidth capacity of the sub-pool tunnel. Excess traffic can be dropped (in the case of delay/jitter guarantees) or can be marked differently for preferential discard (in the case of bandwidth guarantees).

4. Ensure that the amount of traffic entering the GB queue is limited to an appropriate percentage of the total bandwidth of the corresponding outbound link. The exact percentage to use depends on several factors that can contribute to accumulated delay in your network: your QoS performance objective, the total number of tunnel hops, the amount of link fan-in along the tunnel path, burstiness of the input traffic, and so on.

   You do this by setting the sub-pool bandwidth of each outbound link to the appropriate percentage of the total link bandwidth.

Providing Differentiated Service Using DS-TE Global Pool Tunnels

You can configure a tunnel using global pool bandwidth to carry best-effort as well as several other classes of traffic. Traffic from each class can receive differentiated service if you do all of the following:

1. Select a separate queue (a distinct DiffServ PHB) for each traffic class. For example, if there are three classes (gold, silver, and bronze) there must be three queues (DiffServ AF2, AF3, and AF4).
2. Mark each class of traffic using a unique value in the MPLS experimental bits field (for example, gold = 4, silver = 5, bronze = 6).
3. Ensure that packets marked as Gold are placed in the gold queue, Silver in the silver queue, and so on. The tunnel bandwidth is set based on the expected aggregate traffic across all classes of service.

To control the amount of DiffServ tunnel traffic you intend to support on a given link, adjust the size of the global pool on that link.

Providing Strict Guarantees and Differentiated Service in the Same Network

Because DS-TE allows simultaneous constraint-based routing of sub-pool and global pool tunnels, strict guarantees and DiffServ can be supported simultaneously in a given network.

Guaranteed Bandwidth Service Examples

This section describes two example topologies in which Guaranteed Bandwidth Services can be supplied. They illustrate opposite ends of the spectrum of possibilities.

In the first example, the guaranteed bandwidth tunnel can be easily specified by its destination. The forwarding criteria refer to a single destination prefix.

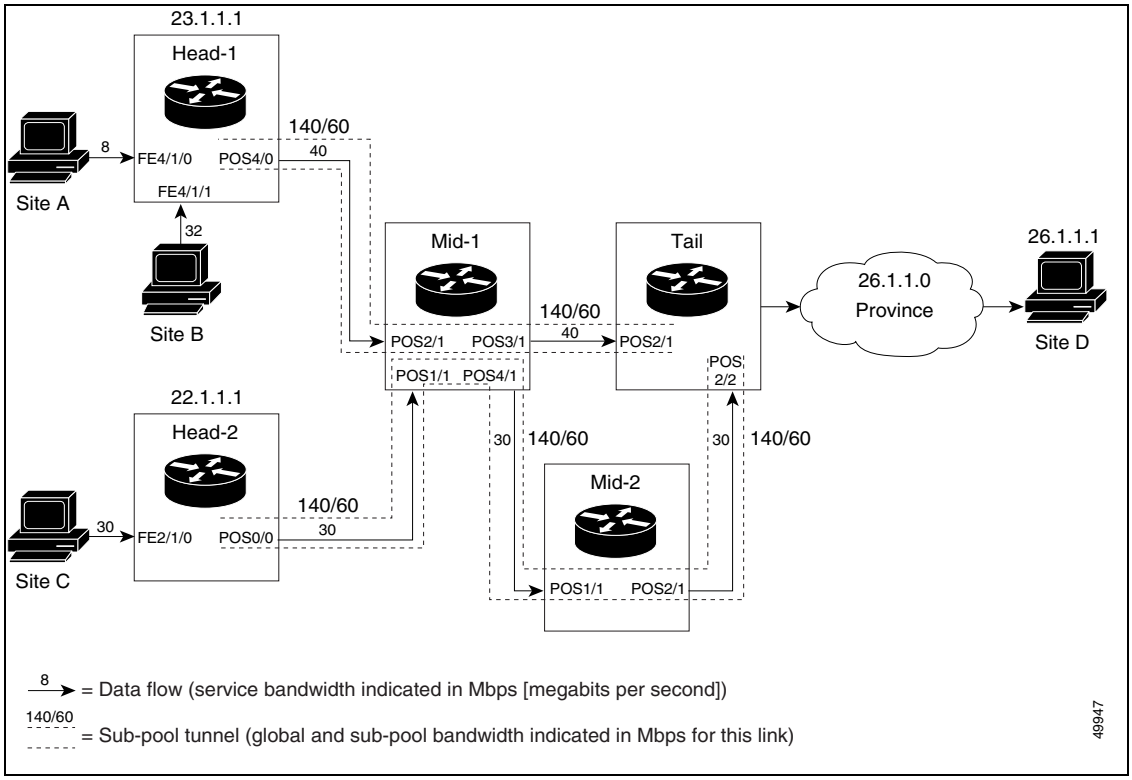
In the second example, there can be many final destinations for the guaranteed bandwidth traffic, including a dynamically changing number of destination prefixes. The forwarding criteria are specified by Border Gateway Protocol (BGP) policies.

Example with Single Destination Prefix

Figure 2 illustrates a topology for guaranteed bandwidth services whose destination is specified by a single prefix, either Site D (like a voice gateway, here bearing prefix 26.1.1.1) or a subnet (like the location of a web farm, here called "Province" and bearing prefix 26.1.1.0). Three services are offered:

- From Site A (defined as all traffic arriving at interface FE4/1/0): to host 26.1.1.1, 8 Mbps of guaranteed bandwidth with low loss, low delay and low jitter
- From Site B (defined as all traffic arriving at interface FE4/1/1): toward subnet 26.1.1.0, 32 Mbps of guaranteed bandwidth with low loss
- From Site C (defined as all traffic arriving at interface FE2/1/0): 30 Mbps of guaranteed bandwidth with low loss

Figure 2 Sample Topology for Guaranteed Bandwidth Services to a Single Destination Prefix



These three services run through two sub-pool tunnels:

- From the Head-1 router, 23.1.1.1, to the router-4 tail
- From the Head-2 router, 22.1.1.1, to the router-4 tail

Both tunnels use the same tail router, though they have different heads. (In Figure 2 one midpoint router is shared by both tunnels. There can be many more midpoints.)

All POS interfaces in this example are OC3, whose capacity is 155 Mbps.

Configuring Tunnel Head-1

First, recapitulate commands that establish two bandwidth pools and a sub-pool tunnel (as presented earlier in the "Configuration Examples" section on page 9. Then present the QoS commands that guarantee end-to-end service on the subpool tunnel. (With the Cisco 7500 router, Modular QoS CLI is used.)

Configuring the Pools and Tunnel

At the device level:

```
Router-1(config)# mpls traffic-eng tunnels
Router-1config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-1(config)# router isis
Router-1(config-router)# net
49.0000.1000.0000.0010.00
Router-1(config-router)# metric-style wide
Router-1(config-router)# is-type level-1
Router-1(config-router)# mpls traffic-eng level-1
Router-1(config-router)# passive-interface Loopback0
```

```
router ospf 100
redistribute connected

network 10.1.1.0 0.0.0.255 area 0
network 23.1.1.1 0.0.0.0 area 0
mpls traffic-eng area 0
```

```
Router-1(config-router)# mpls traffic-eng router-id Loopback0
Router-1(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
Router-1(config)# interface Loopback0
Router-1(config-if)# ip address 23.1.1.1 255.255.255.255
Router-1(config-if)# no ip directed-broadcast
Router-1(config-if)# exit
```

At the outgoing physical interface:

```
Router-1(config)# interface pos4/0
Router-1(config-if)# ip address 10.1.1.1 255.0.0.0
Router-1(config-if)# mpls traffic-eng tunnels
Router-1(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-1(config-if)# ip router isis
```

In all cases:

```
Router-1(config-if)# exit
```

At the tunnel interface:

```
Router-1(config)# interface Tunnel1
Router-1(config-if)# bandwidth 110000
Router-1(config-if)# ip unnumbered Loopback0
Router-1(config-if)# tunnel destination 27.1.1.1
Router-1(config-if)# tunnel mode mpls traffic-eng
Router-1(config-if)# tunnel mpls traffic-eng priority 0 0
Router-1(config-if)# tunnel mpls traffic-eng bandwidth sub-pool 40000
Router-1(config-if)# tunnel mpls traffic-eng path-option 1 dynamic
```

To ensure that packets destined to host 26.1.1.1 and subnet 26.1.1.0 are sent into the sub-pool tunnel, create a static route. At the device level:

```
Router-1(config)# ip route 26.1.1.0 255.255.255.0 Tunnel1
Router-1(config)# exit
```

To make sure that the Interior Gateway Protocol (IGP) will not send any other traffic down this tunnel, disable autoroute announce:

```
Router-1(config)# no tunnel mpls traffic-eng autoroute announce
```

For Service from Site A to Site D

At the inbound physical interface (FE4/1/0):

1. In global configuration mode, create a class of traffic matching ACL 100, called "sla-1-class":

```
class-map match-all sla-1-class
    match access-group 100
```

2. Create an ACL 100 to refer to all packets destined to 26.1.1.1:

```
access-list 100 permit ip any host 26.1.1.1
```

3. Create a policy named “sla-1-input-policy”, and according to that policy:
   a. Packets in the class called “sla-1-class” are rate-limited to:
   – A rate of 8 million bits per second
   – A normal burst of 1 million bytes
   – A maximum burst of 2 million bytes
   b. Packets which conform to this rate are marked with MPLS experimental bit 5 and are forwarded.
   c. Packets which exceed this rate are dropped.
   d. All other packets are marked with experimental bit 0 and are forwarded.

```
policy-map sla-1-input-policy
  class sla-1-class
    police 8000000 1000000 2000000 conform-action set-mpls-exp-transmit 5 \
           exceed-action drop
  class class-default
    set-mpls-exp-transmit 0
```

4. The policy is applied to packets entering interface FE4/1/0.

```
interface FastEthernet4/1/0
    service-policy input sla-1-input-policy
```

For Service from Site B to Subnet "Province"

At the inbound physical interface (FE4/1/1):

1. In global configuration mode, create a class of traffic matching ACL 120, called "sla-2-class":

```
class-map match-all sla-2-class
    match access-group 120
```

2. Create an ACL, 120, to refer to all packets destined to subnet 26.1.1.0:

```
access-list 120 permit ip any 26.1.1.0 0.0.0.255
```

3. Create a policy named "sla-2-input-policy", and according to that policy:
   a. Packets in the class called "sla-2-class" are rate-limited to:
   – A rate of 32 million bits per second
   – A normal burst of 1 million bytes
   – A maximum burst of 2 million bytes
   b. Packets that conform to this rate are marked with MPLS experimental bit 5 and are forwarded.
   c. Packets that exceed this rate are dropped.
   d. All other packets are marked with experimental bit 0 and are forwarded.

```
policy-map sla-2-input-policy
  class sla-2-class
    police 32000000 1000000 2000000 conform-action set-mpls-exp-transmit 5 \
           exceed-action drop
  class class-default
    set-mpls-exp-transmit 0
```

4. The policy is applied to packets entering interface FE4/1/1.

```
interface FastEthernet4/1/1
    service-policy input sla-2-input-policy
```

For Both Services

The outbound interface (POS4/0) is configured as follows:

1. In global configuration mode, create a class of traffic matching experimental bit 5, called "exp-5-traffic".

```
class-map match-all exp-5-traffic
    match mpls experimental 5
```

2. Create a policy named "output-interface-policy". According to that policy, packets in the class "exp-5-traffic" are put in the priority queue (which is rate-limited to 62 kbits/sec).

```
policy-map output-interface-policy
    class exp-5-traffic
    priority 32
```

3. The policy is applied to packets exiting interface POS4/0.

```
interface POS4/0
  service-policy output output-interface-policy
```

The result of the above configuration lines is that packets entering the Head-1 router via interface FE4/1/0 destined to host 26.1.1.1, or entering the router via interface FE4/1/1 destined to subnet 26.1.1.0, will have their MPLS experimental bit set to 5. We assume that no other packets entering the router (on any interface) are using this value. (If this cannot be assumed, an additional configuration must be added to mark all such packets to another experimental value.) Packets marked with experimental bit 5, when exiting the router via interface POS4/0, will be placed into the priority queue.

Note Packets entering the router via FE4/1/0 or FE4/1/1 and exiting POS4/0 enter as IP packets and exit as MPLS packets.

Configuring Tunnel Head-2

First, recapitulate commands that establish two bandwidth pools and a sub-pool tunnel (as presented earlier in the "Configuration Examples" section). Then present the QoS commands that guarantee end-to-end service on the sub-pool tunnel.

Configuring the Pools and Tunnel

At the device level:

```
Router-2(config)# ip cef distributed
Router-2(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-2(config)# router isis                          router ospf 100
 Router-2(config-router)# net                          redistribute connected
 49.0000.1000.0000.0011.00
 Router-2(config-router)# metric-style wide            network 11.1.1.0 0.0.0.255 area 0
 Router-2(config-router)# is-type level-1              network 22.1.1.1 0.0.0.0 area 0
 Router-2(config-router)# mpls traffic-eng level-1     mpls traffic-eng area 0
 Router-2(config-router)# passive-interface
 Loopback0

 Router-2(config-router)# mpls traffic-eng router-id Loopback0
 Router-2(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
Router-2(config)# interface Loopback0
Router-2(config-if)# ip address 22.1.1.1 255.255.255.255
Router-2(config-if)# no ip directed broadcast
Router-2(config-if)# exit
```

At the outgoing physical interface:

```
Router-2(config)# interface pos0/0
Router-2(config-if)# ip address 11.1.1.1 255.0.0.0
Router-2(config-if)# mpls traffic-eng tunnels
Router-2(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-2(config-if)# ip router isis
```

In all cases:

```
Router-2(config-if)# exit
```

At the tunnel interface:

```
Router-2(config)# interface Tunnel2
Router-2(config-if)# ip unnumbered Loopback0
Router-2(config-if)# tunnel destination 27.1.1.1
Router-2(config-if)# tunnel mode mpls traffic-eng
Router-2(config-if)# tunnel mpls traffic-eng priority 0 0
Router-2(config-if)# tunnel mpls traffic-eng bandwidth sub-pool 30000
Router-2(config-if)# tunnel mpls traffic-eng path-option 1 dynamic
Router-2(config-if)# exit
```

To ensure that packets destined to subnet 26.1.1.0 are sent into the sub-pool tunnel, create a static route, at the device level:

```
Router-2(config)# ip route 26.1.1.0 255.255.255.0 Tunnel2
Router-2(config)# exit
```

Finally, in order to make sure that IGP will not send any other traffic down this tunnel, disable autoroute announce:

```
Router-2(config)# no tunnel mpls traffic-eng autoroute announce
```

For Service from Site C to Subnet "Province"

At the inbound physical interface (FE2/1/0):

1. In global configuration mode, create a class of traffic matching ACL 130, called "sla-3-class":

```
class-map match-all sla-3-class
    match access-group 130
```

2. Create an ACL, 130, to refer to all packets destined to subnet 26.1.1.0:

```
access-list 130 permit ip any 26.1.1.0 0.0.0.255
```

3. Create a policy named “sla-3-input-policy”, and according to that policy:
   a. Packets in the class called “sla-3-class” are rate-limited to:
   - A rate of 30 million bits per second
   - A normal burst of 1 million bytes
   - A maximum burst of 2 million bytes

   b. Packets that conform to this rate are marked with MPLS experimental bit 5 and are forwarded.
   c. Packets that exceed this rate are dropped.
   d. All other packets are marked with experimental bit 0 and are forwarded.

```
policy-map sla-3-input-policy
  class sla-3-class
    police 30000000 1000000 2000000 conform-action set-mpls-exp-transmit 5 \
           exceed-action drop
  class class-default
    set-mpls-exp-transmit 0
```

4. The policy is applied to packets entering interface FE2/1/0.

```
interface FastEthernet2/1/0
    service-policy input sla-3-input-policy
```

The outbound interface POS0/0 is configured as follows:

1. In global configuration mode, create a class of traffic matching experimental bit 5, called "exp-5-traffic".

```
class-map match-all exp-5-traffic
    match mpls experimental 5
```

2. Create a policy named “output-interface-policy”. According to that policy, packets in the class “exp-5-traffic” are put in the priority queue (which is rate-limited to 32 kbits/sec).

```
policy-map output-interface-policy
    class exp-5-traffic
       priority 32
```

3. The policy is applied to packets exiting interface POS0/0:

```
interface POS0/0
    service-policy output output-interface-policy
```

As a result of all the above configuration lines, packets entering the Head-2 router via interface FE2/1/0 and destined for subnet 26.1.1.0 have their IP precedence field set to 5. It is assumed that no other packets entering this router (on any interface) are using this precedence. (If this cannot be assumed, an additional configuration must be added to mark all such packets with another precedence value.) When exiting this router via interface POS0/0, packets marked with precedence 5 are placed in the priority queue.

Note Packets entering the router via FE2/1/0 and exiting through POS0/0 enter as IP packets and exit as MPLS packets.

Tunnel Midpoint Configuration [Mid-1]

All four interfaces on the midpoint router are configured identically to the outbound interface of the head router (except the IDs of the individual interfaces):

Configuring the Pools and Tunnels

At the device level:

```
Router-3(config)# ip cef distributed
Router-3(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-3(config)# router isis
Router-3(config-router)# net
49.0000.2400.0000.0011.00
Router-3(config-router)# metric-style wide
Router-3(config-router)# is-type level-1
Router-3(config-router)# mpls traffic-eng level-1
Router-3(config-router)# passive-interface Loopback0
Router-3(config-router)#
Router-3(config-router)#
```

```
router ospf 100
redistribute connected

network 10.1.1.0 0.0.0.255 area 0
network 11.1.1.0 0.0.0.255 area 0
network 24.1.1.1 0.0.0.0 area 0
network 12.1.1.0 0.0.0.255 area 0
network 13.1.1.0 0.0.0.255 area 0
mpls traffic-eng area 0
```

```
Router-3(config-router)# mpls traffic-eng router-id Loopback0
Router-3(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
Router-3(config)# interface Loopback0
Router-3(config-if)# ip address 24.1.1.1 255.255.255.255
Router-3(config-if)# exit
```

At the physical interface level (ingress):

```
Router-3(config)# interface pos2/1
Router-3(config-if)# ip address 10.1.1.2 255.0.0.0
Router-3(config-if)# mpls traffic-eng tunnels
Router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-3(config-if)# ip router isis
```

In all cases:

```
Router-3(config-if)# exit

Router-3(config)# interface pos1/1
Router-3(config-if)# ip address 11.1.1.2 255.0.0.0
Router-3(config-if)# mpls traffic-eng tunnels
Router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-3(config-if)# ip router isis
```

In all cases:

```
Router-3(config-if)# exit
```

At the physical interface level (egress):

```
Router-3(config)# interface pos3/1
Router-3(config-if)# ip address 12.1.1.1 255.0.0.0
Router-3(config-if)# mpls traffic-eng tunnels
Router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-3(config-if)# ip router isis
```

In all cases:

```
Router-3(config-if)# exit

Router-3(config)# interface pos4/1
Router-3(config-if)# ip address 13.1.1.1 255.0.0.0
Router-3(config-if)# mpls traffic-eng tunnels
Router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-3(config-if)# ip router isis
```

In all cases:

```
Router-3(config-if)# exit
```

Tunnel Midpoint Configuration [Mid-2]

Both interfaces on the midpoint router are configured identically to the outbound interface of the head router (except, of course, for the IDs of the individual interfaces):

Configuring the Pools and Tunnel

At the device level:

```
Router-5(config)# ip cef distributed
Router-5(config)# mpls traffic-eng tunnels
```

Use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-5(config)# router isis                          | router ospf 100
 Router-5(config-router)# net                          | redistribute connected
 49.2500.1000.0000.0012.00                             |
 Router-5(config-router)# metric-style wide            | network 13.1.1.0 0.0.0.255 area 0
 Router-5(config-router)# is-type level-1              | network 14.1.1.0 0.0.0.255 area 0
 Router-5(config-router)# mpls traffic-eng             | network 25.1.1.1 0.0.0.0 area 0
 level-1                                               |
 Router-5(config-router)# passive-interface            | mpls traffic-eng area 0
 Loopback0                                             |
```

```
Router-5(config-router)# mpls traffic-eng router-id Loopback0
Router-5(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
Router-5(config)# interface Loopback0
Router-5(config-if)# ip address 25.1.1.1 255.255.255.255
Router-5(config-if)# exit
```

At the physical interface level (ingress):

```
Router-5(config)# interface pos1/1
Router-5(config-if)# ip address 13.1.1.2 255.0.0.0
Router-5(config-if)# mpls traffic-eng tunnels
Router-5(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-5(config-if)# ip router isis
```

In all cases:

```
Router-5(config-if)# exit
```

At the physical interface level (egress):

```
Router-5(config)# interface pos2/1
Router-5(config-if)# ip address 14.1.1.1 255.0.0.0
Router-5(config-if)# mpls traffic-eng tunnels
Router-5(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-5(config-if)# ip router isis
```

In all cases:

```
Router-5(config-if)# exit
```

Tunnel Tail Configuration

The inbound interfaces on the tail router are configured identically to the inbound interfaces of the midpoint routers (except the ID of each particular interface):

Configuring the Pools and Tunnels

At the device level:

```
Router-4(config)# ip cef distributed
Router-4(config)# mpls traffic-eng tunnels
```

Use the IS-IS commands on the left or the OSPF commands on the right:

```
Router-4(config)# router isis                          router ospf 100
 Router-4(config-router)# net                          redistribute connected
 49.0000.2700.0000.0000.00
 Router-4(config-router)# metric-style wide            network 12.1.1.0 0.0.0.255 area 0
 Router-4(config-router)# is-type level-1              network 14.1.1.0 0.0.0.255 area 0
 Router-4(config-router)# mpls traffic-eng level-1     network 27.1.1.1 0.0.0.0 area 0
 Router-4(config-router)# passive-interface            mpls traffic-eng area 0
 Loopback0

 Router-4(config-router)# mpls traffic-eng router-id Loopback0
 Router-4(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
Router-4(config)# interface Loopback0
Router-4(config-if)# ip address 27.1.1.1 255.255.255.255
Router-4(config-if)# exit
```

At the physical interface (ingress):

```
Router-4(config)# interface pos2/1
Router-4(config-if)# ip address 12.1.1.2 255.0.0.0
Router-4(config-if)# mpls traffic-eng tunnels
Router-4(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-4(config-if)# ip router isis
```

In all cases:

```
Router-4(config-if)# exit

Router-4(config)# interface pos2/2
Router-4(config-if)# ip address 14.1.1.2 255.0.0.0
Router-4(config-if)# mpls traffic-eng tunnels
Router-4(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
Router-4(config-if)# ip router isis
```

In all cases:

```
Router-4(config-if)# exit
```

Because the tunnel ends on the tail (does not include any outbound interfaces of the tail router), no outbound QoS configuration is used.

Example with Many Destination Prefixes

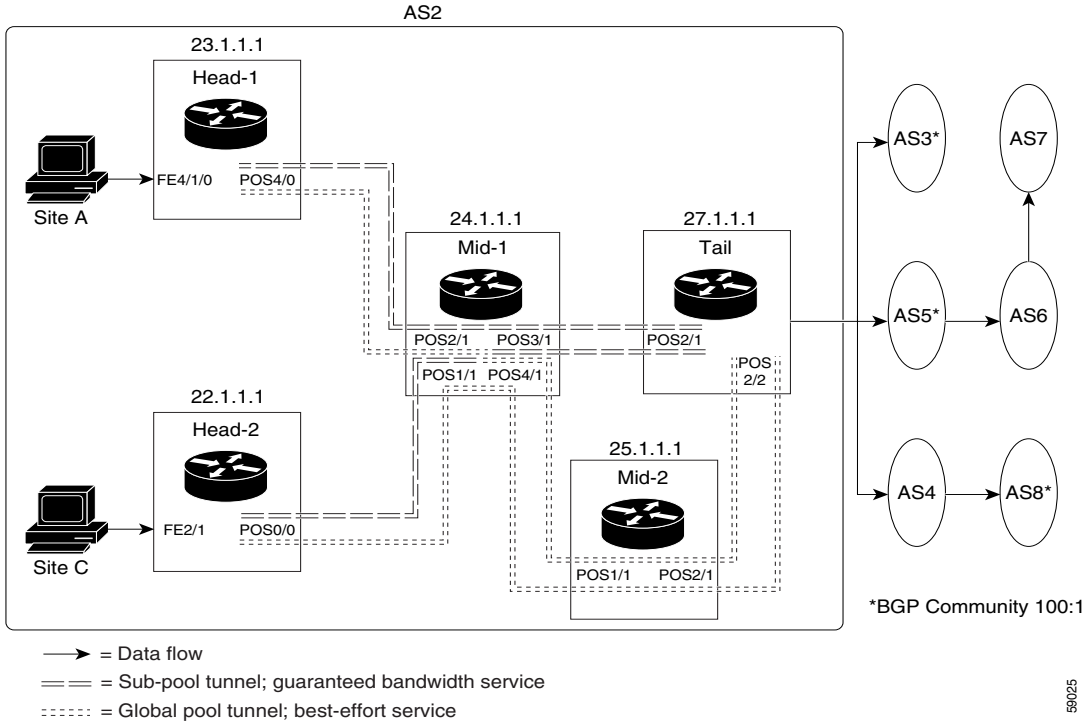
Figure 3 illustrates a topology for guaranteed bandwidth services whose destinations are a set of prefixes. Those prefixes usually share some common properties such as belonging to the same autonomous system (AS) or transiting through the same AS. Although the individual prefixes may change dynamically because of route flaps in the downstream autonomous systems, the properties the prefixes share will not change. Policies addressing the destination prefix set are enforced through Border Gateway Protocol (BGP), which is described in the following documents:

- "Configuring QoS Policy Propagation via Border Gateway Protocol" in the *Cisco IOS Quality of Service Solutions Configuration Guide,* Release 12.2
- "Configuring BGP" in the *Cisco IOS IP Configuration Guide,* Release 12.2
- "BGP Commands" in the *Cisco IOS IP Command Reference,* Release 12.2

In this example, three guaranteed bandwidth services are offered, each coming through a Cisco 7500 or a Cisco 12000 edge device:

- Traffic coming from Site A (defined as all traffic arriving at interface FE4/1/0) and from Site C (defined as all traffic arriving at interface FE2/1) destined to AS5
- Traffic coming from Sites A and C that transits AS5 but is not destined to AS5. (In the figure, the transiting traffic will go to AS6 and AS7)
- Traffic coming from Sites A and C destined to prefixes advertised with a particular BGP community attribute (100:1). In this example, Autonomous Systems #3, #5, and #8 are the BGP community assigned the attribute 100:1.

Figure 3 Sample Topology for Guaranteed Bandwidth Service to Many Destination Prefixes



The applicability of guaranteed bandwidth service is not limited to the three types of multiple destination scenarios described above. There is not room in this document to present all possible scenarios. These three were chosen as representative of the wide range of possible deployments.

The guaranteed bandwidth services run through two sub-pool tunnels:

- From the Head-1 router, 23.1.1.1, to the tail
- From the Head-2 router, 22.1.1.1, to that same tail

In addition, a global pool tunnel has been configured from each head end, to carry best-effort traffic to the same destinations. All four tunnels use the same tail router, even though they have different heads and differ in their passage through the midpoints. (In reality, there would be many more midpoints than just the two shown here.)

All POS interfaces in this example are OC3, whose capacity is 155 Mbps.

Configuring a multi-destination guaranteed bandwidth service involves:

1. Building a sub-pool MPLS-TE tunnel
2. Configuring DiffServ QoS
3. Configuring QoS Policy Propagation via BGP (QPPB)
4. Mapping traffic onto the tunnels

All of these tasks are included in the following example.

Configuration of Tunnel Head-1

First recapitulate commands that establish a sub-pool tunnel (commands presented earlier) and now configure a global pool tunnel. Additionally, we present QoS and BGP commands that guarantee end-to-end service on the sub-pool tunnel. (With the Cisco 7500(VIP) router, Modular QoS CLI is used).

Configuring the Pools and Tunnels

At the device level:

```
router-1(config)# ip cef distributed
router-1(config)# mpls traffic-eng tunnels
```

Use the IS-IS commands on the left or the OSPF commands on the right:

```
router-1(config)# router isis                          router ospf 100
 router-1(config-router)# net                          redistribute connected
 49.0000.1000.0000.0010.00
 router-1(config-router)# metric-style wide            network 10.1.1.0 0.0.0.255 area 0
 router-1(config-router)# is-type level-1              network 23.1.1.1 0.0.0.0 area 0
 router-1(config-router)# mpls traffic-eng level-1     mpls traffic-eng area 0

 router-1(config-router)# mpls traffic-eng router-id Loopback0
 router-1(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
router-1(config)# interface Loopback0
router-1(config-if)# ip address 23.1.1.1 255.255.255.255
router-1(config-if)# exit
```

At the outgoing physical interface:

```
router-1(config)# interface pos4/0
router-1(config-if)# ip address 10.1.1.1 255.0.0.0
router-1(config-if)# mpls traffic-eng tunnels
router-1(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
router-1(config-if)# ip router isis
```

In all cases:

```
router-1(config-if)# exit
```

At one tunnel interface, create a sub-pool tunnel:

```
router-1(config)# interface Tunnel1
router-1(config-if)# ip unnumbered Loopback0
router-1(config-if)# tunnel destination 27.1.1.1
router-1(config-if)# tunnel mode mpls traffic-eng
router-1(config-if)# tunnel mpls traffic-eng priority 0 0
router-1(config-if)# tunnel mpls traffic-eng bandwidth sub-pool 40000
router-1(config-if)# tunnel mpls traffic-eng path-option 1 explicit name gbs-path1
router-1(config-if)# exit
```

At a second tunnel interface, create a global pool tunnel:

```
router-1(config)# interface Tunnel2
router-1(config-if)# ip unnumbered Loopback0
router-1(config-if)# tunnel destination 27.1.1.1
router-1(config-if)# tunnel mode mpls traffic-eng
router-1(config-if)# tunnel mpls traffic-eng priority 0 0
router-1(config-if)# tunnel mpls traffic-eng bandwidth 80000
router-1(config-if)# tunnel mpls traffic-eng path-option 1 explicit name \
   best-effort-path1
router-1(config-if)# exit
```

In this example explicit paths are used instead of dynamic, to ensure that best-effort traffic and guaranteed bandwidth traffic will travel along different paths.

At the device level:

```
router-1(config)# ip explicit-path name gbs-path1
router-1(config-ip-expl-path)# next-address 24.1.1.1
router-1(config-ip-expl-path)# next-address 27.1.1.1
router-1(config-ip-expl-path)# exit
router-1(config)# ip explicit-path name best-effort-path1
router-1(config-ip-expl-path)# next-address 24.1.1.1
router-1(config-ip-expl-path)# next-address 25.1.1.1
router-1(config-ip-expl-path)# next-address 27.1.1.1
router-1(config-ip-expl-path)# exit
```

Note that autoroute is not used, as that could cause the IGP to send other traffic down these tunnels.

Configuring DiffServ QoS

At the inbound physical interface (in Figure 3 this is FE4/1/0), packets received are rate-limited to:

a. A rate of 30 Mbps
b. A normal burst of 1 MB
c. A maximum burst of 2 MB

Packets that are mapped to qos-group 6 and that conform to the rate-limit are marked with experimental value 5 and the BGP destination community string, and are forwarded; packets that do not conform (exceed action) are dropped:

```
router-1(config)# interface FastEthernet4/1/0
router-1(config-if)# rate-limit input qos-group 6 30000000 1000000 2000000 \
conform-action set-mpls-exp-transmit 5 exceed-action drop
router-1(config-if)# bgp-policy destination ip-qos-map
router-1(config-if)# exit
```

At the device level create a class of traffic called “exp5-class” that has MPLS experimental bit set to 5:

```
router-1(config)# class-map match-all exp5-class
router-1(config-cmap)# match mpls experimental 5
router-1(config-cmap)# exit
```

Create a policy that creates a priority queue for “exp5-class”:

```
router-1(config)# policy-map core-out-policy
router-1(config-pmap)# class exp5-class
router-1(config-pmap-c)# priority 100000
router-1(config-pmap-c)# exit
router-1(config-pmap)# class class-default
router-1(config-pmap-c)# bandwidth 55000
router-1(config-pmap-c)# exit
router-1(config-pmap)# exit
```

The policy is applied to packets exiting the outbound interface POS4/0.

```
router-1(config)# interface POS4/0
router-1(config-if)# service-policy output core-out-policy
```

Configuring QoS Policy Propagation via BGP

For All GB Services

Create a table map under BGP to map (tie) the prefixes to a qos-group. At the device level:

```
router-1(config)# ip bgp-community new-format
router-1(config)# router bgp 2
router-1(config-router)# no synchronization
router-1(config-router)# table-map set-qos-group
router-1(config-router)# bgp log-neighbor-changes
router-1(config-router)# neighbor 27.1.1.1 remote-as 2
router-1(config-router)# neighbor 27.1.1.1 update-source Loopback0
router-1(config-router)# no auto-summary
router-1(config-router)# exit
```

For GB Service Destined to AS5

Create a distinct route map for this service. This includes setting the next-hop of packets matching 29.1.1.1 so they will be mapped onto Tunnel #1 (the guaranteed bandwidth service tunnel). At the device level:

```
router-1(config)# route-map set-qos-group permit 10
router-1(config-route-map)# match as-path 100
router-1(config-route-map)# set ip qos-group 6
router-1(config-route-map)# set ip next-hop 29.1.1.1
router-1(config-route-map)# exit
router-1(config)# ip as-path access-list 100 permit ^5$
```

For GB Service Transiting through AS5

Create a distinct route map for this service. (Its traffic will go to AS6 and AS7).

At the device level:

```
router-1(config)# route-map set-qos-group permit 10
router-1(config-route-map)# match as-path 101
router-1(config-route-map)# set ip qos-group 6
router-1(config-route-map)# set ip next-hop 29.1.1.1
router-1(config-route-map)# exit
router-1(config)# ip as-path access-list 101 permit _5_
```

For GB Service Destined to Community 100:1

Create a distinct route map for all traffic destined to prefixes that have community value 100:1. This traffic will go to AS3, AS5, and AS8.

At the device level:

```
router-1(config)# route-map set-qos-group permit 10
router-1(config-route-map)# match community 20
router-1(config-route-map)# set ip qos-group 6
router-1(config-route-map)# set ip next-hop 29.1.1.1
router-1(config-route-map)# exit
router-1(config)# ip community-list 20 permit 100:1
```

Mapping Traffic onto the Tunnels

Map all guaranteed bandwidth traffic onto Tunnel #1:

```
router-1(config)# ip route 29.1.1.1 255.255.255.255 Tunnel1
```

Map all best-effort traffic onto Tunnel #2:

```
router-1(config)# ip route 30.1.1.1 255.255.255.255 Tunnel2
```

Configuration of Tunnel Head-2

As with the Head-1 device and interfaces, the following Head-2 configuration first presents commands that establish a sub-pool tunnel (commands presented earlier) and then also configures a global pool tunnel. After that it presents QoS and BGP commands that guarantee end-to-end service on the sub-pool tunnel. (Because this is a Cisco 7500 (VIP) router, Modular QoS CLI is used).

Configuring the Pools and Tunnels

At the device level:

```
router-2(config)# ip cef distributed
router-2(config)# mpls traffic-eng tunnels
```

Use the IS-IS commands on the left or the OSPF commands on the right:

```
router-2(config)# router isis                          | router ospf 100
router-2(config-router)# net                           | redistribute connected
49.0000.1000.0000.0011.00                              |
router-2(config-router)# metric-style wide             | network 11.1.1.0 0.0.0.255 area 0
router-2(config-router)# is-type level-1               | network 22.1.1.1 0.0.0.0 area 0
router-2(config-router)# mpls traffic-eng level-1      | mpls traffic-eng area 0
```

```
router-2(config-router)# mpls traffic-eng router-id Loopback0
router-2(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
router-2(config)# interface Loopback0
router-2(config-if)# ip address 22.1.1.1 255.255.255.255
router-2(config-if)# exit
```

At the outgoing physical interface:

```
router-2(config)# interface pos0/0
router-2(config-if)# ip address 11.1.1.1 255.0.0.0
router-2(config-if)# mpls traffic-eng tunnels
router-2(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 60000
```

If you are using IS-IS instead of OSPF:

```
router-2(config-if)# ip router isis
```

In all cases:

```
router-2(config-if)# exit
```

At one tunnel interface, create a sub-pool tunnel:

```
router-2(config)# interface Tunnel3
router-2(config-if)# ip unnumbered Loopback0
router-2(config-if)# tunnel destination 27.1.1.1
router-2(config-if)# tunnel mode mpls traffic-eng
router-2(config-if)# tunnel mpls traffic-eng priority 0 0
router-2(config-if)# tunnel mpls traffic-eng bandwidth sub-pool 30000
router-2(config-if)# tunnel mpls traffic-eng path-option 1 explicit name gbs-path2
router-2(config-if)# exit
```

At a second tunnel interface, create a global pool tunnel:

```
router-2(config)# interface Tunnel4
router-2(config-if)# ip unnumbered Loopback0
router-2(config-if)# tunnel destination 27.1.1.1
router-2(config-if)# tunnel mode mpls traffic-eng
router-2(config-if)# tunnel mpls traffic-eng priority 0 0
router-2(config-if)# tunnel mpls traffic-eng bandwidth 70000
router-2(config-if)# tunnel mpls traffic-eng path-option 1 explicit name \
   best-effort-path2
router-2(config-if)# exit
```

In this example explicit paths are used instead of dynamic, to ensure that best-effort traffic and guaranteed bandwidth traffic will travel along different paths.

At the device level:

```
router-2(config)# ip explicit-path name gbs-path2
router-2(config-ip-expl-path)# next-address 24.1.1.1
router-2(config-ip-expl-path)# next-address 27.1.1.1
router-2(config-ip-expl-path)# exit
router-2(config)# ip explicit-path name best-effort-path2
router-2(config-ip-expl-path)# next-address 24.1.1.1
router-2(config-ip-expl-path)# next-address 25.1.1.1
router-2(config-ip-expl-path)# next-address 27.1.1.1
router-2(config-ip-expl-path)# exit
```

Note that autoroute is not used, as that could cause the IGP to send other traffic down these tunnels.

Configuring DiffServ QoS

At the inbound physical interface (in Figure 3 this is FE2/1), packets received are rate-limited to:

a. A rate of 30 Mbps

b. A normal burst of 1 MB

c. A maximum burst of 2 MB

Packets that are mapped to qos-group 6 and that conform to the rate-limit are marked with experimental value 5 and the BGP destination community string, and are forwarded; packets that do not conform (exceed action) are dropped:

```
router-2(config)# interface FastEthernet2/1
router-2(config-if)# rate-limit input qos-group 6 30000000 1000000 2000000 \
conform-action set-mpls-exp-transmit 5 exceed-action drop
router-2(config-if)# bgp-policy destination ip-qos-map
router-1(config-if)# exit
```

At the device level create a class of traffic called “exp5-class” that has MPLS experimental bit set to 5:

```
router-2(config)# class-map match-all exp5-class
router-2(config-cmap)# match mpls experimental 5
router-2(config-cmap)# exit
```

Create a policy that creates a priority queue for "exp5-class":

```
router-2(config)# policy-map core-out-policy
router-2(config-pmap)# class exp5-class
router-2(config-pmap-c)# priority 100000
router-2(config-pmap-c)# exit
router-2(config-pmap)# class class-default
router-2(config-pmap-c)# bandwidth 55000
router-2(config-pmap-c)# exit
router-2(config-pmap)# exit
```

The policy is applied to packets exiting interface POS0/0:

```
interface POS0/0
    service-policy output core-out-policy
```

As a result of all the above configuration lines, packets entering the Head-2 router via interface FE2/1 and destined for AS5, BGP community 100:1, or transiting AS5 will have their experimental field set to 5. It is assumed that no other packets entering this router (on any interface) are using this exp bit value. (If this cannot be assumed, an additional configuration must be added to mark all such packets with another experimental value.) When exiting this router via interface POS0/0, packets marked with experimental value 5 are placed into the priority queue.

Note Packets entering the router via FE2/1 and exiting through POS0/0 enter as IP packets and exit as MPLS packets.

Configuring QoS Policy Propagation via BGP

For All GB Services

Create a table map under BGP to map (tie) the prefixes to a qos-group. At the device level:

```
router-2(config)# ip bgp-community new-format
router-2(config)# router bgp 2
router-2(config-router)# no synchronization
router-2(config-router)# table-map set-qos-group
router-2(config-router)# bgp log-neighbor-changes
router-2(config-router)# neighbor 27.1.1.1 remote-as 2
router-2(config-router)# neighbor 27.1.1.1 update-source Loopback0
router-2(config-router)# no auto-summary
router-2(config-router)# exit
```

For GB Service Destined to AS5

Create a distinct route map for this service. This includes setting the next-hop of packets matching 29.1.1.1 so they will be mapped onto Tunnel #3 (the guaranteed bandwidth service tunnel). At the device level:

```
router-2(config)# route-map set-qos-group permit 10
router-2(config-route-map)# match as-path 100
router-2(config-route-map)# set ip qos-group 6
router-2(config-route-map)# set ip next-hop 29.1.1.1
router-2(config-route-map)# exit
router-2(config)# ip as-path access-list 100 permit ^5$
```

For GB Service Transiting through AS5

Create a distinct route map for this service. (Its traffic will go to AS6 and AS7).

At the device level:

```
router-2(config)# route-map set-qos-group permit 10
router-2(config-route-map)# match as-path 101
router-2(config-route-map)# set ip qos-group 6
router-2(config-route-map)# set ip next-hop 29.1.1.1
router-2(config-route-map)# exit
router-2(config)# ip as-path access-list 101 permit _5_
```

For GB Service Destined to Community 100:1

Create a distinct route map for all traffic destined to prefixes that have community value 100:1. This traffic will go to AS3, AS5, and AS8.

At the device level:

```
router-2(config)# route-map set-qos-group permit 10
router-2(config-route-map)# match community 20
router-2(config-route-map)# set ip qos-group 6
router-2(config-route-map)# set ip next-hop 29.1.1.1
router-2(config-route-map)# exit
router-2(config)# ip community-list 20 permit 100:1
```

Mapping the Traffic onto the Tunnels

Map all guaranteed bandwidth traffic onto Tunnel #3:

```
router-2(config)# ip route 29.1.1.1 255.255.255.255 Tunnel3
```

Map all best-effort traffic onto Tunnel #4:

```
router-2(config)# ip route 30.1.1.1 255.255.255.255 Tunnel4
```

Tunnel Midpoint Configuration [Mid-1]

All four interfaces on the midpoint router are configured very much like the outbound interface of the head router. The strategy is to have all mid-point routers in this autonomous system ready to carry future as well as presently configured sub-pool and global pool tunnels.

Configuring the Pools and Tunnels

At the device level:

```
router-3(config)# ip cef distributed
router-3(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
router-3(config)# router isis
 router-3(config-router)# net
 49.0000.2400.0000.0011.00
 router-3(config-router)# metric-style wide
 router-3(config-router)# is-type level-1
 router-3(config-router)# mpls traffic-eng
 level-1
```

```
router ospf 100
redistribute connected

network 10.1.1.0 0.0.0.255 area 0
network 11.1.1.0 0.0.0.255 area 0
network 24.1.1.1 0.0.0.0 area 0
```

```
router-3(config-router)#                    network 12.1.1.0 0.0.0.255 area 0
router-3(config-router)#                    network 13.1.1.0 0.0.0.255 area 0
router-3(config-router)#                    mpls traffic-eng area 0

router-3(config-router)# mpls traffic-eng router-id Loopback0
router-3(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
router-3(config)# interface Loopback0
router-3(config-if)# ip address 24.1.1.1 255.255.255.255
router-3(config-if)# exit
```

At the physical interface level (ingress):

```
router-3(config)# interface pos2/1
router-3(config-if)# ip address 10.1.1.2 255.0.0.0
router-3(config-if)# mpls traffic-eng tunnels
router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If you are using IS-IS instead of OSPF:

```
router-3(config-if)# ip router isis
```

In all cases:

```
router-3(config-if)# exit

router-3(config)# interface pos1/1
router-3(config-if)# ip address 11.1.1.2 255.0.0.0
router-3(config-if)# mpls traffic-eng tunnels
router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If you are using IS-IS instead of OSPF:

```
router-3(config-if)# ip router isis
```

In all cases:

```
router-3(config-if)# exit
```

At the physical interface level (egress), through which two sub-pool tunnels currently exit:

```
router-3(config)# interface pos3/1
router-3(config-if)# ip address 12.1.1.1 255.0.0.0
router-3(config-if)# mpls traffic-eng tunnels
router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If you are using IS-IS instead of OSPF:

```
router-3(config-if)# ip router isis
```

In all cases:

```
router-3(config-if)# exit
```

At the physical interface level (egress), through which two global pool tunnels currently exit:

```
router-3(config)# interface pos4/1
router-3(config-if)# ip address 13.1.1.1 255.0.0.0
router-3(config-if)# mpls traffic-eng tunnels
router-3(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If using IS-IS instead of OSPF:

```
router-3(config-if)# ip router isis
```

In all cases:

```
router-3(config-if)# exit
```

Tunnel Midpoint Configuration [Mid-2]

Both interfaces on this midpoint router are configured like the outbound interfaces of the Mid-1 router.

Configuring the Pools and Tunnels

At the device level:

```
router-5(config)# ip cef distributed
router-5(config)# mpls traffic-eng tunnels
```

Now use the IS-IS commands on the left or the OSPF commands on the right:

```
router-5(config)# router isis                          router ospf 100
 router-5(config-router)# net                          redistribute connected
 49.2500.1000.0000.0012.00
 router-5(config-router)# metric-style wide            network 13.1.1.0 0.0.0.255 area 0
 router-5(config-router)# is-type level-1              network 14.1.1.0 0.0.0.255 area 0
 router-5(config-router)# mpls traffic-eng level-1     network 25.1.1.1 0.0.0.0 area 0
 router-5(config-router)#                              mpls traffic-eng area 0

 router-5(config-router)# mpls traffic-eng router-id Loopback0
 router-5(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
router-5(config)# interface Loopback0
router-5(config-if)# ip address 25.1.1.1 255.255.255.255
router-5(config-if)# exit
```

At the physical interface level (ingress):

```
router-5(config)# interface pos1/1
router-5(config-if)# ip address 13.1.1.2 255.0.0.0
router-5(config-if)# mpls traffic-eng tunnels
router-5(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If using IS-IS instead of OSPF:

```
router-5(config-if)# ip router isis
```

In all cases:

```
router-5(config-if)# exit
```

At the physical interface level (egress):

```
router-5(config)# interface pos2/1
router-5(config-if)# ip address 14.1.1.1 255.0.0.0
router-5(config-if)# mpls traffic-eng tunnels
router-5(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If using IS-IS instead of OSPF:

```
router-5(config-if)# ip router isis
```

In all cases:

```
router-5(config-if)# exit
```

Tunnel Tail Configuration

The inbound interfaces on the tail router are configured much like the outbound interfaces of the midpoint routers:

Configuring the Pools and Tunnels

At the device level:

```
router-4(config)# ip cef distributed
router-4(config)# mpls traffic-eng tunnels
```

Use the IS-IS commands on the left or the OSPF commands on the right. In the case of OSPF, advertise two new loopback interfaces—29.1.1.1 and 30.1.1.1 in our example—which are defined in the "Configuring QoS Policy Propagation" section on page 37:

```
router-4(config)# router isis                          router ospf 100
router-4(config-router)# net                           redistribute connected
49.0000.2700.0000.0000.00
router-4(config-router)# metric-style wide             network 12.1.1.0 0.0.0.255 area 0
router-4(config-router)# is-type level-1               network 14.1.1.0 0.0.0.255 area 0
router-4(config-router)# mpls traffic-eng level-1      network 27.1.1.1 0.0.0.0 area 0
router-4(config-router)#                               network 29.1.1.1 0.0.0.0 area 0
router-4(config-router)#                               network 30.1.1.1 0.0.0.0 area 0
router-4(config-router)#                               mpls traffic-eng area 0
```

```
router-4(config-router)# mpls traffic-eng router-id Loopback0
router-4(config-router)# mpls traffic-eng router-id Loopback1
router-4(config-router)# mpls traffic-eng router-id Loopback2
router-4(config-router)# exit
```

Now resume the common command set.

Create a virtual interface:

```
router-4(config)# interface Loopback0
router-4(config-if)# ip address 27.1.1.1 255.255.255.255
router-4(config-if)# exit
```

At the physical interface (ingress):

```
router-4(config)# interface pos2/1
router-4(config-if)# ip address 12.1.1.2 255.0.0.0
router-4(config-if)# mpls traffic-eng tunnels
router-4(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If you are using IS-IS instead of OSPF:

```
router-4(config-if)# ip router isis
```

In all cases:

```
router-4(config-if)# exit
```

```
router-4(config)# interface pos2/2
router-4(config-if)# ip address 14.1.1.2 255.0.0.0
router-4(config-if)# mpls traffic-eng tunnels
router-4(config-if)# ip rsvp bandwidth 140000 140000 sub-pool 70000
```

If you are using IS-IS instead of OSPF:

```
router-4(config-if)# ip router isis
```

In all cases:

```
router-4(config-if)# exit
```

Configuring QoS Policy Propagation

On the tail device, you must configure a separate virtual loopback IP address for each class-of-service terminating here. The headend routers need these addresses to map traffic into the proper tunnels. In the current example, four tunnels terminate on the same tail device but they represent only two service classes, so only two additional loopback addresses are needed:

Create two virtual interfaces:

```
router-4(config)# interface Loopback1
router-4(config-if)# ip address 29.1.1.1 255.255.255.255
```

If you are using IS-IS instead of OSPF:

```
router-4(config-if)# ip router isis
```

In all cases:

```
router-4(config-if)# exit
router-4(config)# interface Loopback2
router-4(config-if)# ip address 30.1.1.1 255.255.255.255
```

If you are using IS-IS instead of OSPF:

```
router-4(config-if)# ip router isis
```

In all cases:

```
router-4(config-if)# exit
```

At the device level, configure BGP to send the community to each tunnel head:

```
router-4(config)# ip bgp-community new-format
router-4(config)# router bgp 2
router-4(config-router)# neighbor 23.1.1.1 send-community
router-4(config-router)# neighbor 22.1.1.1 send-community
router-4(config-router)# exit
```

Command Reference

This section describes the following modified commands:

- **ip rsvp bandwidth**
- **mpls traffic-eng backup-path tunnel**
- **show mpls traffic-eng fast-reroute database**
- **show mpls traffic-eng fast-reroute log reroutes**
- **show mpls traffic-eng topology**
- **tunnel mpls traffic-eng bandwidth**
- **tunnel mpls traffic-eng fast-reroute**

All other commands used with this feature are documented in the Cisco IOS Release 12.2 command reference publications.

ip rsvp bandwidth

To enable Resource Reservation Protocol (RSVP) for IP on an interface, use the **ip rsvp bandwidth** command in interface configuration mode. To disable RSVP completely, use the **no** form of this command. To eliminate only the sub-pool portion of the bandwidth, use the **no** form of this command with the keyword **sub-pool**.

ip rsvp bandwidth *interface-kbps single-flow-kbps* [**sub-pool** *kbps*]

no ip rsvp bandwidth *interface-kbps single-flow-kbps* [**sub-pool** *kbps*]

Syntax Description

interface-kbps	Amount of bandwidth (in kbps) on interface to be reserved. The range is 1 to 10000000.
single-flow-kbps	Amount of bandwidth (in kbps) allocated to a single flow. [Ignored in DS-TE]. The range is 1 to 10000000.
sub-pool *kbps*	(Optional) Amount of bandwidth (in kbps) on interface to be reserved to a portion of the total. The range is from 1 to the value of *interface-kbps*.

Defaults

RSVP is disabled if this command is not entered. When enabled without the optional arguments, RSVP is enabled and 75 percent of the link bandwidth is reserved for it.

Command Modes

Interface configuration

Command History

Release	Modification
11.2	This command was introduced.
12.0(11)ST	Sub-pool option was added.
12.2(14)S	This command was integrated into Cisco IOS Release 12.2(14)S.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Usage Guidelines

RSVP cannot be configured with VIP-distributed Cisco Express Forwarding (dCEF).

RSVP is disabled by default to allow backward compatibility with systems that do not implement RSVP.

Weighted Random Early Detection (WRED) or fair queueing must be enabled first.

Related Commands

Command	Description
fair-queue (WFQ)	Enables WFQ for an interface.
ip rsvp neighbor	Enables neighbors to request a reservation.
ip rsvp reservation	Enables a router to behave like it is receiving and forwarding RSVP RESV messages.
ip rsvp sender	Enables a router to behave like it is receiving and forwarding RSVP PATH messages.
ip rsvp udp-multicasts	Instructs the router to generate UDP-encapsulated RSVP multicasts whenever it generates an IP-encapsulated multicast packet.
random-detect (interface)	Enables WRED or DWRED.
show ip rsvp installed	Displays RSVP-related installed filters and corresponding bandwidth information.
show ip rsvp interface	Displays RSVP-related interface information.
show ip rsvp neighbor	Displays current RSVP neighbors.
show ip rsvp reservation	Displays RSVP-related receiver information currently in the database.
show ip rsvp sender	Displays RSVP PATH-related sender information currently in the database.

mpls traffic-eng backup-path tunnel

To configure the physical interface to use a backup tunnel in the event of a detected failure on that interface, use the **mpls traffic-eng backup tunnel** command in interface configuration mode.

mpls traffic-eng backup-path tunnel*interface*

Syntax Description

interface	String that identifies the tunnel interface being created and configured.

Defaults

No default behavior or values.

Command Modes

Interface configuration

Command History

Release	Modification
12.0(810ST	This command was introduced.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Examples

The following example shows you how to specify the traffic engineering backup tunnel with the identifier 1000:

```
Router(config_if)# mpls traffic-eng backup-path Tunnel1000
```

Related Commands

Command	Description
show mpls traffic-eng fast-reroute database	Displays information about existing Fast Reroute configurations.
tunnel mpls traffic-eng fast-reroute	Enables an MPLS traffic engineering tunnel to use a backup tunnel in the event of a link failure (assuming a backup tunnel exists).

show mpls traffic-eng fast-reroute database

To display the contents of the Fast Reroute (FRR) database, use the **show mpls traffic-eng fast-reroute database** command in EXEC mode.

show mpls traffic-eng fast-reroute database [{*network* [*mask* | *masklength*] | **labels** *low label* [*-high label*] | **interface** *ifname* [**backup-interface** *ifname*] | **backup-interface** *ifname*}] [**state {active | ready | partial | complete**}] [**role** {**head | middle**}][**detail**]

Syntax Description

network	IP address of the destination network. This functions as the prefix of the Fast Reroute rewrite.
mask	Bit combination indicating the portion of the IP address that is being used for the subnet address.
masklength	Number of bits in mask of destination.
labels	Shows only database entries that possess in-labels assigned by this router (local labels). You specify either a starting value or a range of values.
low label	Starting label value or lowest value in the range.
- high label	Highest label value in the range.
interface	Shows only database entries related to the primary outgoing interface.
ifname	Name of the primary outgoing interface.
backup-interface	(Optional) Shows only database entries related to the backup outgoing interface.
ifname	Name of the backup outgoing interface.
state	(Optional) Shows entries that match one of four possible states: partial, complete, ready, or active.
active	(Optional) The FRR rewrite has been put into the forwarding database (where it can be placed onto appropriate incoming packets).
ready	(Optional) The FRR rewrite has been created, but has not yet been moved into the forwarding database.
partial	(Optional) State before the FRR rewrite has been fully created; its backup routing information is still incomplete.
complete	State after the FRR rewrite has been assembled: it is either ready or active.
role	(Optional) Shows entries associated either with the tunnel head or tunnel midpoint.
head	(Optional) Entry associated with tunnel head.
middle	(Optional) Entry associated with tunnel midpoint.
detail	(Optional) Shows long-form information: LFIB-FRR total number of clusters, groups and items in addition to the short-form information of prefix, label and state.

Defaults

No default behavior or values.

Command Modes

EXEC

Command History

Release	Modification
12.0(10)ST	This command was introduced.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Examples

The following example shows output from the **show mpls traffic-eng fast-reroute database** command at a tunnel head link:

```
Router# show mpls traffic-eng fast-reroute database 12.0.0.0

Tunnel head fast reroute information:

Prefix       Tunnel  In-label  Out intf/label  FRR intf/label  Status
12.0.0.0/16   Tu111   Tun hd    PO0/0:Untagged  Tu4000:16       ready
12.0.0.0/16   Tu449   Tun hd    PO0/0:Untagged  Tu4000:736      ready
12.0.0.0/16   Tu314   Tun hd    PO0/0:Untagged  Tu4000:757      ready
12.0.0.0/16   Tu313   Tun hd    PO0/0:Untagged  Tu4000:756      ready
```

Table 1 describes significant fields shown in the display.

Table 1 show mpls traffic-eng fast-reroute database Field Descriptions

Field	Description
Prefix	Address to which packets with this label are going.
Tunnel	Tunnel's identifying number.
In Label	Label advertised to other routers to signify a particular prefix. The value "Tunnel head" occurs when no such label has been advertised.
Out intf/label	Out interface—short name of the physical interface through which traffic goes to the protected link. Out label: • At a tunnel head, this is the label advertised by the tunnel destination device. The value "*Untagged*" occurs when no such label has been advertised. • At tunnel midpoints, this is the label selected by the next hop device. The "Pop Tag" value occurs when the next hop is the tunnel's final hop.

Table 1 show mpls traffic-eng fast-reroute database Field Descriptions (continued)

Field	Description
FRR intf/label	Fast Reroute interface—the backup tunnel interface. Fast Reroute label • At a tunnel head, this is the label selected by the tunnel tail to indicate the destination network. The value "`Untagged`" occurs when no such label has been advertised. • At tunnel midpoints, this has the same value as the Out Label.
Status	State of the rewrite: `partial`, `ready`, or `active`. (These terms are defined above, in the "Syntax Description" section).

The following example shows output from the **show mpls traffic-eng fast-reroute database** command with the **labels** keyword specified at a midpoint link:

```
Router# show mpls traffic-eng fast-reroute database labels 250 - 255

Tunnel head fast reroute information:
Prefix   Tunnel   In-label   Outintf/label   FRR intf/label   Status

LSP midpoint frr information:

LSP identifier          In-label   Out intf/label  FRR intf/label  Status
10.110.0.10 229 [7334] 255        PO0/0:694       Tu4000:694      active
10.110.0.10 228 [7332] 254        PO0/0:693       Tu4000:693      active
10.110.0.10 227 [7331] 253        PO0/0:692       Tu4000:692      active
10.110.0.10 226 [7334] 252        PO0/0:691       Tu4000:691      active
10.110.0.10 225 [7333] 251        PO0/0:690       Tu4000:690      active
10.110.0.10 224 [7329] 250        PO0/0:689       Tu4000:689      active
```

The following example shows output from the **show mpls traffic-eng fast-reroute database** command with the **detail** keyword included at a tunnel head link:

```
Router# show mpls traffic-eng fast-reroute database 12.0.0.0. detail

LFIB FRR Database Summary:
  Total Clusters:      2
  Total Groups:        2
  Total Items:         789
Link 10:PO5/0 (Down, 1 group)
  Group 51:PO5/0->Tu4000 (Up, 779 members)
    Prefix 12.0.0.0/16, Tu313, active
      Input label Tun hd, Output label PO0/0:773, FRR label Tu4000:773
    Prefix 12.0.0.0/16, Tu392, active
      Input label Tun hd, Output label PO0/0:775, FRR label Tu4000:775
    Prefix 12.0.0.0/16, Tu111, active
      Input label Tun hd, Output label PO0/0:16, FRR label Tu4000:16
    Prefix 12.0.0.0/16, Tu394, active
      Input label Tun hd, Output label PO0/0:774, FRR label Tu4000:774
```

Table 2 describes significant fields when the **detail** keyword is used.

Table 2 show mpls traffic-eng fast-reroute database with detail Keyword Field Descriptions

Field	Description
Total Clusters	A cluster is the physical interface upon which Fast Reroute link protection has been enabled.
Total Groups	A group is a database record that associates the link-protected physical interface with a backup tunnel. A cluster (physical interface) therefore can have one or more groups. For example, the cluster Ethernet4/0/1 is protected by backup Tunnel1 and backup Tunnel2, and so has two groups.
Total Items	An item is a database record that associates a rewrite with a group. A group therefore can have one or more items.
Link 10:PO5/0 (Down, 1 group)	This describes a cluster (physical interface): • "10" is the interface's unique IOS-assigned ID number. • ":" is followed by the interface's short name. • Parentheses contain the operating state of the interface (Up or Down) and the number of groups associated with it.
Group 51:PO5/0->Tu4000 (Up, 779 members)	This describes a group: • "51" is the ID number of the backup interface. • ":" is followed by the group's physical interface short name. • "->" is followed by the backup tunnel interface short name. • Parentheses contain the operating state of the tunnel interface (Up or Down) and the number of items—also called "members"— associated with it.

Related Commands

Command	Description
show mpls traffic-eng fast-reroute log reroutes	Displays contents of Fast Reroute event log.

show mpls traffic-eng fast-reroute log reroutes

To display the contents of the Fast Reroute event log, use the **show mpls traffic-eng fast-reroute log reroutes** command in EXEC mode.

show mpls traffic-eng fast-reroute log reroutes

Syntax Description

This command has no arguments or keywords.

Defaults

No default behavior or values.

Command Modes

EXEC

Command History

Release	Modification
12.0(10)ST	This command was introduced.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Examples

The following example shows output from the **show mpls traffic-eng fast-reroute log reroutes** command:

```
Router# show mpls traffic-eng fast-reroute log reroutes

When      Interface  Event   Rewrites  Duration  CPU msecs  Suspends  Errors
00:27:39  PO0/0      Down    1079      30 msecs  30         0         0
00:27:35  PO0/0      Up      1079      40 msecs  40         0         0
```

Table 3 describes significant fields shown in the display.

Table 3 show mpls traffic-eng fast-reroute log reroutes Field Descriptions

Display Field	Description
When	Indicates how long ago the logged event occurred (before this line was displayed on your screen). Displayed as hours, minutes, seconds.
Interface	The physical or tunnel interface where the logged event occurred.
Event	The change to Up or Down by the affected interface.
Rewrites	Total number of reroutes accomplished because of this event.
Duration	Time elapsed during the rerouting process.
CPU msecs	CPU time spent processing those reroutes. (This is less than or equal to the Duration value).

Table 3 show mpls traffic-eng fast-reroute log reroutes Field Descriptions (continued)

Display Field	Description
Suspends	Number of times that reroute processing for this event was interrupted to let the CPU handle other tasks.
Errors	Number of unsuccessful reroute attempts.

show mpls traffic-eng topology

To show the MPLS traffic engineering global topology as currently known at this node, use the **show mpls traffic-eng topology** command in privileged EXEC mode.

show mpls traffic-eng topology [{*A.B.C.D* | **igp-id** {**isis** *nsapaddr* | **ospf** *A.B.C.D*}] [**brief**]

Syntax Description

A.B.C.D	Specifies the node by the IP address (router identifier to interface address).
igp-id	Specifies the node by IGP router identifier.
isis *nsapaddr*	Specifies the node by router identification (nsapaddr) if using IS-IS.
ospf *A.B.C.D*	Specifies the node by router identifier if using OSPF.
brief	(Optional) The brief form of the output gives a less detailed version of the topology.

Defaults

No default behavior or values.

Command Modes

Privileged EXEC

Command History

Release	Modification
12.0(5)S	This command was introduced.
12.0(11)ST	The single “Reservable” column was replaced by two columns: one each for “global pool” and for “sub-pool”.
12.2(14)S	This command was integrated into Cisco IOS Release 12.2(14)S.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Examples

The following example shows output from the **show mpls traffic-eng topology** command:

```
Router# show mpls traffic-eng topology

My_System_id: 0000.0025.0003.00

IGP Id: 0000.0024.0004.00, MPLS TE Id:24.4.4.4 Router Node
      link[0 ]:Intf Address: 150.1.1.4
                  Nbr IGP Id: 0000.0024.0004.02,
                admin_weight:10, affinity_bits:0x0
                max_link_bw:10000 max_link_reservable: 10000
       globalpoolsubpool
                total allocated   reservable  reservable
                ---------------   ----------  ----------
                bw[0]:  0         1000        500
                bw[1]:  10        990         490
                bw[2]:  600       390         390
                bw[3]:  0         390         390
                bw[4]:  0         390         390
```

```
    bw[5]:  0          390          390
```

Table 4 describes significant fields shown in the display.

Table 4 show mpls traffic-eng topology Field Descriptions

Field	Description
My-System_id	Unique identifier of the IGP.
IGP Id	Identification of advertising router.
MPLS TE Id	Unique MPLS traffic engineering identification.
Intf Address	This interface address of the link.
Nbr IGP Id	Neighbor IGP router identifier.
admin_weight	Cost of the link.
affinity_bits	The requirements on the attributes of the links that the traffic crosses.
max_link_bw	Physical line rate.
max_link_reservable	The maximum amount of bandwidth that can be reserved on a link.
total allocated	Amount of bandwidth allocated at that priority.
reservable	Amount of available bandwidth reservable at that priority for each of the two pools, global and sub.

tunnel mpls traffic-eng bandwidth

To configure bandwidth required for a Multiprotocol Label Switching (MPLS) traffic engineering tunnel, use the **tunnel mpls traffic-eng bandwidth** command in interface configuration mode. To disable this feature, use the **no** form of this command.

tunnel mpls traffic-eng bandwidth {**sub-pool** | [**global**]} *bandwidth*

no tunnel mpls traffic-eng bandwidth {**sub-pool** | [**global**]} *bandwidth*

Syntax Description

sub-pool	(Optional) Indicates a sub-pool tunnel.
global	(Optional) Indicates a global pool tunnel. Entering this keyword is not necessary, for all tunnels are "global pool" in the absence of the keyword **sub-pool**. But if users of pre-DS-TE images enter this keyword, it will be accepted.
bandwidth	The bandwidth, in kilobits per second, set aside for the MPLS traffic engineering tunnel. Range is between 1 and 4294967295.

Defaults

Default bandwidth is 0.

Default is a global pool tunnel.

Command Modes

Interface configuration

Command History

Release	Modification
12.0(5)S	This command was introduced.
12.0(11)ST	Sub-pool option was added.
12.2(14)S	This command was integrated into Cisco IOS Release 12.2(14)S.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Usage Guidelines

Enter the bandwidth for either a global pool or sub-pool tunnel, not both. Only the **ip rsvp bandwidth** command specifies the two bandwidths within one command.

To set up only a global pool tunnel, leave out the keyword **sub-pool**. If you enter **global** as a keyword, the system will accept it, but will not write it to NVRAM. This is to avoid the problem of having your configuration not understood if you upgrade to an image that contains the DS-TE capability and then return to a non DS-TE image.

Related Commands

Command	Description
show mpls traffic-eng tunnel	Displays information about tunnels.

tunnel mpls traffic-eng fast-reroute

To enable a Multiprotocol Label Switching (MPLS) traffic engineering tunnel to use a backup tunnel in the event of a link failure if a backup tunnel exists, use the **tunnel mpls traffic-eng fast-reroute** command in interface configuration mode.

tunnel mpls traffic-eng fast-reroute

Syntax Description

This command has no arguments or keywords.

Defaults

No default behavior or values.

Command Modes

Interface configuration

Command History

Release	Modification
12.0(8)ST	This command was introduced.
12.2(18)S	This command was integrated into Cisco IOS Release 12.2(18)S.
12.2(18)SXD	This command was integrated into Cisco IOS Release 12.2(18)SX.

Examples

The following example enables an MPLS traffic engineering tunnel to use a backup tunnel if a link fails and a backup tunnel exists:

```
Router(config_if)# tunnel mpls traffic-eng fast-reroute
```

Related Commands

Command	Description
mpls traffic-eng backup-path Tunnel	Configures the interface to use a backup tunnel in the event of a detected failure on the interface.
show tunnel mpls traffic-eng fast-reroute	Displays information about fast reroute for MPLS traffic engineering.

Glossary

CBR—Constraint Based Routing. The computation of traffic paths that simultaneously satisfy label-switched path attributes and current network resource limitations.

CEF—Cisco Express Forwarding. A means for accelerating the forwarding of packets within a router, by storing route lookup information in several data structures instead of in a route cache.

CLI—Command Line Interface. Cisco's interface for configuring and managing its routers.

DS-TE—Diff Serv-aware Traffic Engineering. The capability to configure two bandwidth pools on each link, a *global pool* and a *sub-pool*. MPLS traffic engineering tunnels using the sub-pool bandwidth can be configured with Quality of Service mechanisms to deliver guaranteed bandwidth services end-to-end across the network. Simultaneously, tunnels using the global pool can convey DiffServ traffic.

flooding—A traffic passing technique used by switches and bridges in which traffic received on an interface is sent out through all of the interfaces of that device except the interface on which the information was originally received.

GB queue—Guaranteed Bandwidth queue. A per-hop behavior (PHB) used exclusively by the strict guarantee traffic. If delay/jitter guarantees are sought, the diffserv Expedited Forwarding queue (EF PHB) is used. If only bandwidth guarantees are sought, the diffserv Assured Forwarding PHB (AF PHB) is used.

Global Pool—The total bandwidth allocated to an MPLS traffic engineering link.

IGP—Interior Gateway Protocol. An internet protocol used to exchange routing information within an autonomous system. Examples of common internet IGPs include IGRP, OSPF, and RIP.

label-switched path (LSP) tunnel—A configured connection between two routers, using label switching to carry the packets.

LCAC—Link-level (per-hop) call admission control.

LSP—Label-switched path (see above).
Also Link-state packet—A broadcast packet used by link-state protocols that contains information about neighbors and path costs. LSPs are used by the receiving routers to maintain their routing tables. Also called link-state advertisement (LSA).

MPLS—Multi-Protocol Label Switching (formerly known as Tag Switching). A method for directing packets primarily through Layer 2 switching rather than Layer 3 routing, by assigning the packets short fixed-length labels at the ingress to an MPLS cloud, using the concept of forwarding equivalence classes. Within the MPLS domain, the labels are used to make forwarding decisions mostly without recourse to the original packet headers.

MPLS TE—MPLS Traffic Engineering (formerly known as "RRR" or Resource Reservation Routing). The use of label switching to improve traffic performance along with an efficient use of network resources.

OSPF—Open Shortest Path First. A link-state, hierarchical IGP routing algorithm, derived from the IS-IS protocol. OSPF features include least-cost routing, multipath routing, and load balancing.

RSVP—Resource reSerVation Protocol. An IETF protocol used for signaling requests (to set aside internet services) by a customer before that customer is permitted to transmit data over that portion of the network.

Sub-pool—The more restrictive bandwidth in an MPLS traffic engineering link. The sub-pool is a portion of the link's overall global pool bandwidth.

TE—Traffic engineering. The application of scientific principles and technology to measure, model, and control internet traffic in order to simultaneously optimize traffic performance and network resource utilization.

Note Refer to the *Internetworking Terms and Acronyms* for terms not included in this glossary.