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CHAPTER 1

MPLS Traffic Engineering – Bundled Interface Support

The MPLS Traffic Engineering - Bundled Interface Support feature enables Multiprotocol Label Switching (MPLS) traffic engineering (TE) tunnels over the bundled interfaces—EtherChannel and Gigabit EtherChannel (GEC).

The Resource Reservation Protocol (RSVP) notifies TE about bandwidth changes that occur when member links are added or deleted, or when links become active or inactive. TE notifies other nodes in the network via Interior Gateway Protocol (IGP) flooding. By default, the bandwidth available to TE Label-Switched Paths (LSPs) is 75 percent of the interface bandwidth. You can change the percentage of the global bandwidth available for TE LSPs by using an RSVP command on the bundled interface. Bandwidth reservation and preemption are supported.

The Fast Reroute (FRR) feature is supported on bundled interfaces. FRR is activated when a bundled interface goes down; for example, if you enter the `shutdown` command to shut down the interface or fewer than the required minimum number of links are operational.

- Finding Feature Information, on page 1
- Prerequisites for MPLS TE – Bundled Interface Support, on page 2
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Finding Feature Information

Your software release may not support all the features documented in this module. For the latest caveats and feature information, see Bug Search Tool and the release notes for your platform and software release. To find information about the features documented in this module, and to see a list of the releases in which each feature is supported, see the feature information table.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.
Prerequisites for MPLS TE – Bundled Interface Support

• Configure Multiprotocol Label Switching (MPLS) traffic engineering (TE) tunnels.
• Enable Cisco Express Forwarding in global configuration mode.
• Enable Resource Reservation Protocol (RSVP) feature.
• Configure EtherChannel.
• Configure Gigabit EtherChannel.

Restrictions for MPLS TE – Bundled Interface Support

• Traffic engineering over switch virtual interfaces (SVIs) is not supported unless the SVI consists of a bundle of links that represent a single point-to-point interface.
• There must be a valid IP address configuration on the bundled interface and there must not be an IP address configuration on the member links.

Information About MPLS TE – Bundled Interface Support

Cisco EtherChannel Overview

Cisco EtherChannel technology builds upon standards-based 802.3 full-duplex Fast Ethernet to provide network managers with a reliable, high-speed solution for the campus network backbone. EtherChannel technology provides bandwidth scalability within the campus by providing up to 800 Mbps, 8 Gbps, or 80 Gbps of aggregate bandwidth for a Fast EtherChannel, Gigabit EtherChannel, or 10 Gigabit EtherChannel connection, respectively. Each of these connection speeds can vary in amounts equal to the speed of the links used (100 Mbps, 1 Gbps, or 10 Gbps). Even in the most bandwidth-demanding situations, EtherChannel technology helps to aggregate traffic, keeps oversubscription to a minimum, and provides effective link-resiliency mechanisms.

Cisco EtherChannel Benefits

Cisco EtherChannel technology allows network managers to provide higher bandwidth among servers, routers, and switches than a single-link Ethernet technology can provide.

Cisco EtherChannel technology provides incremental scalable bandwidth and the following benefits:

• Standards-based—Cisco EtherChannel technology builds upon IEEE 802.3-compliant Ethernet by grouping multiple, full-duplex point-to-point links. EtherChannel technology uses IEEE 802.3 mechanisms for full-duplex autonegotiation and autosensing, when applicable.

• Flexible incremental bandwidth—Cisco EtherChannel technology provides bandwidth aggregation in multiples of 100 Mbps, 1 Gbps, or 10 Gbps, depending on the speed of the aggregated links. For example, network managers can deploy EtherChannel technology that consists of pairs of full-duplex Fast Ethernet links to provide more than 400 Mbps between the wiring closet and the data center. In the data center,
bandwidths of up to 800 Mbps can be provided between servers and the network backbone to provide large amounts of scalable incremental bandwidth.

- Load balancing—Cisco EtherChannel technology comprises several Fast Ethernet links and is capable of load balancing traffic across those links. Unicast, broadcast, and multicast traffic is evenly distributed across the links, providing improved performance and redundant parallel paths. When a link fails, traffic is redirected to the remaining links within the channel without user intervention and with minimal packet loss.

- Resiliency and fast convergence—When a link fails, Cisco EtherChannel technology provides automatic recovery by redistributing the load across the remaining links. When a link fails, Cisco EtherChannel technology redirects traffic from the failed link to the remaining links in less than one second. This convergence is transparent to the end user—no host protocol timers expire and no sessions are dropped.

Cisco Gigabit EtherChannel Overview

Cisco Gigabit EtherChannel (GEC) is a high-performance Ethernet technology that provides transmission rates in Gigabit per second (Gbps). A Gigabit EtherChannel bundles individual ethernet links (Gigabit Ethernet and 10 Gigabit Ethernet) into a single logical link that provides the aggregate bandwidth up to four physical links. All LAN ports in each EtherChannel must be of the same speed and must be configured as either Layer 2 or Layer 3 LAN ports. Inbound broadcast and multicast packets on one link in an EtherChannel are blocked from returning on any other link in the EtherChannel.

Load Balancing and Min-Links in EtherChannel

Load balancing affects the actual and practical bandwidth that can be used for TE. Multilink load balancing uses a per-packet load balancing method. All of the bundle interface bandwidth is available. EtherChannel load balancing has various load balancing methods, depending on the traffic pattern and the load balancing configuration. The total bandwidth available for TE may be limited to the bandwidth of a single member link.

On EtherChannel, min-links is supported only in the Link Aggregation Control Protocol (LACP). For other EtherChannel protocols, the minimum is one link, by default, and it is not configurable. To configure min-links for EtherChannel, use the `port-channel min-links` command.

How to Configure MPLS TE – Bundled Interface Support

Configuring MPLS TE on an EtherChannel Interface

SUMMARY STEPS

1. `enable`
2. `configure terminal`
3. `interface type number [name-tag]`
4. `ip address ip-address mask [secondary]`
5. `mpls traffic-eng tunnels`
6. `mpls traffic-eng backup-path tunnel`
7. `port-channel min-links min-num`
8. ip rsvp bandwidth \([\text{interface-kbps}] [\text{single-flow-kbps}]\)
9. end

DETAILED STEPS

<table>
<thead>
<tr>
<th>Step</th>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Step 1 | enable  
Example:  
Device> enable | Enables privileged EXEC mode.  
• Enter your password if prompted. |
| Step 2 | configure terminal  
Example:  
Device# configure terminal | Enters global configuration mode. |
| Step 3 | interface type number [name-tag]  
Example:  
Device(config)# interface port-channel 1 | Creates an EtherChannel bundle, assigns a group number to the bundle, and enters interface configuration mode. |
| Step 4 | ip address ip-address mask [secondary]  
Example:  
Device(config-if)# ip address 10.0.0.4 255.255.255.0 | Specifies an IP address for the EtherChannel group. |
| Step 5 | mpls traffic-eng tunnels  
Example:  
Device(config-if)# mpls traffic-eng tunnels | Enables MPLS TE tunnel signaling on an interface.  
• MPLS TE tunnel should be enabled on the device before enabling the signaling. |
| Step 6 | mpls traffic-eng backup-path tunnel  
Example:  
Device(config-if)# mpls traffic-eng backup-path Tunnel120 | (Optional) Configures the physical interface to use a backup tunnel in the event of a detected failure on that interface. |
| Step 7 | port-channel min-links min-num  
Example:  
Device(config-if)# port-channel min-links 2 | Specifies that a minimum number of bundled ports in an EtherChannel is required before the channel can be active. |
| Step 8 | ip rsvp bandwidth \([\text{interface-kbps}] [\text{single-flow-kbps}]\)  
Example:  
Device(config-if)# ip rsvp bandwidth 100 | Enables RSVP for IP on an interface and specifies a percentage of the total interface bandwidth as available in the RSVP bandwidth pool. |
**Purpose**

**Command or Action**

**Step 9**

**Purpose**

- `end` Exits interface configuration mode and returns to privileged EXEC mode.

---

**Configuration Examples for MPLS TE Bundled Interface Support**

**Example: Configuring MPLS TE on an EtherChannel Interface**

```
Device> enable
Device# configure terminal
Device(config)# interface port-channel 1
Device(config-if)# ip address 10.0.0.4 255.255.255.0
Device(config-if)# mpls traffic-eng tunnels
Device(config-if)# mpls traffic-eng backup-path Tunnel 120
Device(config-if)# port-channel min-links 2
Device(config-if)# ip rsvp bandwidth 100
Device(config-if)# end
```

**Example: Configuring MPLS TE - Bundled Interface Support over Gigabit Etherchannel**

The following example shows how to enable MPLS TE – bundled interface support over GEC on Cisco devices:

```
Device> enable
Device# configure terminal

! Enable global MPLS TE on routers
Device(config)# router ospf 100
Device(config-router)# network 10.0.0.1 0.0.0.255 area 0
Device(config-router)# mpls traffic-eng area 0
Device(config-router)# mpls traffic-eng router-id Loopback 0
Device(config-router)# exit

! Configure GEC interface and enable MPLS TE and RSVP on interface
Device(config)# interface Port-channel 1
Device(config-if)# ip address 10.0.0.1 255.255.255.0
Device(config-if)# mpls traffic-eng tunnels
Device(config-if)# ip rsvp bandwidth
Device(config-if)# exit

! Define explicit path
Device(config)# ip explicit-path name primary enable
Device(cfg-ip-expl-path)# next-address 172.12.1.2
Device(cfg-ip-expl-path)# next-address 172.23.1.2
Device(cfg-ip-expl-path)# next-address 172.34.1.2
Device(cfg-ip-expl-path)# next-address 10.4.4.4
Device(cfg-ip-expl-path)# exit
```
Example: Configuring MPLS TE - Bundled Interface Support over Gigabit Etherchannel

! Configure primary tunnel on head-end device
Device(config)# interface Tunnel 14
Device(config-if)# ip unnumbered Loopback 0
Device(config-if)# tunnel mode mpls traffic-eng
Device(config-if)# tunnel destination 10.10.10.0
Device(config-if)# tunnel mpls traffic-eng autoroute announce
Device(config-if)# tunnel mpls traffic-eng path-option 10 explicit name primary
Device(config-if)# tunnel mpls traffic-eng fast-reroute
Device(config-if)# exit

! Configure backup tunnel on head-end or mid-point device
Device(config)# interface Tunnel 23
Device(config-if)# ip unnumbered Loopback 0
Device(config-if)# tunnel mode mpls traffic-eng
Device(config-if)# tunnel destination 10.20.10.0
Device(config-if)# tunnel mpls traffic-eng path-option 10 explicit name backup
Device(config-if)# exit

! Configure backup tunnel on protected GEC interface
Device(config)# interface Port-channel 1
Device(config-if)# ip address 10.0.0.1 255.255.255.0
Device(config-if)# mpls traffic-eng tunnels
Device(config-if)# mpls traffic-eng backup-path Tunnel 23
Device(config-if)# ip rsvp bandwidth percent 20
Device(config-if)# lacp min-bundle 2
Device(config-if)# exit

! Configure GEC interface
Device(config)# interface GigabitEthernet 0/0/1
Device(config-if)# no ip address
Device(config-if)# channel-group 1 mode active
Device(config-if)# exit

! Configure GEC interface
Device(config)# interface GigabitEthernet 0/0/2
Device(config-if)# no ip address
Device(config-if)# channel-group 1 mode active
Device(config-if)# exit

The `show mpls traffic-eng tunnels` command output displays information about a tunnel or one–line information about all tunnels configured on the device:

Device# show mpls traffic-eng tunnels tunnel 14

Name: ASR1013_t14 (Tunnel10) Destination: 10.4.4.4
Status:
  Admin: up  Oper: up  Path: valid  Signalling: connected
  path option 1, type explicit toR4overR3R3 (Basis for Setup, path weight 3)
Config Parameters:
  Bandwidth: 0 kbps (Global)  Priority: 7 7  Affinity: 0x0/0xFFFF
  Metric Type: TE (default)
  AutoRoute: enabled  LockDown: disabled  Loadshare: 0 [0] bw-based auto-bw: disabled
Active Path Option Parameters:
  State: explicit path option 1 is active
  BandwidthOverride: disabled  LockDown: disabled  Verbatim: disabled

  InLabel : -
  OutLabel : Port-channel1, 1608
Next Hop : 172.16.1.2  
FRR OutLabel : Tunnel23, 4868  
RSVP Signalling Info:  
  Src 10.1.1.1, Dst 10.4.4.4, Tun_Id 14, Tun_Instance 35  
RSVP Path Info:  
  My Address: 172.12.1.1  
  Explicit Route: 172.12.1.2 172.23.1.1 172.23.1.2 172.34.1.1 172.34.1.2 10.4.4.4  

History:  
  Tunnel:  
    Time since created: 17 hours  
    Time since path change: 18 minutes, 22 seconds  
    Number of LSP IDs (Tun_instances) used: 35  
  Current LSP: [ID: 35]  
    Uptime: 18 minutes, 22 seconds  
    Selection: reoptimization  
  Prior LSP: [ID: 32]  
    ID: path option unknown  
    Removal Trigger: signalling shutdown  

Device# `show mpls traffic-eng tunnels brief`

show mpls traffic-eng tunnels brief  
Signalling Summary:  
  LSP Tunnels Process: running  
  Passive LSP Listener: running  
  RSVP Process: running  
  Forwarding: enabled  
  Periodic reoptimization: enabled  
  Periodic FRR Promotion: Not Running  
  Periodic auto-bw collection: enabled  

P2P TUNNELS/LSPs:  
TUNNEL NAME  DESTINATION  UP IF  DOWN IF  STATE/PROT
ASR1013_t14  10.4.1.1  Po12  -  up/up  

On Mid Router:  
P2P TUNNELS/LSPs:  
TUNNEL NAME  DESTINATION  UP IF  DOWN IF  STATE/PROT
ASR1013_t14  10.4.1.1  Po12  Po23  up/up  
ASR1002F_t23  10.2.1.1  Po12  -  up/up  

The `show mpls traffic-eng fast-reroute` command output displays information about FRR-protected MPLS TE tunnels originating, transmitting, or terminating on this device.  

Device# `show mpls traffic-eng fast-reroute database`

P2P Headend FRR information:  
Protected tunnel  In-label Out intf/label  FRR intf/label  Status
---------------------------------  -----------------  -----------------  ------

P2P LSP midpoint frr information:  
LSP identifier  In-label Out intf/label  FRR intf/label  Status
----------------  -----------------  -----------------  ------
Additional References for MPLS TE - Bundled Interface Support

Related Documents

<table>
<thead>
<tr>
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<td>Cisco IOS commands</td>
<td>Cisco IOS Master Command List, All Releases</td>
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<td>MPLS traffic engineering commands</td>
<td>Cisco IOS Multiprotocol Label Switching Command Reference</td>
</tr>
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<td>IPv6 commands</td>
<td>Cisco IOS IPv6 Command Reference</td>
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Technical Assistance

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<td>The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password.</td>
<td><a href="http://www.cisco.com/cisco/web/support/index.html">http://www.cisco.com/cisco/web/support/index.html</a></td>
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Feature Information for MPLS Traffic Engineering—Bundled Interface Support

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

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<thead>
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<th>Feature Name</th>
<th>Releases</th>
<th>Feature Information</th>
</tr>
</thead>
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<tr>
<td>MPLS Traffic Engineering—Bundled Interface Support</td>
<td>Cisco IOS XE Release 3.13.0S</td>
<td>This feature was introduced on the Cisco ASR 920 Series Aggregation Service Routers (ASR-920-12CZ-A, ASR-920-12CZ-D, ASR-920-4SZ-A, ASR-920-4SZ-D).</td>
</tr>
</tbody>
</table>
Glossary

**bundled interface**—Generic terms to represent port-channel, multilink, and VLAN interfaces.

**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.

**CLNS**—Connectionless Network Service. The Open Systems Interconnection (OSI) network layer service that does not require a circuit to be established before data is transmitted. CLNS routes messages to their destination independently of any other messages.

**CSPF**—Constrained Shortest Path First. A routing protocol that calculates the shortest path based on a set of constraints, such as a minimum bandwidth requirement, maximum number of nodes, or nodes to include or exclude.

**enterprise network**—A large and diverse network connecting most major points in a company or other organization.

**FRR**—Fast ReRoute.

**headend**—The endpoint of a broadband network. All stations send toward the headend; the headend then sends toward the destination stations.

**IGP**—Interior Gateway Protocol. An Internet protocol used to exchange routing information within an autonomous system. Examples of common Internet IGPs include Interior Gateway Routing protocol (IGRP), Open Shortest Path First (OSPF), and Routing Information Protocol (RIP).

**interface**—A network connection.

**IS-IS**—Intermediate System to Intermediate System. OSI link-state hierarchical routing protocol based on DECnet Phase V routing, where ISs (routers) exchange routing information based on a single metric, to determine the network topology.

**LDN**—Link Down Notification.

**LSP**—Label-Switched Path. A sequence of hops (R0...Rn) in which a packet travels from R0 to Rn through label switching mechanisms. A label-switched path can be chosen dynamically, based on normal routing mechanisms, or through configuration.

**member links**—Individual interfaces that are grouped into a bundled interface.

**message-pacing**—The former name of the rate limiting feature.

**MPLS**—Formerly known as tag switching, Multiprotocol Label Switching is a method for directing packets primarily through Layer 2 switching rather than Layer 3 routing. In MPLS, packets are assigned short fixed-length labels at the ingress to an MPLS cloud by 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.


**router**—A network layer device that uses one or more metrics to determine the optimal path along which network traffic should be forwarded. Routers forward packets from one network to another based on network layer information.
RSVP — Resource Reservation Protocol. A protocol that supports the reservation of resources across an IP network.

scalability — An indicator showing how quickly some measure of resource usage increases as a network gets larger.

TLV — type, length, value. TLV objects are used in data communication to provide optional information. The type field indicates the type of items in the value field. The length field indicates the length of the value field. The value field is the data portion of the packet.

topology — The physical arrangement of network nodes and media within an enterprise networking structure.

TE (traffic engineering) — Techniques and processes that cause routed traffic to travel through the network on a path other than the one that would have been chosen if standard routing methods were used.

traffic engineering tunnel — A label-switched tunnel that is used for traffic engineering. Such a tunnel is set up through means other than normal Layer 3 routing; it is used to direct traffic over a path different from the one that Layer 3 routing would cause the tunnel to take.
CHAPTER 2

MPLS Point-to-Multipoint Traffic Engineering

The MPLS Point-to-Multipoint Traffic Engineering feature enables you to forward Multiprotocol Label Switching (MPLS) traffic from one source to multiple destinations. Cisco nonstop forwarding (NSF) and stateful switchover (SSO) (NSF/SSO) provides for minimal disruption of Point-to-Multipoint (P2MP) Traffic Engineering (TE) tunnel traffic if a Route Processor has a catastrophic failure. Traffic loss varies by platform.

For more information on configuring NSF/SSO with this feature, see NSF/SSO—MPLS TE and RSVP Graceful Restart.

- Information About MPLS Point-to-Multipoint Traffic Engineering, on page 11
- How to Configure MPLS Point-to-Multipoint Traffic Engineering, on page 21
- Configuration Examples for MPLS Point-to-Multipoint Traffic Engineering, on page 31
- Additional References, on page 37
- Feature Information for MPLS Point-to-Multipoint Traffic Engineering, on page 38
- Glossary, on page 39

Information About MPLS Point-to-Multipoint Traffic Engineering

MPLS Point-to-Multipoint Traffic Engineering Overview

A P2MP TE network contains the following elements, which are shown in the figure below:

- The headend router, also called the source or ingress router, is where the label switched path (LSP) is initiated. The headend router can also be a branch point, which means the router performs packet replication and the sub-LSPs split into different directions.

- The midpoint router is where the sub-LSP signaling is processed. The midpoint router can be a branch point.

- The tailend router, also called the destination, egress, or leaf-node router, is where sub-LSP signaling ends.

- A bud router is a midpoint and tailend router at the same time.

- A P2MP tunnel consists of one or more sub-LSPs. All sub-LSPs belonging to the same P2MP tunnel employ the same constraints, protection policies, and so on, which are configured at the headend router.
P2MP TE tunnels build on the features that exist in basic point-to-point TE tunnels. The P2MP TE tunnels have the following characteristics:

- There is one source (headend) but more than one destination (tailend).
- They are unidirectional.
- They are explicitly routed.
- Multiple sub-LSPs connect the headend router to various tailend routers.

The figure below shows a P2MP TE tunnel that has three destinations.

- PE1 is the headend router.
- P01 is a branch point router, where packet replication occurs.
- PE2, PE3, and PE4 are tailend routers, where the sub-LSP ends.

Between the PE and CE routers, PIM is enabled to exchange multicast routing information with the directly connected customer edge (CE) routers. PIM is not enabled across the P2MP TE tunnel.

**Database of Sub-LSP Failure Errors**

If any sub-LSP, whether P2MP or P2P, fails to recover after an SSO switchover, the failure is noted in an error database for troubleshooting. You can use the `show ip rsvp high database lsp` command to display the error database entries.
How P2MP TE Sub-LSPs Are Signaled

RSVP TE extensions defined in RFC 4875 allow multiple sub-LSPs to be signaled from the headend router. A P2MP TE tunnel consists of multiple sub-LSPs that connect the headend router to various tailend routers.

The headend router sends one RSVP path message to each destination. The tailend router replies with a RESV message. The Label Forwarding Information Base (LFIB) is populated using the RSVP labels allocated by the RESV messages.

The P2MP TE feature does not support signaling of multiple sub-LSPs in the same Path/Resv message. If multiple sub-LSPs occur in the same message, the router sends a PathErr Unknown Objects message, and the Path/Resv message with multiple sub-LSPs is not forwarded.

The tailend routers allocate unreserved labels, which are greater than 15 and do not include implicit or explicit null labels. Using unreserved labels allows IP multicast to perform a Reverse Path Forwarding (RPF) check on the tailend router. Because a sub-LSP tailend router cannot be represented as a regular interface, a special LSP virtual interface (VIF) is automatically created. The LSP VIF represents the originating interface for all IP multicast traffic originating from the P2MP TE tailend router.

The figure below shows the LSP signaling process.
Figure 3: How LSPs Are Signaled

How P2MP TE Traffic Is Forwarded

At the headend of the traffic engineering tunnel, through a static Internet Group Management Protocol (IGMP) group-to-tunnel mapping, IP multicast traffic is encapsulated with a unique MPLS label, which is associated with the P2MP TE tunnel. The multicast traffic is label switched in the P2MP tree and replicated at branch and bud nodes along the P2MP tree. When the labeled packet reaches the tailend (a PE router), the MPLS label is removed and forwarded to the IP multicast tree towards the end point. This process is shown in the figure below.

Note

The P2MP TE feature does not support penultimate-hop popping. Therefore, the egress router must allocate an explicit null or non-null label.
When sub-LSPs share a common router (branch point) and use the same ingress interface of the router, the same MPLS label is used for forwarding. The multicast state is built by reusing the MPLS labels at the branch points, as shown in the figure below, where MPLS label 17 is shared by two sub-LSPs that both use router C.

Computing the IGP Path Using Dynamic Paths or Explicit Paths

You can either specify explicit paths or allow paths to be created dynamically. You can also specify bandwidth parameters, which are flooded throughout the MPLS network through existing RSVP-TE extensions to Open Shortest Path First (OSPF) and Integrated Intermediate System-to-Intermediate System (IS-IS).

The MPLS core network uses RSVP to enable end-to-end IP multicast connectivity. The tailend router and the end point router use PIM to exchange multicast routing information with directly connected CE routers. PIM is not configured in the MPLS core.

P2MP TE tunnels can co-exist with regular P2P TE tunnels. Existing path calculation and bandwidth preemption rules apply in this case.
You create IGP paths by enabling dynamic path computation, configuring explicit paths through CLI commands, or using both methods in your P2MP TE network.

- Dynamic paths are created using Constrained Shortest Path First (CSPF) to determine the best path to a destination. CSPF uses path constraints, such as bandwidth, affinities, priorities, and so on, as part of the computation.

- Explicit paths allows you to manually specify the path a sub-LSP uses from the headend router to the tailend router. You configure static paths on the headend router.

**Remerge Events**

When explicit paths are configured with a limited number of equal cost links or paths, two sub-LSPs might connect at a midpoint router through different ingress interfaces, but use the same egress interface. This is called a remerge event, which can cause duplicate MPLS packets. If a router detects a remerge event, it sends a PathErr Routing Problem: Remerge Detected message toward the headend router and the sub-LSPs are not established. With dynamic paths, the router signals a path that avoids a remerge situation.

**Crossover Events**

With a P2MP tunnel, two sibling sub-LSPs (sub-LSPs that share the same link and label) are said to “cross over” when they have different incoming interfaces and different outgoing interfaces on the same intersecting node. The sibling sub-LSPs neither share input label nor output bandwidth. Avoid configuring crossover LSPs, because they waste bandwidth. However, the duplication of sub-LSPs does not result in an error.

**Benefits of MPLS Point-to-Multipoint Traffic Engineering**

The P2MP TE feature provides the following benefits:

- You can configure signaling attributes, such as affinities, administrative metrics, FRR protection, and bandwidth constraints, when you set up P2MP TE sub-LSPs.

- P2MP TE provides a single point of traffic control. You specify all the signaling and path parameters at the headend router.

- You can configure explicit paths to optimize traffic distribution.

- You can enable FRR link protection for P2MP TE sub-LSPs.

- Protocol Independent Multicast (PIM) is not needed in the MPLS core. Only the non-MPLS interfaces on the tailend routers need to be configured with PIM.

**MPLS Point-to-Multipoint Traffic Engineering—Re-optimizing Traffic**

A P2MP TE tunnel is operational (up) when the first sub-LSP has been successfully signaled. The P2MP TE tunnel is not operational (down) when all sub-LSPs are down. Certain events can trigger a tunnel re-optimization:

- One of the sub-LSPs is fast-rerouted to a backup tunnel (for dynamic LSPs).

- A link is operational. (if the command `mpls traffic-eng reoptimize events link-up` is configured).

- A periodic schedule optimization occurs through the `mpls traffic-eng reoptimize timers frequency` command.
The network administrator forces a tunnel optimization through the `mpls traffic-eng reoptimize` command.

A FRR protected interface becomes operational.

A non-FRR LSP detects a remerge situation.

When a P2MP tunnel is reoptimized, a new LSP is signaled and traffic is moved to the new LSP.

To determine if a tunnel should be reoptimized, the router considers the following criteria:

- The router compares the number of reachable destinations between the new tree and current tree. If the new tree contains more reachable destinations than the current tree, the router performs a reoptimization. If the new tree contains fewer reachable destinations than the current tree, then the router keeps the current tree.

- The router verifies that the same set of reachable destinations in the current tree are also in the new tree. If the new tree does not contain the same destinations, the router keeps the current tree.

- The router compares the number of destinations in the new tree with the number of destinations in the old tree. If the number of destinations in the new tree is greater than the number of destinations in the current tree, the router switches to the new tree. This guarantees that the new tree will contain all of the existing destinations and more.

- The router compares the metric between the current and new tree to ensure the new tree and current tree contain the same set of reachable destinations.

- The router compares the administrative weights of the old tree and the new tree. The router switches to the new tree if the cumulative administrative weight is lower. This step applies as a tie breaker if all the other conditions are the same.

P2MP TE uses make-before-break reoptimization, which uses the following reoptimization process:

- The new LSP is signaled.

- The headend router initiates a timer to ensure sufficient time elapses before traffic moves from the current LSP to the new LSP.

- Traffic is redirected from the current LSP to the new LSP.

- The timer is started for the purpose of tearing down the old sub-LSPs.

**P2P TE Tunnels Coexist with P2MP TE Tunnels**

Both P2P and P2MP TE tunnels share the following characteristics:

- Tunnel bandwidth is configured the same way in both P2P and P2MP tunnels. In P2MP TE tunnels, any bandwidth parameters you configure are applied to all the destination routers. That is, the bandwidth parameters apply to all sub-LSPs. Both P2P and P2MP TE tunnels use the same IGP extension to flood link bandwidth information throughout the network.

- Tunnel setup and hold priorities, attributes flags, affinity and mask, and administrative weight parameters are configured the same way for P2P and P2MP TE tunnels. P2MP TE tunnel parameters apply to all sub-LSPs.

- FRR-enabled P2MP sub-LSPs coexist with FRR-enabled P2P LSPs in a network. For P2P TE, node, link, and bandwidth protection is supported. For P2MP TE, only link protection is supported.
Using FRR to Protect P2MP TE Links

FRR applies to P2P LSPs and P2MP sub-LSPs in the same manner. No new protocol extensions are needed to support P2MP.

Note

For P2MP TE FRR protection, issue the ip routing protocol purge interface command on every penultimate hop router. Otherwise, the router can lose up to 6 seconds worth of traffic during a FRR cutover event.

FRR minimizes interruptions in traffic delivery as a result of link failure. FRR temporarily fast switches LSP traffic to a backup path around a network failure until the headend router signals a new end-to-end LSP.

FRR-enabled P2MP sub-LSPs coexist with FRR-enabled P2P LSPs in a network. For P2MP TE, only link protection is supported. For P2P TE, node, link, and bandwidth protection are supported.

You can configure P2P explicit backup tunnels on point of local repair (PLR) nodes for link protection of P2MP sub-LSPs, similar to LSPs for P2P TE tunnels. You can also enable automatic creation of backup tunnels using the Auto-tunnel Backup feature for P2P TE tunnels. All sibling sub-LSPs that share the same outgoing link are protected by the same backup tunnel. All cousin sub-LSPs that share the same outgoing link can be protected by multiple P2P backup tunnels.

Link protection for a P2MP TE tunnel is illustrated in the figure below, which shows PE1 as the tunnel headend router and PE2, PE3, and PE4 as tunnel tailend routers. The following sub-LSPs are signaled from PE1 in the network:

- From PE1 to PE2, the sub-LSP travels the following path: PE1 -> P01 -> P02 -> PE2
- From PE1 to PE3, the sub-LSP travels the following path: PE1 -> P01 -> P03 -> PE3
- From PE1 to PE4, the sub-LSP travels the following path: PE1 -> P01 -> P04 -> PE4

Node P01 is a branch node that does packet replication in the MPLS forwarding plane; ingress traffic originating from PE1 will be replicated towards routers P02, P03, and P04.
To protect the three sub-LSPs, separate point-to-point backup tunnels are signaled.

Note
Backup tunnels can be created only for links that have an alternative network path.

In this example, router P01 is the Point of Local Repair (PLR) and routers P02, P03, and P04 are Merge Points (MPs).

If a link failure occurs between routers P01 and P04, the following events are triggered:

1. Router P01 switches traffic destined to PE4 to the backup tunnel associated with P04.
2. Router P01 sends RSVP path error messages upstream to the P2MP TE headend router PE1. At the same time, P01 and P04 send IGP updates (link state advertisements (LSAs)) to all adjacent IGP neighbors, indicating that the interfaces associated with links P01 through P04 are down.
3. Upon receiving RSVP path error messages and IGP LSA updates, the headend router triggers a P2MP TE tunnel reoptimization and signals a new sub-LSP. (This occurs if you have specified dynamic path creation.)

Note
If only one sub-LSP becomes active, it remains down until all the sub-LSPs become active.
FRR Failure Detection Mechanisms

To detect link failures in a P2MP TE network, you can use native link and interface failure detection mechanisms, such as bidirectional forwarding detection (BFD), and RSVP hellos.

Bidirectional Forwarding Detection

The MPLS Traffic Engineering: BFD-triggered FRR feature allows you to obtain link by using the Bidirectional Forwarding Detection (BFD) protocol to provide fast forwarding path failure detection times for all media types, encapsulations, topologies, and routing protocols. In addition to fast forwarding path failure detection, BFD provides a consistent failure detection method for network administrators. For more information, see MPLS Traffic Engineering: BFD-triggered Fast Reroute (FRR).

RSVP Hellos

You can configure RSVP hellos on interfaces that do not provide FRR cutover notification during a link failure. The behavior for RSVP hellos is similar for both P2MP TE and P2P TE. For every sub-LSP that has a backup tunnel and has RSVP hellos enabled on its output interface, an RSVP hello instance is created to the neighbor, and the sub-LSP is added to the neighbor's FRR tree in the hello database.

Hello instances between an output interface and neighbor address are shared by fast reroutable P2MP sub-LSPs and P2P LSPs. When a hello session to a neighbor is declared down, all P2P LSPs and P2MP sub-LSPs that are protected by a backup LSP or sub-LSP are switched to their respective backups in the control and data planes.

RSVP hello sessions can also be used to inform the P2MP headend router of failures along a sub-LSP’s path before the RSVP state for the sub-LSP times out, which leads to faster reoptimization. If a sub-LSP cannot select a backup tunnel but has RSVP hellos enabled on its output interface, it looks for a hello instance to its neighbor. If none exists, a hello state time (HST) hello instance is created. If the neighbor goes down, that sub-LSP is torn down. For more information, see MPLS Traffic Engineering (TE) - Fast Reroute (FRR) Link and Node Protection.

Bandwidth Preemption for P2MP TE

Bandwidth Admission Control and preemption mechanisms for P2MP TE sub-LSPs are the same as for LSPs associated with P2P TE tunnels. Any link affinities or constraints defined for the P2MP TE tunnel will be taken into account. The bandwidth signaled for the sub-LSP is removed from the appropriate pool at the appropriate priority, and if needed, lower priority sub-LSPs are preempted with a higher priority sub-LSP.

A P2MP tunnel can be configured to use sub-pool or global-pool bandwidth. When bandwidth is configured, all sub-LSPs of the P2MP tunnel are signaled with the same bandwidth amount and type. If the bandwidth amount or type of a P2MP tunnel is changed, the P2MP tunnel ingress always signals a new set of sub-LSPs (a new P2MP LSP) with the new bandwidth amount and type.

Preemption procedures do not take into account the tunnel type. The same priority rules apply to P2P LSPs and P2MP sub-LSPs. A sub-LSP with a higher setup priority preempts a (sub-)LSP with a lower hold priority, regardless of tunnel type. Thus, a P2MP sub-LSP may preempt a P2P LSP, and vice versa. The determination of which LSPs get preempted is based on hold priority.

You can configure a P2MP TE tunnel to use subpool or global-pool bandwidth. All sub-LSPs associated with the P2MP TE tunnel are signaled with the same bandwidth amount and type. If the bandwidth amount or type is changed, the P2MP tunnel headend router signals a new set of sub-LSPs with the new bandwidth parameters.
Bandwidth sharing is similar for P2MP TE sub-LSPs and P2P TE LSPs. When adding a new sub-LSP, the P2MP-TE headend router determines whether it should share bandwidth with the other sub-LSPs. Two sub-LSPs can share bandwidth as long as they are a “Transit Pair,” meaning the sub-LSPs share the output interface, next-hop and output label.

LSPs and sub-LSPs cannot share bandwidth if they use different bandwidth pools. A change in bandwidth requires reoptimizing P2P or P2MP TE tunnels, which may result in double-counting bandwidth on common links.

Using FRR with Bandwidth Protection has the following requirements:

- A backup tunnel is required to maintain the service level agreement while the new sub-LSP is created.
- The PLR router selects the backup tunnel only if the tunnel has enough bandwidth capacity.
- The backup tunnel might not signal bandwidth.
- The PLR router decides the best backup path to protect the primary path, based on backup bandwidth and class type.

**How to Configure MPLS Point-to-Multipoint Traffic Engineering**

**Configuring the Headend Routers**

The following steps explain how to configure the headend routers for multicast and MPLS point-to-multipoint traffic engineering. As part of the configuration, you specify the tailend routers. You can also specify explicit paths that the tunnel should use or request that the paths be dynamically created or have a combination of dynamic and explicit paths.

Because the configuration of the P2MP TE tunnels is done at the headend router, this feature works best in situations where the destinations do not change often. The P2MP feature does not support dynamic grafting and pruning of sub-LSPs.

**SUMMARY STEPS**

1. enable
2. configure terminal
3. mpls traffic-eng tunnels
4. ip multicast-routing [vrf vrf-name] [distributed]
5. interface tunnel number
6. tunnel mode mpls traffic-eng point-to-multipoint
7. tunnel destination list mpls traffic-eng {identifier dest-list-id | name dest-list-name}
8. ip igmp static-group {* | group-address [source {source-address | ssm-map}] | class-map class-map-name}
9. ip pim {dense-mode [proxy-register {listaccess-list | route-map map-name} | passive | sparse-mode | sparse-dense-mode]
10. exit
11. mpls traffic-eng destination list {namedest-list-name | identifier dest-list-id}
12. ip ip-address path-option id {dynamic | explicit {namename | identifier id}}
13. exit
14. `ip explicit-path {name|identifier}number [enable | disable]`
15. `next-address [loose | strict] ip-address`
16. `end`

**DETAILED STEPS**

<table>
<thead>
<tr>
<th>Step</th>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Step 1 | enable | Enables privileged EXEC mode.  
  * Enter your password if prompted.  
  Example:  
  ```
  Router> enable
  ``` |
| Step 2 | configure terminal | Enters global configuration mode.  
  Example:  
  ```
  Router# configure terminal
  ``` |
| Step 3 | mpls traffic-eng tunnels | Globally enables MPLS Traffic Engineering.  
  * Also issue this command on each network interface that supports a traffic engineering tunnel.  
  Example:  
  ```
  Router(config)# mpls traffic-eng tunnels
  ``` |
| Step 4 | ip multicast-routing [vrfvrf-name] [distributed] | Globally enables IP multicast routing.  
  Example:  
  ```
  Router(config)# ip multicast-routing distributed
  ``` |
| Step 5 | interface tunnel number | Configures a tunnel and enters interface configuration mode.  
  Example:  
  ```
  Router(config)# interface tunnel 100
  ``` |
| Step 6 | tunnel mode mpls traffic-eng point-to-multipoint | Enables MPLS point-to-multipoint traffic engineering on the tunnel.  
  Example:  
  ```
  Router(config-if)# tunnel mode mpls traffic-eng point-to-multipoint
  ``` |
| Step 7 | tunnel destination list mpls traffic-eng {identifier|dest-list-id}[named-list-name] | Specifies a destination list to specify the IP addresses of point-to-multipoint destinations.  
  Example:  
  ```
  Router(config-if)# tunnel destination list mpls traffic-eng name in-list-01
  ``` |
| Step 8 | ip igmp static-group {* | group-address [source source-address | ssm-map]} | Configures static group membership entries on an interface.  
  * Configure this on the TE tunnel interface if the source address (S, G) cannot be resolved.  
  Example:  
  ```
  ```
<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| Router(config-if)# ip igmp static-group 239.100.100.101 source 10.11.11.11 | Enables Protocol Independent Multicast (PIM) on an interface.  
- An interface configured with passive mode does not pass or forward PIM control plane traffic; it passes or forwards only IGMP traffic. |
| **Step 9**  
**ip pim** {dense-mode [proxy-register {list|access-list | route-map-map-name}]} | Enables Protocol Independent Multicast (PIM) on an interface.  
- An interface configured with passive mode does not pass or forward PIM control plane traffic; it passes or forwards only IGMP traffic. |
| exit | Exits interface configuration mode. |
| **Step 10**  
**exit** | Exits interface configuration mode. |
| **Step 11**  
**mpls traffic-eng destination list {name|identifier destin-list-name|dest-list-id}** | Creates a destination list and enters traffic engineering destination list configuration mode. |
| **Step 12**  
**ip ip-address path-option id {dynamic | explicit {name|identifier}}** | Specifies the IP addresses of MPLS point-to-multipoint traffic engineering tunnel destinations.  
- If you use the **explicit** keyword, you must configure explicit paths, using the **ip explicit-path** command.  
- Repeat this step for each destination. |
| exit | Exits traffic engineering destination list configuration mode. |
| **Step 13**  
**exit** | Exits traffic engineering destination list configuration mode. |
| **Step 14**  
**ip explicit-path {name|identifier} number {enable | disable}** | Specifies the name of an IP explicit path and enters IP explicit path configuration mode. |
| **Step 15**  
**next-address {loose | strict} ip-address** | Specifies an explicit path that includes only the addresses specified or loose explicit paths. |
Configuring the Midpoint Routers

No special configuration is needed to support the P2MP TE feature on the midpoint routers. The midpoint routers must have Cisco IOS Release 15.5(02)S or later release installed. They must be able to support and implement the P2MP signaling extensions. The MPLS TE configuration of the midpoint routers supports both P2P and P2MP TE. All multicast traffic is label switched. The midpoint routers do not require IPv4 multicast routing or PIM.

All the core interfaces on the mid-point routers, should have this configuration:  
```markdown
ip rsvp bandwidth, mpls traffic-eng tunnels
```

The IGP, should have this configuration:
```markdown
router ospf 1  mpls traffic-eng router-id Loopback0 , mpls traffic-eng area 0
```

For information on configuring MPLS TE, see MPLS Traffic Engineering and Enhancements.

Configuring the Tailend Routers

The tailend routers remove the MPLS labels from the IP multicast packets and send the packets to the MFIB for regular multicast forwarding processing. You must issue the `ip mroute` command to configure a static route back to the headend router, thus enabling RPF checks.

The following task explains how to configure PIM on the egress interface of the PE router. PIM is needed when the egress PE router is connected to a CE router, which is connected to a LAN where one or more multicast receivers are connected.

If the egress PE router is directly connected to a decoder device/system (e.g., DCM), you must configure Internet Group Management Protocol (IGMP) on the egress interface of the PE router. For more information on configuring IGMP, see Customizing IGMP.

SUMMARY STEPS

1. `enable`
2. `configure terminal`
3. `ip multicast-routing [vrfvrf-name] [distributed]`
4. `ip multicast mpls traffic-eng [rangeaccess-list-number | access-list-name]`
5. `interface type slot / port`
6. `ip pim {dense-mode [proxy-register {listaccess-list | route-mapmap-name}] | passive | sparse-mode | sparse-dense-mode}`
7. `exit`
8. `ip mroute [vrfvrf-name] source-addressmask {fallback-lookup {global | vrfvrf-name} | rpf-address | interface-typeinterface-number} [distance]`
9. `end`
**DETAILED STEPS**

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 1** enable | Enables privileged EXEC mode.  
  Example:  
  Router> enable |
| **Step 2** configure terminal | Enters global configuration mode.  
  Example:  
  Router# configure terminal |
| **Step 3** ip multicast-routing [vrfvrf-name] [distributed] | Enables IP multicast routing globally.  
  Example:  
  Router(config)# ip multicast-routing |
| **Step 4** ip multicast mpls traffic-eng [rangeaccess-list-number | access-list-name] | Enables IP multicast routing for MPLS traffic engineering point-to-multipoint tunnels.  
  Example:  
  Router(config)# ip multicast mpls traffic-eng |
| **Step 5** interface type slot / port | Configures an interface type and enters interface configuration mode.  
  Example:  
  or  
  Example:  
  interface type slot/port-adapter/port  
  Example:  
  Router(config)# interface ethernet 1/1  
  Example:  
  or  
  Example:  
  Router(config)# interface fastethernet 1/0/0 |
| **Step 6** ip pim {dense-mode [proxy-register {listaccess-list | route-mapmap-name} | passive | sparse-mode | sparse-dense-mode]} | Enables Protocol Independent Multicast (PIM) on an interface.  
  Example: |
### Configuring FRR with P2MP TE Tunnels

To enable link protection for sub-LSPs associated with a P2MP TE tunnel, perform the following configuration tasks:

- Enable FRR on the headend router for each P2MP TE tunnel.
- Configure P2P backup tunnels for network interfaces that require protection.

See MPLS Traffic Engineering—Fast Reroute Link and Node Protection for information and configuration instructions.

### Enabling MPLS Traffic Engineering System Logging of Events

MPLS Traffic Engineering system logging allows you to view the following events:

- Setting up and tearing down of LSPs
- RSVP Path and RESV requests
- Sub-LSP status (through path-change messages)

Commands to enable system logging include:

- `mpls traffic-eng logging lsp path-errors`
- `mpls traffic-eng logging lsp preemption`
- `mpls traffic-eng logging lsp reservation-errors`
• mpls traffic-eng logging lsp setups
• mpls traffic-eng logging lsp teardowns
• mpls traffic-eng logging tunnel path change

Verifying the Configuration of MPLS Point-to-Multipoint Traffic Engineering

This section includes the following tasks:

Verifying the Configuration of the Headend Router

At the headend router, use the following steps to verify that:
• All sub-LSPs are enabled.
• IP multicast traffic is being forwarded onto the P2MP TE tunnel.

The following commands may also be helpful in the verification of the headend router:
• show cef path set and show cef path set detail (when the headend router is also a branch point)
• show ip mfib and show ipmfb verbose
• show ip rsvp fast-reroute
• show mpls traffic-eng destination list
• show mpls traffic-eng fast-reroute database
• show mpls traffic-eng tunnels with the dest-mode p2mp, detail, and summary keywords

SUMMARY STEPS

1. enable
2. show mpls traffic-eng tunnels brief
3. show mpls traffic-eng forwarding path-set brief
4. show mpls traffic-eng forwarding path-set detail
5. show ip mroute

DETAILED STEPS

Step 1  enable
Issue the enable command to enter privileged EXEC mode.

Step 2  show mpls traffic-eng tunnels brief
Use the show mpls traffic-eng tunnels brief command to display the P2MP TE tunnels originating from the headend router. For example:

Example:

Router# show mpls traffic-eng tunnels brief
Verifying the Configuration of the Headend Router

Signaling Summary:
- LSP Tunnels Process: running
- Passive LSP Listener: running
- RSVP Process: running
- Forwarding: enabled
- Periodic reoptimization: every 60 seconds, next in 5 seconds
- Periodic FRR Promotion: Not Running
- Periodic auto-bw collection: disabled

P2P TUNNELS:
- TUNNEL NAME: p2p-LSP
  - DESTINATION: 10.2.0.1
  - IF: Se2/0

Displayed 2 (of 2) heads, 0 (of 0) midpoints, 0 (of 0) tails

P2P SUB-LSPS:
- SOURCE: 10.1.0.1
- TUNID: 2
- LSPID: 1
- DESTINATION: 10.2.0.1
- SUBID: 1
  - InLabel: none
  - Next Hop: 10.0.1.2
  - I/F: Et0/0

Displayed 7 P2MP sub-LSPs:
  5 (of 5) heads, 1 (of 1) midpoints, 1 (of 1) tails

Step 3 show mpls traffic-eng forwarding path-set brief

Use the `show mpls traffic-eng forwarding path-set brief` command to show the sub-LSPs that originate from the headend router. The following example shows three sub-LSPs originating at the headend router and going to different destinations. All the sub-LSPs belong to the same path set, which is a collection of paths. The path set is given a unique ID, which is shown in the PSID column of the example:

Example:

```
Router# show mpls traffic-eng forwarding path-set brief
Sub-LSP Identifier
src_lspid[subid]->dst_tunid   InLabel Next Hop   I/F   PSID
----------------------------------------- ----------- ------ ------
10.0.0.1_19->10.0.0.8_1          none  10.0.1.2  Et0/0  C5000002
10.0.0.1_19->10.0.0.6_1          none  10.0.1.2  Et0/0  C5000002
10.0.0.1_19->10.0.0.7_1          none  10.0.1.2  Et0/0  C5000002
```

Step 4 show mpls traffic-eng forwarding path-set detail

Use the `show mpls traffic-eng forwarding path-set detail` command to show more information about the sub-LSPs that originate from the headend router. For example:

Example:

```
Router# show mpls traffic-eng forwarding path-set detail
LSP: Source: 10.1.0.1, TunID: 100, LSPID: 7
  Destination: 10.2.0.1, P2MP Subgroup ID: 1
  Path Set ID: 0x300000001
  OutLabel : Serial2/0, 16
  Next Hop : 10.1.3.2
```
Step 5  
**show ip mroute**

Use the **show ip mroute** command to verify that IP multicast traffic is being forwarded to the P2MP TE tunnel. In the following example, the output shown in bold shows that Tunnel 1 is part of the outgoing interface list for multicast group 232.0.1.4 with a source address of 10.10.10.10:

**Example:**

```
Router# show ip mroute
IP Multicast Routing Table
Flags: D = Dense, S = Sparse, B = Bidir Group, s = SSM Group, C = Connected,
L = Local, P = Pruned, R = RP-bit set, F = Register flag,
T = SPT-bit set, J = Join SPT, M = MSDP created entry, E = Extranet,
X = Proxy Join Timer Running, A = Candidate for MSDP Advertisement,
U = URD, I = Received Source Specific Host Report,
Z = Multicast Tunnel, z = MDT-data group sender,
Y = Joined MDT-data group, y = Sending to MDT-data group,
V = RD & Vector, v = Vector
Outgoing interface flags: H = Hardware switched, A = Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode
(10.10.10.10, 232.0.1.4), 1d00h/stopped, flags: sTI
  Incoming interface: Ethernet2/0, RPF nbr 10.10.1.1
  Outgoing interface list:
    Tunnel1, Forward/Sparse-Dense, 1d00h/00:01:17
(*) 224.0.1.40, 1d00h/00:02:48, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet2/0, Forward/Sparse, 1d00h/00:02:48
```

**Verifying the Configuration of the Midpoint Routers**

At the midpoint router, use the following commands to verify that MPLS forwarding occurs. If the midpoint router is branch router, you can also use **show mpls forwarding-table labels** command to display show specific labels.

**SUMMARY STEPS**

1. enable
2. show mpls forwarding-table

**DETAILED STEPS**

**Step 1**  
**enable**

Issue the **enable** command to enter privileged EXEC mode.

**Step 2**  
**show mpls forwarding-table**
Verifying the Configuration of the Tailend Routers

At the tailend router, use the following steps to verify that:

- MPLS forwarding occurs.
- IP multicast forwarding occurs.

You can also use the `show ip mfib`, `showmpls traffic-eng destination list`, and `show mpls traffic-eng tunnels dest-mode p2mp` commands for verification.

SUMMARY STEPS

1. **enable**
2. **show mpls forwarding-table**
3. **show ip mrout**

DETAILED STEPS

**Step 1**  
**enable**  
Issue the `enable` command to enter privileged EXEC mode.

**Step 2**  
**show mpls forwarding-table**  
Use the `show mpls forwarding-table` command to show that MPLS labeled packets are forwarded from the tailend router without any label.

**Example:**

```
Router# show mpls forwarding-table
Local Outgoing Prefix Bytes Label Outgoing Next Hop
Label Label or Tunnel Id Switched interface
16 16 10.0.0.1 1 [19] 0 E1/0 10.0.1.30
```

MAC/Encaps=14/18, MRU=1500, Label Stack(16)
AABBCC032800AABBCC0325018847 00010000
No output feature configured
Broadcast
Step 3

**show ip mroute**

Use the `show ip mroute` command to display IP multicast traffic. In the following example, the output in bold shows the incoming interface is Lspvif0 and the outgoing interface is Ethernet1/0 is for multicast group 232.0.1.4 with source address 10.10.10.10:

**Example:**

```
Router# show ip mroute
IP Multicast Routing Table
... (*, 232.0.1.4), 1d02h/stopped, RP 0.0.0.0, flags: SP
   Incoming interface: Null, RPF nbr 0.0.0.0
   Outgoing interface list: Null
(10.10.10.10, 232.0.1.4), 00:01:51/00:01:38, flags: SP
   Incoming interface: Lspvif0, RPF nbr 10.0.0.1, Mroute
   Outgoing interface list:
      Ethernet1/0, Forward/Sparse, 00:01:51/00:02:37
(*, 224.0.1.40), 1d02h/00:02:57, RP 0.0.0.0, flags: DCL
   Incoming interface: Null, RPF nbr 0.0.0.0
   Outgoing interface list:
      Ethernet1/0, Forward/Sparse, 1d02h/00:02:57
```

---

**Configuration Examples for MPLS Point-to-Multipoint Traffic Engineering**

The following examples show point-to-multipoint traffic engineering configurations on the headend router (PE5), a midpoint router (P1), and a tailend router (PE1):
Example Configuration of the Headend Router (PE5)

In the following example configuration of the headend router, note the following:

- IPv4 multicast routing is enabled with the `ipmulticast-routing` command.
- Two destination lists are specified, one for dynamic paths and one for explicit paths. The destination list specifies one path-option per destination.
- The `tunnelempmplstraffe-engpoint-to-multipoint` command enables the P2MP tunnel.
- On the tunnel interfaces, the `ippimpassive` command is used.
- On the non-MPLS interfaces, the `ippimsparse-mode` command is used.
- The `ipigmpstatic-group` commands map the multicast groups to the P2MP tunnel.
• FRR is enabled on the router, with tunnel 3 as the backup path. An explicit path called PE5->P1-BKUP provides the alternative path.

hostname [PE5]
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
clock timezone PST -8
ip subnet-zero
ip source-route
ip cef
no ip domain lookup
!
ip multicast-routing
!
no ipv6 cef
mpls traffic-eng tunnels
!
  mpls traffic-eng destination list name P2MP-DYN-DST-LIST
    ip 172.16.255.1 path-option 10 dynamic
    ip 172.16.255.2 path-option 10 dynamic
    ip 172.16.255.3 path-option 10 dynamic
    ip 172.16.255.4 path-option 10 dynamic
!
  mpls traffic-eng destination list name P2MP-EXCIT-DST-LIST
    ip 172.16.255.1 path-option 10 explicit identifier 101
    ip 172.16.255.2 path-option 10 explicit identifier 102
    ip 172.16.255.3 path-option 10 explicit identifier 103
    ip 172.16.255.4 path-option 10 explicit identifier 104
!
multilink bundle-name authenticated
!
interface Tunnel1
description PE5->PE1,PE2,PE3,PE4-DYN
ip unnumbered Loopback0
ip pim passive
ip igmp static-group 232.0.1.4 source 192.168.5.255
ip igmp static-group 232.0.1.3 source 192.168.5.255
ip igmp static-group 232.0.1.2 source 192.168.5.255
ip igmp static-group 232.0.1.1 source 192.168.5.255
tunnel mode mpls traffic-eng point-to-multipoint
tunnel destination list mpls traffic-eng name P2MP-DYN-DST-LIST
tunnel mpls traffic-eng priority 7 7
tunnel mpls traffic-eng bandwidth 10000
!
interface Tunnel2
description PE5->PE1,PE2,PE3,PE4-EXCIT
ip unnumbered Loopback0
ip pim passive
ip igmp static-group 232.0.1.8 source 192.168.5.255
ip igmp static-group 232.0.1.7 source 192.168.5.255
ip igmp static-group 232.0.1.6 source 192.168.5.255
ip igmp static-group 232.0.1.5 source 192.168.5.255
tunnel mode mpls traffic-eng point-to-multipoint
tunnel destination list mpls traffic-eng name P2MP-EXCIT-DST-LIST
tunnel mpls traffic-eng priority 7 7
tunnel mpls traffic-eng bandwidth 20000
!
interface Tunnel3
description PE5->P1
ip unnumbered Loopback0
tunnel mode mpls traffic-eng
tunnel destination 172.16.255.201
tunnel mpls traffic-eng path-option 10 explicit name PE5->P1-BKUP

interface Loopback0
ip address 172.16.255.5 255.255.255.255

interface Ethernet0/0
description CONNECTS to CE5
ip address 192.168.5.1 255.255.255.252
ip pim sparse-mode

interface Ethernet1/0
description CONNECTS TO P1
bandwidth 1000000
ip address 172.16.0.13 255.255.255.254
ip router isis
mpls traffic-eng tunnels
mpls traffic-eng backup-path Tunnel3
isis network point-to-point
ip rsvp bandwidth percent 100

interface Ethernet2/0
description CONNECTS TO P2
bandwidth 1000000
ip address 172.16.0.14 255.255.255.254
ip router isis
mpls traffic-eng tunnels
isis network point-to-point
ip rsvp bandwidth percent 100
router isis
net 49.0001.1720.1625.5005.00
is-type level-2-only
metric-style wide
passive-interface Loopback0
mpls traffic-eng router-id Loopback0
mpls traffic-eng level-2

ip classless

ip http server

ip pim ssm default

ip explicit-path identifier 101 enable
next-address 172.16.0.12
next-address 172.16.192.0
next-address 172.16.0.0

ip explicit-path identifier 102 enable
next-address 172.16.0.12
next-address 172.16.192.0
next-address 172.16.0.3

ip explicit-path identifier 103 enable
next-address 172.16.0.12
next-address 172.16.192.0
next-address 172.16.192.6
next-address 172.16.0.6
Example Configuration of the Midpoint Router (P1)

In the following example configuration of the midpoint router, note the following:

- MPLS Traffic Engineering is enabled both globally and on the interface connecting to other core routers.
- MPLE TE extensions are enabled through the `mplstraffic-engrouter-id` and `mplstraffic-englevel` commands.

```plaintext
hostname [P1]
!
no aaa new-model
clock timezone PST -8
ip subnet-zero
ip source-route
ip cef
no ip domain lookup
!
no ipv6 cef
mpls traffic-eng tunnels
multilink bundle-name authenticated
!
interface Loopback0
  ip address 172.16.255.201 255.255.255.255
!
interface Ethernet0/0
description CONNECTS TO P2
bandwidth 1000000
ip address 172.16.192.2 255.255.255.254
ip router isis
mpls traffic-eng tunnels
isis network point-to-point
ip rsvp bandwidth percent 100
!
interface Ethernet0/1
no ip address
shutdown
!
interface Ethernet0/2
no ip address
shutdown
!
interface Ethernet0/3
no ip address
shutdown
!
interface Ethernet1/0
description CONNECTS TO P3
bandwidth 1000000
ip address 172.16.192.1 255.255.255.254
ip router isis
```
Example Configuration of the Tailend Router (PE1)

In the following example configuration of the tailend router, note the following:

- IPv4 multicast routing is enabled with the `ip multicast-routing` command.
- On the non-MPLS interfaces, the `ip pim sparse-mode` command is used.
- The `ip multicastmpls` commands enable multicast routing of traffic.

```plaintext
hostname [PE1]
!
no aaa new-model
clock timezone PST -8
ip subnet-zero
ip source-route
ip cef
no ip domain lookup
!
ip multicast-routing
!
no ipv6 cef
mpls traffic-eng tunnels
multilink bundle-name authenticated
!
interface Loopback0
ip address 172.16.255.1 255.255.255.255
!
interface Ethernet0/0
description CONNECTS TO CE1
ip address 192.168.1.1 255.255.255.252
ip pim sparse-mode
!
interface Ethernet0/3
description CONNECTS TO P3
bandwidth 155000
```
no ip address
shutdown
mpls traffic-eng tunnels
ip rsvp bandwidth 155000
!
interface Ethernet1/0
description CONNECTS TO PE2
bandwidth 1000000
ip address 172.16.0.5 255.255.255.254
ip router isis
mpls traffic-eng tunnels
isis network point-to-point
ip rsvp bandwidth percent 100
!
interface Ethernet2/0
description CONNECTS TO P3
bandwidth 1000000
ip address 172.16.0.0 255.255.255.254
ip router isis
mpls traffic-eng tunnels
isis network point-to-point
ip rsvp bandwidth percent 100
!
router isis
net 49.0001.1720.1625.5001.00
is-type level-2-only
metric-style wide
passive-interface Loopback0
mpls traffic-eng router-id Loopback0
mpls traffic-eng level-2
!
!
ip classless
!
no ip http server
!
ip multicast mpls traffic-eng
ip pim ssm default
ip mroute 192.168.5.0 255.255.255.0 172.16.255.5

Additional References

Related Documents

<table>
<thead>
<tr>
<th>Related Topic</th>
<th>Document Title</th>
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</thead>
<tbody>
<tr>
<td>Cisco IOS commands</td>
<td>Cisco IOS Master Commands List, All Releases</td>
</tr>
<tr>
<td>MPLS TE command descriptions</td>
<td>Cisco IOS Multiprotocol Label Switching Command Reference</td>
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Standards

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MIBs

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<td>To locate and download MIBs for selected platforms, Cisco software releases, and feature sets, use Cisco MIB Locator found at the following URL: <a href="http://www.cisco.com/go/mibs">http://www.cisco.com/go/mibs</a></td>
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RFCs

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Technical Assistance

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<tr>
<td>The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password.</td>
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**Feature Information for MPLS Point-to-Multipoint Traffic Engineering**

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

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

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<tr>
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</tbody>
</table>
Glossary

**Branch router** — A router that has more than one directly connected downstream routers. A router where packet replication occurs.

**Bud router** — An egress router that has one or more directly connected downstream routers. A bud node can be a branch node and a destination.

**Crossover** — A condition that occurs at an intersecting node when two or more incoming sub-LSPs that belong to the same LSP have different input interfaces and different output interfaces.

**Egress router** — One of potentially many destinations of the P2MP TE sub-LSP. Egress routers may also be referred to as tailend routers, leaf nodes, or leaves.

**Data duplication** — A condition that occurs when an egress router receives duplicate packets. The condition can happen as a result of re-optimization of LSPs, remerge, or crossover. It causes network bandwidth to be wasted and should be minimized.

**Grafting** — The process of adding a new sub-LSP to a P2MP TE tunnel.

**Headend router** — An ingress PE router that is at the “headend” of a P2MP tunnel.

**Ingress router** — The router that initiates the signaling messages that set up the P2MP TE LSP. Also known as the headend router.

**MDT** — A Multicast Domain/Distribution tree in the core that carries traffic and/or control messages for a given VPN. An MDT implicitly implies that we are discussing the Domain-Model. And MDT can have multiple types of encapsulation in the core, for example, GRE, IP-in-IP or MPLS.

**MFI** — MPLS forwarding infrastructure.

**mLDP** — Multicast signaling extensions to LDP.

**P2MP ID (P2ID)** — A unique identifier of a P2MP TE LSP, which is constant for the whole LSP regardless of the number of branches and/or leaves.

**P2MP LSP** — One or more source to leaf sub-LSPs. It is identified by 5-tuple key:

- Session
  - P2MP ID
  - Tunnel ID
  - Extended Tunnel ID

- Sender Template
  - Tunnel sender address
  - LSP ID

**P2MP Sub-LSP** — A segment of a P2MP TE LSP that runs from the headend router to one destination. A sub-LSP is identified by the following 7-tuple key:

- P2MP session
  - P2MP ID
  - Tunnel ID
• Extended tunnel ID

Sender template
• Tunnel sender address
• LSP ID
• Subgroup ID originator
• Subgroup ID

P2MP-TE — point to multipoint traffic engineering

P2MP tree — The ordered set of routers and TE links that comprise the paths of P2MP TE sub-LSPs from the ingress router to all of the egress routers.

P2MP tunnel — A group of one or more P2MP LSPs. A tunnel has the following 3-tuple key:
• P2MP ID
• Tunnel ID
• Extended tunnel ID.

PIM — Protocol Independent Multicast

PIM-SM — PIM Sparse Mode, see RFC 4601

PIM-SSM — PIM Source Specific Multicast, a subset of PIM-SM. See RFC 4601.

Pruning — The process of removing a sub-LSP from a a P2MP LSP.

Receiver — A recipient of traffic carried on a P2MP service supported by a P2MP sub-LSP. A receiver is not necessarily an egress router of the P2MP LSP. Zero, one, or more receivers may receive data through a given egress router.

Remerge — A condition that occurs at an intersecting node when two data streams belonging to the same P2MP LSP merge into onto one data stream as they exit the intersecting node.

Sibling LSP — Two LSPs that belong to the same P2MP tunnel, meaning that the session objects are the same for both LSPs.

Sibling sub-LSP — Two sub-LSPs that belong to the same P2MP LSP, meaning that the session and sender template objects are the same for both sub-LSPs.

Source — The sender of traffic that is carried on a P2MP service supported by a P2MP LSP. The sender is not necessarily the ingress router of the P2MP LSP.

Tailend router — An egress PE router that is at the “tailend” of a P2MP tunnel.
CHAPTER 3

MPLS Traffic Engineering over Bridge Domain Interfaces

The MPLS Traffic Engineering (TE) over Bridge Domain Interfaces (BDI) feature enables MPLS traffic engineering over Bridge Domain Interfaces.

- Prerequisites for Configuring MPLS TE over BDI, on page 41
- Restrictions for MPLS TE over BDI, on page 41
- Information About MPLS Traffic Engineering over BDI, on page 42
- How to Configure MPLS Traffic Engineering over BDI, on page 42
- Configuration Example for MPLS Traffic Engineering over BDI, on page 46

Prerequisites for Configuring MPLS TE over BDI

You must have:

- Enabled MPLS TE on all relevant routers and interfaces
- Configured MPLS TE tunnels

Your network must support the following Cisco IOS features:

- IP Cisco Express Forwarding
- Multiprotocol Label Switching (MPLS)

Your network must support at least one of the following protocols:

- Intermediate System to Intermediate System (ISIS)
- Open Shortest Path First (OSPF)

Restrictions for MPLS TE over BDI

- MPLS TE - Verbatim Path Support
- Explicit Path Node exclusion
- P2MP TE Tunnels
- Auto-tunnel one-hops and backups
Information About MPLS Traffic Engineering over BDI

Features of MPLS Traffic Engineering over BDI

The MPLS Traffic Engineering over BDI feature enables MPLS TE tunnels over BDI.

Supported Features

Your network must support the following:

- MPLS TE tunnels
- Policy Routing onto MPLS TE Tunnels
- MPLS TE - Forwarding Adjacency
- MPLS TE – RSVP Hello State Timer
- MPLS TE - LSP Attributes
- MPLS TE - IP Explicit Address Exclusion
- MPLS TE - Configurable Path Calculation Metric for Tunnels
- MPLS TE - Verbatim Path Support
- Pseudo-wire mapping onto TE tunnels.

How to Configure MPLS Traffic Engineering over BDI

This section assumes that you want to configure MPLS TE over BDI.

Configuring MPLS TE over BDI

SUMMARY STEPS

1. enable
2. configure terminal
3. interface bdi30
4. mpls traffic-eng tunnels
5. end
### DETAILED STEPS

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Enables privileged EXEC mode.</td>
</tr>
<tr>
<td>enable</td>
<td>Enables privileged EXEC mode.</td>
</tr>
<tr>
<td>Example:</td>
<td>• Enter your password if prompted.</td>
</tr>
<tr>
<td>Router&gt; enable</td>
<td></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td>Enters interface configuration mode.</td>
</tr>
<tr>
<td>configure terminal</td>
<td>Enters interface configuration mode.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
</tr>
<tr>
<td>Router# configure terminal</td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>Specifies the bridge domain interface and enters interface configuration mode.</td>
</tr>
<tr>
<td>interface bdi30</td>
<td>Specifies the bridge domain interface and enters interface configuration mode.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
</tr>
<tr>
<td>Router(config)# interface bdi30</td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>Enables an MPLS TE tunnel to use an established tunnel for the bridge domain interface.</td>
</tr>
<tr>
<td>mpls traffic-eng tunnels</td>
<td>Enables an MPLS TE tunnel to use an established tunnel for the bridge domain interface.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
</tr>
<tr>
<td>Router(config-if)# mpls traffic-eng tunnels</td>
<td></td>
</tr>
<tr>
<td><strong>Step 5</strong></td>
<td>Returns to privileged EXEC mode.</td>
</tr>
<tr>
<td>end</td>
<td>Returns to privileged EXEC mode.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
</tr>
<tr>
<td>Router(config-if)# end</td>
<td></td>
</tr>
</tbody>
</table>

### Configuring the RSVP Bandwidth

#### SUMMARY STEPS

1. enable
2. configure terminal
3. interface type slot / subslot / port
5. end

#### DETAILED STEPS

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Enables privileged EXEC mode.</td>
</tr>
<tr>
<td>enable</td>
<td>Enables privileged EXEC mode.</td>
</tr>
<tr>
<td>Example:</td>
<td>• Enter your password if prompted.</td>
</tr>
<tr>
<td>Router&gt; enable</td>
<td></td>
</tr>
</tbody>
</table>
### Purpose

- **Command or Action**: `configure terminal`  
  **Example**:  
  ```  
  Router# configure terminal  
  ```

### Purpose

- **Command or Action**: `interface type slot / subslot / port`  
  **Example**:  
  ```  
  Router(config)# interface gigabitEthernet 0/0/0  
  ```

### Purpose

- **Command or Action**: `ip rsvp bandwidth [interface-kbps [single-flow-kbps[bc1 kbps | sub-pool kbps]]] percent percent-bandwidth [single-flow-kbps]`  
  **Example**:  
  ```  
  Router(config-if)# ip rsvp bandwidth 7500 7500  
  ```

#### Note
- Repeat this command for each interface on which you want to enable RSVP.

### Purpose

- **Command or Action**: `end`  
  **Example**:  
  ```  
  Router(config-if)# end  
  ```

### Verifying That MPLS TE over BDI Is Operational

To verify that MPLS TE over BDI can function, perform the following task.

### SUMMARY STEPS

1. `enable`
2. `show mpls traffic-eng tunnels brief`
3. `show mpls traffic-eng tunnels summary`
4. `show mpls traffic-eng tunnels tunnel1`

### DETAILED STEPS

#### Step 1
- `enable`
  Enables privileged EXEC mode.
Step 2  show mpls traffic-eng tunnels brief
Use this command to monitor and verify the state of the tunnels.

Step 3  show mpls traffic-eng tunnels summary
Use this command to monitor and verify the state of the tunnels.

Step 4  show mpls traffic-eng tunnels tunnel1
Use this command to verify that tunnels are up and using BDI.

Troubleshooting Tips

This section describes how you can use the show mpls traffic-eng tunnels tunnel5 to check for issues.

Router# show mpls traffic-eng tunnels tunnel5
Name: router_t5  (Tunnel5) Destination: 3.3.3.3
Status:
  Admin: up  Oper: up  Path: valid  Signalling: connected
  path option 1, type dynamic (Basis for Setup, path weight 2)
Config Parameters:
  Bandwidth: 0 kbps (Global)  Priority: 5 5  Affinity: 0x0/0xFFFF
  Metric Type: TE (default)
  AutoRoute: disabled  LockDown: disabled  Loadshare: 0 [0] bw-based
  auto-bw: disabled
Active Path Option Parameters:
  State: dynamic path option 1 is active
  BandwidthOverride: disabled  LockDown: disabled  Verbatim: disabled
InLabel : -
OutLabel : BDI31, 21
Next Hop : 12.0.0.2
RSVP Signalling Info:
  Src 1.1.1.1, Dst 3.3.3.3, Tun_Id 5, Tun_Instance 1
RSVP Path Info:
  My Address: 12.0.0.1
  Explicit Route: 12.0.0.2 14.0.0.2 14.0.0.1 3.3.3.3
  Record Route: NONE
  Tspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
  RSVP Resv Info:
    Record Route: NONE
    Fspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
Shortest Unconstrained Path Info:
  Path Weight: 2 (TE)
  Explicit Route: 12.0.0.1 12.0.0.2 14.0.0.2 14.0.0.1 3.3.3.3
  Record Route: NONE
History:
  Tunnel:
    Time since created: 1 minutes, 38 seconds
    Time since path change: 1 minutes, 36 seconds
    Number of LSP IDs (Tun_Instances) used: 1
    Current LSP: [ID: 1]
    Uptime: 1 minutes, 36 seconds
**Configuration Example for MPLS Traffic Engineering over BDI**

The following example enables the BDI on the router:

Router(config)#interface bdi30
Router(config-if)#mpls traffic-eng tunnels

**Configuring Interface Tunnel Example**

The following example configures an interface tunnel:

```
interface Tunnel1
ip unnumbered Loopback0
tunnel source Loopback0
tunnel mode mpls traffic-eng
tunnel destination 4.4.4.4
tunnel mpls traffic-eng path-option 1 dynamic
```

**Configuring RSVP Bandwidth Example**

The following example configures RSVP bandwidth:

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

```
Router(config-if)# ip rsvp bandwidth 500 500
```