Implementing MPLS Traffic Engineering

This module describes how to implement MPLS Traffic Engineering on Cisco ASR 9000 Series Router.

Multiprotocol Label Switching (MPLS) is a standards-based solution driven by the Internet Engineering Task Force (IETF) that was devised to convert the Internet and IP backbones from best-effort networks into business-class transport mediums.

MPLS, with its label switching capabilities, eliminates the need for an IP route look-up and creates a virtual circuit (VC) switching function, allowing enterprises the same performance on their IP-based network services as with those delivered over traditional networks such as Frame Relay or Asynchronous Transfer Mode (ATM).

MPLS traffic engineering (MPLS-TE) software enables an MPLS backbone to replicate and expand upon the TE capabilities of Layer 2 ATM and Frame Relay networks. MPLS is an integration of Layer 2 and Layer 3 technologies. By making traditional Layer 2 features available to Layer 3, MPLS enables traffic engineering. Thus, you can offer in a one-tier network what now can be achieved only by overlaying a Layer 3 network on a Layer 2 network.

Note The LMP and GMPLS-NNI features are not supported on PRP hardware.

Feature History for Implementing MPLS-TE

Release	Modification
Release 3.7.2	This feature was introduced.
Release 3.9.0	The MPLS Traffic Engineering (TE): Path Protection feature was added.
Release 3.9.1	The MPLS-TE automatic bandwidth feature is supported.
Release 4.1.0	Support was added for the following features: • Ignore Intermediate System-to-Intermediate System Overload Bit Setting in MPLS-TE • Point-to-Multipoint Traffic-Engineering
Release 4.1.1	The Auto-Tunnel Mesh feature was added.

Release	Modification
Release 4.2.0	Support was added for the following features: • Soft-Preemption • Path Option Attributes
Release 4.2.1	The Auto-Tunnel Attribute-set feature was added for auto-backup tunnels.
Release 4.2.3	Support was added for the following features: • End-to-End TE Path Protection Enhancements — Explicit Path Protection and Co-existence of Path Protection with Fast Reroute • P2MP-TE Inter-area Enhancements
	Support was added for the following features: • P2MP-TE Auto-tunnels • Set DF Bit
Release 5.2.2	Make-Before-Break feature was added.
Release 5.3.2	Policy-Based Tunnel Selection for IPv6 feature was added.
Release 5.3.2	Stateful PCE Enhancements were made.
Release 6.0	Introduced Service Path Preference
Release 6.0.1	Point-to-Multipoint Implicit Null feature was added.
Release 6.1.2	Named Tunnel feature was added.
Release 6.4.1	Enabling Forward Class Zero in PBTS feature was added.
Release 7.1.1	IS-IS autoroute announce function was enhanced. Traffic from MPLS-TE tunnel traffic source IP address prefixes can be steered towards matching IP addresses assigned on tunnel destination interfaces.
Release 7.3.2	In case of an LSP error on a head-end router, this feature introduces the flexibility to either set a timer for the router to retry sending traffic, or resend traffic across a different LSP without a waiting period.

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- Information About Implementing MPLS Traffic Engineering, on page 3
- How to Implement Traffic Engineering, on page 61
- Configuration Examples for Cisco MPLS-TE, on page 172
- Configuring Performance Measurement, on page 204
- Additional References, on page 205

Prerequisites for Implementing Cisco MPLS Traffic Engineering

These prerequisites are required to implement MPLS TE:

- You must be in a user group associated with a task group that includes the proper task IDs. The command reference guides include the task IDs required for each command. If you suspect user group assignment is preventing you from using a command, contact your AAA administrator for assistance.
- Router that runs Cisco IOS XR software .
- Installed composite mini-image and the MPLS package, or a full composite image.
- IGP activated.

Information About Implementing MPLS Traffic Engineering

To implement MPLS-TE, you should understand these concepts:

Overview of MPLS Traffic Engineering

MPLS-TE software enables an MPLS backbone to replicate and expand upon the traffic engineering capabilities of Layer 2 ATM and Frame Relay networks. MPLS is an integration of Layer 2 and Layer 3 technologies. By making traditional Layer 2 features available to Layer 3, MPLS enables traffic engineering. Thus, you can offer in a one-tier network what now can be achieved only by overlaying a Layer 3 network on a Layer 2 network.

MPLS-TE is essential for service provider and Internet service provider (ISP) backbones. Such backbones must support a high use of transmission capacity, and the networks must be very resilient so that they can withstand link or node failures. MPLS-TE provides an integrated approach to traffic engineering. With MPLS, traffic engineering capabilities are integrated into Layer 3, which optimizes the routing of IP traffic, given the constraints imposed by backbone capacity and topology.

Note MPLS-TE Nonstop Routing (NSR) is enabled by default without any user configuration and cannot be disabled.

MPLS-TE NSR means the application is in hot-standby mode and standby MPLS-TE instance is ready to take over from the active instance quickly on RP failover.

Note that the MPLS-TE does not do routing. If there is standby card available then the MPLS-TE instance is in a hot-standby position.

The following output shows the status of MPLS-TE NSR:

```
Router#show mpls traffic-eng nsr status

TE Process Role        : V1 Active
Current Status      : Ready
    Ready since        : Tue Nov 01 10:42:34 UTC 2022 (1w3d ago)
   IDT started         : Tue Nov 01 03:28:48 UTC 2022 (1w3d ago)
    IDT ended          : Tue Nov 01 03:28:48 UTC 2022 (1w3d ago)
Previous Status        : Not ready
    Not ready reason   : Collaborator disconnected
    Not ready since    : Tue Nov 01 10:42:34 UTC 2022 (1w3d ago)
```

During any issues with the MPLS-TE, the NSR on the router gets affected which is displayed in the show redundancy output as follows:

```
Router#show mpls traffic-eng nsr status details
.
.
.

Current active rmf state: 4 (I_READY)
All standby not-ready bits clear - standby should be ready

Current active rmf state for NSR: Not ready
<jid> <node> <name> Reason for standby not NSR-ready
1082 0/RP0/CPU0 te_control TE NSR session not synchronized
Not ready set Wed Nov 19 17:28:14 2022: 5 hours, 23 minutes ago
1082 0/RP1/CPU0 te_control Standby not connected
Not ready set Wed Nov 19 17:29:11 2022: 5 hours, 22 minutes ago
```

Related Topics

Configuring Forwarding over the MPLS-TE Tunnel , on page 66

Benefits of MPLS Traffic Engineering

MPLS-TE enables ISPs to route network traffic to offer the best service to their users in terms of throughput and delay. By making the service provider more efficient, traffic engineering reduces the cost of the network.

Currently, some ISPs base their services on an overlay model. In the overlay model, transmission facilities are managed by Layer 2 switching. The routers see only a fully meshed virtual topology, making most destinations appear one hop away. If you use the explicit Layer 2 transit layer, you can precisely control how traffic uses available bandwidth. However, the overlay model has numerous disadvantages. MPLS-TE achieves the TE benefits of the overlay model without running a separate network and without a non-scalable, full mesh of router interconnects.

How MPLS-TE Works

MPLS-TE automatically establishes and maintains label switched paths (LSPs) across the backbone by using RSVP. The path that an LSP uses is determined by the LSP resource requirements and network resources, such as bandwidth. Available resources are flooded by means of extensions to a link-state-based Interior Gateway Protocol (IGP).

MPLS-TE tunnels are calculated at the LSP headend router, based on a fit between the required and available resources (constraint-based routing). The IGP automatically routes the traffic to these LSPs.

Typically, a packet crossing the MPLS-TE backbone travels on a single LSP that connects the ingress point to the egress point. MPLS-TE is built on these mechanisms:

Tunnel interfaces

From a Layer 2 standpoint, an MPLS tunnel interface represents the headend of an LSP. It is configured with a set of resource requirements, such as bandwidth and media requirements, and priority. From a Layer 3 standpoint, an LSP tunnel interface is the headend of a unidirectional virtual link to the tunnel destination.

MPLS-TE path calculation module

This calculation module operates at the LSP headend. The module determines a path to use for an LSP. The path calculation uses a link-state database containing flooded topology and resource information.

RSVP with TE extensions

RSVP operates at each LSP hop and is used to signal and maintain LSPs based on the calculated path.

MPLS-TE link management module

This module operates at each LSP hop, performs link call admission on the RSVP signaling messages, and performs bookkeeping on topology and resource information to be flooded.

Link-state IGP (Intermediate System-to-Intermediate System [IS-IS] or Open Shortest Path First [OSPF]—each with traffic engineering extensions)

These IGPs are used to globally flood topology and resource information from the link management module.

Enhancements to the shortest path first (SPF) calculation used by the link-state IGP (IS-IS or OSPF)

The IGP automatically routes traffic to the appropriate LSP tunnel, based on tunnel destination. Static routes can also be used to direct traffic to LSP tunnels.

Label switching forwarding

This forwarding mechanism provides routers with a Layer 2-like ability to direct traffic across multiple hops of the LSP established by RSVP signaling.

One approach to engineering a backbone is to define a mesh of tunnels from every ingress device to every egress device. The MPLS-TE path calculation and signaling modules determine the path taken by the LSPs for these tunnels, subject to resource availability and the dynamic state of the network.

The IGP (operating at an ingress device) determines which traffic should go to which egress device, and steers that traffic into the tunnel from ingress to egress. A flow from an ingress device to an egress device might be so large that it cannot fit over a single link, so it cannot be carried by a single tunnel. In this case, multiple tunnels between a given ingress and egress can be configured, and the flow is distributed using load sharing among the tunnels.

Note GRE over MPLS-TE tunnel is not supported. Hence, you cannot carry GRE traffic over an LSP established for MPLS-TE tunnel using RSVP-TE. This restriction also applies to SR-TE tunnels.

Related Topics

Building MPLS-TE Topology, on page 61
Creating an MPLS-TE Tunnel, on page 63
Build MPLS-TE Topology and Tunnels: Example, on page 172

MPLS Traffic Engineering

Multiprotocol Label Switching (MPLS) is an Internet Engineering Task Force (IETF)-specified framework that provides efficient designation, routing, forwarding, and switching of traffic flows through the network.

TE is the process of adjusting bandwidth allocations to ensure that enough bandwidth is available for high-priority traffic.

In MPLS TE, the upstream router creates a network tunnel for a particular traffic stream and sets the bandwidth available for that tunnel.

Backup AutoTunnels

The MPLS Traffic Engineering AutoTunnel Backup feature enables a router to dynamically build backup tunnels on the interfaces that are configured with MPLS TE tunnels. This feature enables a router to dynamically build backup tunnels when they are needed. This prevents you from having to build MPLS TE tunnels **statically**.

The MPLS Traffic Engineering (TE)—AutoTunnel Backup feature has these benefits:

- Backup tunnels are built automatically, eliminating the need for users to preconfigure each backup tunnel and then assign the backup tunnel to the protected interface.
- Protection is expanded—FRR does not protect IP traffic that is not using the TE tunnel or Label Distribution Protocol (LDP) labels that are not using the TE tunnel.

This feature protects against these failures:

- **P2P Tunnel NHOP protection**—Protects against link failure for the associated P2P protected tunnel
- **P2P Tunnel NNHOP protection**—Protects against node failure for the associated P2P protected tunnel
- **P2MP Tunnel NHOP protection**—Protects against link failure for the associated P2MP protected tunnel

Related Topics

Enabling an AutoTunnel Backup, on page 72
Removing an AutoTunnel Backup, on page 73
Establishing MPLS Backup AutoTunnels to Protect Fast Reroutable TE LSPs, on page 74
Establishing Next-Hop Tunnels with Link Protection, on page 75
Configure the MPLS-TE Auto-Tunnel Backup: Example, on page 187

AutoTunnel Attribute-set

This feature supports auto-tunnels configuration using attribute templates, known as attribute-set. The TE attribute-set template that specifies a set of TE tunnel attributes, is locally configured at the head-end of auto-tunnels. The control plane triggers the automatic provisioning of a corresponding TE tunnel, whose characteristics are specified in the respective attribute-set.

Currently, auto-tunnel backups are created with the default values of all tunnel attributes. To support configurable attributes for auto-tunnel backup, it is required to configure attribute-set and assign it to the backup tunnels. The attribute-set consists of a set of tunnel attributes such as priority, affinity, signaled bandwidth, logging, policy-class, record-route and so on.

The following rules (consistent across all auto-tunnels) apply while configuring the attribute-set:

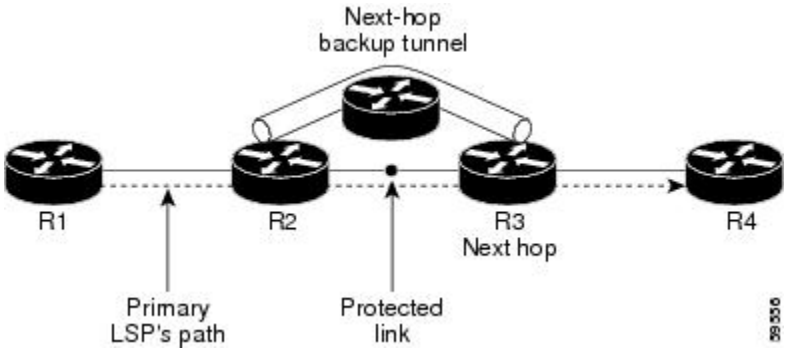
- If no attribute-set template is defined, the auto-tunnels is created using default attribute values.
- If an attribute-set is defined and the attribute-set template is already configured, the auto-tunnel is created using the attributes specified in the associated attribute-set.
- If an attribute-set is assigned, but it is not defined or configured, auto-tunnel is not created.
- Any number of attribute-sets can be configured with same attribute settings.
- Empty tunnel attribute implies all parameters have default values.
- When specific attribute is not specified in the attribute-set, a default value for that attribute is used.

Link Protection

The backup tunnels that bypass only a single link of the LSP path provide link protection. They protect LSPs, if a link along their path fails, by rerouting the LSP traffic to the next hop, thereby bypassing the failed link. These are referred to as NHOP backup tunnels because they terminate at the LSP's next hop beyond the point of failure.

This figure illustrates link protection.

Figure 1: Link Protection

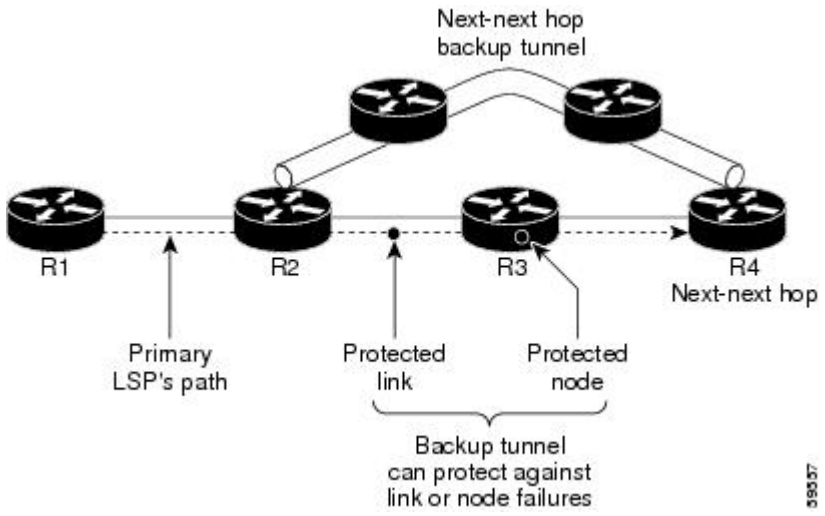


Node Protection

The backup tunnels that bypass next-hop nodes along LSP paths are called NNHOP backup tunnels because they terminate at the node following the next-hop node of the LSPs, thereby bypassing the next-hop node. They protect LSPs by enabling the node upstream of a link or node failure to reroute the LSPs and their traffic around a node failure to the next-hop node. NNHOP backup tunnels also provide protection from link failures because they bypass the failed link and the node.

This figure illustrates node protection.

Figure 2: Node Protection



Backup AutoTunnel Assignment

At the head or mid points of a tunnel, the backup assignment finds an appropriate backup to protect a given primary tunnel for FRR protection.

The backup assignment logic is performed differently based on the type of backup configured on the output interface used by the primary tunnel. Configured backup types are:

- Static Backup
- AutoTunnel Backup
- No Backup (In this case no backup assignment is performed and the tunnels is unprotected.)

Note Static backup and Backup AutoTunnel cannot exist together on the same interface or link.

Note Node protection is always preferred over link protection in the Backup AutoTunnel assignment.

In order that the Backup AutoTunnel feature operates successfully, the following configuration must be applied at global configuration level:

```
ipv4 unnumbered mpls traffic-eng Loopback 0
```

Note The Loopback 0 is used as router ID.

Explicit Paths

Explicit paths are used to create backup autotunnels as follows:

For NHOP Backup Autotunnels:

- NHOP excludes the protected link's local IP address.
- NHOP excludes the protected link’s remote IP address.
- The explicit-path name is _autob_nhop_tunnelxxx, where xxx matches the dynamically created backup tunnel ID.

For NNHOP Backup Autotunnels:

- NNHOP excludes the protected link’s local IP address.
- NNHOP excludes the protected link’s remote IP address (link address on next hop).
- NNHOP excludes the NHOP router ID of the protected primary tunnel next hop.
- The explicit-path name is _autob_nnhop_tunnelxxx, where xxx matches the dynamically created backup tunnel ID.

Periodic Backup Promotion

The periodic backup promotion attempts to find and assign a better backup for primary tunnels that are already protected.

With AutoTunnel Backup, the only scenario where two backups can protect the same primary tunnel is when both an NHOP and NNHOP AutoTunnel Backups get created. The backup assignment takes place as soon as the NHOP and NNHOP backup tunnels come up. So, there is no need to wait for the periodic promotion.

Although there is no exception for AutoTunnel Backups, periodic backup promotion has no impact on primary tunnels protected by AutoTunnel Backup.

One exception is when a manual promotion is triggered by the user using the **mpls traffic-eng fast-reroute timers promotion** command, where backup assignment or promotion is triggered on all FRR protected primary tunnels--even unprotected ones. This may trigger the immediate creation of some AutoTunnel Backup, if the command is entered within the time window when a required AutoTunnel Backup has not been yet created.

You can configure the periodic promotion timer using the global configuration **mpls traffic-eng fast-reroute timers promotion** *sec* command. The range is 0 to 604800 seconds.

Note A value of 0 for the periodic promotion timer disables the periodic promotion.

Protocol-Based CLI

Cisco IOS XR software provides a protocol-based command line interface. The CLI provides commands that can be used with the multiple IGP protocols supported by MPLS-TE.

Differentiated Services Traffic Engineering

MPLS Differentiated Services (Diff-Serv) Aware Traffic Engineering (DS-TE) is an extension of the regular MPLS-TE feature. Regular traffic engineering does not provide bandwidth guarantees to different traffic classes. A single bandwidth constraint is used in regular TE that is shared by all traffic. To support various classes of service (CoS), users can configure multiple bandwidth constraints. These bandwidth constraints can be treated differently based on the requirement for the traffic class using that constraint.

MPLS DS-TE provides the ability to configure multiple bandwidth constraints on an MPLS-enabled interface. Available bandwidths from all configured bandwidth constraints are advertised using IGP. TE tunnel is configured with bandwidth value and class-type requirements. Path calculation and admission control take the bandwidth and class-type into consideration. RSVP is used to signal the TE tunnel with bandwidth and class-type requirements.

MPLS DS-TE is deployed with either Russian Doll Model (RDM) or Maximum Allocation Model (MAM) for bandwidth calculations.

Cisco IOS XR software supports two DS-TE modes: Prestandard and IETF.

Related Topics

Confirming DiffServ-TE Bandwidth
Bandwidth Configuration (MAM): Example
Bandwidth Configuration (RDM): Example

Prestandard DS-TE Mode

Prestandard DS-TE uses the Cisco proprietary mechanisms for RSVP signaling and IGP advertisements. This DS-TE mode does not interoperate with third-party vendor equipment. Note that prestandard DS-TE is enabled only after configuring the sub-pool bandwidth values on MPLS-enabled interfaces.

Prestandard Diff-Serve TE mode supports a single bandwidth constraint model a Russian Doll Model (RDM) with two bandwidth pools: global-pool and sub-pool.

TE class map is not used with Prestandard DS-TE mode.

Related Topics

Configuring a Prestandard DS-TE Tunnel, on page 76
Configure IETF DS-TE Tunnels: Example, on page 173

IETF DS-TE Mode

IETF DS-TE mode uses IETF-defined extensions for RSVP and IGP. This mode interoperates with third-party vendor equipment.

IETF mode supports multiple bandwidth constraint models, including RDM and MAM, both with two bandwidth pools. In an IETF DS-TE network, identical bandwidth constraint models must be configured on all nodes.

TE class map is used with IETF DS-TE mode and must be configured the same way on all nodes in the network.

Bandwidth Constraint Models

IETF DS-TE mode provides support for the RDM and MAM bandwidth constraints models. Both models support up to two bandwidth pools.

Cisco IOS XR software provides global configuration for the switching between bandwidth constraint models. Both models can be configured on a single interface to preconfigure the bandwidth constraints before swapping to an alternate bandwidth constraint model.

Note NSF is not guaranteed when you change the bandwidth constraint model or configuration information.

By default, RDM is the default bandwidth constraint model used in both pre-standard and IETF mode.

Maximum Allocation Bandwidth Constraint Model

The MAM constraint model has the following characteristics:

- Easy to use and intuitive.
- Isolation across class types.
- Simultaneously achieves isolation, bandwidth efficiency, and protection against QoS degradation.

Related Topics

Configuring an IETF DS-TE Tunnel Using MAM, on page 80

Russian Doll Bandwidth Constraint Model

The RDM constraint model has these characteristics:

- Allows greater sharing of bandwidth among different class types.
- Ensures bandwidth efficiency simultaneously and protection against QoS degradation of all class types.
- Specifies that it is used in conjunction with preemption to simultaneously achieve isolation across class-types such that each class-type is guaranteed its share of bandwidth, bandwidth efficiency, and protection against QoS degradation of all class types.

Note We recommend that RDM not be used in DS-TE environments in which the use of preemption is precluded. Although RDM ensures bandwidth efficiency and protection against QoS degradation of class types, it does guarantee isolation across class types.

Related Topics

Configuring an IETF DS-TE Tunnel Using RDM, on page 78

TE Class Mapping

Each of the eight available bandwidth values advertised in the IGP corresponds to a TE class. Because the IGP advertises only eight bandwidth values, there can be a maximum of only eight TE classes supported in an IETF DS-TE network.

TE class mapping must be exactly the same on all routers in a DS-TE domain. It is the responsibility of the operator configure these settings properly as there is no way to automatically check or enforce consistency.

The operator must configure TE tunnel class types and priority levels to form a valid TE class. When the TE class map configuration is changed, tunnels already up are brought down. Tunnels in the down state, can be set up if a valid TE class map is found.

The default TE class and attributes are listed. The default mapping includes four class types.

Table 1: TE Classes and Priority

TE Class	Class Type	Priority
0	0	7
1	1	7
2	Unused	—
3	Unused	—
4	0	0
5	1	0
6	Unused	—
7	Unused	—

Flooding

Available bandwidth in all configured bandwidth pools is flooded on the network to calculate accurate constraint paths when a new TE tunnel is configured. Flooding uses IGP protocol extensions and mechanisms to determine when to flood the network with bandwidth.

Flooding Triggers

TE Link Management (TE-Link) notifies IGP for both global pool and sub-pool available bandwidth and maximum bandwidth to flood the network in these events:

- Periodic timer expires (this does not depend on bandwidth pool type).
- Tunnel origination node has out-of-date information for either available global pool or sub-pool bandwidth, causing tunnel admission failure at the midpoint.
- Consumed bandwidth crosses user-configured thresholds. The same threshold is used for both global pool and sub-pool. If one bandwidth crosses the threshold, both bandwidths are flooded.

Flooding Thresholds

Flooding frequently can burden a network because all routers must send out and process these updates. Infrequent flooding causes tunnel heads (tunnel-originating nodes) to have out-of-date information, causing tunnel admission to fail at the midpoints.

You can control the frequency of flooding by configuring a set of thresholds. When locked bandwidth (at one or more priority levels) crosses one of these thresholds, flooding is triggered.

Thresholds apply to a percentage of the maximum available bandwidth (the global pool), which is locked, and the percentage of maximum available guaranteed bandwidth (the sub-pool), which is locked. If, for one or more priority levels, either of these percentages crosses a threshold, flooding is triggered.

Note Setting up a global pool TE tunnel can cause the locked bandwidth allocated to sub-pool tunnels to be reduced (and hence to cross a threshold). A sub-pool TE tunnel setup can similarly cause the locked bandwidth for global pool TE tunnels to cross a threshold. Thus, sub-pool TE and global pool TE tunnels can affect each other when flooding is triggered by thresholds.

Fast Reroute

Fast Reroute (FRR) provides link protection to LSPs enabling the traffic carried by LSPs that encounter a failed link to be rerouted around the failure. The reroute decision is controlled locally by the router connected to the failed link. The headend router on the tunnel is notified of the link failure through IGP or through RSVP. When it is notified of a link failure, the headend router attempts to establish a new LSP that bypasses the failure. This provides a path to reestablish links that fail, providing protection to data transfer.

FRR (link or node) is supported over sub-pool tunnels the same way as for regular TE tunnels. In particular, when link protection is activated for a given link, TE tunnels eligible for FRR are redirected into the protection LSP, regardless of whether they are sub-pool or global pool tunnels.

Note The ability to configure FRR on a per-LSP basis makes it possible to provide different levels of fast restoration to tunnels from different bandwidth pools.

You should be aware of these requirements for the backup tunnel path:

- Backup tunnel must not pass through the element it protects.
- Primary tunnel and a backup tunnel should intersect at least at two points (nodes) on the path: point of local repair (PLR) and merge point (MP). PLR is the headend of the backup tunnel, and MP is the tailend of the backup tunnel.

Note When you configure TE tunnel with multiple protection on its path and merge point is the same node for more than one protection, you must configure record-route for that tunnel.

Note If FRR is greater than 50ms, it might lead to a loss of traffic.

Related Topics

Protecting MPLS Tunnels with Fast Reroute, on page 68

MPLS-TE and Fast Reroute over Link Bundles

MPLS Traffic Engineering (TE) and Fast Reroute (FRR) are supported over bundle interfaces and virtual local area network (VLAN) interfaces. Bidirectional forwarding detection (BFD) over VLAN is used as an FRR trigger to obtain less than 50 milliseconds of switchover time.

These link bundle types are supported for MPLS-TE/FRR:

- Over Ethernet link bundles.
- Over VLANs over Ethernet link bundles.
- Number of links are limited to 100 for MPLS-TE and FRR.
- VLANs go over any Ethernet interface (for example, GigabitEthernet and TenGigE).

FRR is supported over bundle interfaces in the following ways:

- Uses minimum links as a threshold to trigger FRR over a bundle interface.
- Uses the minimum total available bandwidth as a threshold to trigger FRR.

Ignore Intermediate System-to-Intermediate System Overload Bit Setting in MPLS-TE

The Ignore Intermediate System-to-Intermediate System (IS-IS) overload bit avoidance feature allows network administrators to prevent RSVP-TE label switched paths (LSPs) from being disabled, when a router in that path has its Intermediate System-to-Intermediate System (IS-IS) overload bit set.

The IS-IS overload bit avoidance feature is activated using this command:

```
mpls traffic-eng path-selection ignore overload
```

The IS-IS overload bit avoidance feature is deactivated using the **no** form of this command:

```
no mpls traffic-eng path-selection ignore overload
```

When the IS-IS overload bit avoidance feature is activated, all nodes, including head nodes, mid nodes, and tail nodes, with the overload bit set, are ignored. This means that they are still available for use with RSVP-TE label switched paths (LSPs). This feature enables you to include an overloaded node in CSPF.

Enhancement Options of IS-IS OLA

You can restrict configuring IS-IS overload bit avoidance with the following enhancement options:

- **path-selection ignore overload head**

  The tunnels stay up if **set-overload-bit** is set by IS-IS on the head router. Ignores overload during CSPF for LSPs originating from an overloaded node. In all other cases (mid, tail, or both), the tunnel stays down.

- **path-selection ignore overload mid**

  The tunnels stay up if **set-overload-bit** is set by IS-IS on the mid router. Ignores overload during CSPF for LSPs transiting from an overloaded node. In all other cases (head, tail, or both), the tunnel stays down.

- **path-selection ignore overload tail**

  The tunnels stay up if **set-overload-bit** is set by IS-IS on the tail router. Ignores overload during CSPF for LSPs terminating at an overloaded node. In all other cases (head, mid, or both), the tunnel stays down.

- **path-selection ignore overload**

  The tunnels stay up irrespective of on which router the **set-overload-bit** is set by IS-IS.

Note When you do not select any of the options, including head nodes, mid nodes, and tail nodes, you get a behavior that is applicable to all nodes. This behavior is backward compatible in nature.

For more information related to IS-IS overload avoidance related commands, see *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Related Topics

Configuring the Ignore Integrated IS-IS Overload Bit Setting in MPLS-TE, on page 84
Configure the Ignore IS-IS Overload Bit Setting in MPLS-TE: Example, on page 174

Flexible Name-based Tunnel Constraints

MPLS-TE Flexible Name-based Tunnel Constraints provides a simplified and more flexible means of configuring link attributes and path affinities to compute paths for MPLS-TE tunnels.

In the traditional TE scheme, links are configured with attribute-flags that are flooded with TE link-state parameters using Interior Gateway Protocols (IGPs), such as Open Shortest Path First (OSPF).

MPLS-TE Flexible Name-based Tunnel Constraints lets you assign, or map, up to 32 color names for affinity and attribute-flag attributes instead of 32-bit hexadecimal numbers. After mappings are defined, the attributes can be referred to by the corresponding color name in the command-line interface (CLI). Furthermore, you can define constraints using *include*, *include-strict*, *exclude*, and *exclude-all* arguments, where each statement can contain up to 10 colors, and define include constraints in both loose and strict sense.

Note You can configure affinity constraints using attribute flags or the Flexible Name Based Tunnel Constraints scheme; however, when configurations for both schemes exist, only the configuration pertaining to the new scheme is applied.

Related Topics

Assigning Color Names to Numeric Values, on page 85
Associating Affinity-Names with TE Links, on page 86
Associating Affinity Constraints for TE Tunnels, on page 87
Configure Flexible Name-based Tunnel Constraints: Example, on page 175

MPLS Traffic Engineering Interarea Tunneling

These topics describe the following new extensions of MPLS-TE:

• Interarea Support, on page 16
• Multiarea Support, on page 17
• Loose Hop Expansion, on page 17
• Loose Hop Reoptimization, on page 18
• Fast Reroute Node Protection, on page 18

Interarea Support

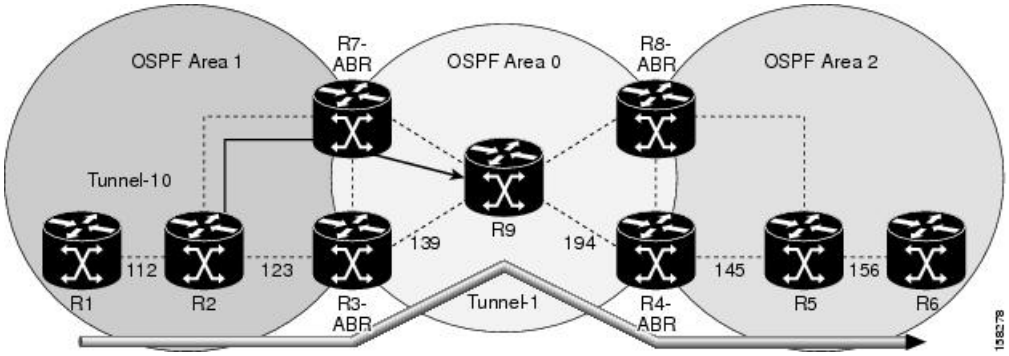
The MPLS-TE interarea tunneling feature allows you to establish P2P and P2MP TE tunnels spanning multiple Interior Gateway Protocol (IGP) areas and levels, thereby eliminating the requirement that headend and tailend routers reside in a single area.

Interarea support allows the configuration of a TE LSP that spans multiple areas, where its headend and tailend label switched routers (LSRs) reside in different IGP areas.

Multiarea and Interarea TE are required by the customers running multiple IGP area backbones (primarily for scalability reasons). This lets you limit the amount of flooded information, reduces the SPF duration, and lessens the impact of a link or node failure within an area, particularly with large WAN backbones split in multiple areas.

Figure 3: Interarea (OSPF) TE Network Diagram

This figure shows a typical interarea TE network.



Note Interarea MPLS-TE tunnels per-area path computation based on ERO expansion on the head-end LSR and on ABRs have the following options while selecting ABR:

- Static configuration of ABRs as loose hops at the head-end LSR.
- Dynamic ABR selection.

When a static configuration is used, a loosely routed explicit path must be defined for the tunnel LSP that identifies each ABR the LSP should traverse. The head-end router and the ABRs along the specified explicit path must expand automatically the loose hops, each one computing the strict path segment to the next ABR or tunnel destination.

Restrictions

MPLS-TE Interarea tunnels cannot use **next-address strict** to the ABRs.

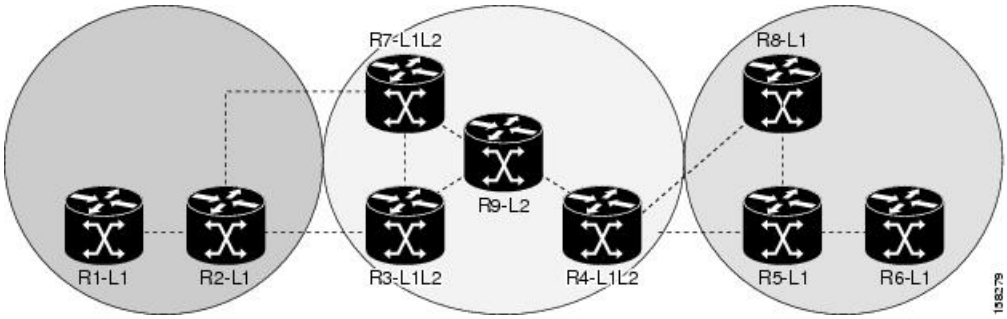
Multiarea Support

Multiarea support allows an area border router (ABR) LSR to support MPLS-TE in more than one IGP area. A TE LSP is still confined to a single area.

Multiarea and Interarea TE are required when you run multiple IGP area backbones. The Multiarea and Interarea TE allows you to:

- Limit the volume of flooded information.
- Reduce the SPF duration.
- Decrease the impact of a link or node failure within an area.

Figure 4: Interlevel (IS-IS) TE Network



As shown in the figure, R2, R3, R7, and R4 maintain two databases for routing and TE information. For example, R3 has TE topology information related to R2, flooded through Level-1 IS-IS LSPs plus the TE topology information related to R4, R9, and R7, flooded as Level 2 IS-IS Link State PDUs (LSPs) (plus, its own IS-IS LSP).

Note You can configure multiple areas within an IS-IS Level 1. This is transparent to TE. TE has topology information about the IS-IS level, but not the area ID.

Loose Hop Expansion

Loose hop optimization allows the reoptimization of tunnels spanning multiple areas and solves the problem which occurs when an MPLS-TE LSP traverses hops that are not in the LSP's headend's OSPF area and IS-IS level.

Interarea MPLS-TE allows you to configure an interarea traffic engineering (TE) label switched path (LSP) by specifying a loose source route of ABRs along the path. It is the then the responsibility of the ABR (having a complete view of both areas) to find a path obeying the TE LSP constraints within the next area to reach the next hop ABR (as specified on the headend). The same operation is performed by the last ABR connected to the tailend area to reach the tailend LSR.

For P2MP-TE tunnels, ABRs support loose hop ERO expansion to find path to the next ABR until it reaches to the tail-end LSR, without introducing remerge.

You must be aware of these considerations when using loose hop optimization:

- You must specify the router ID of the ABR node (as opposed to a link address on the ABR).
- When multiarea is deployed in a network that contains subareas, you must enable MPLS-TE in the subarea for TE to find a path when loose hop is specified.
- You must specify the reachable explicit path for the interarea tunnel.

Loose Hop Reoptimization

Loose hop reoptimization allows the reoptimization of the tunnels spanning multiple areas and solves the problem which occurs when an MPLS-TE headend does not have visibility into other IGP areas.

Whenever the headend attempts to reoptimize a tunnel, it tries to find a better path to the ABR in the headend area. If a better path is found then the headend initiates the setup of a new LSP. In case a suitable path is not found in the headend area, the headend initiates a querying message. The purpose of this message is to query the ABRs in the areas other than the headend area to check if there exist any better paths in those areas. The purpose of this message is to query the ABRs in the areas other than the headend area, to check if a better path exists. If a better path does not exist, ABR forwards the query to the next router downstream. Alternatively, if better path is found, ABR responds with a special Path Error to the headend to indicate the existence of a better path outside the headend area. Upon receiving the Path Error that indicates the existence of a better path, the headend router initiates the reoptimization.

ABR Node Protection

Because one IGP area does not have visibility into another IGP area, it is not possible to assign backup to protect ABR node. To overcome this problem, node ID sub-object is added into the record route object of the primary tunnel so that at a PLR node, backup destination address can be checked against primary tunnel record-route object and assign a backup tunnel.

Fast Reroute Node Protection

If a link failure occurs within an area, the upstream router directly connected to the failed link generates an RSVP path error message to the headend. As a response to the message, the headend sends an RSVP path tear message and the corresponding path option is marked as invalid for a specified period and the next path-option (if any) is evaluated.

To retry the ABR immediately, a second path option (identical to the first one) should be configured. Alternatively, the retry period (path-option hold-down, 2 minutes by default) can be tuned to achieve a faster retry.

Related Topics

Protecting MPLS Tunnels with Fast Reroute, on page 68

Make-Before-Break

The MPLS TE Make-Before-Break (MBB) explicit path and path option feature allows tunnels whose explicit paths or path options are modified to be reoptimized without losing any data. An explicit path or a path option modification is entirely configuration driven. Any change to an in-use path option or an in-use explicit path of a tunnel triggers the MBB procedure.

MBB lets the LSP hold on to the existing resources until the new path is successfully established and traffic has been directed over to the new LSP before the original LSP is torn down. This ensures that no data packets are lost during the transition to the new LSP.

With this feature the flapping of tunnels whose explicit paths or path options are modified, is avoided. This feature is enabled by default.

MPLS-TE Forwarding Adjacency

The MPLS-TE Forwarding Adjacency feature allows a network administrator to handle a traffic engineering, label-switched path (LSP) tunnel as a link in an Interior Gateway Protocol (IGP) network based on the Shortest Path First (SPF) algorithm. A forwarding adjacency can be created between routers regardless of their location in the network.

MPLS-TE Forwarding Adjacency Benefits

TE tunnel interfaces are advertised in the IGP network just like any other links. Routers can then use these advertisements in their IGPs to compute the SPF even if they are not the head end of any TE tunnels.

Related Topics

Configuring MPLS-TE Forwarding Adjacency, on page 91
Configure Forwarding Adjacency: Example, on page 178

MPLS-TE Forwarding Adjacency Restrictions

The MPLS-TE Forwarding Adjacency feature has these restrictions:

- Using the MPLS-TE Forwarding Adjacency increases the size of the IGP database by advertising a TE tunnel as a link.
- The MPLS-TE Forwarding Adjacency is supported by Intermediate System-to-Intermediate System (IS-IS).
- When the MPLS-TE Forwarding Adjacency is enabled on a TE tunnel, the link is advertised in the IGP network as a Type-Length-Value (TLV) 22 without any TE sub-TLV.
- MPLS-TE forwarding adjacency tunnels must be configured bidirectionally.
- Multicast intact is not supported with MPLS-TE Forwarding Adjacency.

MPLS-TE Forwarding Adjacency Prerequisites

Your network must support the following features before enabling the MPLS -TE Forwarding Adjacency feature:

- MPLS
- IP Cisco Express Forwarding
- Intermediate System-to-Intermediate System (IS-IS)
- OSPF

Path Computation Element

Path Computation Element (PCE) solves the specific issue of inter-domain path computation for MPLS-TE label switched path (LSPs), when the head-end router does not possess full network topology information (for example, when the head-end and tail-end routers of an LSP reside in different IGP areas).

PCE uses area border routers (ABRs) to compute a TE LSP spanning multiple IGP areas as well as computation of Inter-AS TE LSP.

PCE is usually used to define an overall architecture, which is made of several components, as follows:

Path Computation Element (PCE)

Represents a software module (which can be a component or application) that enables the router to compute paths applying a set of constraints between any pair of nodes within the router's TE topology database. PCEs are discovered through IGP.

Path Computation Client (PCC)

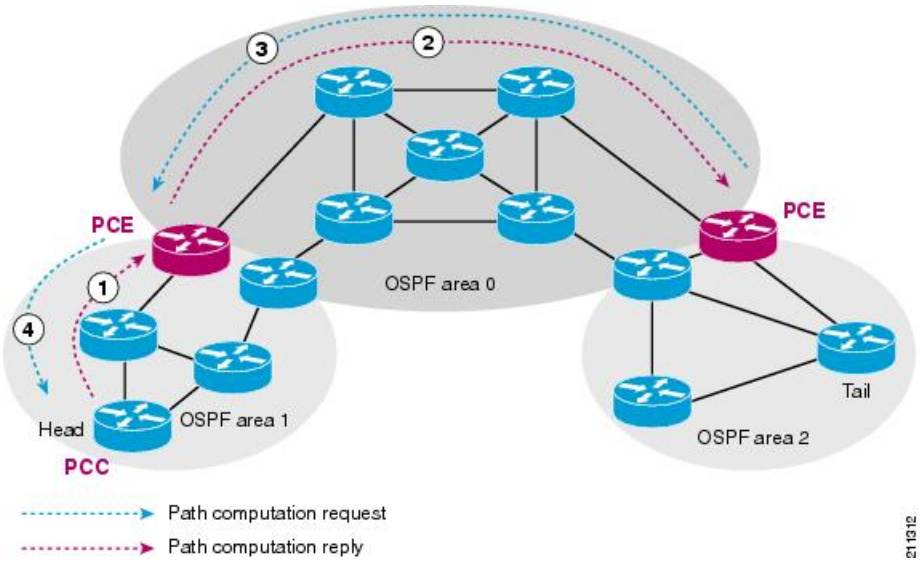
Represents a software module running on a router that is capable of sending and receiving path computation requests and responses to and from PCEs. The PCC is typically an LSR (Label Switching Router).

PCC-PCE communication protocol (PCEP)

Specifies that PCEP is a TCP-based protocol defined by the IETF PCE WG, and defines a set of messages and objects used to manage PCEP sessions and to request and send paths for multi-domain TE LSPs. PCEP is used for communication between PCC and PCE (as well as between two PCEs) and employs IGP extensions to dynamically discover PCE.

Figure 5: Path Computation Element Network Diagram

This figure shows a typical PCE implementation.



Path computation elements provides support for the following message types and objects:

- Message types: Open, PCReq, PCRep, PCErr, Close
- Objects: OPEN, CLOSE, RP, END-POINT, LSPA, BANDWIDTH, METRIC, and NO-PATH

Related Topics

Configuring a Path Computation Client, on page 92
Configuring a Path Computation Element Address, on page 93
Configuring PCE Parameters, on page 94
Configure PCE: Example, on page 178

Policy-Based Tunnel Selection

These topics provide information about policy-based tunnel selection (PBTS):

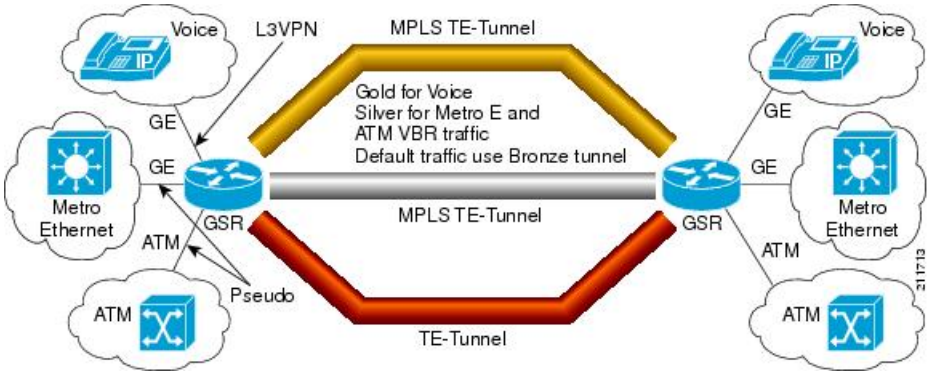
Policy-Based Tunnel Selection

Policy-Based Tunnel Selection (PBTS) provides a mechanism that lets you direct traffic into specific TE tunnels based on different criteria. PBTS will benefit Internet service providers (ISPs) who carry voice and data traffic through their MPLS and MPLS/VPN networks, who want to route this traffic to provide optimized voice service.

PBTS works by selecting tunnels based on the classification criteria of the incoming packets, which are based on the IP precedence, experimental (EXP), differentiated services code point (DSCP), or type of service (ToS) field in the packet. Default-class configured for paths is always zero (0). If there is no TE for a given forward-class, then the default-class (0) will be tried. If there is no default-class, then the packet is dropped.PBTS supports up to seven (exp 1 - 7) EXP values associated with a single TE tunnel.

Figure 6: Policy-Based Tunnel Selection Implementation

This figure illustrates a PBTS implementation.



Related Topics

Configuring Forwarding Path, on page 99

Policy-Based Tunnel Selection Functions

The following PBTS functions are supported on the Cisco ASR 9000 series router:

- Classify the IPv4 packets based on 5-Tuple values (source IP, destination IP, source port, destination port, and protocol) specified via ACL.
- Classify the IPv4 packets based on DSCP/ToS/IPP value carried in the packet, configured via ACL.
- Classify the MPLS packets based on EXP bit value carried in the packet.

- Classify the MPLS packets based on remarked EXP value (i.e., the value after taking QoS marking action).
- Ability to associate the class-map with forwarding group.
- Ability to define the forward-class for TE interface. Only one forward-class can be associated with a TE at any time. The forward-class provides ability to map multiple/any EXP or multiple classes of packets to the same forward-class.
- Support for default forward-class (0). If the TE interface is not explicitly associated with a forward-class, it is by default associated with default forward-class (0).
- PBTS is turned on the ingress interface by applying the service-policy at the targeted input interface(s).
- PBTS can be enabled on any of the L3 interfaces—physical, sub-interface, and bundle interface.
- PBTS allows in-place modification of the configuration (both class-map and forward-group to TE association).

Related Topics

Configuring Forwarding Path, on page 99

PBTS Forward Class

In PBTS, a class-map is defined for various types of packet, and associating this class-map with a forward-class. The class-map defines the matching criteria for classifying a particular type of traffic, while the forward-class defines the forwarding path these packets should take. Once a class-map is associated with a forwarding-class in the policy map, all the packets that match the class-map are forwarded as defined in the policy-map. The egress traffic engineering (TE) tunnel interfaces that the packets should take for each forwarding-class is specified by associating the TE interface explicitly, or implicitly in the case of default value, with the forward-group. When the TE interfaces are associated with the forward-class, they can be exported to the routing protocol module using the **auto-route** command, which will then associate the route in the FIB database with these tunnels. If the TE interface is not explicitly associated with a forward-class, it gets associated with a default-class (0). All non-TE interfaces through the destination route was learned will be pushed down by routing protocol to the forwarding plane with forwarding class set to default-class.

When PBR is configured, TE tunnel interfaces are selected to forward traffic based on matching class-types in policy-map. When a forward-class value for a TE tunnel is configured, that TE process pass to LSD process as part of the label rewrite for the tunnel head. The TE allows one 32-bit value for a forward-class per tunnel that is opaque to TE and TE will use it to program the tunnel in forwarding.

PBTS supports a maximum of eight forward-class and eight TE tunnels with in each forward-class. A maximum of 32 TE tunnels can be associated with the destination route.

Forward-class configuration is supported for auto-mesh tunnels and forward-class can be configured in the attribute-set used by the auto-mesh tunnels. Changing the forward-class configuration does not affect the tunnel state. TE updates the forwarding with the new forward-class value. For TE path protection, both primary and standby LSPs use the same forward-class value for the tunnel. Unequal load-sharing of traffic is supported for the ECMP TE tunnels across forward-classes.

Forward-class configuration does not apply to the FRR backup tunnels and will be ignored. The forward-class configuration is not supported for the auto-backup tunnels and P2MP-TE (MTE) tunnels.

PBTS Restrictions

When implementing PBTS, the following restrictions are listed:

- When QoS EXP remarking on an interface is enabled, the EXP value is used to determine the egress tunnel interface, not the incoming EXP value.
- Egress-side remarking does not affect PBTS tunnel selection.
- When no default tunnel is available for forwarding, traffic is dropped.
- PBTS does not support selecting a TE tunnel for the route driven from Access Based Forwarding (ABF) lookup result.
- PBTS does not support generic routing encapsulation over traffic engineering (GREoTE).
- PBTS is supported only on L3 interfaces.
- Configuring PBTS using policy-map command is not supported. Instead, you should use forward-class configuration.
- PBTS tunnel selection is not supported on the tunnels with L2VPN configuration.
- PBTS does not support VidMon feature.
- PBTS does not support slow path, instead, default forward class is used.
- PBTS does not support subscriber sessions.
- Forward-class configuration does not apply to the FRR backup tunnels and will be ignored.
- Note that forward-class configuration will not be supported for the auto-backup tunnels.
- Forward-class configuration is not supported for P2MP-TE (MTE) tunnels.
- The policy-class configuration does not co-exist with forward-class configuration.
- DSCP, precedence, or ToS based classification has to be configured through ACL.
- PBTS supports multi-pass implementation only for IPv4 packets.

PBTS Default Class Enhancement

Policy Based Tunnel Selection (PBTS) provides a mechanism that directs traffic into TE tunnels based on incoming packets TOS/EXP bits. The PBTS default class enhancement can be explained as follows:

- Add a new class called default so that you can configure a tunnel of class (1-7 or default). You can configure more than one default tunnels. By default, tunnels of class 0 no longer serves as default tunnel.
- The control plane can pick up to 8 default tunnels to carry default traffic.
- The forwarding plane applies the same load-balancing logic on the default tunnels such that default traffic load is shared over them.
- Default tunnels are not used to forward traffic if each class of traffic is served by at least one tunnel of the respective class.
- A tunnel is implicitly assigned to class 0 if the tunnel is not configured with a specific class.
- If no default tunnel is available for forwarding, the traffic is dropped.
- Both LDP and IGP paths are assigned to a new default class. LDP and IGP no longer statically associate to class 0 in the platforms, which support this new default class enhancement.

PBTS Default Class Enhancement Restrictions

The class 0 tunnel is not the default tunnel. The **default** class that does not associate with any of existing classes starting from 1 to 7. For a class of traffic that does not have a respective class tunnel to serve it, the forwarding plane uses the available default tunnels and IGP and LDP paths to carry that class of traffic.

The new behavior becomes effective only when the control plan resolves a prefix to use at least one default tunnel to forward the traffic. When a prefix is resolved to not use any default tunnel to forward traffic, it will fall back to the existing behavior. The lowest class tunnels are used to serve as default tunnels. The class 0 tunnels are used as default tunnels, if no default tunnel is configured, supporting the backward compatibility to support the existing configurations.

Enabling Forward Class Zero in PBTS

This PBTS feature enhancement allows you to configure forward class zero or the default class as a PBTS forwarding class effective with Cisco IOS-XR release 6.4.1. Earlier, only values from one to seven were configurable as PBTS forwarding classes.

Set DF Bit

The Set DF Bit feature enables to apply 'set df (do not fragment)' policy to an interface. Any packet that matches with the set df policy will either clear the bit or set the bit.

The set df bit policy can be enabled to clear the df bit before forwarding the packet in IPv4 traffic.

For more information on Set DF Bit, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on Set DF Bit commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Policy-Based Tunnel Selection for IPv6

Policy-Based Tunnel Selection (PBTS) for IPv6 (Internet Protocol version 6) feature allows a user to manually configure the manner received packets should be routed into specific TE tunnels for IPv6. PBTS allows the user to identify packets using several attributes and to specify the TE tunnel to which a packet should be sent. For example, one selection criterion is TE tunnel selection based on differentiated services code point (DSCP) values. This is accomplished by mapping multiple DCSPs to a single forwarding class. Other criteria for selecting tunnels are based on the IP precedence, experimental (EXP), or type of service (ToS) field in the packet.

The PBTS for IPv6 feature lets the IPv6 traffic acknowledge the PBTS configuration.

Policies can be based on IPv6 address, port numbers, protocols, or packet size. For a simple policy, you use any one of the descriptors; for a complex policy, you use all descriptors.

Enabling PBTS for IPv6 on an Interface

To enable the PBTS for IPv6 feature, a prerequisite is to enable IPv6 on the core interfaces, so that the tunnel can handle IPv6 traffic. The IPv6 forwarding adjacency (FA) configuration should be made to send IPv6 traffic over IPv6 tunnels.

IPv6 PBTS allows users to override normal destination IPv6 address-based routing and forwarding results. Virtual Private Network (VPN) Routing and Forwarding (VRF) allows multiple routing instances in the Cisco IOS XR Software. The PBTS feature is VRF-aware; this means it works under multiple routing instances, beyond the default or global routing table.

Service Path Preference for MPLS VPN Sessions

Service Path Preference feature (SPP) helps control transport path for L3VPN services in traffic engineering (TE) tunnels. SPP feature provides a way for services to influence path selection while forwarding in Multiprotocol Label Switching (MPLS) or Segment Routing networks. SPP is achieved by associating a control plane policy with a forward-class based on attributes like community, next hop, or vrf (virtual routing and forwarding).

This is helpful to the service provider in situations where instead of assigning a tunnel for a specific data type like VOIP or Data, the service provider can use a BGP-attribute for a customer and traffic for this customer can be directed towards a specific TE tunnel. This helps the service provider maintain the service level agreements (SLA) for data and voice value-added services.

For more information on this feature, see the *Implementing Service Path Preference* chapter in the Cisco ASR 9000 Aggregation Services Router MPLS Configuration Guide.

For complete command reference of this feature specific commands, see the*MPLS Traffic Engineering Commands* chapter in the Cisco ASR 9000 Series Aggregation Services Router MPLS Command Reference.

Features of Service Path Preference

Service Path Preference (SPP) includes the following features:

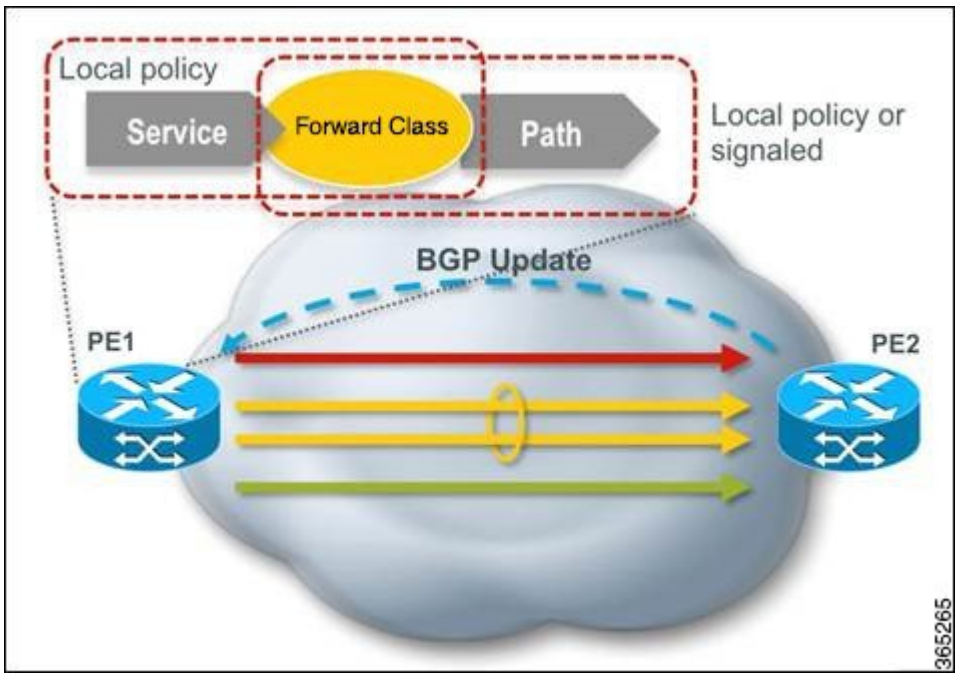
- SPP and BGP Flow Spec are mutually exclusive
- SPP is service agnostic and can be applied to L3VPN services on an MPLS or Segment Routing core network
- SPP provides the facility to separate L3VPN services in dedicated LSPs or tunnels within the core transport network based on SLA. Therefore service delivery on PE devices is simplified.
- If you configure SPP in a setup where PBTS is already configured, the PBTS configuration is given preference. If a packet matches the PBTS lookup, the specified forwarding class is used and SPP configuration is ignored.
- SPP extends the concept PBTS by associating a control plane policy with a forwarding class. The route policy is configured to use a forward-class when specific conditions are met
- SPP is supported for interface paths such as Traffic-Engineering Tunnels, RSVP-TE, and Segment Routing Tunnels (SR-TE).

Understanding How Service Path Preference Works

SPP allows services to select a path based on policies configured in the control plane or based on the preferences set in the egress PE node.

Consider a scenario where you have two Provider Edge (PE) routers in a setup. PE1 functions as ingress node and PE2 functions as egress node.

Figure 7: Sample Service Path Preference scenario



The egress PE (PE2) receives the routes from the customers and assigns the routes with prefixes such as BGP community, next hop attribute or vrf attribute. The local policies determine the attribute to be assigned to the customer.

PE1 associates a forward-class to the prefix based on the local policies that are created based on a combination of vrf, address-family, next-hop, and community, to match a forward-class. The pre-configured tunnel with matching forward-class is selected for forwarding the traffic.

Configuring Service Path Preference

Perform this task to configure Service Path Preference:

SUMMARY STEPS

1. **configure**
2. **route-policy** *name*
3. **set forward-class** *range*
4. **end policy**

DETAILED STEPS

Procedure

Step 1 **configure**

Enters global configuration mode.

Example:

```
RP/0/RSP0/CPU0:router(config)#configure
```

Step 2 **route-policy** *name*

Defines a route policy and enters the route-policy configuration mode.

Example:

```
RP/0/RSP0/CPU0:router(config)#route-policy SPP_POLICY
```

Step 3 **set forward-class** *range*

If the community value matches the specified condition, forward class 1 is set.

Note
This task uses community attribute as an example to explain how to configure SPP. In the same manner, you can use vrf, address family, or next hop to configure route policies for SPP.

For details on configuring route policies, see *Cisco ASR 9000 Series Aggregation Services Router Routing Configuration guide*.

Example:

```
RP/0/RSP0/CPU0:router(config-dynamic-template)#type ipsubscriber ipoe_ipv6
```

Step 4 **end policy**

(Optional) Ends the definition of a route policy and exits route policy configuration mode.

Sample Routing Policies to Configure Service Path Preference

The following samples explain how to configure route policies for service path preference:

Configuring a Route Policy to Select a Forward Class that Matches a Specific Community Attribute

```
route-policy  C1
  if community matches-any (6500:1) then
      set forward-class 1
  end-if
end-policy
!
router bgp 55
 bgp router-id 20.0.0.1
 address-family ipv4 unicast
   table-policy C1
  !
!

interface tunnel-te1
   forward-class 1
!
```

In this example, BGP on the receiving PE is configured with a table policy.

The policy logic matches against specific community value (signaled by egress PE) and sets forward-class 1. From the available TE paths, the tunnel with forward-class 1 is selected for forwarding.

Configuring a Route Policy to Select a Forward Class that Matches a Specific VRF

The following example explains how to configure route policies with a VRF attribute and set a forward class.

```
route-policy  C1
      set forward-class 1
end-policy
!
route-policy C2
      set forward-class 2
 end-policy
!

router bgp 55
 bgp router-id 20.0.0.1
 address-family vpnv4 unicast
 !
 vrf one
  rd 1:1
  address-family ipv4 unicast
   table-policy C1
  !
 !
 vrf two
  rd 2:2
  address-family ipv4 unicast
   table-policy C2
  !
 !
!

interface tunnel-te1
   forward-class 1
!
interface tunnel-te2
   forward-class 2
!
```

In this example, BGP on receiving PE is configured with a table-policy (C1) and (C2) for two different VRFs.

The policy (C1) sets forward-class 1. From the available TE paths, tunnel-te1 with forward-class 1 is selected for forwarding. Similarly for VRF two, traffic tunnel-te2 associated with forward-class 2 is selected for forwarding.

Configuring a Route Policy to Select a Forward Class that Matches an Address Family

The following example explains how to configure route policies with an address family and set a forward class.

```
route-policy  C1
      set forward-class 1
end-policy
!
route-policy C2
     set forward-class 2
!

router bgp 55
 bgp router-id 20.0.0.1
 address-family vpnv4 unicast
```

```
    vrf all
       table-policy  C1
   !
 !
 vrf one
  rd 1:1
  address-family ipv4 unicast
  !
 !
 vrf two
  rd 2:2
  address-family ipv4 unicast
  !
 !
!

interface tunnel-te1
   forward-class 1
!
interface tunnel-te2
   forward-class 2
!
```

In this example, BGP on receiving PE is configured with a table-policy (C1) for vpnv4 address family routes. The policy (C1) sets forward-class 1. The vpnv4 prefixes are imported into VRFs and downloaded into RIB/FIB with this forward-class info.

From the available TE paths, forward-class 1 is selected for forwarding.

Configuring a Route Policy to Select a Forward Class that Matches a Next Hop

The following example explains how you can configure route policies with next hop and set a forward class.

```
prefix-set   nh-set-1
  10.10.0.1
end-set

route-policy  C1
  if  next-hop in nh-set-1 then
      set forward-class 1
  end-if
end-policy
!

router bgp 55
 bgp router-id 20.0.0.1
 address-family ipv4 unicast
   table-policy C1
  !

!
interface tunnel-te1
   forward-class 1

!
```

In this example, BGP on receiving PE is configured with a table-policy (C1) on ipv4 unicast address family (AF). The policy (C1) sets forward-class. From the available TE paths, tunnel-te1 with forward-class 1 is selected for forwarding.

Path Protection

Path protection provides an end-to-end failure recovery mechanism (that is, a full path protection) for MPLS-TE tunnels. A secondary Label Switched Path (LSP) is established, in advance, to provide failure protection for the protected LSP that is carrying a tunnel's TE traffic. When there is a failure on the protected LSP, the source router immediately enables the secondary LSP to temporarily carry the tunnel's traffic. If there is a failure on the secondary LSP, the tunnel no longer has path protection until the failure along the secondary path is cleared. Path protection can be used within a single area (OSPF or IS-IS), external BGP [eBGP], and static routes.

The failure detection mechanisms triggers a switchover to a secondary tunnel by:

- Path error or resv-tear from Resource Reservation Protocol (RSVP) signaling
- Notification from the Bidirectional Forwarding Detection (BFD) protocol that a neighbor is lost
- Notification from the Interior Gateway Protocol (IGP) that the adjacency is down
- Local teardown of the protected tunnel's LSP due to preemption in order to signal higher priority LSPs, a Packet over SONET (POS) alarm, online insertion and removal (OIR), and so on

An alternate recovery mechanism is Fast Reroute (FRR), which protects MPLS-TE LSPs only from link and node failures, by locally repairing the LSPs at the point of failure.

Although not as fast as link or node protection, presignaling a secondary LSP is faster than configuring a secondary primary path option, or allowing the tunnel's source router to dynamically recalculate a path. The actual recovery time is topology-dependent, and affected by delay factors such as propagation delay or switch fabric latency.

Related Topics

Enabling Path Protection for an Interface, on page 100
Assigning a Dynamic Path Option to a Tunnel, on page 101
Forcing a Manual Switchover on a Path-Protected Tunnel, on page 102
Configuring the Delay the Tunnel Takes Before Reoptimization, on page 103
Configure Tunnels for Path Protection: Example, on page 182

Pre-requisites for Path Protection

These are the pre-requisites for enabling path protection:

- Ensure that your network supports MPLS-TE, Cisco Express Forwarding, and Intermediate System-to-Intermediate System (IS-IS) or Open Shortest Path First (OSPF).
- Enable MPLS.
- Configure TE on the routers.
- Configure a TE tunnel with a dynamic path option by using the **path-option** command with the **dynamic** keyword.

Related Topics

Enabling Path Protection for an Interface, on page 100
Assigning a Dynamic Path Option to a Tunnel, on page 101
Forcing a Manual Switchover on a Path-Protected Tunnel, on page 102
Configuring the Delay the Tunnel Takes Before Reoptimization, on page 103

Configure Tunnels for Path Protection: Example, on page 182

Restrictions for Path Protection

- Only Point-to-Point (P2P) tunnels are supported.
- Point-to-Multipoint (P2MP) TE tunnels are not supported.
- A maximum of one standby LSP is supported.
- There can be only one secondary path for each dynamic path option.
- Explicit path option can be configured for the path protected TE with the secondary path option as dynamic.
- A maximum number of path protected tunnel TE heads is 2000.
- A maximum number of TE tunnel heads is equal to 4000.
- When path protection is enabled for a tunnel, and the primary label switched path (LSP) is not assigned a backup tunnel, but the standby LSP is assigned fast-reroute (FRR), the MPLS TE FRR protected value displayed is different from the Cisco express forwarding (CEF) fast-reroute value.

Related Topics

Enabling Path Protection for an Interface, on page 100
Assigning a Dynamic Path Option to a Tunnel, on page 101
Forcing a Manual Switchover on a Path-Protected Tunnel, on page 102
Configuring the Delay the Tunnel Takes Before Reoptimization, on page 103
Configure Tunnels for Path Protection: Example, on page 182

MPLS-TE Automatic Bandwidth

The MPLS-TE automatic bandwidth feature measures the traffic in a tunnel and periodically adjusts the signaled bandwidth for the tunnel.

These topics provide information about MPLS-TE automatic bandwidth:

MPLS-TE Automatic Bandwidth Overview

MPLS-TE automatic bandwidth is configured on individual Label Switched Paths (LSPs) at every head-end. MPLS-TE monitors the traffic rate on a tunnel interface. Periodically, MPLS-TE resizes the bandwidth on the tunnel interface to align it closely with the traffic in the tunnel. MPLS-TE automatic bandwidth can perform these functions:

- Monitors periodic polling of the tunnel output rate
- Resizes the tunnel bandwidth by adjusting the highest rate observed during a given period

For every traffic-engineered tunnel that is configured for an automatic bandwidth, the average output rate is sampled, based on various configurable parameters. Then, the tunnel bandwidth is readjusted automatically based upon either the largest average output rate that was noticed during a certain interval, or a configured maximum bandwidth value.

This table lists the automatic bandwidth functions.

Table 2: Automatic Bandwidth Variables

Function	Command	Description	Default Value
Application frequency	**application** command	Configures how often the tunnel bandwidths changed for each tunnel. The application period is the period of A minutes between the bandwidth applications during which the output rate collection is done.	24 hours
Requested bandwidth	**bw-limit** command	Limits the range of bandwidth within the automatic-bandwidth feature that can request a bandwidth.	0 Kbps
Collection frequency	**auto-bw collect** command	Configures how often the tunnel output rate is polled globally for all tunnels.	5 min
Highest collected bandwidth	—	You cannot configure this value.	—
Delta	—	You cannot configure this value.	—

The output rate on a tunnel is collected at regular intervals that are configured by using the **application** command in MPLS-TE auto bandwidth interface configuration mode. When the application period timer expires, and when the difference between the measured and the current bandwidth exceeds the adjustment threshold, the tunnel is reoptimized. Then, the bandwidth samples are cleared to record the new largest output rate at the next interval.

When reoptimizing the LSP with the new bandwidth, a new path request is generated. If the new bandwidth is not available, the last good LSP continues to be used. This way, the network experiences no traffic interruptions.

If minimum or maximum bandwidth values are configured for a tunnel, the bandwidth, which the automatic bandwidth signals, stays within these values.

Note When more than 100 tunnels are **auto-bw** enabled, the algorithm will jitter the first application of every tunnel by a maximum of 20% (max 1hour). The algorithm does this to avoid too many tunnels running auto bandwidth applications at the same time.

If a tunnel is shut down, and is later brought again, the adjusted bandwidth is lost and the tunnel is brought back with the initial configured bandwidth. In addition, the application period is reset when the tunnel is brought back.

Related Topics

Configuring the Collection Frequency, on page 104
Configuring the Automatic Bandwidth Functions, on page 106
Configure Automatic Bandwidth: Example, on page 182

Adjustment Threshold

Adjustment Threshold is defined as a percentage of the current tunnel bandwidth and an absolute (minimum) bandwidth. Both thresholds must be fulfilled for the automatic bandwidth to resignal the tunnel. The tunnel bandwidth is resized only if the difference between the largest sample output rate and the current tunnel bandwidth is larger than the adjustment thresholds.

For example, assume that the automatic bandwidth is enabled on a tunnel in which the highest observed bandwidth B is 30 Mbps. Also, assume that the tunnel was initially configured for 45 Mbps. Therefore, the difference is 15 mbit/s. Now, assuming the default adjustment thresholds of 10% and 10kbps, the tunnel is signalled with 30 Mbps when the application timer expires. This is because 10% of 45Mbit/s is 4.5 Mbit/s, which is smaller than 15 Mbit/s. The absolute threshold, which by default is 10kbps, is also crossed.

Overflow Detection

Overflow detection is used if a bandwidth must be resized as soon as an overflow condition is detected, without having to wait for the expiry of an automatic bandwidth application frequency interval.

For overflow detection one configures a limit N, a percentage threshold Y% and optionally, a minimum bandwidth threshold Z. The percentage threshold is defined as the percentage of the actual signalled tunnel bandwidth. When the difference between the measured bandwidth and the actual bandwidth are both larger than Y% and Z threshold, for N consecutive times, then the system triggers an overflow detection.

The bandwidth adjustment by the overflow detection is triggered only by an increase of traffic volume through the tunnel, and not by a decrease in the traffic volume. When you trigger an overflow detection, the automatic bandwidth application interval is reset.

By default, the overflow detection is disabled and needs to be manually configured.

Underflow Detection

Underflow detection is used when the bandwidth on a tunnel drops significantly, which is similar to overflow but in reverse.

Underflow detection applies the highest bandwidth value from the samples which triggered the underflow. For example, if you have an underflow limit of three, and the following samples trigger the underflow for 10 kbps, 20 kbps, and 15 kbps, then, 20 kbps is applied.

Unlike overflow, the underflow count is not reset across an application period. For example, with an underflow limit of three, you can have the first two samples taken at the end of an application period and then the underflow gets triggered by the first sample of the next application period.

Restrictions for MPLS-TE Automatic Bandwidth

When the automatic bandwidth cannot update the tunnel bandwidth, the following restrictions are listed:

- Tunnel is in a fast reroute (FRR) backup, active, or path protect active state. This occurs because of the assumption that protection is a temporary state, and there is no need to reserve the bandwidth on a backup tunnel. You should prevent taking away the bandwidth from other primary or backup tunnels.
- Reoptimization fails to occur during a lockdown. In this case, the automatic bandwidth does not update the bandwidth unless the bandwidth application is manually triggered by using the **mpls traffic-eng auto-bw apply** command in EXEC mode.

Point-to-Multipoint Traffic-Engineering

Point-to-Multipoint Traffic-Engineering Overview

The Point-to-Multipoint (P2MP) Resource Reservation Protocol-Traffic Engineering (RSVP-TE) solution allows service providers to implement IP multicast applications, such as IPTV and real-time video, broadcast over the MPLS label switch network. The RSVP-TE protocol is extended to signal point-to-point (P2P) and P2MP label switched paths (LSPs) across the MPLS networks.

By using RSVP-TE extensions as defined in RFC 4875, multiple subLSPs are signaled for a given TE source. The P2MP tunnel is considered as a set of Source-to-Leaf (S2L) subLSPs that connect the TE source to multiple leaf Provider Edge (PE) nodes.

At the TE source, the ingress point of the P2MP-TE tunnel, IP multicast traffic is encapsulated with a unique MPLS label, which is associated with the P2MP-TE tunnel. The traffic continues to be label-switched in the P2MP tree. If needed, the labeled packet is replicated at branch nodes along the P2MP tree. When the labeled packet reaches the egress leaf (PE) node, the MPLS label is removed and forwarded onto the IP multicast tree across the PE-CE link.

To enable end-to-end IP multicast connectivity, RSVP is used in the MPLS-core for P2MP-TE signaling and PIM is used for PE-CE link signaling.

- All edge routers are running PIM-SSM or Source-Specific Multicast (SSM) to exchange multicast routing information with the directly-connected Customer Edge (CE) routers.
- In the MPLS network, RSVP P2MP-TE replaces PIM as the tree building mechanism, RSVP-TE grafts or prunes a given P2MP tree when the end-points are added or removed in the TE source configuration (explicit user operation).

These are the definitions for Point-to-Multipoint (P2MP) tunnels:

Source

Configures the node in which Label Switched Path (LSP) signaling is initiated.

Mid-point

Specifies the transit node in which LSP signaling is processed (for example, not a source or receiver).

Receiver, Leaf, and Destination

Specifies the node in which LSP signaling ends.

Branch Point

Specifies the node in which packet replication is performed.

Bud Node

Specifies the node that not only acts as a transit for some S2Ls but also acts as a termination point for a S2L of a P2MP TE tunnel.

Source-to-Leaf (S2L) SubLSP

Specifies the P2MP-TE LSP segment that runs from the source to one leaf.

Point-to-Multipoint Traffic-Engineering Features

- P2MP RSVP-TE (RFC 4875) is supported. RFC 4875 is based on nonaggregate signaling; for example, per S2L signaling. Only P2MP LSP is supported.

- **interface tunnel-mte** command identifies the P2MP interface type .
- P2MP tunnel setup is supported with label replication.
- Fast-Reroute (FRR) link protection is supported with sub-50 msec for traffic loss.
- Explicit routing is supported by using under utilized links.
- Reoptimization is supported by calculating a better set of paths to the destination with no traffic loss.

Note Per-S2L reoptimization is not supported.

- IPv4 and IPv6 payloads are supported.
- IPv4 and IPv6 multicast forwarding are supported on a P2MP tunnel interface through a static IGMP and MLD group configuration .
- Both IP multicast and P2MP Label Switch Multicast (LSM) coexist in the same network; therefore, both use the same forwarding plane (LFIB or MPLS Forwarding Infrastructure [MFI]).
- P2MP label replication supports only Source-Specific Multicast (SSM) traffic. SSM configuration supports the default value, none.
- Static mapping for multicast groups to the P2MP-TE tunnel is required .

Point-to-Multipoint Traffic-Engineering Benefits

- Single point of traffic control ensures that signaling and path engineering parameters (for example, protection and diversity) are configured only at the TE source node.
- Ability to configure explicit paths to enable optimized traffic distribution and prevention of single point of failures in the network.
- Link protection of MPLS-labeled traffic traversing branch paths of the P2MP-TE tree.
- Ability to do bandwidth Admission Control (AC) during set up and signaling of P2MP-TE paths in the MPLS network.

Related Topics

Configure Point-to-Multipoint for the Source: Example, on page 198
Configure the Point-to-Multipoint Solution: Example, on page 200
Disable a Destination: Example, on page 200
Configure the Point-to-Multipoint Tunnel: Example, on page 199
Point-to-Multipoint RSVP-TE , on page 35

Point-to-Multipoint RSVP-TE

RSVP-TE signals a P2MP tunnel base that is based on a manual configuration. If all Source-to-Leaf (S2L)s use an explicit path, the P2MP tunnel creates a static tree that follows a predefined path based on a constraint such as a deterministic Label Switched Path (LSP). If the S2L uses a dynamic path, RSVP-TE creates a P2MP tunnel base on the best path in the RSVP-TE topology. RSVP-TE supports bandwidth reservation for constraint-based routing.

When an explicit path option is used, specify both the local and peer IP addresses in the explicit path option, provided the link is a GigabitEthernet or a TenGigE based interface. For point-to-point links like POS or bundle POS, it is sufficient to mention the remote or peer IP address in the explicit path option.

RSVP-TE distributes stream information in which the topology tree does not change often (where the source and receivers are). For example, large scale video distribution between major sites is suitable for a subset of multicast applications. Because multicast traffic is already in the tunnel, the RSVP-TE tree is protected as long as you build a backup path.

Fast-Reroute (FRR) capability is supported for P2MP RSVP-TE by using the unicast link protection. You can choose the type of traffic to go to the backup link.

The P2MP tunnel is applicable for all TE Tunnel destination (IntraArea and InterArea). Inter-AS is not supported.

The P2MP tunnel is signaled by the dynamic and explicit path option in the IGP intra area. Only interArea and interAS, which are used for the P2MP tunnels, are signaled by the verbatim path option.

Related Topics

Configure Point-to-Multipoint for the Source: Example, on page 198
Configure the Point-to-Multipoint Solution: Example, on page 200
Point-to-Multipoint Fast Reroute, on page 36

Point-to-Multipoint Fast Reroute

MPLS-TE Fast Reroute (FRR) is a mechanism to minimize interruption in traffic delivery to a TE Label Switched Path (LSP) destination as a result of link failures. FRR enables temporarily fast switching of LSP traffic along an alternative backup path around a network failure, until the TE tunnel source signals a new end-to-end LSP.

Both Point-to-Point (P2P) and P2MP-TE support only the Facility FRR method from RFC 4090.

P2P LSPs are used to backup P2MP S2L (source 2 Leaf). Only link and bandwidth protection for P2MP S2Ls are supported. Node protection is not supported.

MPLS-TE link protection relies on the fact that labels for all primary LSPs and subLSPs are using the MPLS global label allocation. For example, one single (global) label space is used for all MPLS-TE enabled physical interfaces on a given MPLS LSP.

Related Topics

Point-to-Multipoint Traffic-Engineering Overview, on page 34
Point-to-Multipoint RSVP-TE , on page 35

Point-to-Multipoint Label Switch Path

The Point-to-Multipoint Label Switch Path (P2MP LSP) has only a single root, which is the Ingress Label Switch Router (LSR). The P2MP LSP is created based on a receiver that is connected to the Egress LSR. The Egress LSR initiates the creation of the tree (for example, tunnel grafting or pruning is done by performing an individual sub-LSP operation) by creating the Forwarding Equivalency Class (FEC) and Opaque Value.

Note Grafting and pruning operate on a per destination basis.

The Opaque Value contains the stream information that uniquely identifies the tree to the root. To receive label switched multicast packets, the Egress Provider Edge (PE) indicates to the upstream router (the next hop closest to the root) which label it uses for the multicast source by applying the label mapping message.

The upstream router does not need to have any knowledge of the source; it needs only the received FEC to identify the correct P2MP LSP. If the upstream router does not have any FEC state, it creates it and installs the assigned downstream outgoing label into the label forwarding table. If the upstream router is not the root of the tree, it must forward the label mapping message to the next hop upstream. This process is repeated hop-by-hop until the root is reached.

By using downstream allocation, the router that wants to receive the multicast traffic assigns the label for it. The label request, which is sent to the upstream router, is similar to an unsolicited label mapping (that is, the upstream does not request it). The upstream router that receives that label mapping uses the specific label to send multicast packets downstream to the receiver. The advantage is that the router, which allocates the labels, does not get into a situation where it has the same label for two different multicast sources. This is because it manages its own label space allocation locally.

Path Option for Point-to-Multipoint RSVP-TE

P2MP tunnels are signaled by using the dynamic and explicit path-options in an IGP intra area. InterArea cases for P2MP tunnels are signaled by the verbatim path option.

Path options for P2MP tunnels are individually configured for each sub-LSP. Only one path option per sub-LSP (destination) is allowed. You can choose whether the corresponding sub-LSP is dynamically or explicitly routed. For the explicit option, you can configure the verbatim path option to bypass the topology database lookup and verification for the specified destination.

Both dynamic and explicit path options are supported on a per destination basis by using the **path-option (P2MP-TE)** command. In addition, you can combine both path options.

Explicit Path Option

Configures the intermediate hops that are traversed by a sub-LSP going from the TE source to the egress MPLS node. Although an explicit path configuration enables granular control sub-LSP paths in an MPLS network, multiple explicit paths are configured for specific network topologies with a limited number of (equal cost) links or paths.

Dynamic Path Option

Computes the IGP path of a P2MP tree sub-LSP that is based on the OSPF and ISIS algorithm. The TE source is dynamically calculated based on the IGP topology.

Note Dynamic path option can only compute fully-diverse standby paths. While, explicit path option supports partially diverse standby paths as well.

Dynamic Path Calculation Requirements

Dynamic path calculation for each sub-LSP uses the same path parameters as those for the path calculation of regular point-to-point TE tunnels. As part of the sub-LSP path calculation, the link resource (bandwidth) is included, which is flooded throughout the MPLS network through the existing RSVP-TE extensions to OSPF and ISIS. Instead of dynamic calculated paths, explicit paths are also configured for one or more sub-LSPs that are associated with the P2MP-TE tunnel.

- OSPF or ISIS are used for each destination.

- TE topology and tunnel constraints are used to input the path calculation.
- Tunnel constraints such as affinity, bandwidth, and priorities are used for all destinations in a tunnel.
- Path calculation yields an explicit route to each destination.

Static Path Calculation Requirements

The static path calculation does not require any new extensions to IGP to advertise link availability.

- Explicit path is required for every destination.
- Offline path calculation is used.
- TE topology database is not needed.
- If the topology changes, reoptimization is not required.

Related Topics

Configure the Point-to-Multipoint Tunnel: Example, on page 199
Configure the Point-to-Multipoint Solution: Example, on page 200
Point-to-Multipoint Traffic-Engineering Overview, on page 34
Point-to-Multipoint RSVP-TE , on page 35

Point-to-Multipoint Implicit Null

The Point-to-Multipoint (P2MP) implicit null feature enables the forwarding of unicast traffic over P2MP tunnels. This feature is enabled by default and requires no configuration.

In a P2MP tunnel, the tailend router signals the implicit null label to the midpoint router. If the given MPI leg of the P2MP tunnel is implicit null capable (where the penultimate router is capable to do penultimate hop popping), the FIB (Forwarding Information Base) creates two NRLDI (Non Recursive Load Distribution Index) entries, one for forwarding the IPv6 labeled packets, and the other for non-labeled IPv4 unicast traffic.

The headend and the tailend routers handle the unicast traffic arriving on the P2MP tunnel. The midpoint router forwards the unicast traffic to its bud and tailend routers.

The use of implicit null at the end of a tunnel is called penultimate hop popping (PHP). The FIB entry for the tunnel on the PHP router shows a "pop label" as the outgoing label.

In some cases, it could be that the packets have two or three or more labels in the label stack. Then the implicit null label used at the tailend router would signal the penultimate hop router to pop one label and send the labeled packet with one label less to the tailend router. Then the tailend router does not have to perform two label lookups. The use of the implicit null label does not mean that all labels of the label stack must be removed; only one label is "popped" off (remove the top label on the stack). In any case, the use of the implicit null label prevents the tailend router from performing two lookups.

Restriction

The P2MP implicit null feature may cause multicast traffic drop with implicit null label on the tailend routers. This is because the P2MP implicit null feature does not support forwarding of multicast traffic when no label is received on the tailend router.

MPLS Traffic Engineering Shared Risk Link Groups

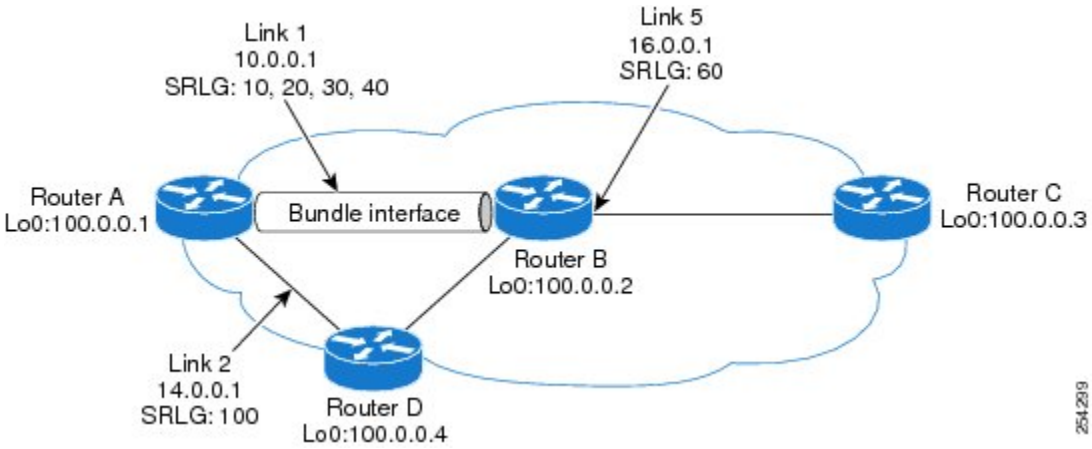
Shared Risk Link Groups (SRLG) in MPLS traffic engineering refer to situations in which links in a network share a common fiber (or a common physical attribute). These links have a shared risk, and that is when one link fails, other links in the group might fail too.

OSPF and Intermediate System-to-Intermediate System (IS-IS) flood the SRLG value information (including other TE link attributes such as bandwidth availability and affinity) using a sub-type length value (sub-TLV), so that all routers in the network have the SRLG information for each link.

To activate the SRLG feature, configure the SRLG value of each link that has a shared risk with another link. A maximum of 30 SRLGs per interface is allowed. You can configure this feature on multiple interfaces including the bundle interface.

Figure 8: Shared Risk Link Group illustrates the MPLS TE SRLG values configured on the bundle interface.

Figure 8: Shared Risk Link Group



Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Explicit Path

The Explicit Path configuration allows you to configure the explicit path. An IP explicit path is a list of IP addresses, each representing a node or link in the explicit path.

The MPLS Traffic Engineering (TE)—IP Explicit Address Exclusion feature provides a means to exclude a link or node from the path for an Multiprotocol Label Switching (MPLS) TE label-switched path (LSP).

This feature is enabled through the **explicit-path** command that allows you to create an IP explicit path and enter a configuration submode for specifying the path. The feature adds to the submode commands of the **exclude-address** command for specifying addresses to exclude from the path.

The feature also adds to the submode commands of the **exclude-srlg** command that allows you to specify the IP address to get SRLGs to be excluded from the explicit path.

If the excluded address or excluded srlg for an MPLS TE LSP identifies a flooded link, the constraint-based shortest path first (CSPF) routing algorithm does not consider that link when computing paths for the LSP. If the excluded address specifies a flooded MPLS TE router ID, the CSPF routing algorithm does not allow paths for the LSP to traverse the node identified by the router ID.

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
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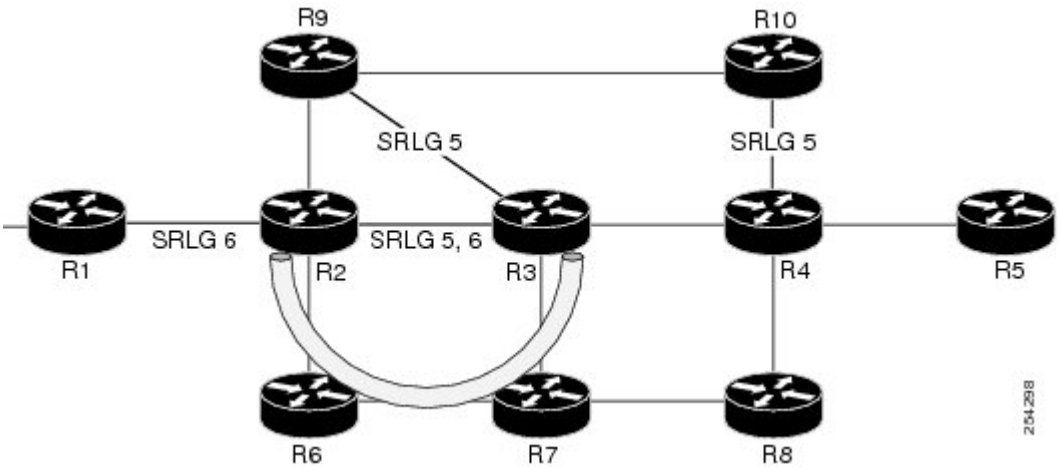
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Fast ReRoute with SRLG Constraints

Fast ReRoute (FRR) protects MPLS TE Label Switch Paths (LSPs) from link and node failures by locally repairing the LSPs at the point of failure. This protection allows data to continue to flow on LSPs, while their headend routers attempt to establish new end-to-end LSPs to replace them. FRR locally repairs the protected LSPs by rerouting them over backup tunnels that bypass failed links or nodes.

Backup tunnels that bypass only a single link of the LSP's path provide Link Protection. They protect LSPs by specifying the protected link IP addresses to extract SRLG values that are to be excluded from the explicit path, thereby bypassing the failed link. These are referred to as **next-hop (NHOP) backup tunnels** because they terminate at the LSP's next hop beyond the point of failure. Figure 9: NHOP Backup Tunnel with SRLG constraint illustrates an NHOP backup tunnel.

Figure 9: NHOP Backup Tunnel with SRLG constraint



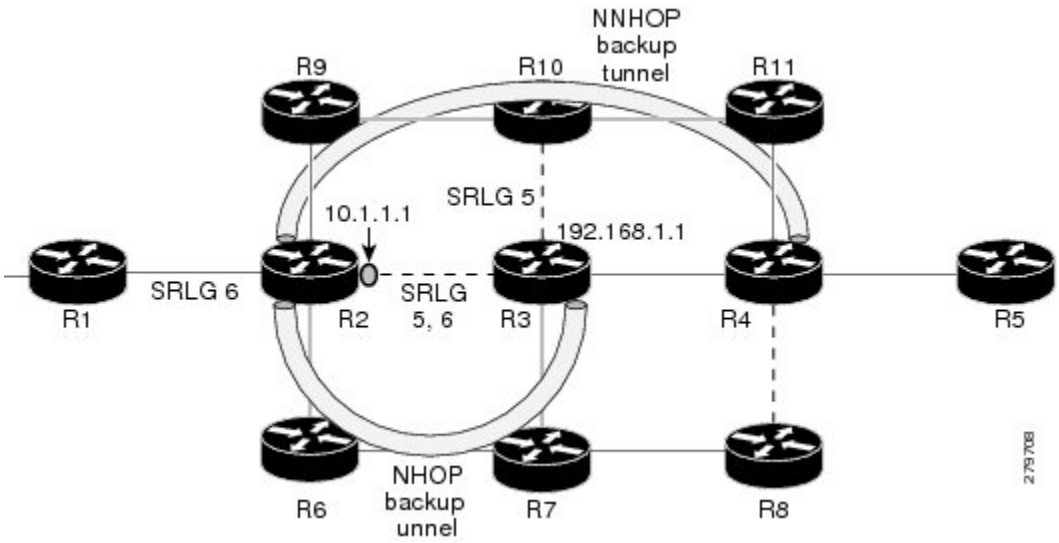
In the topology shown in the above figure, the backup tunnel path computation can be performed in this manner:

- Get all SRLG values from the exclude-SRLG link (SRLG values 5 and 6)
- Mark all the links with the same SRLG value to be excluded from SPF

- Path computation as CSPF R2->R6->R7->R3

FRR provides Node Protection for LSPs. Backup tunnels that bypass next-hop nodes along LSP paths are called **NNHOP backup tunnels** because they terminate at the node following the next-hop node of the LSP paths, thereby bypassing the next-hop node. They protect LSPs when a node along their path fails, by enabling the node upstream to the point of failure to reroute the LSPs and their traffic, around the failed node to the next-next hop. They also protect LSPs by specifying the protected link IP addresses that are to be excluded from the explicit path, and the SRLG values associated with the IP addresses excluded from the explicit path. NNHOP backup tunnels also provide protection from link failures by bypassing the failed link as well as the node. Figure 10: NNHOP Backup Tunnel with SRLG constraint illustrates an NNHOP backup tunnel.

Figure 10: NNHOP Backup Tunnel with SRLG constraint



In the topology shown in the above figure, the backup tunnel path computation can be performed in this manner:

- Get all SRLG values from the exclude-SRLG link (SRLG values 5 and 6)
- Mark all links with the same SRLG value to be excluded from SPF
- Verify path with SRLG constraint
- Path computation as CSPF R2->R9->R10->R4

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Importance of Protection

This section describes the following:

- Delivery of Packets During a Failure
- Multiple Backup Tunnels Protecting the Same Interface

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
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Delivery of Packets During a Failure

Backup tunnels that terminate at the NNHOP protect both the downstream link and node. This provides protection for link and node failures.

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
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Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Multiple Backup Tunnels Protecting the Same Interface

- Redundancy—If one backup tunnel is down, other backup tunnels protect LSPs.
- Increased backup capacity—If the protected interface is a high-capacity link and no single backup path exists with an equal capacity, multiple backup tunnels can protect that one high-capacity link. The LSPs using this link falls over to different backup tunnels, allowing all of the LSPs to have adequate bandwidth protection during failure (rerouting). If bandwidth protection is not desired, the router spreads LSPs across all available backup tunnels (that is, there is load balancing across backup tunnels).

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
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Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Weighted-SRLG Auto-backup Path Computation

In shared-risk link groups (SRLG) fate-sharing, links are assigned one or more numbers to represent risks. When two links are assigned a common number then this indicates that these two links are sharing fate. In the weighted-SRLG auto-backup path computation mode, the links that share SRLG numbers with the protected link are not excluded from the topology. The admin-weight of these links is set to reflect the sharing of SRLG with the protected link. Setting the admin weight consists of adding a penalty metric to make using the link less desirable.

For more information about Weighted-SRLG auto-backup path computation, see *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information about Weighted-SRLG auto-backup path computation, see *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

SRLG Limitations

There are few limitations to the configured SRLG feature:

- The **exclude-address** and **exclude-srlg** options are not allowed in the IP **explicit path strict-address** network.
- Whenever SRLG values are modified after tunnels are signalled, they are verified dynamically in the next path verification cycle.

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

MPLS TE SRLG Scale Enhancements

MPLS Traffic Engineering Shared Risk Link Groups (SRLG) feature has been enhanced to support:

- Increase from 32 to 64 (59 for ISIS) groups.
- Increase from 250 to 500 interfaces.

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Soft-Preemption

MPLS-TE preemption consists of freeing the resources of an established LSP, and assigning them to a new LSP. The freeing of resources causes a traffic disruption to the LSP that is being preempted. Soft preemption is an extension to the RSVP-TE protocol to minimize and even eliminate such traffic disruption over the preempted LSP.

The soft-preemption feature attempts to preempt the LSPs in a graceful manner to minimize or eliminate traffic loss. However, the link might be over-subscribed for a period of time.

In a network that implements soft preemption, zero traffic loss is achieved in this manner:

- When signaling a new LSP, the ingress router indicates to all the intermediate nodes that the existing LSP is to be softly preempted, in case its resources are needed and is to be reassigned.
- When a given intermediate node needs to soft-preempt the existing LSP, it sends a new or special path error (preemption pending) to the ingress router. The intermediate node does not dismantle the LSP and maintains its state.
- When the ingress router receives the path error (preemption pending) from the intermediate node, it immediately starts a re-optimization that avoids the link that caused the preemption.
- When the re-optimization is complete, the ingress router tears down the soft-preempted LSP.

Related Topics

Enabling Soft-Preemption on a Node, on page 130
Enabling Soft-Preemption on a Tunnel, on page 131

Path Option Attributes

The path option attributes are configurable through a template configuration. This template, named **attribute-set**, is configured globally in the MPLS traffic-engineering mode.

You can apply an **attribute-set** to a path option on a per-LSP basis. The path option configuration is extended to take a path option attribute name. LSPs computed with a particular path option uses the attributes as specified by the attribute-set under that path option.

These prerequisites are required to implement path option attributes:

- Path option type attribute-set is configured in the MPLS TE mode
- Path option CLI extended to accept an attribute-set name

Note The **signalled-bandwidth** and **affinity** attributes are supported under the attribute-set template.

Related Topics

Configuring Attributes within a Path-Option Attribute, on page 132

Configuration Hierarchy of Path Option Attributes

You can specify a value for an attribute within a path option **attribute-set** template. This does not prevent the configuring of the same attribute at a tunnel level. However, it is important to note that only one level is

taken into account. So, the configuration at the LSP level is considered more specific than the one at the level of the tunnel, and it is used from this point onwards.

Attributes that are not specified within an attribute-set take their values as usual--configuration at the tunnel level, configuration at the global MPLS level, or default values. Here is an example:

```
attribute-set path-option MYSET
   affinity 0xBEEF mask 0xBEEF

interface tunnel-te 10
   affinity 0xCAFE mask 0xCAFE
   signalled-bandwidth 1000
   path-option 1 dynamic attribute-set name MYSET
   path-option 2 dynamic
```

In this example, the attribute-set named **MYSET** is specifying affinity as 0xBEEF. The signalled bandwidth has not been configured in this **MYSET**. The **tunnel 10**, meanwhile, has affinity 0xCAFE configured. LSPs computed from path-option 1 uses the affinity 0xBEEF/0xBEEF, while LSPs computed from path-option 2 uses the affinity 0xCAFE/0xCAFE. All LSPs computed using any of these path-options use **signalled-bandwidth** as 1000, as this is the only value that is specified only at the tunnel level.

Note The attributes configured in a path option **attribute-set** template takes precedence over the same attribute configured under a tunnel. An attribute configured under a tunnel is used only if the equivalent attribute is **not** specified by the in-use path option **attribute-set** template.

Related Topics

Configuring Attributes within a Path-Option Attribute, on page 132

Traffic Engineering Bandwidth and Bandwidth Pools

MPLS traffic engineering allows constraint-based routing (CBR) of IP traffic. One of the constraints satisfied by CBR is the availability of required bandwidth over a selected path. Regular TE tunnel bandwidth is called the **global pool**. The **subpool bandwidth** is a portion of the global pool. If it is not in use, the subpool bandwidth is not reserved from the global pool. Therefore, subpool tunnels require a priority higher than that of non-subpool tunnels.

You can configure the signalled-bandwidth path option attribute to use either the global pool (default) or the subpool bandwidth. The signalled-bandwidth value for the path option may be any valid value and the pool does not have to be the same as that which is configured on the tunnel.

Note When you configure signalled-bandwidth for path options with the **signalled-bandwidth bandwidth [sub-pool | global]** *kbps* command, use either all subpool bandwidths or all global-pool bandwidth values.

Related Topics

Configuring Attributes within a Path-Option Attribute, on page 132

Path Option Switchover

Reoptimization to a particular path option is not possible if the in-use path option and the new path option do not share the same bandwidth class. The path option switchover operation would fail in such a scenario. Use this command at the EXEC configuration mode to switchover to a newer path option :

```
mpls traffic-eng switchover tunnel-xx ID path-option index
```

The switchover to a newer path option is achieved, in these instances:

- when a lower index path option is available
- when any signalling message or topology update causes the primary LSP to go down
- when a local interface fails on the primary LSP or a path error is received on the primary LSP

Note Path option switchover between various path options with different bandwidth classes is not allowed.

Related Topics

Configuring Attributes within a Path-Option Attribute, on page 132

Path Option and Path Protection

When path-protection is enabled, a standby LSP is established to protect traffic going over the tunnel. The standby LSP may be established using either the same path option as the primary LSP, or a different one.

The standby LSP is computed to be diverse from the primary LSP, so bandwidth class differences does not matter. This is true in all cases of diversity except node-diversity. With node diversity, it is possible for the standby LSP to share up to two links with the primary LSP, the link exiting the head node, and the link entering the tail node.

If you want to switchover from one path option to another path option and these path options have different classes, the path option switchover is rejected. However, the path option switchover can not be blocked in the path-protection feature. When the standby LSP becomes active using another path option of a different class type, the path option switchover cannot be rejected at the head end. It might get rejected by the downstream node.

Node-diversity is only possible under limited conditions. The conditions that must be met are:

- there is no second path that is both node and link diverse
- the current LSP uses a shared-media link at the head egress or tail ingress
- the shared-media link used by the current LSP permits computation of a node-diverse path

In Cisco IOS XR, reoptimization between different class types would actually be rejected by the next hop. This rejection will occur by an admission failure.

Related Topics

Configuring Attributes within a Path-Option Attribute, on page 132

Auto-Tunnel Mesh

The MPLS traffic engineering auto-tunnel mesh (Auto-mesh) feature allows you to set up full mesh of TE P2P tunnels automatically with a minimal set of MPLS traffic engineering configurations. You may configure one or more mesh-groups. Each mesh-group requires a destination-list (IPv4 prefix-list) listing destinations, which are used as destinations for creating tunnels for that mesh-group.

You may configure MPLS TE auto-mesh type attribute-sets (templates) and associate them to mesh-groups. LSR creates tunnels using the tunnel properties defined in the attribute-set.

Auto-Tunnel mesh provides benefits:

- Minimizes the initial configuration of the network.

  You may configure tunnel properties template and mesh-groups or destination-lists on each TE LSRs that further creates full mesh of TE tunnels between those LSRs.

- Minimizes future configurations resulting due to network growth.

  It eliminates the need to reconfigure each existing TE LSR in order to establish a full mesh of TE tunnels whenever a new TE LSR is added in the network.

Related Topics

Configuring Auto-Tunnel Mesh Tunnel ID, on page 133
Configuring Auto-tunnel Mesh Unused Timeout, on page 134
Configuring Auto-Tunnel Mesh Group, on page 135
Configuring Tunnel Attribute-Set Templates, on page 137
Enabling LDP on Auto-Tunnel Mesh, on page 138

Destination List (Prefix-List)

Auto-mesh tunnels can be automatically created using prefix-list. Each TE enabled router in the network learns about the TE router IDs through a existing IGP extension.

You can view the router IDs on the router using this command:

```
show mpls traffic-eng topology | include TE Id
IGP Id: 0001.0000.0010.00, MPLS TE Id:10.1.1.1 Router Node  (ISIS 1 level-2)
IGP Id: 0001.0000.0011.00, MPLS TE Id:10.2.2.2 Router Node  (ISIS 1 level-2)
IGP Id: 0001.0000.0012.00, MPLS TE Id:10.3.3.3 Router Node  (ISIS 1 level-2)
```

A prefix-list may be configured on each TE router to match a desired set of router IDs (MPLS TE ID as shown in the above output). For example, if a prefix-list is configured to match addresses of 10.0.0.0 with wildcard 0.255.255.255, then all 10.x.x.x router IDs are included in the auto-mesh group.

When a new TE router is added in the network and its router ID is also in the block of addresses described by the prefix-list, for example, 10.x.x.x, then it is added in the auto-mesh group on each existing TE router without having to explicitly modify the prefix-list or perform any additional configuration.

Auto-mesh does not create tunnels to its own (local) TE router IDs.

Note When prefix-list configurations on all routers are not identical, it can result in non- symmetrical mesh of tunnels between those routers.

Related Topics

Configuring Auto-Tunnel Mesh Tunnel ID, on page 133
Configuring Auto-tunnel Mesh Unused Timeout, on page 134
Configuring Auto-Tunnel Mesh Group, on page 135
Configuring Tunnel Attribute-Set Templates, on page 137
Enabling LDP on Auto-Tunnel Mesh, on page 138

P2MP-TE Auto-tunnels

The MPLS point-to-multi point traffic-engineering auto-tunnels (P2MP-TE Auto-tunnels) feature enables dynamic creation and management of P2MP auto-tunnels for the transport of VPLS traffic on Cisco IOS XR Software. The P2MP-TE auto-tunnel configuration is disabled by default. Use the **auto-tunnel p2mp-te tunnel-id** configuration to enable P2MP-TE Auto-tunnel. This configures the tunnel ID range that can be allocated to P2MP auto-tunnels. This also determines the maximum number of P2MP auto-tunnels that can be created.

For more information on P2MP_TE Auto-tunnels, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on Set DF Bit commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Related Topics

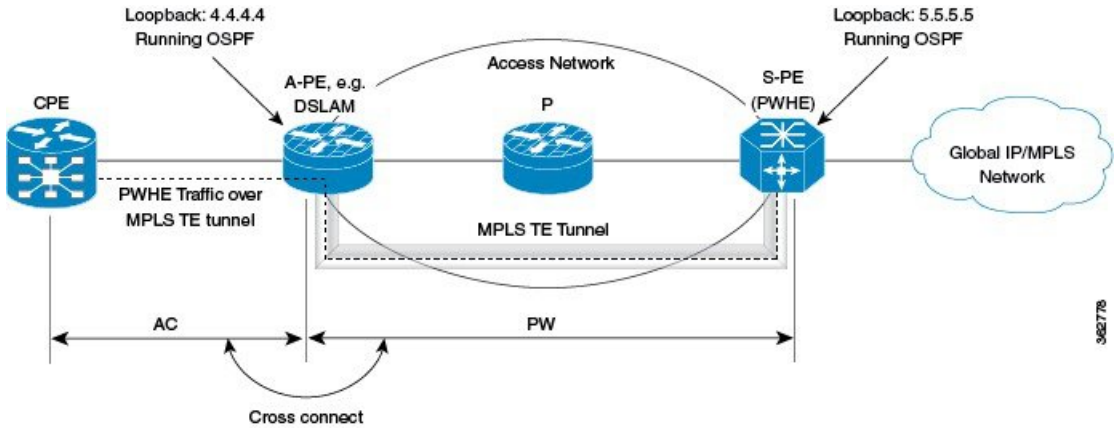
Configuring P2MP TE Auto-tunnels, on page 139

PWHE over MPLS TE Tunnels

The Pseudowire Headend (PWHE) over MPLS TE Tunnels feature enables the PWHE traffic to pass through MPLS traffic engineering (TE) tunnels.

The PWHE and the MPLS TE tunnels are configured independently. No specific configuration is required for a TE tunnel to forward PWHE traffic through it. The pseudowire traffic automatically passes through the TE tunnel, after the routing protocol is configured in such a way that the routing algorithm considers the TE tunnel as the route to reach the pseudowire endpoint.

Figure 11: PWHE over MPLS TE Tunnel



In this figure, S-PE is the PWHE and OSPF manages the routing. A MPLS TE tunnel is configured between A-PE and S-PE. After the MPLS TE tunnel is defined (either by defining a static route or using the **autoroute announce** command) as the path through which to forward traffic to S-PE, the PWHE traffic passes through that tunnel.

Workflow - Sending PWHE Traffic over MPLS TE Tunnels

Complete these configurations on the S-PE to enable PWHE traffic to flow through the MPLS TE tunnel.

Task Number	Task Description	Sample Configuration	Details

1	Configure interfaces that connect to A-PE.	`interface Bundle-Ether1`
		` description TO-APE`
		` ipv4 address 145.0.2.5 255.255.255.0`
		` load-interval 30`
		`!`
		`interface TenGigE0/2/1/2`
		` description TO-APE-VKG4-0-1-1-0`
		` bundle id 1 mode on`
		` load-interval 30`
		`!`
		`interface TenGigE0/2/1/3`
		` description TO-APE-VKG4-0-1-1-1`
		` bundle id 1 mode on`
		` load-interval 30`
			See the *Configuring Ethernet Link Bundles* task in Chapter *Configuring Link Bundling* of *Interface and Hardware Component Configuration Guide for Cisco ASR 9000 Series Routers*.
			Note You can configure any supported interface; not just bundle interfaces.

2	Define loopback address.	`interface Loopback0`
		` ipv4 address 5.5.5.5 255.255.255.255`
		`!`	

3	Configure tunnel interface.
	TE tunnels can be configured with either an "explicit" or a "dynamic" path.
		`interface tunnel-te1`
		` bandwidth 10000000`
		` ipv4 unnumbered Loopback0`
		` autoroute announce`
		` destination 4.4.4.4`
		` fast-reroute`
		` path-option 10 explicit name main-path`
		`!`
			See Creating an MPLS-TE Tunnel, on page 63

4	Provide path definition of path that the tunnel uses as the forwarding path.	`explicit-path name main-path`
		` index 10 next-address strict ipv4 unicast 145.0.2.4`
		`!`
			See Configuring Explicit Paths with ABRs Configured as Loose Addresses, on page 91

5	Specify tunnel bandwidth.	`rsvp`
		` interface Bundle-Ether1`
		`  bandwidth mam max-reservable-bw 10000000 1000000`
		` !`
		` signalling graceful-restart`
		`!`
		`mpls traffic-eng`
		` interface Bundle-Ether1`
		`!`
			See Configuring an IETF DS-TE Tunnel Using MAM, on page 80

Task Number	Task Description	Sample Configuration	Details

6	Configure PWHE.	`interface PW-Ether1`
		` mtu 1518`
		` mac-address 4000.5.1`
		` load-interval 30`
		` attach generic-interface-list il1`
		`!`
			See the *Configuring PWHE Interfaces* task in Chapter *Implementing Multipoint Layer 2 Services* of *L2VPN and Ethernet Services Configuration Guide for Cisco ASR 9000 Series Routers*.

7	Define, for PWHE, the list of interfaces that PW uses to forward traffic.	`generic-interface-list il1`
		` interface Bundle-Ether1`
		`!`
			See the *Configuring Generic Interface List* task in Chapter *Implementing Multipoint Layer 2 Services* of *L2VPN and Ethernet Services Configuration Guide for Cisco ASR 9000 Series Routers*.

8	Define PW source address.	`l2vpn`
		` pw-class pwhe`
		`  encapsulation mpls`
		`  control-word`
		`  ipv4 source 5.5.5.5`
		`  !`
		` !`
			See the *Configuring the Source Address* task in Chapter *Implementing Multipoint Layer 2 Services* of *L2VPN and Ethernet Services Configuration Guide for Cisco ASR 9000 Series Routers*.

9	Define PWHE cross-connect.	`xconnect group xc452`
		`  p2p pwhe452`
		`  interface PW-Ether2`
		`  neighbor ipv4 4.4.4.4 pw-id 452`
		`  mpls static label local 5542 remote 5452`
		`  pw-class pwhe`
		`  !`
			See the *Configuring PWHE Crossconnect* task in Chapter *Implementing Multipoint Layer 2 Services* of *L2VPN and Ethernet Services Configuration Guide for Cisco ASR 9000 Series Routers*.

10	Setup interfaces running LDP.	`mpls ldp`
		` nsr`
		` graceful-restart`
		` graceful-restart reconnect-timeout 60`
		` graceful-restart forwarding-state-holdtime 60`
		` interface Bundle-Ether1`
		` !`
		`!`
			See Setting Up LDP NSF Using Graceful Restart

Task Number	Task Description	Sample Configuration	Details

11	Configure routing.	`router ospf 100`
		` nsr`
		` router-id 5.5.5.5`
		` nsf cisco`
		` area 0`
		`  mpls traffic-eng`
		`  interface Bundle-Ether1`
		`  !`
		`  interface Loopback0`
		`  !`
		`mpls traffic-eng router-id 192.168.70.1`
		`!`
			See the *Configuring OSPF Version 2 for MPLS Traffic Engineering* task in Chapter *Implementing OSPF* of *Routing Configuration Guide for Cisco ASR 9000 Series Routers*.

Note A-PE has a similar configuration, except for the fact that there is no PWHE defined on it.

In a PWHE-based pseudowire configuration, the TE tunnel cannot be configured as the preferred-path for pseudowire traffic. Therefore, the preferred-path tunnel-te option under the L2VPN XConnect PW-Class is not supported. However, the TE tunnel redundancy and TE fast-reroute mechanisms are supported with PWHE over MPLS TE tunnels.

VRF Redirection to MPLS TE Tunnels

The VRF redirection to MPLS TE tunnels feature adds automatic route MPLS TE tunnels through autoroute destination configuration. The VRF redirection to MPLS TE tunnels maps VRF prefixes over TE tunnels in the core to reach the same egress provider edge (PE). This enables to load-balance prefix traffic on multiple tunnels based on equal cost multi-path (ECMP). The ECMP is used to load-share the flow(s) on multiple available paths towards the destination PE. The route added by autoroute destination inherits the same IGP computed metric to the tunnel endpoint. Any changes to the IGP route metric to the tunnel endpoint is automatically reflected on the autoroute destination route too.

In a typical VPN deployment over a TE core network, an operator creates a mesh of TE tunnels between PE routers and then configures autoroute announce to these tunnels. This leads to a mix of default VRF and VPNv4 traffic on the same tunnel connecting the PE routers. An operator my want to segregate their VPNv4 traffic on different tunnels. This can be achieved by creating multiple tunnels to the egress PE(s). The limitation of this approach is that the static routes are added with zero metrics. The VRF Redirection to MPLS TE Tunnels feature is a solution to resolve this limitation. Multiple VRFs can be mapped on the same tunnel by adding multiple autoroute destination addresses (BGP next-hops) to the same tunnel.

Routes added by static route are always added with zero cost metric. This results in traffic that is mapped on multiple tunnels to always load-balance due to ECMP. This may be undesirable when some of those tunnels have sub-optimal paths (have higher underlying cost to the endpoint). With autoroute destination, only the tunnel whose IGP cost to its endpoint is lowest will be considered for carrying traffic.

VRF redirection over TE tunnels feature supports:

- Automatic redirection of VRF traffic over TE tunnels.

- Multiple autoroute destinations under one tunnel to aggregate VRF traffic. If two VRFs are to be mapped on same tunnel, then two autoroute destination prefixes (BGP next-hops) will be configured under the tunnel.
- One autoroute destination under multiple tunnels to enable ECMP load-balance of VRF traffic.
- Implicit /32 mask for each route. Only host addresses residing on the tunnel endpoint are supported.
- High availability, RP failover, and non-stop forwarding (NSF) scenarios by proving hitless to traffic mechanisms.

Note Configuring Segment Routing and Autoroute Destination together is not supported. If autoroute functionality is required in an Segment Routing network, we recommend you to configure Autoroute Announce.

For more information on VRF Redirection to MPLS TE Tunnels, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on VRF Redirection to MPLS TE Tunnels commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

MPLS TE Extended Admin Groups

The MPLS TE extended admin groups (EAG) configuration assigns EAG/AG name to bit-position and associates affinity-names with TE links. The configuration extends to assign names, up to 256, to TE links over the selected interface and assigns 32 names per attribute-set and index.

For more information on MPLS TE Extended Admin Groups, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on MPLS TE Extended Admin Groups commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Stateful Path Computation Element

The stateful path computation element (PCE) describes a set of procedures by which a path computation client (PCC) can report and delegate control of head-end tunnels sourced from the PCC to a PCE peer. The PCE peer can request the PCC to update and modify parameters of label switched paths (LSPs) it controls. The stateful model also enables a PCC to allow the PCE to initiate computations allowing the PCE to perform network-wide orchestration.

For more information on Stateful PCE, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on Stateful PCE commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

- Request types
  - PCReq—requests used by current stateless PCE implementation
  - PCCreate—LSP instantiation requests
  - PCUpd—LSP update requests

- LSP Objects
  - Operational flag
  - Delegation flag
  - Remove flag
  - Symbolic path name
  - LSP Identifiers
- Path List
  - ERO

Stateful PCE State Reporting

State reporting refers to the PCC sending information to PCEs about the state of LSPs. This is done as state changes occur and is used to keep PCEs informed of changes to the LSP as they occur. State reporting is also used as part of *state synchronization* and *delegation*.

A state report is a message sent by a PCC to a PCE reporting on the state of one or more TE tunnels. This allows the PCE to stay abreast of changes as they occur. Reports are triggered when the PCE needs to be informed of state. These occur when:

- State synchronization happens
- The PCC attempts to delegate control of a tunnel to a PCE
- The PCC revokes control of a tunnel from a PCE
- The PCC deletes a tunnel
- A signalling error occurs on a tunnel
- Reportable information about a tunnel changes

Stateful PCE State Synchronization

Synchronization refers to a procedure that occurs after a PCEP session is established between a PCE and a PCC. The purpose of state synchronization is to download the current LSP database of the PCC to a PCE. This is done through a set of state reports which are marked as *synchronizations*. This is the first communication to occur after the session is brought up. A full re-send of state reports can also be avoided when the PCE already has an up-to-date version of the LSP database as the version number can be indicated by the PCE during PCEP session establishment.

Stateful PCE Delegation

Delegation is the action by which control of a state is granted to a PCE by the PCC. A PCE to which control was delegated can alter attributes of the LSP. Control is only delegated to one PCE at a time.

- Delegation of control can be revoked from a PCE by the PCC.
- Delegation of control can also be returned to the PCC by the PCE.

Stateful PCE State Updating

State updating refers to the PCE sending information to a PCC to alter the attributes of an LSP. A state update is a message sent by a PCE to a PCC to alter the state of one or more TE tunnels. State updating is allowed only if the PCE has previously been delegated control of the LSP. State updating is also used to return delegated control.

Stateful PCE Creation of LSPs

Creation (or instantiation) of an LSP is a procedure by which a PCE instructs a PCC to create an LSP respecting certain attributes. For LSPs created in this manner, the PCE is delegated control automatically. Stateful PCE procedures enable a PCE to instruct a PCC to create a locally sourced tunnel.

Delegation of PCC Initiated Tunnels

The delegation of path computation client (PCC) initiated tunnels feature enables the ability to control PCC initiated tunnels through stateful path computation element (PCE).

When a PCC is connected to multiple PCEs, use the **precedence** command to select stateful PCEs for delegating LSPs. Precedence can take any value between 0 and 255. The default precedence value is 255. When there are multiple stateful PCEs with active PCEP sessions, PCC selects the PCE with the lowest precedence value. If multiple PCEs have the same precedence, PCC selects a PCE with the lowest IP address. A PCC considers only the PCEs with active PCEP session for delegating LSPs.

When a PCEP session over which tunnels have been delegated is terminated, the PCC waits till the re-delegation timer expires before re-delegating tunnels. If a PCEP session comes back up within re-delegation timer expiration, tunnels will be delegated back to the same PCE.

For information on PCC, see Path Computation Element, on page 20.

Stateful PCE Enhancements

These topics describe the enhancements made to the stateful path computation element (PCE):

Fast Repair

Fast repair feature minimizes the tunnel down time by allowing the path computation client (headend) to determine a new optimal path for delegated tunnels that went down, or are under fast reroute (FRR) or soft-preemption. Previously, Path Computation Client (PCC) was not designated to take any action on delegated tunnels. To configure the fast repair feature, use the **fast-repair** command under PCE stateful client in MPLS-TE configuration.

PCE is still the primary controller, but the time taken to notify the PCE and the wait till the PCE takes an action, amounts to considerable time. This disadvantage is overcome by the fast repair feature.

Automatic Bandwidth Backoff

Automatic bandwidth backoff is enabled automatically, if the tunnel's current bandwidth is different from the requested bandwidth due to automatic bandwidth update.

In cases where automatic bandwidth is enabled for a tunnel, fast repair tries to determine a path with:

1. Current signaled bandwidth

2. If option (1) fails and the configured bandwidth has a lower value than the current bandwidth, second attempt is made with the average bandwidth value: (current bandwidth + configured bandwidth)/2

Note If configured bandwidth is equal to or higher than the current bandwidth, fast repair fails at this point.

3. If option (2) fails, PCC tries to find a path with the configured bandwidth value
4. If option (3) fails, fast repair is unsuccessful and the tunnel is at the discretion of the PCE

For detailed configuration steps, see Configuring Fast Repair, on page 96.

Optional Vendor Specific PCEP Extension

An optional vendor specific Path Computation Element Protocol (PCEP) extension, *cisco-tlv* is added in this IOS XR release. The vendor information TLV (Type-Length-Variable) is used to carry vendor specific information that applies to a specific PCEP object by including the TLV in the object.

Vendor specific PCEP extension (cisco-tlv) in not sent in PC report (PCReport), or accepted in PC update (PCUpdate) or PC initiate (PCInitiate) by default, for compatibility reasons. This helps in interoperability with PCE implementation which does not understand or support Cisco specific information.

Vendor specific PCEP extension is optional and can be enabled using the **cisco-extension** command under PCE stateful client in MPLS-TE configuration.

For detailed steps to enable vendor specific PCEP extension, see Enabling PCEP Cisco Extension, on page 97.

Automatic Bandwidth Support for Delegated Tunnels

Automatic bandwidth feature allows a tunnel to automatically and dynamically adjust its reserved bandwidth over time, without network operator intervention. The automatic bandwidth feature support has been extended to delegated tunnels. Previously, tunnels configured with automatic bandwidth were switched to *collect-only* mode upon delegation.

New Style Affinities

Affinity is MPLS traffic engineering (TE) tunnel's requirements on the attributes of the links it will cross. The tunnel's affinity bits and affinity mask bits must match the attribute bits of the various links carrying the tunnel.

A new style of affinity reporting support is added in this IOS XR release. Even though TE ignores any affinities from the PCE, the new style affinities in PC update (PCUpdate) or PC initiate (PCInitiate) override the existing tunnel affinities. Previously, only old style affinities (value + mask) were reported. The new affinity mapping has PCEP affinities on the left and IOS XR affinities on the right.

- Lspa.exclude_any = AFFINITY_NEWSTYLE_EXCLUDE **OR** AFFINITY_NEWSTYLE_EXCLUDE_ALL
- Lspa.include_all = AFFINITY_NEWSTYLE_INCLUDE_STRICT
- Lspa.include_any = AFFINITY_NEWSTYLE_INCLUDE_STRICT **OR** AFFINITY_NEWSTYLE_INCLUDE

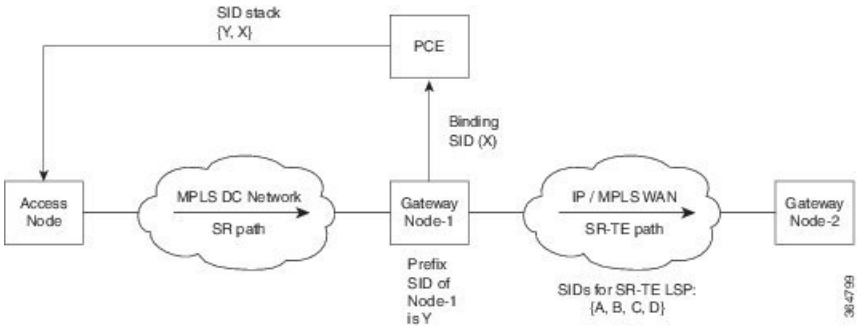
Binding Segment-ID

A binding Segment-ID (SID) can be used to enforce traffic engineering (TE) policy using RSVP-TE or SR-TE label switching path (LSP) tunnel. If the topmost label of an incoming packet is the binding SID, the packet is steered to the appropriate LSP tunnel. As such, a SID can be used by an upstream router to steer traffic originating from a downstream router into the appropriate TE path. If an LSP tunnel is PCE controlled, that is, either initiated by PCE or delegated to PCE, or simply reported (without delegation) to a PCE, the router allocates binding label and reports it to the PCE.

Use Case Scenario

A sample use case for binding SID is illustrated in the following diagram.

Figure 12: Sample Use of Binding SID



1. In the MPLS Data Center (DC) network, an SR LSP (without traffic engineering) is established using a prefix SID advertised by BGP.
2. In IP/MPLS WAN, an SR-TE LSP is setup using the PCE. The list of SIDs of the SR-TE LSP is {A, B, C, D}.
3. The gateway node 1 (which is the PCC) allocates a binding SID X and reports it to the PCE.
4. In order for the access node to steer the traffic over the SR-TE LSP, the PCE passes the SID stack {Y, X} where Y is the prefix SID of the gateway node 1 to the access node. In the absence of the binding SID X, the PCE passes the SID stack {Y, A, B, C, D} to the access node.

This example also illustrates the additional benefit of using the binding SID to reduce the number of SIDs imposed on the access nodes with a limited forwarding capacity.

MPLS TE Usability Enhancements

MPLS traffic engineering command line interface and logging output messages are enhanced as follows:

- The **show mpls traffic engineering** commands display **signaled-name** and supports **signaled-name** filter.
- Ability to allow immediate teardown of all labelled switched paths (LSPs) of the specified tunnel and to create new LSPs.
- Default behavior when affinity check fails at head-end is to reoptimize all LSP types.
- Logging output messages include MPLS TE tunnel signaled name.

- Logging of path change events and available bandwidth on the new for all auto-bandwidth operations.
- Auto-bandwidth logging output includes signaled name.

MPLS TE IPv6 Autoroute

The MPLS TE IPv6 Autoroute feature enables the use of IPv4 MPLS TE tunnels for IPv6 routing. The routing protocol IGP (IS-IS) considers the IPv4 MPLS TE tunnel for IPv6 routing path calculation only if the tunnel is advertised to carry IPv6 traffic. To advertise the tunnel, either IPv6 autoroute announce (AA) configuration or IPv6 forwarding adjacency (FA) configuration should be made on the tunnel. Also, the IPv6 has to be enabled on the tunnel so that the tunnel can handle IPv6 traffic.

For more information on MPLS TE IPv6 Autoroute, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on MPLS TE IPv6 Autoroute commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

MPLS TE IPv6 Autoroute Restrictions

- IGP support is only for IS-IS.
- IS-IS IPv4 and IPv6 must be configured under the same IS-IS instance.
- Unequal load balancing (UELB) does not apply to IPv6 traffic. While it may still be configured and used for IPv4 traffic, IPv6 traffic does not acknowledge the UELB configuration. However, equal loadsharing works for IPv6.
- Policy-based tunnel selection (PBTS) does not apply for IPv6 traffic. While it may still be configured and used for IPv4 traffic, IPv6 traffic does not acknowledge the PBTS configuration.
- MPLS auto tunnels do not support IPv6 autoroute announce and IPv6 forwarding adjacency configurations.

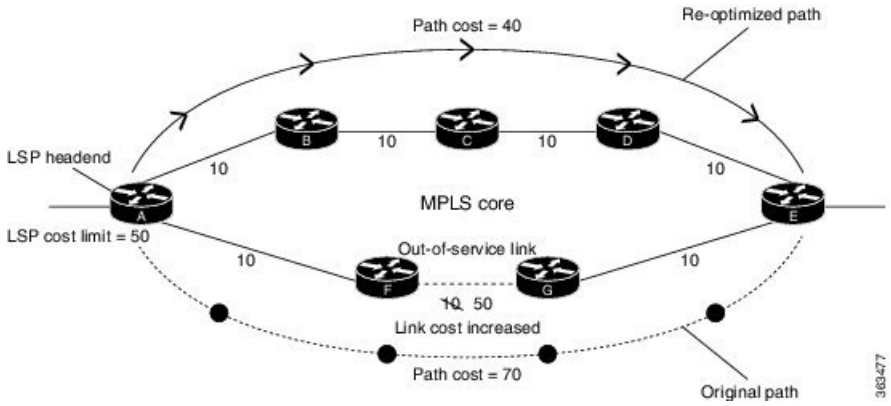
MPLS TE Path Cost Limit

The MPLS TE path cost limit feature enables graceful migration of TE label switched paths (LSPs) away from a link without affecting the traffic. This is useful when a link is scheduled to be decommissioned or brought down for maintenance.

In order to take a link out of service and gracefully migrate the LSPs away from it, the cost assigned to the link is to be set higher than the path cost limit (path aggregate admin-weight) assigned at the LSP headend. The cost of the tunnel is equal to the aggregate cost of the links through which the tunnel passes. The headend routers recalculate the total path costs at the time of periodic path verification. At this stage, the headend routers automatically check if the path limit is crossed and reroute the LSPs away from the out-of-service link.

This sample illustration explains the TE path cost limit application:

Figure 13: MPLS TE path cost limit application



Here, the path cost limit for the LSP is set at 50. To move the LSP away from the link between F and G, the link cost is increased to 50.

For more information on MPLS TE Path Cost Limit, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on MPLS TE Path Cost Limit commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Soft-preemption over FRR Backup Tunnels

The soft-preemption over FRR backup tunnels feature enables to move LSP traffic over the backup tunnels when the LSP is soft- preempted. MPLS TE tunnel soft-preemption allows removal of extra TE traffic in a graceful manner, by giving the preempted LSP a grace period to move away from the link. Though this mechanism saves the traffic of the preempted LSP from being dropped, this might cause traffic drops due to congestion as more bandwidth is reserved on the link than what is available. When the soft-preemption over FRR backup tunnel is enabled, the traffic of the preempted LSP is moved onto the FRR backup, if it is available and ready. This way, the capacity of the backup tunnel is used to remove the potential congestion that might be caused by soft-preemption.

For more information on Soft-Preemption over FRR Backup, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on Soft-Preemption over FRR Backup commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

MPLS TE Auto-tunnel Mesh One-hop

The MPLS TE Auto-tunnel primary one-hop feature allows automatic creation of tunnels over TE enabled interfaces to next hop neighbors. The Auto-tunnel primary one-hop is configurable under the MPLS TE Auto-tunnel mesh group mode and for each mesh group. The Auto-tunnel primary one-hop configuration automatically creates one-hop tunnels to next hop neighbors. A router that becomes a next hop neighbor will have a set of one-hop tunnels created automatically.

For more information on MPLS TE Auto-tunnel Primary One-hop, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*. For more information on MPLS TE Auto-tunnel Primary One-hop commands, see the *MPLS Traffic Engineering Commands* chapter in the *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Inter-area Traffic Engineering with Dynamic ABR Discovery

The inter-area traffic engineering with dynamic ABR discovery feature adds support for inter-area point-to-point (P2P) and point-to-multi-point (P2MP) traffic engineering with dynamic ABR discovery. With this feature, there is no need to specify transit ABR addresses in the explicit paths to allow for dynamic/best path computation for inter-area tunnels.

For more information on Inter-area Traffic Engineering with Dynamic ABR Discovery, see the *Implementing MPLS Traffic Engineering* chapter in the *MPLS Configuration Guide for Cisco ASR 9000 Series Routers*.

Named Tunnel

The Named Tunnel feature provides a simplified and flexible means of naming MPLS-TE tunnels.

In the traditional TE tunnel naming scheme, the tunnels are configured with IDs, where an ID is a 16-bit number. With increased TE tunnel scale in the network, and with the 64K limit, there is scarcity of unique tunnel IDs.

The Named Tunnel feature lets you name the TE tunnels in the network with unique tunnel IDs, which lets you manage the network more efficiently. This feature allows you to provision TE tunnels using STRING names.

For example: TUNNEL-NY-TO-LA

Named Path Option

For a given tunnel, you can configure one or more path options - each identified by a unique name. The path option expresses the preference for the path; lower numbers have a higher preference, with 1 having the highest preference. You can also configure the computation method for the path.

RSVP-TE Bandwidth Accounting

The total interface bandwidth utilization in the data plane, excluding RSVP-TE bandwidth, is called dark bandwidth. A network may have dark bandwidth due to IP, LDP, or segment routing traffic flowing in the network. Dark bandwidth effectively reduces the link bandwidth available to RSVP-TE LSPs.

When segment routing is enabled on the network, you should be aware of the segment routing traffic over the links so that RSVP-TE bandwidth reservations can avoid overbooking the links in the network. The RSVP-TE bandwidth accounting feature allows you to perform proper accounting of the traffic.

You can enable RSVP-TE bandwidth accounting, and start dark bandwidth advertisement based on accounting samples, for all MPLS-TE enabled links using the **bandwidth-accounting** command in MPLS-TE configuration mode.

Computing the Effective Maximum Reservable Bandwidth

The statistics collector process (statsD) is responsible for returning statistics counters for each feature. For each traffic engineering (TE)-enabled interface, the TE process collects new RSVP-TE bandwidth rate statistics (samples) from the statsD process, within a specified sampling interval. These samples are collected over a period of time called an application interval.

After each application interval, the average value of the collected rate samples is used to compute the dark bandwidth rate and the effective maximum reservable bandwidth (Max-Reservable-BW) rate.

The dark bandwidth rate is calculated as total rate - RSVP rate:

- The total rate includes IPv4 , IPv6, and MPLS rate (MPLS includes RSVP/LDP/BGP label packets)
- The RSVP rate includes IPv4/IPv6 encapsulation over tunnel, and MPLS label packet counters for RSVP-TE tunnels

The following example shows how the effective maximum reservable bandwidth (Effective-Max-Reservable-BW) is computed (assuming a link capacity of 10Gbps and a configured RSVP bandwidth of 90%):

- Link capacity = 10Gbps
- Max-reservable-bw = RSVP percentage of link capacity = 9Gbps
- Total rate (from statsD) = 5Gpbs
- RSVP rate (from statsD) = 3Gpbs
- Dark-bw = Total rate - RSVP rate = 2Gpbs
- Effective-Max-Reservable-BW = max-reservable-bw (9Gbps) - dark-bw (2Gbps) = 7Gbps

In this example, the bandwidth available for RSVP-TE LSP admission is 7Gbps. This value is flooded in the network if the flooding threshold is crossed.

Note When you change the RSVP bandwidth percentage configuration or when the bundle capacity changes due to bundle-member state change, TE accounts for the dark bandwidth when new bandwidth values are advertised.

Note The measured dark bandwidth can be increased or decreased based on a configurable adjustment factor.

When the computed dark bandwidth increases for a link, it will lower the max-reservable-bw of that link, which might trigger preemption of the RSVP-TE LSPs. Preemption consists of freeing the resources of an established LSP, and assigning them to a new LSP. The freeing of resources causes a traffic disruption to the LSP that is being preempted.

Note SR-TE LSPs at the head-end are treated with the highest priority and cannot be preempted.

You can apply measured rates immediately using the **bandwidth-accounting apply all** command. When you apply measured rates immediately, the RSVP-TE bandwidth-accounting might flood the updated bandwidth values immediately. Applying measured rates immediately does not affect the periodic application of the bandwidth.

How to Implement Traffic Engineering

Traffic engineering requires coordination among several global neighbor routers, creating traffic engineering tunnels, setting up forwarding across traffic engineering tunnels, setting up FRR, and creating differential service.

These procedures are used to implement MPLS-TE:

Building MPLS-TE Topology

Perform this task to configure MPLS-TE topology (required for traffic engineering tunnel operations).

Before you begin

Before you start to build the MPLS-TE topology, you must have enabled:

- IGP such as OSPF or IS-IS for MPLS-TE.
- MPLS Label Distribution Protocol (LDP).
- RSVP on the port interface.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.
- If you are going to use nondefault holdtime or intervals, you must decide the values to which they are set.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **exit**
5. **exit**
6. **router ospf** *process-name*
7. **area** *area-id*
8. **exit**
9. **mpls traffic-eng router-id** *ip-address*
10. **commit**
11. (Optional) **show mpls traffic-eng topology**
12. (Optional) **show mpls traffic-eng link-management advertisements**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 3	**interface** *type interface-path-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te)#interface POS0/6/0/0`
	`RP/0/RSP0/CPU0:router(config-mpls-te-if)#`
		Enables traffic engineering on a particular interface on the originating node and enters MPLS-TE interface configuration mode.

Step 4	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te-if)# exit`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Exits the current configuration mode.

Step 5	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te)# exit`
	`RP/0/RSP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 6	**router ospf** *process-name* **Example:** `RP/0/RSP0/CPU0:router(config)# router ospf 1`	Enters a name for the OSPF process.
Step 7	**area** *area-id* **Example:** `RP/0/RSP0/CPU0:router(config-router)# area 0`	Configures an area for the OSPF process. • Backbone areas have an area ID of 0. • Non-backbone areas have a non-zero area ID.
Step 8	**exit** **Example:**	Exits the current configuration mode.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-ospf-ar)# exit` `RP/0/RSP0/CPU0:router(config-ospf)#`	
Step 9	**mpls traffic-eng router-id** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-ospf)# mpls traffic-eng router-id 192.168.70.1`	Sets the MPLS-TE loopback interface.
Step 10	**commit**	
Step 11	(Optional) **show mpls traffic-eng topology** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng topology`	Verifies the traffic engineering topology.
Step 12	(Optional) **show mpls traffic-eng link-management advertisements** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng link-management advertisements`	Displays all the link-management advertisements for the links on this node.

Related Topics

How MPLS-TE Works, on page 5
Build MPLS-TE Topology and Tunnels: Example, on page 172

Creating an MPLS-TE Tunnel

Creating an MPLS-TE tunnel is a process of customizing the traffic engineering to fit your network topology.

Perform this task to create an MPLS-TE tunnel after you have built the traffic engineering topology.

Before you begin

The following prerequisites are required to create an MPLS-TE tunnel:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.
- If you are going to use nondefault holdtime or intervals, you must decide the values to which they are set.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **destination** *ip-address*
4. **ipv4 unnumbered** *type interface-path-id*
5. **path-option** *preference - priority* **dynamic**
6. **signalled- bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*}
7. **commit**
8. (Optional) **show mpls traffic-eng tunnels**
9. (Optional) **show ipv4 interface brief**
10. (Optional) **show mpls traffic-eng link-management admission-control**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**destination** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-if)# destination 192.168.92.125`	Assigns a destination address on the new tunnel. The destination address is the remote node's MPLS-TE router ID.
Step 4	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.
Step 5	**path-option** *preference - priority* **dynamic** **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 dynamic`	Sets the path option to dynamic and assigns the path ID.

	Command or Action	Purpose
Step 6	**signalled- bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RSP0/CPU0:router(config-if)# signalled-bandwidth 100`	Sets the CT0 bandwidth required on this interface. Because the default tunnel priority is 7, tunnels use the default TE class map (namely, class-type 1, priority 7).
Step 7	**commit**	
Step 8	(Optional) **show mpls traffic-eng tunnels** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels`	Verifies that the tunnel is connected (in the UP state) and displays all configured TE tunnels.
Step 9	(Optional) **show ipv4 interface brief** **Example:** `RP/0/RSP0/CPU0:router# show ipv4 interface brief`	Displays all TE tunnel interfaces.
Step 10	(Optional) **show mpls traffic-eng link-management admission-control** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng link-management admission-control`	Displays all the tunnels on this node.

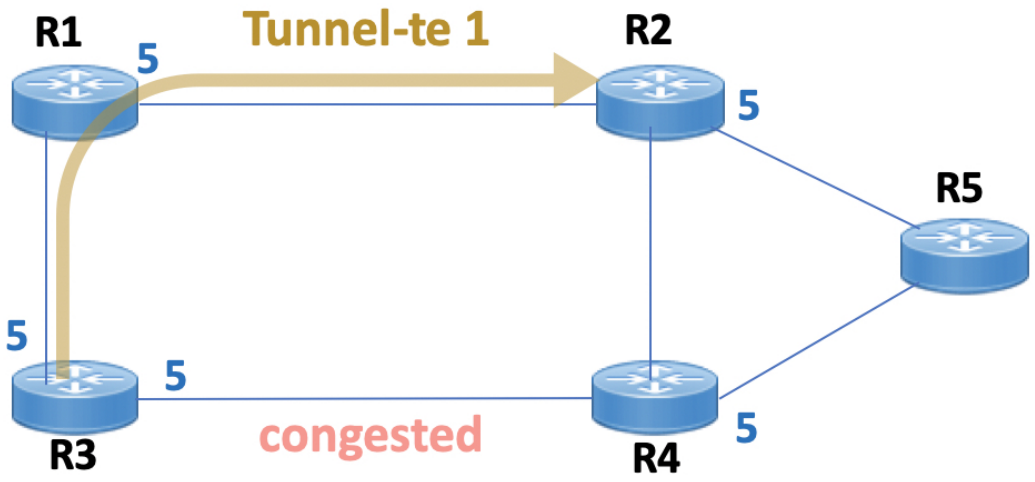
Related Topics

How MPLS-TE Works, on page 5
Build MPLS-TE Topology and Tunnels: Example, on page 172
Building MPLS-TE Topology, on page 61

Automatic Modification Of An MPLS-TE Tunnel's Metric

If the IGP calculation on a router results in an equal cost multipath (ECMP) scenario where next-hop interfaces are a mix of MPLS-TE tunnels and physical interfaces, you may want to ensure that a TE tunnel is preferred. Consider this topology:

Figure 14: MPLS-TE Tunnel



1. All links in the network have a metric of 5.
2. To offload a congested link between R3 and R4, an MPLS-TE tunnel is created from R3 to R2.
3. If the metric of the tunnel is also 5, traffic from R3 to R5 is load-balanced between the tunnel and the physical R3-R4 link.

To ensure that the MPLS-TE tunnel is preferred in such scenarios, configure the **autoroute metric** command on the tunnel interface. The modified metric is applied in the routing information base (RIB), and the tunnel is preferred over the physical path of the same metric. Sample configuration:

```
Router# configure
Router(config)# interface tunnel-te 1
Router(config-if)# autoroute metric relative -1
```

The **autoroute metric** command syntax is **autoroute metric** {**absolute**|**relative**} *value*

- **absolute** enables the absolute metric mode, for a metric range between 1 and 2147483647.
- **relative** enables the relative metric mode, for a metric range between -10 and 10, including zero.

Note Since the **relative** metric is not saved in the IGP database, the advertised metric of the MPLS-TE tunnel remains 5, and doesn't affect SPF calculation outcomes on other nodes.

Configuring Forwarding over the MPLS-TE Tunnel

Perform this task to configure forwarding over the MPLS-TE tunnel created in the previous task . This task allows MPLS packets to be forwarded on the link between network neighbors.

Before you begin

The following prerequisites are required to configure forwarding over the MPLS-TE tunnel:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.

Note From the 7.1.1 release, IS-IS autoroute announce function is enhanced to redirect traffic from a source IP address prefix to a matching IP address assigned to an MPLS-TE tunnel destination interface.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **autoroute announce**
5. **exit**
6. **router static address-family ipv4 unicast** *prefix mask ip-address interface type*
7. **commit**
8. (Optional) **ping** {*ip-address* | *hostname*}
9. (Optional) **show mpls traffic-eng autoroute**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 1`	Enters MPLS-TE interface configuration mode.
Step 3	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address so that forwarding can be performed on the new tunnel.
Step 4	**autoroute announce** **Example:**	Enables messages that notify the neighbor nodes about the routes that are forwarding.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-if)# autoroute announce`	
Step 5	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-if)# exit`	Exits the current configuration mode.
Step 6	**router static address-family ipv4 unicast** *prefix mask ip-address interface type* **Example:** `RP/0/RSP0/CPU0:router(config)# router static address-family ipv4 unicast 172.16.0.1/32 tunnel-te 1`	Enables a route using IP version 4 addressing, identifies the destination address and the tunnel where forwarding is enabled. This configuration is used for static routes when the **autoroute announce** command is not used.
Step 7	**commit**	
Step 8	(Optional) **ping** {*ip-address* | *hostname*} **Example:** `RP/0/RSP0/CPU0:router# ping 192.168.12.52`	Checks for connectivity to a particular IP address or host name.
Step 9	(Optional) **show mpls traffic-eng autoroute** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng autoroute`	Verifies forwarding by displaying what is advertised to IGP for the TE tunnel.

Related Topics

Overview of MPLS Traffic Engineering, on page 3
Creating an MPLS-TE Tunnel, on page 63

Protecting MPLS Tunnels with Fast Reroute

Perform this task to protect MPLS-TE tunnels, as created in the previous task.

Note Although this task is similar to the previous task, its importance makes it necessary to present as part of the tasks required for traffic engineering on Cisco IOS XR software.

Before you begin

The following prerequisites are required to protect MPLS-TE tunnels:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.
- You must first configure a primary tunnel.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **fast-reroute**
4. **exit**
5. **mpls traffic-eng**
6. **interface** *type interface-path-id*
7. **backup-path tunnel-te** *tunnel-number*
8. **exit**
9. **exit**
10. **interface tunnel-te** *tunnel-id*
11. **backup-bw** {*backup bandwidth* | **sub-pool** {*bandwidth* | **unlimited**} | **global-pool** {*bandwidth* | **unlimited**} }
12. **ipv4 unnumbered** *type interface-path-id*
13. **path-option** *preference-priority* {**explicit name** *explicit-path-name*}
14. **destination** *ip-address*
15. **commit**
16. (Optional) **show mpls traffic-eng tunnels backup**
17. (Optional) **show mpls traffic-eng tunnels protection frr**
18. (Optional) **show mpls traffic-eng fast-reroute database**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**fast-reroute** **Example:**	Enables fast reroute.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-if)# fast-reroute`	
Step 4	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-if)# exit`	Exits the current configuration mode.

Step 5	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 6	**interface** *type interface-path-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te)# interface pos0/6/0/0`
	`RP/0/RSP0/CPU0:router(config-mpls-te-if)#`
		Enables traffic engineering on a particular interface on the originating node.

Step 7	**backup-path tunnel-te** *tunnel-number* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# backup-path tunnel-te 2`	Sets the backup path to the backup tunnel.

Step 8	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te-if)# exit`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Exits the current configuration mode.

Step 9	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te)# exit`
	`RP/0/RSP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 10	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.

	Command or Action	Purpose
Step 11	**backup-bw** {*backup bandwidth* | **sub-pool** {*bandwidth* | **unlimited**} | **global-pool** {*bandwidth* | **unlimited**} } **Example:** `RP/0/RSP0/CPU0:router(config-if)#backup-bw global-pool 5000`	Sets the CT0 bandwidth required on this interface. **Note** Because the default tunnel priority is 7, tunnels use the default TE class map.
Step 12	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address to set up forwarding on the new tunnel.
Step 13	**path-option** *preference-priority* {**explicit name** *explicit-path-name*} **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 explicit name backup-path`	Sets the path option to explicit with a given name (previously configured) and assigns the path ID.
Step 14	**destination** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-if)# destination 192.168.92.125`	Assigns a destination address on the new tunnel. • Destination address is the remote node's MPLS-TE router ID. • Destination address is the merge point between backup and protected tunnels. **Note** When you configure TE tunnel with multiple protection on its path and merge point is the same node for more than one protection, you must configure record-route for that tunnel.
Step 15	**commit**	
Step 16	(Optional) **show mpls traffic-eng tunnels backup** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels backup`	Displays the backup tunnel information.
Step 17	(Optional) **show mpls traffic-eng tunnels protection frr** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng`	Displays the tunnel protection information for Fast-Reroute (FRR).

	Command or Action	Purpose
	`tunnels protection frr`	
Step 18	(Optional) **show mpls traffic-eng fast-reroute database** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng fast-reroute database`	Displays the protected tunnel state (for example, the tunnel's current ready or active state).

Related Topics

Fast Reroute, on page 13
Fast Reroute Node Protection, on page 18
Creating an MPLS-TE Tunnel, on page 63
Configuring Forwarding over the MPLS-TE Tunnel , on page 66

Enabling an AutoTunnel Backup

Perform this task to configure the AutoTunnel Backup feature. By default, this feature is disabled. You can configure the AutoTunnel Backup feature for each interface. It has to be explicitly enabled for each interface or link.

SUMMARY STEPS

1. **configure**
2. **ipv4 unnumbered mpls traffic-eng Loopback** *0*
3. **mpls traffic-eng**
4. **auto-tunnel backup timers removal unused** *frequency*
5. **auto-tunnel backup tunnel-id min** *min***max** *max*
6. **commit**
7. **show mpls traffic-eng auto-tunnel backup summary**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**ipv4 unnumbered mpls traffic-eng Loopback** *0* **Example:** `RP/0/RSP0/CPU0:router(config)#ipv4 unnumbered mpls traffic-eng Loopback 0`	Configures the globally configured IPv4 address that can be used by the AutoTunnel Backup Tunnels. **Note** Loopback 0 is the router ID. The AutoTunnel Backup tunnels will not come up until a global IPv4 address is configured.

	Command or Action	Purpose
Step 3	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 4	**auto-tunnel backup timers removal unused** *frequency* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-tunnel backup timers removal unused 20`	Configures how frequently a timer scans the backup automatic tunnels and removes tunnels that are not in use. • Use the frequency argument to scan the backup automatic tunnel. Range is 0 to 10080. **Note** You can also configure the auto-tunnel backup command at mpls traffic-eng interface mode.
Step 5	**auto-tunnel backup tunnel-id min** *min***max** *max* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-tunnel backup tunnel-id min 6000 max 6500`	Configures the range of tunnel interface numbers to be used for automatic backup tunnels. Range is 0 to 65535.
Step 6	**commit**	
Step 7	**show mpls traffic-eng auto-tunnel backup summary** **Example:** RP/0/RSP0/CPU0:router# show mpls traffic-eng auto-tunnel backup summary	Displays information about configured MPLS-TE backup autotunnels.

Related Topics

Backup AutoTunnels, on page 6
Configure the MPLS-TE Auto-Tunnel Backup: Example, on page 187

Removing an AutoTunnel Backup

To remove all the backup autotunnels, perform this task to remove the AutoTunnel Backup feature.

SUMMARY STEPS

1. **clear mpls traffic-eng auto-tunnel backup unused** { **all** | **tunnel-te***number*}
2. **commit**
3. **show mpls traffic-eng auto-tunnel summary**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**clear mpls traffic-eng auto-tunnel backup unused** { **all** | **tunnel-te***number*} **Example:** `RP/0/RSP0/CPU0:router# clear mpls traffic-eng auto-tunnel backup unused all`	Clears all MPLS-TE automatic backup tunnels from the EXEC mode. You can also remove the automatic backup tunnel marked with specific tunnel-te, provided it is currently unused.
Step 2	**commit**	
Step 3	**show mpls traffic-eng auto-tunnel summary** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng auto-tunnel summary`	Displays information about MPLS-TE autotunnels including the ones removed.

Related Topics

Backup AutoTunnels, on page 6
Configure the MPLS-TE Auto-Tunnel Backup: Example, on page 187

Establishing MPLS Backup AutoTunnels to Protect Fast Reroutable TE LSPs

To establish an MPLS backup autotunnel to protect fast reroutable TE LSPs, perform these steps:

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **auto-tunnel backup**
5. **attribute-set** *attribute-set-name*
6. **commit**
7. **show mpls traffic-eng auto-tunnel backup summary**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# interface POS 0/6/0/0`	Enables traffic engineering on a specific interface on the originating node.
Step 4	**auto-tunnel backup** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# auto-tunnel backup`	Enables an auto-tunnel backup feature for the specified interface. **Note** You cannot configure the static backup on the similar link.
Step 5	**attribute-set** *attribute-set-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if-auto-backup)#attribute-set ab`	Configures attribute-set template for auto-tunnel backup tunnels.
Step 6	**commit**	
Step 7	**show mpls traffic-eng auto-tunnel backup summary** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic auto-tunnel backup summary`	Displays information about configured MPLS-TE backup autotunnels.

Related Topics

Backup AutoTunnels, on page 6
Configure the MPLS-TE Auto-Tunnel Backup: Example, on page 187

Establishing Next-Hop Tunnels with Link Protection

To establish a next-hop tunnel and link protection on the primary tunnel, perform these steps:

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **auto-tunnel backup nhop-only**
5. **auto-tunnel backup exclude srlg** [preferred]
6. **attribute-set** *attribute-set-name*
7. **commit**
8. **show mpls traffic-eng tunnels** *number* **detail**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# interface POS 0/6/0/0`	Enables traffic engineering on a specific interface on the originating node.
Step 4	**auto-tunnel backup nhop-only** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# auto-tunnel backup nhop-only`	Enables the creation of dynamic NHOP backup tunnels. By default, both NHOP and NNHOP protection are enabled. **Note** Using this nhop-only option, only link protection is provided.
Step 5	**auto-tunnel backup exclude srlg** [preferred] **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# auto-tunnel backup exclude srlg preferred`	Enables the exclusion of SRLG values on a given link for the AutoTunnel backup associated with a given interface. The preferred option allows the AutoTunnel Backup tunnels to come up even if no path excluding all SRLG is found.
Step 6	**attribute-set** *attribute-set-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if-auto-backup)#attribute-set ab`	Configures attribute-set template for auto-tunnel backup tunnels.
Step 7	**commit**	
Step 8	**show mpls traffic-eng tunnels** *number* **detail** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 1 detail`	Displays information about configured NHOP tunnels and SRLG information.

Related Topics

Backup AutoTunnels, on page 6
Configure the MPLS-TE Auto-Tunnel Backup: Example, on page 187

Configuring a Prestandard DS-TE Tunnel

Perform this task to configure a Prestandard DS-TE tunnel.

Before you begin

The following prerequisites are required to configure a Prestandard DS-TE tunnel:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.

SUMMARY STEPS

1. **configure**
2. **rsvp interface** *type interface-path-id*
3. **bandwidth** [*total reservable bandwidth*] [**bc0** *bandwidth*] [**global-pool** *bandwidth*] [**sub-pool** *reservable-bw*]
4. **exit**
5. **exit**
6. **interface tunnel-te** *tunnel-id*
7. **signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*}
8. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config)# rsvp interface pos0/6/0/0`	Enters RSVP configuration mode and selects an RSVP interface.
Step 3	**bandwidth** [*total reservable bandwidth*] [**bc0** *bandwidth*] [**global-pool** *bandwidth*] [**sub-pool** *reservable-bw*] **Example:** `RP/0/RSP0/CPU0:router(config-rsvp-if)# bandwidth 100 150 sub-pool 50`	Sets the reserved RSVP bandwidth available on this interface by using the prestandard DS-TE mode. The range for the *total reserve bandwidth* argument is 0 to 4294967295. Physical interface bandwidth is not used by MPLS-TE.

Step 4	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RSP0/CPU0:router(config-rsvp)#`
		Exits the current configuration mode.

	Command or Action	Purpose

Step 5	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-rsvp)# exit`
	`RP/0/RSP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 6	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 7	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RSP0/CPU0:router(config-if)# signalled-bandwidth sub-pool 10`	Sets the bandwidth required on this interface. Because the default tunnel priority is 7, tunnels use the default TE class map (namely, class-type 1, priority 7).
Step 8	**commit**	

Related Topics

Configuring Traffic Engineering Tunnel Bandwidth
Prestandard DS-TE Mode, on page 10
Configure IETF DS-TE Tunnels: Example, on page 173

Configuring an IETF DS-TE Tunnel Using RDM

Perform this task to create an IETF mode DS-TE tunnel using RDM.

Before you begin

The following prerequisites are required to create an IETF mode DS-TE tunnel using RDM:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.

SUMMARY STEPS

1. **configure**
2. **rsvp interface** *type interface-path-id*
3. **bandwidth rdm** {*total-reservable-bw* | **bc0** | **global-pool**} {**sub-pool** | **bc1** *reservable-bw*}
4. **exit**

5. **exit**
6. **mpls traffic-eng**
7. **ds-te mode ietf**
8. **exit**
9. **interface tunnel-te** *tunnel-id*
10. **signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*}
11. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config)# rsvp interface pos0/6/0/0`	Enters RSVP configuration mode and selects an RSVP interface.
Step 3	**bandwidth rdm** {*total-reservable-bw* | **bc0** | **global-pool**} {**sub-pool** | **bc1** *reservable-bw*} **Example:** `RP/0/RSP0/CPU0:router(config-rsvp-if)# bandwidth rdm 100 150`	Sets the reserved RSVP bandwidth available on this interface by using the Russian Doll Model (RDM) bandwidth constraints model. The range for the *total reserve bandwidth* argument is 0 to 4294967295. **Note** Physical interface bandwidth is not used by MPLS-TE.

Step 4	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RSP0/CPU0:router(config-rsvp)`
		Exits the current configuration mode.

Step 5	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-rsvp) exit`
	`RP/0/RSP0/CPU0:router(config)`
		Exits the current configuration mode.

Step 6	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 7	**ds-te mode ietf** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# ds-te mode ietf`	Enables IETF DS-TE mode and default TE class map. IETF DS-TE mode is configured on all network nodes.
Step 8	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.

Step 9	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-te 4`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface.

Step 10	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RSP0/CPU0:router(config-if)# signalled-bandwidth 10 class-type 1`	Configures the bandwidth required for an MPLS TE tunnel. Because the default tunnel priority is 7, tunnels use the default TE class map (namely, class-type 1, priority 7).
Step 11	**commit**	

Related Topics

Configuring Traffic Engineering Tunnel Bandwidth
Russian Doll Bandwidth Constraint Model, on page 11

Configuring an IETF DS-TE Tunnel Using MAM

Perform this task to configure an IETF mode differentiated services traffic engineering tunnel using the Maximum Allocation Model (MAM) bandwidth constraint model.

Before you begin

The following prerequisites are required to configure an IETF mode differentiated services traffic engineering tunnel using the MAM bandwidth constraint model:

- You must have a router ID for the neighboring router.
- Stable router ID is required at either end of the link to ensure that the link is successful. If you do not assign a router ID to the routers, the system defaults to the global router ID. Default router IDs are subject to change, which can result in an unstable link.

SUMMARY STEPS

1. **configure**
2. **rsvp interface** *type interface-path-id*
3. **bandwidth mam** {*total reservable bandwidth* | **max-reservable-bw** *maximum-reservable-bw*} [**bc0** *reservable bandwidth*] [**bc1** *reservable bandwidth*]
4. **exit**
5. **exit**
6. **mpls traffic-eng**
7. **ds-te mode ietf**
8. **ds-te bc-model mam**
9. **exit**
10. **interface tunnel-te** *tunnel-id*
11. **signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*}
12. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config)# rsvp interface pos0/6/0/0`	Enters RSVP configuration mode and selects the RSVP interface.
Step 3	**bandwidth mam** {*total reservable bandwidth*	**max-reservable-bw** *maximum-reservable-bw*} [**bc0** *reservable bandwidth*] [**bc1** *reservable bandwidth*] **Example:** `RP/0/RSP0/CPU0:router(config-rsvp-if)# bandwidth mam max-reservable-bw 400 bc0 300 bc1 200`	Sets the reserved RSVP bandwidth available on this interface. **Note** Physical interface bandwidth is not used by MPLS-TE.

Step 4	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RSP0/CPU0:router(config-rsvp)#`
		Exits the current configuration mode.

Step 5	**exit** **Example:**	Exits the current configuration mode.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-rsvp)# exit` `RP/0/RSP0/CPU0:router(config)#`	

Step 6	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 7	**ds-te mode ietf** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# ds-te mode ietf`	Enables IETF DS-TE mode and default TE class map. Configure IETF DS-TE mode on all nodes in the network.
Step 8	**ds-te bc-model mam** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# ds-te bc-model mam`	Enables the MAM bandwidth constraint model globally.
Step 9	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.

Step 10	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-te 4`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface.

Step 11	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RSP0/CPU0:router(config-rsvp-if)# signalled-bandwidth 10 class-type 1`	Configures the bandwidth required for an MPLS TE tunnel. Because the default tunnel priority is 7, tunnels use the default TE class map (namely, class-type 1, priority 7).
Step 12	**commit**	

Related Topics

Configuring Traffic Engineering Tunnel Bandwidth
Maximum Allocation Bandwidth Constraint Model, on page 11

Configuring MPLS -TE and Fast-Reroute on OSPF

Perform this task to configure MPLS-TE and Fast Reroute (FRR) on OSPF.

Before you begin

Note Only point-to-point (P2P) interfaces are supported for OSPF multiple adjacencies. These may be either native P2P interfaces or broadcast interfaces on which the **OSPF P2P configuration** command is applied to force them to behave as P2P interfaces as far as OSPF is concerned. This restriction does not apply to IS-IS.

The tunnel-te interface is not supported under IS-IS.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **path-option** [**protecting**] *preference-priority* {**dynamic** [**pce** [**address ipv4** *address*] | **explicit** {**name** *pathname* | **identifier** *path-number* } } [**isis** *instance name* {**level** *level*}] [**ospf** *instance name* {**area** *area ID*}]] [**verbatim**] [**lockdown**]
4. Repeat Step 3 as many times as needed.
5. **commit**
6. **show mpls traffic-eng tunnels** [*tunnel-number*]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-te 1`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface. The range for the tunnel ID number is 0 to 65535.

Step 3	**path-option** [**protecting**] *preference-priority* {**dynamic** [**pce** [**address ipv4** *address*] | **explicit** {**name** *pathname* | **identifier** *path-number* } } [**isis** *instance name* {**level** *level*}] [**ospf** *instance name* {**area** *area ID*}]] [**verbatim**] [**lockdown**]	Configures an explicit path option for an MPLS-TE tunnel. OSPF is limited to a single OSPF instance and area.

	Command or Action	Purpose
	Example: `RP/0/RSP0/CPU0:router(config-if)# path-option 1 explicit identifier 6 ospf green area 0`	
Step 4	Repeat Step 3 as many times as needed. **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 2 explicit name 234 ospf 3 area 7 verbatim`	Configures another explicit path option.
Step 5	**commit**	
Step 6	**show mpls traffic-eng tunnels** [*tunnel-number*] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 1`	Displays information about MPLS-TE tunnels.

Configuring the Ignore Integrated IS-IS Overload Bit Setting in MPLS-TE

Perform this task to configure an overload node avoidance in MPLS-TE. When the overload bit is enabled, tunnels are brought down when the overload node is found in the tunnel path.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **path-selection ignore overload {head | mid | tail}**
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 3	**path-selection ignore overload {head | mid | tail}** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# path-selection ignore overload head`	Ignores the Intermediate System-to-Intermediate System (IS-IS) overload bit setting for MPLS-TE. If **set-overload-bit** is set by IS-IS on the head router, the tunnels stay up.
Step 4	**commit**	

Related Topics

Ignore Intermediate System-to-Intermediate System Overload Bit Setting in MPLS-TE, on page 14
Configure the Ignore IS-IS Overload Bit Setting in MPLS-TE: Example, on page 174

Configuring Flexible Name-based Tunnel Constraints

To fully configure MPLS-TE flexible name-based tunnel constraints, you must complete these high-level tasks in order:

1. Assigning Color Names to Numeric Values, on page 85
2. Associating Affinity-Names with TE Links, on page 86
3. Associating Affinity Constraints for TE Tunnels, on page 87

Assigning Color Names to Numeric Values

The first task in enabling the new coloring scheme is to assign a numerical value (in hexadecimal) to each value (color).

Note An affinity color name cannot exceed 64 characters. An affinity value cannot exceed a single digit. For example, magenta1.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **affinity-map** *affinity name* {*affinity value* | **bit-position** *value*}
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 3	**affinity-map** *affinity name* {*affinity value* | **bit-position** *value*} **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# affinity-map red 1`	Enters an affinity name and a map value by using a color name (repeat this command to assign multiple colors up to a maximum of 64 colors). An affinity color name cannot exceed 64 characters. The value you assign to a color name must be a single digit.
Step 4	**commit**	

Related Topics

Flexible Name-based Tunnel Constraints, on page 15
Configure Flexible Name-based Tunnel Constraints: Example, on page 175

Associating Affinity-Names with TE Links

The next step in the configuration of MPLS-TE Flexible Name-based Tunnel Constraints is to assign affinity names and values to TE links. You can assign up to a maximum of 32 colors. Before you assign a color to a link, you must define the name-to-value mapping for each color.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **attribute-names** *attribute name*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

	Command or Action	Purpose

Step 3	**interface** *type interface-path-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mpls-te)# interface tunnel-te 2`
	`RP/0/RSP0/CPU0:router(config-mpls-te-if)#`
		Enables MPLS-TE on an interface and enters MPLS-TE interface configuration mode.

Step 4	**attribute-names** *attribute name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# attribute-names red`	Assigns colors to TE links over the selected interface.
Step 5	**commit**	

Related Topics

Flexible Name-based Tunnel Constraints, on page 15
Configure Flexible Name-based Tunnel Constraints: Example, on page 175
Assigning Color Names to Numeric Values, on page 85

Associating Affinity Constraints for TE Tunnels

The final step in the configuration of MPLS-TE Flexible Name-based Tunnel Constraints requires that you associate a tunnel with affinity constraints.

Using this model, there are no masks. Instead, there is support for four types of affinity constraints:

- include
- include-strict
- exclude
- exclude-all

Note For the affinity constraints above, all but the exclude-all constraint may be associated with up to 10 colors.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **affinity** {*affinity-value* **mask** *mask-value* | **exclude** *name* | **exclude -all** | **include** *name* | **include-strict** *name*}
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**affinity** {*affinity-value* **mask** *mask-value* | **exclude** *name* | **exclude -all** | **include** *name* | **include-strict** *name*} **Example:** `RP/0/RSP0/CPU0:router(config-if)# affinity include red`	Configures link attributes for links comprising a tunnel. You can have up to ten colors. Multiple include statements can be specified under tunnel configuration. With this configuration, a link is eligible for CSPF if it has at least a red color or has at least a green color. Thus, a link with red and any other colors as well as a link with green and any additional colors meet the above constraint.
Step 4	**commit**	

Related Topics

Flexible Name-based Tunnel Constraints, on page 15
Configure Flexible Name-based Tunnel Constraints: Example, on page 175

Configuring IS-IS to Flood MPLS-TE Link Information

Perform this task to configure a router running the Intermediate System-to-Intermediate System (IS-IS) protocol to flood MPLS-TE link information into multiple IS-IS levels.

This procedure shows how to enable MPLS-TE in both IS-IS Level 1 and Level 2.

SUMMARY STEPS

1. **configure**
2. **router isis** *instance-id*
3. **net** *network-entity-title*
4. **address-family** {**ipv4** | **ipv6**} {**unicast**}
5. **mpls traffic-eng tunnel restricted**
6. **metric-style wide**
7. **mpls traffic-eng** *level*
8. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**router isis** *instance-id* **Example:** `RP/0/RSP0/CPU0:router(config)# router isis 1`	Enters an IS-IS instance.
Step 3	**net** *network-entity-title* **Example:** `RP/0/RSP0/CPU0:router(config-isis)# net 47.0001.0000.0000.0002.00`	Enters an IS-IS network entity title (NET) for the routing process.
Step 4	**address-family** {**ipv4** | **ipv6**} {**unicast**} **Example:** `RP/0/RSP0/CPU0:router(config-isis)# address-family ipv4 unicast`	Enters address family configuration mode for configuring IS-IS routing that uses IPv4 and IPv6 address prefixes.
Step 5	**mpls traffic-eng tunnel restricted** **Example:** `RP/0/RSP0/CPU0:router(config-isis-af)# mpls traffic-eng tunnel restricted`	(Optional) Steers traffic from MPLS-TE tunnel source IP address prefixes towards matching IP addresses assigned on MPLS-TE tunnel destination interfaces.
Step 6	**metric-style wide** **Example:** `RP/0/RSP0/CPU0:router(config-isis-af)# metric-style wide`	Enters the new-style type, length, and value (TLV) objects.
Step 7	**mpls traffic-eng** *level* **Example:** `RP/0/RSP0/CPU0:router(config-isis-af)# mpls traffic-eng level-1-2`	Enters the required MPLS-TE level or levels.
Step 8	**commit**	

Configuring an OSPF Area of MPLS-TE

Perform this task to configure an OSPF area for MPLS-TE in both the OSPF backbone area 0 and area 1.

SUMMARY STEPS

1. **configure**
2. **router ospf** *process-name*
3. **mpls traffic-eng router-id** *ip-address*
4. **area** *area-id*
5. **interface** *type interface-path-id*
6. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**router ospf** *process-name* **Example:** `RP/0/RSP0/CPU0:router(config)# router ospf 100`	Enters a name that uniquely identifies an OSPF routing process. ***process-name*** Any alphanumeric string no longer than 40 characters without spaces.
Step 3	**mpls traffic-eng router-id** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-ospf)# mpls traffic-eng router-id 192.168.70.1`	Enters the MPLS interface type. For more information, use the question mark (?) online help function.
Step 4	**area** *area-id* **Example:** `RP/0/RSP0/CPU0:router(config-ospf)# area 0`	Enters an OSPF area identifier. ***area-id*** Either a decimal value or an IP address.
Step 5	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-ospf-ar)# interface POS 0/2/0/0`	Identifies an interface ID. For more information, use the question mark (?) online help function.
Step 6	**commit**	

Configuring Explicit Paths with ABRs Configured as Loose Addresses

Perform this task to specify an IPv4 explicit path with ABRs configured as loose addresses.

SUMMARY STEPS

1. **configure**
2. **explicit-path name** *name*
3. **index** *index-id* **next-address** [**loose**] **ipv4 unicast** *ip-address*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**explicit-path name** *name* **Example:** `RP/0/RSP0/CPU0:router(config)# explicit-path name interarea1`	Enters a name for the explicit path.
Step 3	**index** *index-id* **next-address** [**loose**] **ipv4 unicast** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-expl-path)# index 1 next-address loose ipv4 unicast 10.10.10.10`	Includes an address in an IP explicit path of a tunnel.
Step 4	**commit**	

Configuring MPLS-TE Forwarding Adjacency

Perform this task to configure forwarding adjacency on a specific tunnel-te interface.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **forwarding-adjacency holdtime** *value*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 1`	Enters MPLS-TE interface configuration mode.
Step 3	**forwarding-adjacency holdtime** *value* **Example:** `RP/0/RSP0/CPU0:router(config-if)# forwarding-adjacency holdtime 60`	Configures forwarding adjacency using an optional specific holdtime value. By default, this value is 0 (milliseconds).
Step 4	**commit**	

Related Topics

MPLS-TE Forwarding Adjacency Benefits, on page 19
Configure Forwarding Adjacency: Example, on page 178

Configuring a Path Computation Client and Element

Perform these tasks to configure Path Comptation Client (PCC) and Path Computation Element (PCE):

- Configuring a Path Computation Client, on page 92
- Configuring a Path Computation Element Address, on page 93
- Configuring PCE Parameters, on page 94

Configuring a Path Computation Client

Perform this task to configure a TE tunnel as a PCC.

Note Only one TE-enabled IGP instance can be used at a time.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **path-option** *preference-priority* **dynamic pce**

4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 6`	Enters MPLS-TE interface configuration mode and enables traffic engineering on a particular interface on the originating node.
Step 3	**path-option** *preference-priority* **dynamic pce** **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 dynamic pce`	Configures a TE tunnel as a PCC.
Step 4	**commit**	

Related Topics

Path Computation Element, on page 20
Configure PCE: Example, on page 178

Configuring a Path Computation Element Address

Perform this task to configure a PCE address.

Note Only one TE-enabled IGP instance can be used at a time.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **pce address ipv4** *address*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters the MPLS-TE configuration mode.
Step 3	**pce address ipv4** *address* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce address ipv4 10.1.1.1`	Configures a PCE IPv4 address.
Step 4	**commit**	

Related Topics

Path Computation Element, on page 20
Configure PCE: Example, on page 178

Configuring PCE Parameters

Perform this task to configure PCE parameters, including a static PCE peer, periodic reoptimization timer values, and request timeout values.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **pce address ipv4** *address*
4. **pce peer ipv4** *address*
5. **pce keepalive** *interval*
6. **pce deadtimer** *value*
7. **pce reoptimize** *value*
8. **pce request-timeout** *value*
9. **pce tolerance keepalive** *value*
10. **commit**
11. **show mpls traffic-eng pce peer** [*address* | **all**]
12. **show mpls traffic-eng pce tunnels**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**pce address ipv4** *address* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce address ipv4 10.1.1.1`	Configures a PCE IPv4 address.
Step 4	**pce peer ipv4** *address* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce peer address ipv4 10.1.1.1`	Configures a static PCE peer address. PCE peers are also discovered dynamically through OSPF or ISIS.
Step 5	**pce keepalive** *interval* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce keepalive 10`	Configures a PCEP keepalive interval. The range is from 0 to 255 seconds. When the keepalive interval is 0, the LSR does not send keepalive messages.
Step 6	**pce deadtimer** *value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce deadtimer 50`	Configures a PCE deadtimer value. The range is from 0 to 255 seconds. When the dead interval is 0, the LSR does not timeout a PCEP session to a remote peer.
Step 7	**pce reoptimize** *value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce reoptimize 200`	Configures a periodic reoptimization timer value. The range is from 60 to 604800 seconds. When the dead interval is 0, the LSR does not timeout a PCEP session to a remote peer.

	Command or Action	Purpose
Step 8	**pce request-timeout** *value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce request-timeout 10`	Configures a PCE request-timeout. Range is from 5 to 100 seconds. PCC or PCE keeps a pending path request only for the request-timeout period.
Step 9	**pce tolerance keepalive** *value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# pce tolerance keepalive 10`	Configures a PCE tolerance keepalive value (which is the minimum acceptable peer proposed keepalive).
Step 10	**commit**	
Step 11	**show mpls traffic-eng pce peer** [*address* | **all**] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng pce peer`	Displays the PCE peer address and state.
Step 12	**show mpls traffic-eng pce tunnels** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng pce tunnels`	Displays the status of the PCE tunnels.

Related Topics

Path Computation Element, on page 20
Configure PCE: Example, on page 178

Configuring Fast Repair

Perform this task to configure fast repair to minimize the tunnel down time.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **pce**
4. **stateful-client**
5. **fast-repair**
6. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters Global Configuration mode.
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**pce** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#pce`	Enters PCE configuration mode.
Step 4	**stateful-client** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce)#stateful-client`	Enters stateful PCE client configuration mode. When the stateful-client configuration is added to the node, it will close all existing PCEP peer connections, and add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment. When the stateful-client configuration is removed from the node, it will delete all PCE instantiated tunnels, close all existing PCEP connections, and no longer add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment.
Step 5	**fast-repair** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce-stateful)#fast-repair`	Configures fast repair.
Step 6	**commit**	

Enabling PCEP Cisco Extension

Perform this task to enable PCEP Cisco extension.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **pce**
4. **stateful-client**
5. **cisco-extension**
6. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters Global Configuration mode.
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**pce** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#pce`	Enters PCE configuration mode.
Step 4	**stateful-client** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce)#stateful-client`	Enters stateful PCE client configuration mode. When the stateful-client configuration is added to the node, it will close all existing PCEP peer connections, and add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment. When the stateful-client configuration is removed from the node, it will delete all PCE instantiated tunnels, close all existing PCEP connections, and no longer add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment.
Step 5	**cisco-extension** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce-stateful)#cisco-extension`	Enables PCEP Cisco extension.
Step 6	**commit**	

Configuring MPLS-TE LSP Timers

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
MPLS-TE: Backoff Timer	Release 7.3.2	In case of an LSP error on a head-end router, this feature introduces the flexibility to either set a timer for the router to retry sending traffic, or resend traffic across a different LSP without a waiting period. New command: • **mpls traffic-eng timers backoff-timer**

When an LSP path error occurs, the head-end router attempts to send traffic over the LSP after a 3-second interval. The router continues these attempts, with the time interval doubled between each attempt, till the total time from the first path error is 300 seconds. This timer function is the *MPLS-TE backoff timer*. You can update the default initial and final time duration (3 seconds and 300 seconds, respectively) using the **mpls traffic-eng timers backoff-timer** command.

Backoff Timer Configuration

```
Router# configure
Router (config)# mpls traffic-eng timers backoff-timer initial-interval 3 final-interval
600
Router (config)# commit
```

To enable MPLS-TE to send traffic over a different LSP immediately after a path error occurs, set the initial and final backoff timer values to 0, as shown below.

```
Router# configure
Router (config)# mpls traffic-eng timers backoff-timer initial-interval 0 final-interval 0
Router (config)# commit
```

Running Configuration

```
Router# show run mpls traffic-eng

mpls traffic-eng
 timers backoff-timer initial-interval 10 final-interval 400
!
```

Configuring Forwarding Path

Perform this task to configure forwarding path in the MPLS-TE interface.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*

3. **forward-class** *forward-class*
4. **exit**
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 1`	Enters MPLS-TE configuration mode.
Step 3	**forward-class** *forward-class* **Example:** `RP/0/RSP0/CPU0:router(config-if)# forward-class 1`	Defines forwarding path in the MPLS-TE interface.

Step 4	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# exit`
	`RP/0/RSP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 5	**commit**	

Related Topics

Policy-Based Tunnel Selection Functions, on page 21
Policy-Based Tunnel Selection, on page 21

Configuring Path Protection on MPLS-TE

These tasks show how to configure path protection on MPLS-TE:

Enabling Path Protection for an Interface

Perform this task to enable path protection for a given tunnel interface.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*

3. **path-protection**
4. **commit**
5. **show mpls traffic-eng tunnels** [*tunnel-number*]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 6`	Configures an MPLS-TE tunnel interface and enables traffic engineering on a particular interface on the originating node.
Step 3	**path-protection** **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-protection`	Enables path protection on the tunnel-te interface.
Step 4	**commit**	
Step 5	**show mpls traffic-eng tunnels** [*tunnel-number*] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 6`	Displays information that path protection is enabled on the tunnel-te interface for tunnel number 6.

Related Topics

Path Protection, on page 30
Pre-requisites for Path Protection, on page 30
Restrictions for Path Protection, on page 31
Configure Tunnels for Path Protection: Example, on page 182

Assigning a Dynamic Path Option to a Tunnel

Perform this task to assign a secondary path option in case there is a link or node failure along a path and all interfaces in your network are not protected.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **path-option** *preference-priority* **dynamic**

4. **commit**
5. **show mpls traffic-eng tunnels** [*tunnel-number*]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 6`	Configures an MPLS-TE tunnel interface and enables traffic engineering on a particular interface on the originating node.
Step 3	**path-option** *preference-priority* **dynamic** **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 10 dynamic`	Configures a secondary path option for an MPLS-TE tunnel.
Step 4	**commit**	
Step 5	**show mpls traffic-eng tunnels** [*tunnel-number*] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 6`	Displays information about the secondary path option that on the tunnel-te interface for tunnel number 6.

Related Topics

Path Protection, on page 30
Pre-requisites for Path Protection, on page 30
Restrictions for Path Protection, on page 31
Configure Tunnels for Path Protection: Example, on page 182

Forcing a Manual Switchover on a Path-Protected Tunnel

Perform this task to force a manual switchover on a path-protected tunnel.

SUMMARY STEPS

1. **mpls traffic-eng path-protection switchover tunnel-te** *tunnel-ID*
2. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**mpls traffic-eng path-protection switchover tunnel-te** *tunnel-ID* **Example:** `RP/0/RSP0/CPU0:router# mpls traffic-eng path-protection switchover tunnel-te 6`	Forces the path protection switchover of the Point-to-Point (P2P) tunnel on the tunnel-te interface.
Step 2	**commit**	

Related Topics

Path Protection, on page 30
Pre-requisites for Path Protection, on page 30
Restrictions for Path Protection, on page 31
Configure Tunnels for Path Protection: Example, on page 182

Configuring the Delay the Tunnel Takes Before Reoptimization

Perform this task to configure the time between when a path-protection switchover event is effected on a tunnel head to when a reoptimization is performed on that tunnel. This timer affects only the required reoptimization that is attempted due to a switchover and does not override the global reoptimization timer.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **reoptimize timers delay path-protection** *seconds*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router# mpls traffic-eng`	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 3	**reoptimize timers delay path-protection** *seconds* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# reoptimize timers delay path-protection 180`	Adjusts the number of seconds that the tunnel takes before triggering reoptimization after switchover has happened. **Note** The restriction is that at least one dynamic path-option must be configured for a standby LSP to come up. The strict (explicit) path option is not supported for the standby LSP.
Step 4	**commit**	

Related Topics

Path Protection, on page 30
Pre-requisites for Path Protection, on page 30
Restrictions for Path Protection, on page 31
Configure Tunnels for Path Protection: Example, on page 182

Configuring the Automatic Bandwidth

Perform these tasks to configure the automatic bandwidth:

Configuring the Collection Frequency

Perform this task to configure the collection frequency. You can configure only one global collection frequency.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **auto-bw collect frequency** *minutes*
4. **commit**
5. **show mpls traffic-eng tunnels** [**auto-bw**]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RSP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 3	**auto-bw collect frequency** *minutes* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-bw collect frequency 1`	Configures the automatic bandwidth collection frequency, and controls the manner in which the bandwidth for a tunnel collects output rate information; but does not adjust the tunnel bandwidth. ***minutes*** Configures the interval between automatic bandwidth adjustments in minutes. Range is from 1 to 10080.
Step 4	**commit**	
Step 5	**show mpls traffic-eng tunnels** [**auto-bw**] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic tunnels auto-bw`	Displays information about MPLS-TE tunnels for the automatic bandwidth. The globally configured collection frequency is displayed.

Related Topics

MPLS-TE Automatic Bandwidth Overview, on page 31
Configure Automatic Bandwidth: Example, on page 182

Forcing the Current Application Period to Expire Immediately

Perform this task to force the current application period to expire immediately on the specified tunnel. The highest bandwidth is applied on the tunnel before waiting for the application period to end on its own.

SUMMARY STEPS

1. **mpls traffic-eng auto-bw apply** {**all** | **tunnel-te** *tunnel-number*}
2. **commit**
3. **show mpls traffic-eng tunnels** [**auto-bw**]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**mpls traffic-eng auto-bw apply** {**all**	**tunnel-te** *tunnel-number*} **Example:** `RP/0/RSP0/CPU0:router# mpls traffic-eng auto-bw apply tunnel-te 1`	Configures the highest bandwidth available on a tunnel without waiting for the current application period to end. **all** Configures the highest bandwidth available instantly on all the tunnels. **tunnel-te** Configures the highest bandwidth instantly to the specified tunnel. Range is from 0 to 65535.

	Command or Action	Purpose
Step 2	**commit**	
Step 3	**show mpls traffic-eng tunnels** [**auto-bw**] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels auto-bw`	Displays information about MPLS-TE tunnels for the automatic bandwidth.

Configuring the Automatic Bandwidth Functions

Perform this task to configure the following automatic bandwidth functions:

Application frequency

Configures the application frequency in which a tunnel bandwidth is updated by the automatic bandwidth.

Bandwidth collection

Configures only the bandwidth collection.

Bandwidth parameters

Configures the minimum and maximum automatic bandwidth to set on a tunnel.

Adjustment threshold

Configures the adjustment threshold for each tunnel.

Overflow detection

Configures the overflow detection for each tunnel.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **auto-bw**
4. **application** *minutes*
5. **bw-limit** {**min** *bandwidth* } {**max** *bandwidth*}
6. **adjustment-threshold** *percentage* [**min** *minimum-bandwidth*]
7. **overflow threshold** *percentage* [**min** *bandwidth*] **limit** *limit*
8. **commit**
9. **show mpls traffic-eng tunnels** [**auto-bw**]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose

Step 2	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-te 6`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface and enables traffic engineering on a particular interface on the originating node.

Step 3	**auto-bw**
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# auto-bw`
	`RP/0/RSP0/CPU0:router(config-if-tunte-autobw)#`
		Configures automatic bandwidth on a tunnel interface and enters MPLS-TE automatic bandwidth interface configuration mode.

Step 4	**application** *minutes* **Example:** `RP/0/RSP0/CPU0:router(config-if-tunte-autobw)# application 1000`	Configures the application frequency in minutes for the applicable tunnel. ***minutes*** Frequency in minutes for the automatic bandwidth application. Range is from 5 to 10080 (7 days). The default value is 1440 (24 hours).
Step 5	**bw-limit** {**min** *bandwidth* } {**max** *bandwidth*} **Example:** `RP/0/RSP0/CPU0:router(config-if-tunte-autobw)# bw-limit min 30 max 80`	Configures the minimum and maximum automatic bandwidth set on a tunnel. **min** Applies the minimum automatic bandwidth in kbps on a tunnel. Range is from 0 to 4294967295. **max** Applies the maximum automatic bandwidth in kbps on a tunnel. Range is from 0 to 4294967295.
Step 6	**adjustment-threshold** *percentage* [**min** *minimum-bandwidth*] **Example:** `RP/0/RSP0/CPU0:router(config-if-tunte-autobw)# adjustment-threshold 50 min 800`	Configures the tunnel bandwidth change threshold to trigger an adjustment. ***percentage*** Bandwidth change percent threshold to trigger an adjustment if the largest sample percentage is higher or lower than the current tunnel bandwidth. Range is from 1 to 100 percent. The default value is 5 percent. **min** Configures the bandwidth change value to trigger an adjustment. The tunnel bandwidth is changed only if the largest sample is higher or lower than the current tunnel bandwidth. Range is from 10 to 4294967295 kilobits per second (kbps). The default value is 10 kbps.

	Command or Action	Purpose
Step 7	**overflow threshold** *percentage* [**min** *bandwidth*] **limit** *limit* **Example:** `RP/0/RSP0/CPU0:router(config-if-tunte-autobw)# overflow threshold 100 limit 1`	Configures the tunnel overflow detection. ***percentage*** Bandwidth change percent to trigger an overflow. Range is from 1 to 100 percent. **limit** Configures the number of consecutive collection intervals that exceeds the threshold. The bandwidth overflow triggers an early tunnel bandwidth update. Range is from 1 to 10 collection periods. The default value is none. **min** Configures the bandwidth change value in kbps to trigger an overflow. Range is from 10 to 4294967295. The default value is 10.
Step 8	**commit**	
Step 9	**show mpls traffic-eng tunnels** [**auto-bw**] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels auto-bw`	Displays the MPLS-TE tunnel information only for tunnels in which the automatic bandwidth is enabled.

Related Topics

MPLS-TE Automatic Bandwidth Overview, on page 31
Configure Automatic Bandwidth: Example, on page 182

Configuring the Shared Risk Link Groups

To activate the MPLS traffic engineering SRLG feature, you must configure the SRLG value of each link that has a shared risk with another link.

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link

Perform this task to configure the SRLG value for each link that has a shared risk with another link.

Note You can configure up to 30 SRLGs per interface.

SUMMARY STEPS

1. **configure**
2. **srlg**

3. **interface** *type interface-path-id*
4. **value** *value*
5. **commit**
6. **show srlg interface** *type interface-path-id*
7. **show srlg**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**srlg** **Example:** `RP/0/RSP0/CPU0:router(config)# srlg`	Configures SRLG configuration commands on a specific interface configuration mode and assigns this SRLG a value.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-srlg)# interface POS 0/6/0/0`	Configures an interface type and path ID to be associated with an SRLG and enters SRLG interface configuration mode.

Step 4	**value** *value*
	Example:
	`RP/0/RSP0/CPU0:router(config-srlg-if)# value 100`
	`RP/0/RSP0/CPU0:router (config-srlg-if)# value 200`
	`RP/0/RSP0/CPU0:router(config-srlg-if)# value 300`
		Configures SRLG network values for a specific interface. Range is 0 to 4294967295.
		Note
		You can also set SRLG values on multiple interfaces including bundle interface.

Step 5	**commit**	
Step 6	**show srlg interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router# show srlg interface POS 0/6/0/0`	(Optional) Displays the SRLG values configured for a specific interface.
Step 7	**show srlg** **Example:** `RP/0/RSP0/CPU0:router# show srlg`	(Optional) Displays the SRLG values for all the configured interfaces. **Note** You can configure up to 250 interfaces.

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41
Delivery of Packets During a Failure, on page 42

Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Creating an Explicit Path With Exclude SRLG

Perform this task to create an explicit path with the exclude SRLG option.

SUMMARY STEPS

1. **configure**
2. **explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*}
3. **index 1 exclude-address** 192.168.92.1
4. **index 2 exclude-srlg** *192.168.92.2*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*} **Example:** `RP/0/RSP0/CPU0:router(config)# explicit-path name backup-srlg`	Enters the explicit path configuration mode. Identifer range is 1 to 65535.
Step 3	**index 1 exclude-address** 192.168.92.1 **Example:** `RP/0/RSP0/CPU0:router router(config-expl-path)# index 1 exclude-address 192.168.92.1`	Specifies the IP address to be excluded from the explicit path.
Step 4	**index 2 exclude-srlg** *192.168.92.2* **Example:** `RP/0/RSP0/CPU0:router(config-expl-path)# index 2 exclude-srlg 192.168.192.2`	Specifies the IP address to extract SRLGs to be excluded from the explicit path.
Step 5	**commit**	

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41

Delivery of Packets During a Failure, on page 42
Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Using Explicit Path With Exclude SRLG

Perform this task to use an explicit path with the exclude SRLG option on the static backup tunnel.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **backup-path tunnel-te** *tunnel-number*
5. **exit**
6. **exit**
7. **interface tunnel-te***tunnel-id*
8. **ipv4 unnumbered** *type interface-path-id*
9. **path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}}
10. **destination** *ip-address*
11. **exit**
12. **commit**
13. **show run explicit-path name** *name*
14. **show mpls traffic-eng topology path destination** *name* **explicit-path** *name*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# interface POS 0/6/0/0`	Enables traffic engineering on a specific interface on the originating node.
Step 4	**backup-path tunnel-te** *tunnel-number* **Example:**	Configures an MPLS TE backup path for a specific interface.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-mpls-te)# backup-path tunnel-te 2`	
Step 5	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.
Step 6	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address to set up forwarding on the new tunnel.
Step 9	**path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}} **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option l explicit name backup-srlg`	Sets the path option to explicit with a given name (previously configured) and assigns the path ID. **Note** You can use the dynamic option to dynamically assign a path.
Step 10	**destination** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-if)# destination 192.168.92.125`	Assigns a destination address on the new tunnel. • Destination address is the remote node's MPLS-TE router ID. • Destination address is the merge point between backup and protected tunnels. **Note** When you configure TE tunnel with multiple protection on its path and merge point is the same node for more than one protection, you must configure record-route for that tunnel.
Step 11	**exit** **Example:** RP/0/RSP0/CPU0:router(config-if)# exit	Exits the current configuration mode.
Step 12	**commit**	

	Command or Action	Purpose
Step 13	**show run explicit-path name** *name* **Example:** `RP/0/RSP0/CPU0:router# show run explicit-path name backup-srlg`	Displays the SRLG values that are configured for the link.
Step 14	**show mpls traffic-eng topology path destination** *name* **explicit-path** *name* **Example:** `RP/0/RSP0/CPU0:router#show mpls traffic-eng topology path destination 192.168.92.125 explicit-path backup-srlg`	Displays the SRLG values that are configured for the link.

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41
Delivery of Packets During a Failure, on page 42
Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Creating a Link Protection on Backup Tunnel with SRLG Constraint

Perform this task to create an explicit path with the exclude SRLG option on the static backup tunnel.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **backup-path tunnel-te** *tunnel-number*
5. **exit**
6. **exit**
7. **interface tunnel-te***tunnel-id*
8. **ipv4 unnumbered** *type interface-path-id*
9. **path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}}
10. **destination** *ip-address*
11. **exit**
12. **explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*}
13. **index 1 exclude-srlg** 192.168.92.2
14. **commit**
15. **show mpls traffic-eng tunnels***tunnel-number* **detail**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# interface POS 0/6/0/0`	Enables traffic engineering on a particular interface on the originating node.
Step 4	**backup-path tunnel-te** *tunnel-number* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# backup-path tunnel-te 2`	Sets the backup path to the primary tunnel outgoing interface.
Step 5	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.
Step 6	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address to set up forwarding on the new tunnel.
Step 9	**path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}} **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 explicit name backup-srlg`	Sets the path option to explicit with a given name (previously configured) and assigns the path ID. Identifier range is from 1 to 4294967295. **Note** You can use the dynamic option to dynamically assign a path.
Step 10	**destination** *ip-address*	Assigns a destination address on the new tunnel.

	Command or Action	Purpose
	Example: `RP/0/RSP0/CPU0:router(config-if)# destination 192.168.92.125`	• Destination address is the remote node's MPLS-TE router ID. • Destination address is the merge point between backup and protected tunnels. **Note** When you configure TE tunnel with multiple protection on its path and merge point is the same node for more than one protection, you must configure record-route for that tunnel.
Step 11	**exit** **Example:** RP/0/RSP0/CPU0:router(config-if)# exit	Exits the current configuration mode.
Step 12	**explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*} **Example:** `RP/0/RSP0/CPU0:router(config)# explicit-path name backup-srlg-nodep`	Enters the explicit path configuration mode. Identifer range is 1 to 65535.
Step 13	**index 1 exclude-srlg** 192.168.92.2 **Example:** `RP/0/RSP0/CPU0:router:router(config-if)# index 1 exclude-srlg 192.168.192.2`	Specifies the protected link IP address to get SRLGs to be excluded from the explicit path.
Step 14	**commit**	
Step 15	**show mpls traffic-eng tunnels***tunnel-number* **detail** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 2 detail`	Display the tunnel details with SRLG values that are configured for the link.

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41
Delivery of Packets During a Failure, on page 42
Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Creating a Node Protection on Backup Tunnel with SRLG Constraint

Perform this task to configure node protection on backup tunnel with SRLG constraint.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **interface** *type interface-path-id*
4. **backup-path tunnel-te** *tunnel-number*
5. **exit**
6. **exit**
7. **interface tunnel-te***tunnel-id*
8. **ipv4 unnumbered** *type interface-path-id*
9. **path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}}
10. **destination** *ip-address*
11. **exit**
12. **explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*}
13. **index 1 exclude-address** 192.168.92.1
14. **index 2 exclude-srlg** *192.168.92.2*
15. **commit**
16. **show mpls traffic-eng tunnels topology path destination** *ip-address* **explicit-path-name** *name*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# interface POS 0/6/0/0`	Enables traffic engineering on a particular interface on the originating node.
Step 4	**backup-path tunnel-te** *tunnel-number* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# backup-path tunnel-te 2`	Sets the backup path for the primary tunnel outgoing interface.
Step 5	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.

	Command or Action	Purpose
Step 6	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address to set up forwarding on the new tunnel.
Step 9	**path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}} **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 explicit name backup-srlg`	Sets the path option to explicit with a given name (previously configured) and assigns the path ID. Identifier range is 1 to 4294967295. **Note** You can use the dynamic option to dynamically assign path.
Step 10	**destination** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-if)# destination 192.168.92.125`	Assigns a destination address on the new tunnel. • Destination address is the remote node's MPLS-TE router ID. • Destination address is the merge point between backup and protected tunnels. **Note** When you configure TE tunnel with multiple protection on its path and merge point is the same node for more than one protection, you must configure record-route for that tunnel.
Step 11	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-if)# exit`	Exits the current configuration mode.
Step 12	**explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*} **Example:** `RP/0/RSP0/CPU0:router(config)# explicit-path name backup-srlg-nodep`	Enters the explicit path configuration mode. Identifer range is 1 to 65535.
Step 13	**index 1 exclude-address** 192.168.92.1 **Example:**	Specifies the protected node IP address to be excluded from the explicit path.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router:router(config-if)# index 1 exclude-address 192.168.92.1`	
Step 14	**index 2 exclude-srlg** *192.168.92.2* **Example:** `RP/0/RSP0/CPU0:router(config-if)# index 2 exclude-srlg 192.168.192.2`	Specifies the protected link IP address to get SRLGs to be excluded from the explicit path.
Step 15	**commit**	
Step 16	**show mpls traffic-eng tunnels topology path destination** *ip-address* **explicit-path-name** *name* **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels topology path destination 192.168.92.125 explicit-path-name backup-srlg-nodep`	Displays the path to the destination with the constraint specified in the explicit path.

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41
Delivery of Packets During a Failure, on page 42
Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 183

Configuring Default Admin Weight

Perform this task to configure a default admin weight to apply to all SRLG values if a specific admin weight is not configured under the SRLG value configuration mode.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng srlg**
3. **admin-weight** *weight*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**mpls traffic-eng srlg** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng srlg`	Enters MPLS TE SRLG configuration mode.
Step 3	**admin-weight** *weight* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-srlg)# admin-weight 10`	Configures default admin-weight for all the SRLG values. Range is from 0-4294967295. Default is 1. The example shows how to configure an admin-weight of 10 for all the SRLG values.
Step 4	**commit**	

Configuring Static SRLG Value to Topology Link

Perform this task to assign static SRLG value to a topology link based on its IP address. Use this command for platforms that do not support SRLG flooding, so that the local node auto-tunnel backup diverse path calculation is based on static SRLG.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng srlg**
3. **value** *srlg-value*
4. **static ipv4 address** *ip-address* **next-hop ipv4 address** *next-hop-ip-address*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng srlg** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng srlg`	Enters MPLS TE SRLG configuration mode.
Step 3	**value** *srlg-value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-srlg)# value 5`	Enters MPLS TE SRLG value configuration mode and configures SRLG value. The example shows how to enter MPLS TE SRLG value configuration mode and configure a SRLG value of 5.
Step 4	**static ipv4 address** *ip-address* **next-hop ipv4 address** *next-hop-ip-address* **Example:**	Configures static SRLG value to a topology link. The example shows how to configure static SRLG value for a topology link with source IP address of 10.0.0.1 and next-hop IP address of 10.1.1.2.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-mpls-te-srlg)# static ipv4 address 10.0.0.1 next-hop ipv4 address 10.1.1.2`	
Step 5	**commit**	

Configuring Admin-Weight Associated with an SRLG Value

Perform this task to configure admin-weight associated with an SRLG value. This admin-weight will be added to the link admin weight during SRLG aware path calculation when the link matches the SRLG value of the protected link. The admin-weight configured in the MPLS TE SRLG value configuration mode overwrites the admin-weight configured in the MPLS TE SRLG configuration mode.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng srlg**
3. **value** *srlg-value*
4. **admin-weight** *weight*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng srlg** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng srlg`	Enters MPLS TE SRLG configuration mode.
Step 3	**value** *srlg-value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-srlg)# value 150`	Enters MPLS TE SRLG value configuration mode and configures SRLG value. The example shows how to enter MPLS TE SRLG value configuration mode and configure a SRLG value of 150.
Step 4	**admin-weight** *weight* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-srlg)# admin-weight 100`	Configures admin-weight for SRLG value. Range is from 0-4294967295. Default is 1. The example shows how to configure an admin-weight of 100 for the SRLG value of 150.
Step 5	**commit**	

Configuring Point-to-Multipoint TE

You must enable multicast routing on the edge router before performing Point-to-Multipoint (P2MP) TE configurations. To configure Point-to-Multipoint TE, perform these procedures:

Enabling Multicast Routing on the Router

Perform this task to enable multicast routing on the router to configure P2MP tunnels.

Before you begin

- To configure Point-to-Multipoint (P2MP) tunnels, you must enable multicast routing on the router.
- The customer-facing interface must enable multicast.

SUMMARY STEPS

1. **configure**
2. **multicast-routing**
3. **address-family** {**ipv4** | **ipv6** }
4. **interface tunnel-mte** *tunnel-id*
5. **enable**
6. **exit**
7. **interface** *type interface-path-id*
8. **enable**
9. **commit**
10. **show pim ipv6 interface** *type interface-path-id*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**multicast-routing**
	Example:
	`RP/0/RSP0/CPU0:router(config)# multicast-routing`
	`RP/0/RSP0/CPU0:router(config-mcast)#`
		Enters multicast routing configuration mode.

Step 3	**address-family** {**ipv4**	**ipv6** }
		Example:
		`RP/0/RSP0/CPU0:router(config-mcast)#`
		`address-family ipv6`
		`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6)#`
			Configures the available IPv4 or IPv6 address prefixes to enable multicast routing and forwarding on all router interfaces.

	Command or Action	Purpose

Step 4	**interface tunnel-mte** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6)# interface tunnel-mte 1`
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6-if)#`
		Configures an MPLS-TE P2MP tunnel interface.

Step 5	**enable** **Example:** `RP/0/RSP0/CPU0:router(config-mcast-default-ipv6-if)# enable`	Enables multicast routing on the tunnel-mte interface.

Step 6	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6-if)# exit`
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6)#`
		Exits the current configuration mode.

Step 7	**interface** *type interface-path-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6)# interface GigabitEthernet0/2/0/3`
	`RP/0/RSP0/CPU0:router(config-mcast-default-ipv6-if)#`
		Configures multicast routing on the GigabitEthernet interface.

Step 8	**enable** **Example:** `RP/0/RSP0/CPU0:router(config-mcast-default-ipv6-if)# enable`	Enables multicast routing on the GigabitEthernet interface.
Step 9	**commit**	
Step 10	**show pim ipv6 interface** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router# show pim ipv6 interface tunnel-mte 1`	Displays the output for the P2MP-TE tunnel interface that has IPv6 multicast enabled.

Related Topics

Configuring the Static Group for the Point-to-Multipoint Interface, on page 123

Configuring the Static Group for the Point-to-Multipoint Interface

Perform this task to configure the static group on the Point-to-Multipoint (P2MP) interface to forward specified multicast traffic over P2MP LSP.

SUMMARY STEPS

1. **configure**
2. **router mld**
3. **vrf** *vrf-name*
4. **interface tunnel-mte** *tunnel-id*
5. **static-group** *group-address*
6. **commit**
7. **show mrib ipv6 route** *source-address*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**router mld**
	Example:
	`RP/0/RSP0/CPU0:router(config)# router mld`
	`RP/0/RSP0/CPU0:router(config-mld)#`
		Enters router MLD configuration mode.

Step 3	**vrf** *vrf-name*
	Example:
	`RP/0/RSP0/CPU0:router(config-mld)#vrf default`
	`RP/0/RSP0/CPU0:router(config-mld-default)#`
		Configures a virtual private network (VRF) instance.

Step 4	**interface tunnel-mte** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config-mld-default)#interface tunnel-mte 1`
	`RP/0/RSP0/CPU0:router(config-mld-default-if)#`
		Configures an MPLS-TE P2MP tunnel interface.

	Command or Action	Purpose
Step 5	**static-group** *group-address* **Example:** `RP/0/RSP0/CPU0:router(config-mld-default-if)# static-group ff35::1 2000::1`	Configures the multicast group address in the Source-Specific Multicast (SSM) address range (ff35::/16) for the IPv6 address prefix.
Step 6	**commit**	
Step 7	**show mrib ipv6 route** *source-address* **Example:** `RP/0/RSP0/CPU0:router# show mrib ipv6 route ff35::1`	Verifies the multicast static mapping.

Related Topics

Enabling Multicast Routing on the Router, on page 121

Configuring Destinations for the Tunnel Interface

Perform this task to configure three destinations for the tunnel interface for Point-to-Multipoint (P2MP).

These variations are listed to ensure that the destination and path option configurations are separate from the tunnel interface.

- Different path option is used for different destinations. This task shows three destinations.
- Explicit path option is based on an ID or a name.
- Default path option is similar to the Point-to-Point (P2P) LSP.

Before you begin

These prerequisites are required to configure destinations for the tunnel interface.

- Multicast routing must be enabled on both the tunnel-mte interface and customer-facing interface from the source.
- Static-group must be configured on the tunnel-mte interface to forward specified multicast traffic over P2MP LSP.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-mte** *tunnel-id*
3. **destination** *ip-address*
4. **path-option** *preference-priority* **explicit identifier** *path-number*
5. **path-option** *preference-priority* **dynamic**
6. **exit**
7. **destination** *ip-address*
8. **path-option** *preference-priority* **explicit name** *pathname*

9. **path-option** *preference-priority* **dynamic**
10. **exit**
11. **destination** *ip-address*
12. **path-option** *preference-priority* **explicit name** *pathname* [**verbatim**]
13. **commit**
14. **show mpls traffic-eng tunnels** [**brief**] [**p2mp** *tunnel-number*]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-mte** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-mte 10`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE P2MP tunnel interface.

Step 3	**destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# destination 172.16.255.1`
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`
		Sets the destination address for tunnel-mte 10 to 172.16.255.1. This destination uses the explicit path identified by explicit path ID 10. If destination 172.16.255.1 cannot come with explicit path ID 10, the fall back path option is dynamic.

Step 4	**path-option** *preference-priority* **explicit identifier** *path-number* **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# path-option 1 explicit identifier 10`	Configures the path number of the IP explicit path.
Step 5	**path-option** *preference-priority* **dynamic** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# path-option 2 dynamic`	Specifies that label switched paths (LSP) are dynamically calculated.
Step 6	**exit** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# exit`	Exits the current configuration mode.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-if)#`	

Step 7	**destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# destination 172.16.255.2`
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`
		Sets the destination address for tunnel-mte 10 to 172.16.255.2.

Step 8	**path-option** *preference-priority* **explicit name** *pathname* **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# path-option 1 explicit name how-to-get-to-172.16.255.2`	Specifies the path name of the IP explicit path. Destination 172.16.255.2 uses the explicit path that is identified by the explicit path name "how-to-get-to-172.16.255.2."
Step 9	**path-option** *preference-priority* **dynamic** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# path-option 2 dynamic`	Sets the fall back path option as dynamic when the destination cannot come to the explicit path.

Step 10	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# exit`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Exits the current configuration mode.

Step 11	**destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# destination 172.16.255.3`
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`
		Specifies that destination 172.16.255.3 uses only the dynamically computed path.

Step 12	**path-option** *preference-priority* **explicit name** *pathname* [**verbatim**] **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# path-option 1 explicit name how-to-get-to-172.16.255.3 verbatim`	Specifies that destination 172.16.255.3 uses the explicit path identified by the explicit path name "how-to-get-to-172.16.255.3" in verbatim mode.
Step 13	**commit**	

	Command or Action	Purpose
Step 14	**show mpls traffic-eng tunnels** [**brief**] [**p2mp** *tunnel-number*] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels brief p2mp 10`	Displays the brief summary of the P2MP tunnel status and configuration.

Related Topics

Enabling Multicast Routing on the Router, on page 121
Configuring the Static Group for the Point-to-Multipoint Interface, on page 123

Disabling Destinations

Perform this task to disable the given destination for the Point-to-Multipoint (P2MP) tunnel interface.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-mte** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **destination** *ip-address*
5. **disable**
6. **path-option** *preference-priority* **dynamic**
7. **path-option** *preference-priority* **explicit name** *pathname*
8. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-mte** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-mte 101`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE P2MP tunnel interface.

Step 3	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered`	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.

	Command or Action	Purpose
	`Loopback0`	

Step 4	**destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# destination 140.140.140.140`
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`
		Sets the destination address for tunnel-mte 10 to 140.140.140.140.

Step 5	**disable** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#disable`	Disables destination 140.140.140.140 for tunnel-mte 10.
Step 6	**path-option** *preference-priority* **dynamic** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#path-option 1 dynamic`	Specifies that label switched paths (LSP) are dynamically calculated.
Step 7	**path-option** *preference-priority* **explicit name** *pathname* **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#path-option 2 explicit name to4`	Specifies that destination 140.140.140.140 uses the explicit path identified by the explicit path name "to4."
Step 8	**commit**	

Logging Per Destinations for Point-to-Multipoint

Perform this task to log destinations for Point-to-Multipoint (P2MP).

SUMMARY STEPS

1. **configure**
2. **interface tunnel-mte** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **destination** *ip-address*
5. **logging events lsp-status state**
6. **logging events lsp-status reroute**
7. **path-option** *preference-priority* **explicit name** *pathname*
8. **exit**
9. **fast-reroute**
10. **commit**

11. **show mpls traffic-eng tunnels** [**p2mp**]

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-mte** *tunnel-id*
	Example:
	`RP/0/RSP0/CPU0:router(config)# interface tunnel-mte 1000`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Configures an MPLS-TE P2MP tunnel interface.

Step 3	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered loopback0`	Configures the MPLS-TE tunnel to use the IPv4 address on loopback interface 0.

Step 4	**destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)# destination 100.0.0.3`
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`
		Sets the destination address for tunnel-mte from 1000 to 100.0.0.3.

Step 5	**logging events lsp-status state** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# logging events lsp-status state`	Sends out the log message when the tunnel LSP goes up or down when the software is enabled.
Step 6	**logging events lsp-status reroute** **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# logging events lsp-status reroute`	Sends out the log message when the tunnel LSP is rerouted due to an FRR event when the software is enabled.
Step 7	**path-option** *preference-priority* **explicit name** *pathname* **Example:** `RP/0/RSP0/CPU0:router(config-if-p2mp-dest)#`	Specifies the path name of the IP explicit path. Destination 100.0.0.3 uses the explicit path that is identified by the explicit path name "path123."

	Command or Action	Purpose
	`path-option 1 explicit name path123`	

Step 8	**exit**
	Example:
	`RP/0/RSP0/CPU0:router(config-if-p2mp-dest)# exit`
	`RP/0/RSP0/CPU0:router(config-if)#`
		Exits the current configuration mode.

Step 9	**fast-reroute** **Example:** `RP/0/RSP0/CPU0:router(config-if)# fast-reroute`	Enables fast-reroute (FRR) protection for a P2MP TE tunnel.
Step 10	**commit**	
Step 11	**show mpls traffic-eng tunnels** [**p2mp**] **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels p2mp`	Displays the information for all P2MP tunnels.

Enabling Soft-Preemption on a Node

Perform this task to enable the soft-preemption feature in the MPLS TE configuration mode. By default, this feature is disabled. You can configure the soft-preemption feature for each node. It has to be explicitly enabled for each node.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **soft-preemption**
4. **timeout** *seconds*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:**	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	
Step 3	**soft-preemption** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# soft-preemption`	Enables soft-preemption on a node. **Note** If soft-preemption is enabled, the head-end node tracks whether an LSP desires the soft-preemption treatment. However, when a soft-preemption feature is disabled on a node, this node continues to track all LSPs desiring soft-preemption. This is needed in a case when soft-preemption is re-enabled, TE will have the property of the existing LSPs without any re-signaling.
Step 4	**timeout** *seconds* **Example:** `RP/0/RSP0/CPU0:router(config-soft-preemption)# timeout 20`	Specifies the timeout for the soft-preempted LSP, in seconds. The range is from 1 to 300.
Step 5	**commit**	

Related Topics

Soft-Preemption, on page 44

Enabling Soft-Preemption on a Tunnel

Perform this task to enable the soft-preemption feature on a MPLS TE tunnel. By default, this feature is disabled. It has to be explicitly enabled.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **soft-preemption**
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router# interface tunnel-te 10`	Configures an MPLS-TE tunnel interface.
Step 3	**soft-preemption**	Enables soft-preemption on a tunnel.

	Command or Action	Purpose
	Example: `RP/0/RSP0/CPU0:router(config-if)# soft-preemption`	When soft preemption is enabled on a tunnel, these actions occur: • A path-modify message is sent for the current LSP with the **soft preemption desired** property. • A path-modify message is sent for the reopt LSP with the **soft preemption desired** property. • A path-modify message is sent for the path protection LSP with the **soft preemption desired** property. • A path-modify message is sent for the current LSP in FRR active state with the **soft preemption desired** property. **Note** The soft-preemption is not available in the interface tunnel-mte and interface tunnel-gte configuration modes.
Step 4	**commit**	

Related Topics

Soft-Preemption, on page 44

Configuring Attributes within a Path-Option Attribute

Perform this task to configure attributes within a path option attribute-set template.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **attribute-set path-option** *attribute-set-name*
4. **affinity** *affinity-value* **mask** *mask-value*
5. **signalled-bandwidth** *kbps* **class-type** *class-type number*
6. **commit**
7. **show mpls traffic-eng attribute-set**
8. **show mpls traffic-eng tunnels***detail*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**attribute-set path-option** *attribute-set-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# attribute-set path-option myset`	Enters attribute-set path option configuration mode. **Note** The configuration at the **path-option** level takes precedence over the values configured at the level of the tunnel, and therefore is applied.
Step 4	**affinity** *affinity-value* **mask** *mask-value* **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# affinity 0xBEEF mask 0xBEEF`	Configures affinity attribute under a path option attribute-set. The attribute values that are required for links to carry this tunnel.
Step 5	**signalled-bandwidth** *kbps* **class-type** *class-type number* **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# signalled-bandwidth 1000 class-type 0`	Configures the bandwidth attribute required for an MPLS-TE tunnel under a path option attribute-set. **Note** You can configure the class type of the tunnel bandwidth request. The class-type 0 is strictly equivalent to **global-pool** and class-type 1 is strictly equivalent to **subpool.**
Step 6	**commit**	
Step 7	**show mpls traffic-eng attribute-set** **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng attribute-set`	Displays the attributes that are defined in the attribute-set for the link.
Step 8	**show mpls traffic-eng tunnels***detail* **Example:** `RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels detail`	Displays the attribute-set path option information on a specific tunnel.

Related Topics

Path Option Attributes, on page 44
Configuration Hierarchy of Path Option Attributes, on page 44
Traffic Engineering Bandwidth and Bandwidth Pools, on page 45
Path Option Switchover, on page 46
Path Option and Path Protection, on page 46

Configuring Auto-Tunnel Mesh Tunnel ID

Perform this activity to configure the tunnel ID range that can be allocated to Auto-tunnel mesh tunnels.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **auto-tunnel mesh**
4. **tunnel-id min** *value* **max** *value*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-tunnel mesh`	Enters auto-tunnel mesh configuration mode. You can configure auto-tunnel mesh related options from this mode.
Step 4	**tunnel-id min** *value* **max** *value* **Example:** `RP/0/RSP0/CPU0:router(config-te-auto-mesh)# tunnel-id min 10 max 50`	Specifies the minimum and maximum number of auto-tunnel mesh tunnels that can be created on this router. The range of tunnel ID is from 0 to 65535.
Step 5	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 47
Destination List (Prefix-List), on page 47

Configuring Auto-tunnel Mesh Unused Timeout

Perform this task to configure a global timer to remove unused auto-mesh tunnels.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **auto-tunnel mesh**
4. **timer removal unused** *timeout*

5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-tunnel mesh`	Enables auto-tunnel mesh groups globally.
Step 4	**timer removal unused** *timeout* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-auto-mesh)# timers removal unused 10`	Specifies a timer, in minutes, after which a down auto-tunnel mesh gets deleted whose destination was not in TE topology. The default value for this timer is 60. The timer gets started when these conditions are met: • Tunnel destination node is removed from the topology • Tunnel is in down state **Note** The unused timer runs per tunnel because the same destination in different mesh-groups may have different tunnels created.
Step 5	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 47
Destination List (Prefix-List), on page 47

Configuring Auto-Tunnel Mesh Group

Perform this task to configure an auto-tunnel mesh group globally on the router.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **auto-tunnel mesh**

4. **group** *value*
5. **disable**
6. **attribute-set***name*
7. **destination-list**
8. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# auto-tunnel mesh`	Enables auto-tunnel mesh groups globally.
Step 4	**group** *value* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-auto-mesh)# group 65`	Specifies the membership of auto-tunnel mesh. The range is from 0 to 4294967295. **Note** When the destination-list is not supplied, head-end will automatically build destination list belonging for the given mesh-group membership using TE topology.
Step 5	**disable** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-auto-mesh-group)# disable`	Disables the meshgroup and deletes all tunnels created for this meshgroup.
Step 6	**attribute-set***name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-auto-mesh-group)# attribute-set am-65`	Specifies the attributes used for all tunnels created for the meshgroup. If it is not defined, this meshgroup does not create any tunnel.
Step 7	**destination-list** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-auto-mesh-group)# destination-list dl-65`	This is a mandatory configuration under a meshgroup. If a given destination-list is not defined as a prefix-list, this meshgroup create tunnels to all nodes available in TE topology.

	Command or Action	Purpose
Step 8	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 47
Destination List (Prefix-List), on page 47

Configuring Tunnel Attribute-Set Templates

Perform this task to define attribute-set templates for auto-mesh tunnels.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **attribute-set auto-mesh** *attribute-set-name*
4. **affinity** *value* **mask** *mask-value*
5. **signalled-bandwidth** *kbps* **class-type** *class-type number*
6. **autoroute announce**
7. **fast-reroute protect bandwidth node**
8. **auto-bw collect-bw-only**
9. **logging events lsp-status {state | insufficient-bandwidth | reoptimize | reroute** }
10. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**attribute-set auto-mesh** *attribute-set-name* **Example:** `RP/0/RSP0/CPU0:router(config-te)# attribute-set auto-mesh attribute-set-mesh`	Specifies name of the attribute-set of auto-mesh type.
Step 4	**affinity** *value* **mask** *mask-value* **Example:** `RP/0/RSP0/CPU0:router(config-te)# affinity 0101 mask 320`	Configures the affinity properties the tunnel requires in its links for an MPLS-TE tunnel under an auto-mesh attribute-set.

	Command or Action	Purpose
Step 5	**signalled-bandwidth** *kbps* **class-type** *class-type number* **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# signalled-bandwidth 1000 class-type 0`	Configures the bandwidth attribute required for an MPLS-TE tunnel under an auto-mesh attribute-set. Because the default tunnel priority is 7, tunnels use the default TE class map (namely, class-type 0, priority 7). **Note** You can configure the class type of the tunnel bandwidth request. The class-type 0 is strictly equivalent to **global-pool** and class-type 1 is strictly equivalent to **subpool**.
Step 6	**autoroute announce** **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# autoroute announce`	Enables parameters for IGP routing over tunnel.
Step 7	**fast-reroute protect bandwidth node** **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# fast-reroute`	Enables fast-reroute bandwidth protection and node protection for auto-mesh tunnels.
Step 8	**auto-bw collect-bw-only** **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# auto-bw collect-bw-only`	Enables automatic bandwidth collection frequency, and controls the manner in which the bandwidth for a tunnel collects output rate information, but does not adjust the tunnel bandwidth.
Step 9	**logging events lsp-status {state | insufficient-bandwidth | reoptimize | reroute** } **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# logging events lsp-status state`	Sends out the log message when the tunnel LSP goes up or down when the software is enabled. Sends out the log message when the tunnel LSP undergoes setup or reoptimize failure due to bandwidth issues. Sends out the log message for the LSP reoptimize change alarms. Sends out the log message for the LSP reroute change alarms.
Step 10	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 47
Destination List (Prefix-List), on page 47

Enabling LDP on Auto-Tunnel Mesh

Perform this task to enable LDP on auto-tunnel mesh group.

SUMMARY STEPS

1. **configure**
2. **mpls ldp**
3. **traffic-eng auto-tunnel mesh**
4. **group***id***all**
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls ldp** **Example:** `RP/0/RSP0/CPU0:router(config-ldp)# mpls ldp`	Enters MPLS LDP configuration mode.
Step 3	**traffic-eng auto-tunnel mesh** **Example:** `RP/0/RSP0/CPU0:router(config-ldp-te-auto-mesh)# traffic-eng auto-tunnel mesh`	Enters auto-tunnel mesh configuration mode. You can configure TE auto-tunnel mesh groups from this mode.
Step 4	**group***id***all** **Example:** `RP/0/RSP0/CPU0:router(config-ldp-te-auto-mesh)# group all`	Configures an auto-tunnel mesh group of interfaces in LDP. You can enable LDP on all TE meshgroup interfaces or you can specify the TE mesh group ID on which the LDP is enabled. The range of group ID is from 0 to 4294967295.
Step 5	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 47
Destination List (Prefix-List), on page 47

Configuring P2MP TE Auto-tunnels

Perform these tasks to enable P2MP TE Auto-tunnels. These steps configure the tunnel ID range to be allocated to P2MP auto-tunnels and determine the maximum number of P2MP auto-tunnels that can be created.

Before you begin

The P2MP TE Auto-tunnel configuration is disabled by default.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **auto-tunnel p2mp**
4. **tunnel-id min** *number* **max** *value*
5. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enables MPLS traffic engineering (TE) configuration mode.
Step 3	**auto-tunnel p2mp** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#auto-tunnel p2mp`	Enables automatically created tunnel configuration and enters the auto-tunnel P2MP configuration mode.
Step 4	**tunnel-id min** *number* **max** *value* **Example:** `RP/0/RSP0/CPU0:router(config-te-auto-p2mp)#tunnel-id min 10000 max 11000`	Configures the tunnel ID range that can be allocated to P2MP auto-tunnels and determines the maximum number of P2MP auto-tunnels that can be created.
Step 5	**commit**	

Related Topics

P2MP-TE Auto-tunnels, on page 48

Enabling Stateful PCE Client

Perform these steps to enable stateful PCE client.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **pce**
4. **stateful-client**
5. **capabilities** { **instantiation** | **update** }
6. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enters MPLS TE configuration mode.
Step 3	**pce** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#pce`	Enters PCE configuration mode.
Step 4	**stateful-client** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce)#stateful-client`	Enters stateful PCE client configuration mode. When the stateful-client configuration is added to the node, it will close all existing PCEP peer connections, and add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment. When the stateful-client configuration is removed from the node, it will delete all PCE instantiated tunnels, close all existing PCEP connections, and no longer add the stateful capabilities TLV to the OPEN object it exchanges during the PCEP session establishment.
Step 5	**capabilities** { **instantiation** | **update** } **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-pce-stateful)#capabilities instantiation`	Enables stateful client capabilities. • **instantiation**—enables stateful instantiate capability • **update**—enables stateful update capability
Step 6	**commit**	

Configuring VRF Redirection

Perform these steps to configure VRF redirection by installing multiple routes in the routing information base (RIB) per MPLS TE tunnel:

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **autoroute destination** *ip-address*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)#interface tunnel-te 10`	Configures an MPLS-TE tunnel interface.

Step 3	**autoroute destination** *ip-address*
	Example:
	`RP/0/RSP0/CPU0:router(config-if)#autoroute destination 192.168.1.2`
	`RP/0/RSP0/CPU0:router(config-if)#autoroute destination 192.168.2.2`
	`RP/0/RSP0/CPU0:router(config-if)#autoroute destination 192.168.3.2`
	`RP/0/RSP0/CPU0:router(config-if)#autoroute destination 192.168.4.2`
		Adds a route (ip-address) in RIB with TE tunnel as outgoing interface. to the tunnel destination.

Step 4	**commit**	

Example

This example shows how to configure installing four autoroute destination routes into the RIB along with the default route:

```
interface tunnel-te10
 autoroute destination 192.168.1.2
 autoroute destination 192.168.2.2
 autoroute destination 192.168.3.2
 autoroute destination 192.168.4.2
```

Configure IPv6 routing over IPv4 MPLS-TE tunnels

Perform these steps to configure IPv6 routing over IPv4 MPLS-TE tunnels:

Procedure

Step 1 **configure**

Step 2 **interface tunnel-te** *tunnel-id*

Example:

```
RP/0/RSP0/CPU0:router# interface tunnel-te 1
```

Configures an MPLS-TE tunnel interface.

Step 3 **ipv4 unnumbered** *type interface-path-id*

Example:

```
RP/0/RSP0/CPU0:router(config-if)#ipv4 unnumbered Loopback 0
```

Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is the commonly-used interface type.

Step 4 **ipv6 enable**

Example:

```
RP/0/RSP0/CPU0:router(config-if)#ipv6 enable
```

Enables IPv6 on interface.

Step 5 **signalled-bandwidth** *bandwidth*

Example:

```
RP/0/RSP0/CPU0:router(config-if)# signalled-bandwidth 10
```

Sets the tunnel bandwidth requirement to be signalled in Kbps.

Step 6 **destination** *ip-address*

Example:

```
RP/0/RSP0/CPU0:router(config-if)#destination 192.168.0.1
```

Specifies the IPv4 destination address.

Step 7 Use one of these options:

- **autoroute announce include-ipv6**
- **forwarding-adjacency include-ipv6**

Example:

```
RP/0/RSP0/CPU0:router(config-if)#autoroute announce include-ipv6
```

Or

```
RP/0/RSP0/CPU0:router(config-if)#forwarding-adjacency include-ipv6
```

Announces the tunnel as an IPv6 autoroute or an IPv6 forwarding adjacency.

Step 8 **path-option** *preference-priority* **dynamic**

Example:

```
RP/0/RSP0/CPU0:router(config-if)#path-option 1 dynamic
```

Sets the path option to dynamic and assigns the path ID.

Step 9 **commit**

Step 10 (Optional) **show mpls traffic-eng autoroute**

Example:

```
RP/0/RSP0/CPU0:router#show mpls traffic-eng autoroute
```

```
  Destination 192.168.0.2 has 1 tunnels in IS-IS ring level 1
    tunnel-te1 (traffic share 0, nexthop 192.168.0.2)
               (IPv4 unicast)
               (IPv6 unicast)
```

Verifies that the tunnel announces IPv6 autoroute information.

Step 11 (Optional) **show mpls traffic-eng forwarding-adjacency**

Example:

```
RP/0/RSP0/CPU0:router#show mpls traffic-eng forwarding-adjacency

 destination 192.168.0.1 has 1 tunnels

              tunnel-te10    (traffic share 0, next-hop 192.168.0.1)
                             (Adjacency Announced: yes, holdtime 0)
                             (IS-IS 100, IPv4 unicast)
                             (IS-IS 100, IPv6 unicast)
```

Verifies that the tunnel announces IPv6 forwarding adjacency information.

Using ePBR for MPLS Packets on Subscriber Interfaces

The enhanced policy based routing (ePBR) match/redirect MPLS packets on subscriber interfaces feature enables the capability to match MPLS labeled packets and redirect those to an external server by re-writing the source and destination IP addresses of the packets. This feature is applicable when the DNS server (an external server) is hidden in the MPLS cloud.

The traffic that is entering the MPLS cloud will be matched for a specific destination address and based on it, the new destination will be set. When the packet returns from the DNS server, the source address is changed back to the original source address.

For information on the commands used for configuring Enhanced Policy Based Routing Match/Redirect MPLS Packets on Subscriber Interfaces, see *MPLS Traffic Engineering Commands* module in *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Use Case: Using ePBR for MPLS Packets on Subscriber Interfaces

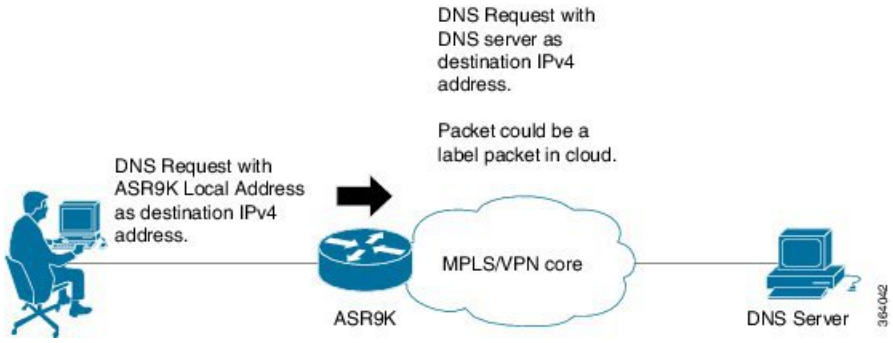
The ePBR match/redirect MPLS packets on subscriber Interfaces feature is applicable when a packet arrives at an interface with a destination address of a known server. This feature changes the known destination address to a required address that is hidden in the DNS cloud. For example, when the packet reaches a known interface with a specific IP address, say 10.0.0.1, it can to be redirected to a new IP address, say 172.16.0.1 , that is hidden in the cloud.

For subscriber to core DNS packets, the sequence for match and redirect is:

- Match the incoming packet for the known DNS server. This address could be a local address on the Cisco ASR 9000 Series Router, which the subscriber uses as DNS server address.
- Set the destination address to a new IP address to which the packet has to be redirected.

This figure explains the match and redirect sequence for subscriber to core DNS packets.

Figure 15: Subscriber to core DNS packets

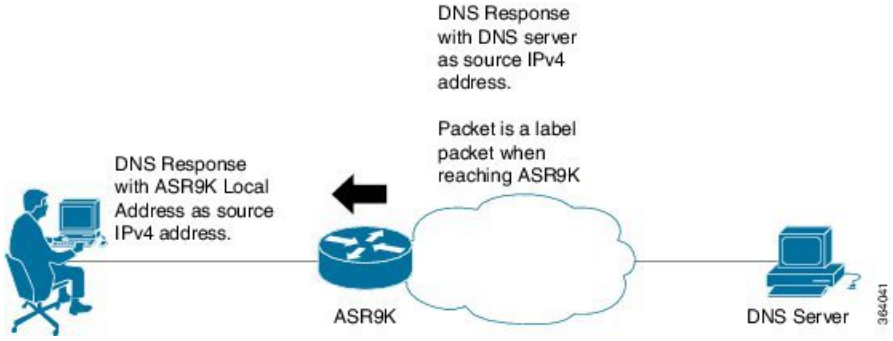


For core to subscriber DNS packets, the sequence for match and redirect is :

- Match the incoming labeled DNS packet's source IP address from the core.
- Set the source address to a local address, which the subscriber uses as DNS server address. The packet would be forwarded based on label + destination IP address, which is the subscriber address.

This figure explains the match and redirect sequence for core to subscriber DNS packets.

Figure 16: Core to subscriber DNS packets



Configuring ePBR-Based MPLS Redirection

These examples show how to configure ePBR-based MPLS match/redirect configuration.

Match configuration for IPv4 packets:

```
policy-map type pbr policy_mpls_src_test
class type traffic class_mpls_src_test
  set source-address ipv4 17.17.18.18
!
class type traffic class-default
 !
end-policy-map
!

RP/0/RSP0/CPU0:ASR9K-0#show running-config class-map type traffic class_mpls_src_test
Wed Sep  3 02:52:31.411 UTC
class-map type traffic match-any class_mpls_src_test
match mpls disposition access-group ipv4 ACL_MPLS_SRC
 end-class-map
```

```
!

show running-config ipv4 access-list ACL_MPLS_SRC
Wed Sep  3 02:53:40.918 UTC
ipv4 access-list ACL_MPLS_SRC
10 permit ipv4 30.1.1.1/24 112.112.0.1/24
!
```

Match configuration for IPv6 packets:

```
policy-map type pbr policy_mpls_src_test
class type traffic class_mpls_ipv6_src_test
  set source-address ipv4 10.10.10.10
!
class type traffic class-default
 !
end-policy-map
!

RP/0/RSP0/CPU0:ASR9K-0# show running-config class-map type traffic class_mpls_ipv6_src_test
Wed Sep  3 02:52:31.411 UTC
class-map type traffic match-any class_mpls_ipv6_src_test
match mpls disposition access-group ipv6 ACL_MPLS_IPV6__SRC
 end-class-map
!

show running-config ipv6 access-list ACL_MPLS_IPV6_SRC
Wed Sep  3 02:53:40.918 UTC
Ipv6 access-list ACL_MPLS_IPV6_SRC
10 permit ipv6 any any
!
```

Set destination configuration:

```
show running-config policy-map type pbr pbr_prec_exp
Wed Sep  3 03:11:16.000 UTC
policy-map type pbr pbr_prec_exp
class type traffic class_prec_exp
  set destination-address ipv4 192.168.0.1
!
class type traffic class-default
 !
end-policy-map
!

RP/0/RSP0/CPU0:ASR9K-0#show running-config class-map type traffic class_prec_e$
Wed Sep  3 03:11:30.339 UTC
class-map type traffic match-all class_prec_exp
match mpls experimental topmost 2
 match mpls disposition access-group ipv4 acl2
 end-class-map
!

RP/0/RSP0/CPU0:ASR9K-0# show running-config ipv4 access-list acl2
Wed Sep  3 03:11:47.963 UTC
ipv4 access-list acl2
5 permit ipv4 host 10.10.10.10 any
10 permit ipv4 any any
!
```

Multi Nexthop Tracking

The multi nexthop tracking feature enables the setting of virtual routing and forwarding (VRF) with nexthop and nexthop tracking, for an incoming MPLS or IP packet. When a MPLS/IP packet reaches an interface, a new VRF or a new nexthop is set. This feature enables the capability of matching the packet and redirecting to a new VRF or IP. This is extremely useful in cases of DNS redirect or HTTP redirect. If an incoming packet is redirected to an IP without specifying the VRF, it refers to the default VRF.

The multi nexthop tracking feature sets the nexthop by matching an incoming packet on the current VRF and then sets the VRF to the new value. The matching of the packets can also be based on the length of the packets.

A maximum number of three nexthops can be configured. The first nexthop configured has the highest priority as compared to the last nexthop, which has the least priority. The nexthops configured must be either IPv4 or IPv6. For a given nexthop, a VRF name, an IPv4/IPv6 address or both can be configured. When VRF is not configured, it is presumed to be an ingress interface VRF.

For the nexthop policy based routing (PBR) action, the available highest priority nexthop is chosen when setting the policy based route nexthop, though this may not be the highest priority configured nexthop. When a higher priority route comes up, it replaces the programmed nexthop.

Configuring Multi Nexthop Tracking for IPv4

Perform this task to configure multi nexthop tracking on a VRF for IPv4.

SUMMARY STEPS

1. **configure**
2. **policy-map type pbr** *policy-map name*
3. **class type traffic** *class name*
4. **redirect ipv4 nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address*
5. **end** or **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters Global Configuration mode.
Step 2	**policy-map type pbr** *policy-map name* **Example:** `RP/0/RSP0/CPU0:router(config)# policy-map type pbr multi-vrf`	Enters policy-map configuration mode.
Step 3	**class type traffic** *class name* **Example:**	Specifies a traffic class previously created with the class-map command.

	Command or Action	Purpose
	`RP/0/RSP0/CPU0:router(config-pmap)# class type traffic class_all`	
Step 4	**redirect ipv4 nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **Example:** `RP/0/RSP0/CPU0:router(config-pmap-c)# redirect ipv4 nexthop vrf vpn1 3.2.1.2 nexthop vrf vpn2 3.2.3.2 nexthop vrf vpn3 3.2.4.2`	Configures a maximum of three nexthops for VRFs and IPv4 addresses specified. **Note** The first nexthop will have the highest priority and the last nexthop will have the least priority.

Step 5	**end** or **commit**
	Example:
	`RP/0/RSP0/CPU0:router(config-pmap-c)# end`
	or
	`RP/0/RSP0/CPU0:router(config-pmap-c)# commit`
		Saves configuration changes.
		• When you issue the **end** command, the system prompts you to commit changes:
		`Uncommitted changes found, commit them before exiting(yes/no/cancel)? [cancel]:`
		- Entering **yes** saves configuration changes to the running configuration file, exits the configuration session, and returns the router to EXEC mode.
		- Entering **no** exits the configuration session and returns the router to EXEC mode without committing the configuration changes.
		- Entering **cancel** leaves the router in the current configuration session without exiting or committing the configuration changes.
		• Use the **commit** command to save the configuration changes to the running configuration file and remain within the configuration session.

Configuring Multi Nexthop Tracking for IPv6

Perform this task to configure multi nexthop tracking on a VRF for IPv6.

SUMMARY STEPS

1. **configure**
2. **policy-map type pbr** *policy-map name*
3. **class type traffic** *class name*
4. **redirect ipv6 nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address*
5. **end** or **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters Global Configuration mode.
Step 2	**policy-map type pbr** *policy-map name* **Example:** `RP/0/RSP0/CPU0:router(config)# policy-map type pbr multi-vrf`	Enters policy-map configuration mode.
Step 3	**class type traffic** *class name* **Example:** `RP/0/RSP0/CPU0:router(config-pmap)# class type traffic class_all`	Specifies a traffic class previously created with the class-map command.
Step 4	**redirect ipv6 nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **nexthop vrf** *vrf-name nexthop address* **Example:** `RP/0/RSP0/CPU0:router(config-pmap-c)# redirect ipv6 nexthop vrf vpn1 3.2.1.2 nexthop vrf vpn2 3.2.3.2 nexthop vrf vpn3 3.2.4.2`	Configures a maximum of three nexthops for VRFs and IPv6 addresses specified. **Note** The first nexthop will have the highest priority and the last nexthop will have the least priority.

Step 5	**end** or **commit**
	Example:
	`RP/0/RSP0/CPU0:router(config-pmap-c)# end`
	or
	`RP/0/RSP0/CPU0:router(config-pmap-c)# commit`
		Saves configuration changes.
		• When you issue the **end** command, the system prompts you to commit changes:
		`Uncommitted changes found, commit them before exiting(yes/no/cancel)? [cancel]:`
		- Entering **yes** saves configuration changes to the running configuration file, exits the configuration session, and returns the router to EXEC mode.
		- Entering **no** exits the configuration session and returns the router to EXEC mode without committing the configuration changes.
		- Entering **cancel** leaves the router in the current configuration session without exiting or committing the configuration changes.
		• Use the **commit** command to save the configuration changes to the running configuration file and remain within the configuration session.

Verifying Multi Nexthop Tracking Configuration

Use the **show running-config policy-map type pbr multi-vrf** command to verify the multi nexthop tracking configuration. The following example shows sample output for the command:

```
show running-config policy-map type pbr multi-vrf

policy-map type pbr multi-vrf
 class type traffic class_all
  redirect ipv4 nexthop vrf vpn1 3.2.1.2 nexthop vrf vpn3 3.2.3.2 nexthop vrf vpn4 3.2.4.2

 !
class type traffic class-default
 !
end-policy-map
!
```

Configuring Path-selection Cost Limit

Apply the path-selection cost-limit configuration to set the upper limit on the path aggregate admin-weight when computing paths for MPLS-TE LSPs. Once the path-selection cost is configured, the periodic path verification will check if the cost-limit is crossed. Path-selection cost limit can be configured at global MPLS TE, per interface tunnel, and per path-option attribute set. The path-selection cost limit per path-option attribute set takes the highest priority, followed by per interface and MPLS TE global path-selection cost limit values.

Configuring Global Path-selection Cost Limit on MPLS TE Tunnels

Perform these steps to configure path-selection cost limit globally for MPLS TE tunnels:

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **path-selection cost-limit** *cost-limit*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**path-selection cost-limit** *cost-limit* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# path-selection cost-limit 3`	Sets the upper limit on the path aggregate admin-weight when computing paths for MPLS TE LSPs.

	Command or Action	Purpose
Step 4	**commit**	

Configuring Path-selection Cost Limit per TE Tunnel

Perform these steps to configure path-selection cost limit per MPLS TE tunnel:

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **path-selection cost-limit** *cost-limit*
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router(config)#interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**path-selection cost-limit** *cost-limit* **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-selection cost-limit 2`	Sets the upper limit on the path aggregate admin-weight when computing paths for MPLS TE LSPs for the specified MPLS TE tunnel.
Step 4	**commit**	

Configuring Path-selection Cost Limit per Path-option Attribute-set

Perform these steps to configure path-selection cost limit per path-option attribute-set:

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **attribute-set path-option** *attribute-set-name*
4. **path-selection cost-limit** *3*

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**attribute-set path-option** *attribute-set-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# attribute-set path-option PO3AttrSet`	Enters attribute-set path option configuration mode. **Note** The configuration at the **attribute-set path-option** level takes precedence over the values configured at global and interface tunnel level.
Step 4	**path-selection cost-limit** *3* **Example:** `RP/0/RSP0/CPU0:router(config-te-attribute-set)# path-selection cost-limit 3`	Sets the upper limit on the path aggregate admin-weight when computing paths for MPLS TE LSPs per path-option attribute set.

Enabling Soft-preemption over FRR Backup Tunnels

Perform these tasks to enable LSP traffic to be moved over the backup tunnel when the LSP is soft-preempted. With this configuration, when there is a soft-preemption, the MPLS TE process triggers a rewrite to move the traffic on the backup tunnel, if the backup tunnel is ready. The rest of the soft-preemption process remains unchanged.

Before you begin

Ensure that the following configurations are enabled before enabling soft-preemption over FRR backup:

- Soft-preemption enabled.
- Fast-reroute (FRR) backup tunnel is activated.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **soft-preemption frr-rewrite**
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**soft-preemption frr-rewrite** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#soft-preemption frr-rewrite`	Moves FRR LSP traffic over the backup tunnel, when LSP is soft-preempted.
Step 4	**commit**	

Enabling Auto-onehop Tunnels to Next-hop Neighbors

Perform these tasks to enable automatic creation of one-hop tunnels over MPLS traffic-engineering enabled interfaces to nexthop neighbors. A router that becomes a next hop neighbor will have a set of one-hop tunnels created automatically.

Before you begin

The **ipv4 unnumbered mpls traffic-eng Loopback** *Number* configuration must be applied at the global configuration level.

SUMMARY STEPS

1. **configure**
2. **ipv4 unnumbered mpls traffic-eng Loopback** *N*
3. **mpls traffic-eng**
4. **auto-tunnel mesh**
5. **tunne-id min** *value* **max** *value*
6. **group** *group-id*
7. **onehop**
8. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**ipv4 unnumbered mpls traffic-eng Loopback** *N* **Example:** `RP/0/RSP0/CPU0:router(config)#ipv4 unnumbered mpls traffic-eng loopback 0`	Configures the globally configured IPv4 address that can be used by the Auto-tunnel backup tunnels.
Step 3	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)#mpls traffic-eng`	Enters the MPLS-TE submode.
Step 4	**auto-tunnel mesh** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)#auto-tunnel mesh`	Enters the auto-tunnel mesh configuration submode.
Step 5	**tunne-id min** *value* **max** *value* **Example:** `RP/0/0/CPU0:ios(config-te-auto-mesh)# tunnel-id min 4000 max 6000`	Specifies the minimum and maximum number of auto-tunnel mesh tunnels that can be created on this router. The range of tunnel ID is from 0 to 65535.
Step 6	**group** *group-id* **Example:** `RP/0/RSP0/CPU0:router(config-te-auto-mesh)#group 50`	Enters the auto-tunnel mesh group configuration submode and creates a group ID.
Step 7	**onehop** **Example:** `RP/0/RSP0/CPU0:router(config-te-mesh-group)#onehop`	Enables automatic creation of one-hop tunnels to all next hop neighbors. The onehop keyword can be applied to as many mesh groups as desired.
Step 8	**commit**	

Implementing Associated Bidirectional Label Switched Paths

Associated Bidirectional Label Switched Paths are LSP instances where the forward and the reverse direction paths are setup, monitored and protected independently and associated together during signaling. You use a RSVP Association object to bind the two forward and reverse LSPs together to form either a co-routed or non co-routed associated bidirectional TE tunnel.

You can associate a protecting MPLS-TE tunnel with either a working MPLS-TE LSP, protecting MPLS-TE LSP, or both. The working LSP is the primary LSP backed up by the protecting LSP. When a working LSP goes down, the protecting LSP is automatically activated. You can configure a MPLS-TE tunnel to operate without protection as well.

For more information on Associated Bidirectional Co-routed LSPs, see the *Cisco ASR 9000 Series Aggregation Services Router MPLS Configuration Guide, Release 5.2.x*. For information on the commands used for Associated Bidirectional Co-routed LSPs, see the *Cisco ASR 9000 Series Aggregation Services Router MPLS Command Reference, Release 5.2.x*.

Signaling Methods and Object Association for Bidirectional LSPs

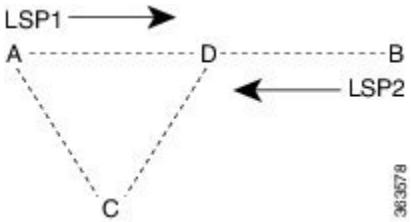
This section provides an overview of the association signaling methods for the bidirectional LSPs. Two unidirectional LSPs can be bound to form an associated bidirectional LSP in the following scenarios:

- No unidirectional LSP exists, and both must be established.
- Both unidirectional LSPs exist, but the association must be established.
- One unidirectional LSP exists, but the reverse associated LSP must be established.

Configuration information regarding the LSPs can be provided at one or both endpoints of the associated bidirectional LSP. Depending on the method chosen, there are two models of creating an associated bidirectional LSP; single-sided provisioning, and double-sided provisioning.

- **Single-sided Provisioning:** For the single-sided provisioning, the TE tunnel is configured only on one side. An LSP for this tunnel is initiated by the initiating endpoint with the Association Object inserted in the Path message. The other endpoint then creates the corresponding reverse TE tunnel and signals the reverse LSP in response to this. Currently, there is no support available for configuring single-sided provisioning.
- **Double-sided Provisioning:** For the double-sided provisioning, two unidirectional TE tunnels are configured independently on both sides. The LSPs for the tunnels are signaled with Association Objects inserted in the Path message by both sides to indicate that the two LSPs are to be associated to form a bidirectional LSP.

Consider this topology (an example of associated bidirectional LSP):



Here, LSP1 from A to B, takes the path A,D,B and LSP2 from B to A takes the path B,D,C,A. These two LSPs, once established and associated, form an associated bidirectional LSP between node A and node B. For the double sided provisioning model, both LSP1 and LSP2 are signaled independently with (Extended) Association Object inserted in the Path message, in which the Association Type indicating double-sided provisioning. In this case, the two unidirectional LSPs are bound together to form an associated bidirectional LSP based on identical Association Objects in the two LSPs' Path messages.

Association Object: An Association Object is used to bind unidirectional LSPs originating from both endpoints. The Association Object takes the following values:

- **Association Type**: In order to bind two reverse unidirectional LSPs to be an associated bidirectional LSP, the Association Type must be set to indicate either single sided or double sided LSPs.
- **Association ID**: For both single sided and double sided provisioning, Association ID must be set to a value assigned by the node that originates the association for the bidirectional LSP. This is set to the Tunnel ID of the bound LSP or the Tunnel ID of the binding LSP.
- **Association Source:** For double sided provisioning, Association Source must be set to an address selected by the node that originates the association for the bidirectional LSP. For single sided provisioning, Association Source must be set to an address assigned to the node that originates the LSP.
- **Global ID**: This is the global ID for the association global source. This must be set to the global ID of the node that originates the association for the bidirectional LSP.

Note You must provide identical values for the content of the Association Object on either end of the participating LSPs to ensure successful binding of the LSPs.

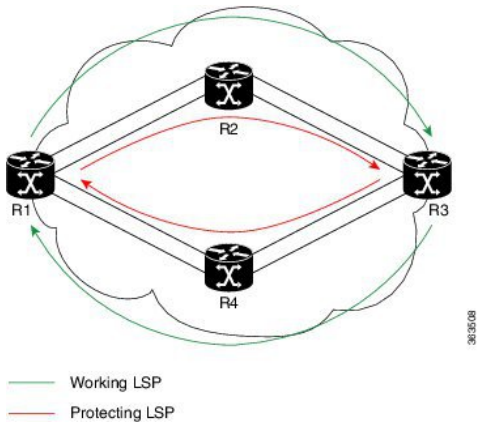
Configure Associated Bidirectional Co-routed LSPs, on page 157 describes the procedure to create associated bidirectional co-routed LSPs.

Associated Bidirectional Non Co-routed and Co-routed LSPs

This section provides an overview of associated bidirectional non co-routed and co-routed LSPs. Establishment of MPLS TE-LSP involves computation of a path between a head-end node to a tail-end node, signaling along the path, and modification of intermediate nodes along the path. The signaling process ensures bandwidth reservation (if signaled bandwidth is lesser than 0 and programming of forwarding entries.

Path computation is performed by the head-end nodes of both the participating LSPs using Constrained Shortest Path First (CSPF). CSPF is the 'shortest path (measured in terms of cost) that satisfies all relevant LSP TE constraints or attributes, such as required bandwidth, priority and so on.

Associated Bidirectional Non Co-routed LSPs: A non co-routed bidirectional TE LSP follows two different paths, that is, the forward direction LSP path is different than the reverse direction LSP path. Here is an illustration.



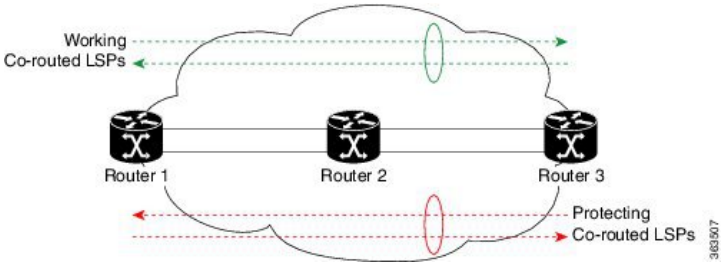
In the above topology:

- The outer paths (in green) are working LSP pairs.
- The inner paths (in red) are protecting LSP pairs.
- Router 1 sets up working LSP to Router 3 and protecting LSP to Router 3 independently.
- Router 3 sets up working LSP to Router 1 and protecting LSP to Router 1 independently.

Non co-routed bidirectional TE LSP is available by default, and no configuration is required.

Note In case of non co-routed LSPs, the head-end nodes relax the constraint on having identical forward and reverse paths. Hence, depending on network state you can have identical forward and reverse paths, though the bidirectional LSP is co-routed.

Associated Bidirectional Co-routed LSPs: A co-routed bidirectional TE LSP denotes a bidirectional tunnel where the forward direction LSP and reverse direction LSP must follow the same path, for example, the same nodes and paths. Here is an illustration.



In the above topology:

- Paths at the top of the figure (in green) indicate working co-routed LSP pairs.
- Paths at the bottom of the figure (in red) indicate protecting co-routed LSP pairs.
- Router 1 sets up working LSP to Router 3 (in red) after performing bidirectional CSPF and sends reverse explicit route object (ERO) to Router 3. Node Router 3 uses the received reverse ERO to set up reverse red working LSP to Router 1.
- Router 3 sets up protecting LSP to Router 1 (in green) after performing bidirectional CSPF and sends reverse ERO to Router 1. Node Router 1 uses the received reverse ERO to set up reverse green protecting LSP to Router 3.

Configure Associated Bidirectional Co-routed LSPs, on page 157 describes the procedure to configure an associated bidirectional co-routed LSP.

Configure Associated Bidirectional Co-routed LSPs

A co-routed bidirectional packet LSP is a combination of two LSPs (one in the forward direction and the other in reverse direction) sharing the same path between a pair of ingress and egress nodes. It is established using the extensions to RSVP-TE. This type of LSP can be used to carry any of the standard types of MPLS-based traffic, including Layer 2 VPNs, Layer 2 circuits, and Layer 3 VPNs. You can configure a single BFD session for the bidirectional LSP (that is, you do not need to configure a BFD session for each LSP in each direction). You can also configure a single standby bidirectional LSP to provide a backup for the primary bidirectional LSP.

Before you begin

- You must have symmetric source and destination TE router IDs in order for bidirectional LSPs to be associated.
- Tunnels attributes must be configured identically on both sides of co-routed bidirectional LSP.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **bidirectional**
4. **association** {**id** <0-65535> | **source-address** <IP address>} [**global-id** <0-4294967295>]
5. **association type co-routed**
6. **commit**
7. **show mpls traffic-eng tunnels bidirectional-associated co-routed**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**bidirectional** **Example:** `RP/0/0/CPU0:router(config-if)# bidirectional`	Configure the ingress router for the LSP and include the bidirectional statement to specify that the LSP be established as a bidirectional LSP.
Step 4	**association** {**id** <0-65535> | **source-address** <IP address>} [**global-id** <0-4294967295>] **Example:** `RP/0/0/CPU0:router(config-if-bidir)# association id 1 source-address 11.0.0.1`	Set the association ID that uniquely identifies the association of LSPs, which is the tunnel ID of the bound LSP or the tunnel ID of the binding LSP. Also, set the source address to the tunnel sender address of the bound LSP or the tunnel sender address of the binding LSP. Optionally, specify the global ID for association global source. **Note** Association ID, association source and global ID must be configured identically on both the endpoints.
Step 5	**association type co-routed** **Example:** `RP/0/0/CPU0:router(config-if-bidir)#association type co-routed`	Specify that the LSP be established as a associated co-routed bidirectional LSP.
Step 6	**commit**	
Step 7	**show mpls traffic-eng tunnels bidirectional-associated co-routed** **Example:** `RP/0/0/CPU0:router#show mpls traffic-eng tunnels bidirectional-associated co-routed`	Shows details of an associated co-routed bidirectional LSP.

Show output for an associated co-routed bidirectional LSP configuration

This is a sample of the output for the **show mpls traffic-eng tunnels role head** command.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels role head

Name: tunnel-te1  Destination: 49.49.49.2
  Signalled-Name: IMC0_t1
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 1,  type dynamic  (Basis for Setup, path weight 20 (reverse 20))
```

```
  path option 1,  type dynamic  (Basis for Standby, path weight 20 (reverse 20))
  G-PID: 0x0800 (derived from egress interface properties)
  Bandwidth Requested: 0 kbps  CT0
  Creation Time: Sun May  4 12:09:56 2014 (03:24:11 ago)
Config Parameters:
  Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
  Metric Type: TE (default)
  Hop-limit: disabled
  Cost-limit: disabled
  AutoRoute: disabled  LockDown: disabled   Policy class: not set
  Forward class: 0 (default)
  Forwarding-Adjacency: disabled
  Loadshare:          0 equal loadshares
  Auto-bw: disabled
  Fast Reroute: Disabled, Protection Desired: None
  Path Protection: Enabled
  Association Type: Single Sided Bidirectional LSPs, Co-routed: YES
  Association ID: 100, Source: 49.49.49.2
  Reverse Bandwidth: 0 kbps (CT0), Standby: 0 kbps (CT0)
  BFD Fast Detection: Enabled
  BFD Parameters: Min-interval 100 ms (default), Multiplier 3 (default)
  BFD Bringup Timeout: Interval 60 seconds (default)
  BFD Initial Dampening: 16000 ms (default)
  BFD Maximum Dampening: 600000 ms (default)
  BFD Secondary Dampening: 20000 ms (default)
  Periodic LSP Ping: Interval 120 seconds (default)
  Session Down Action: ACTION_REOPTIMIZE, Reopt Timeout: 300
  BFD Encap Mode: GAL
  Reoptimization after affinity failure: Enabled
  Soft Preemption: Disabled
```

Path Protection

Path protection provides an end-to-end failure recovery mechanism (that is, full path protection) for associated bidirectional MPLS-TE LSPs. Associated bidirectional MPLS-TE LSPs support 1:1 path protection. You can configure the working and protecting LSPs as part of configuring the MPLS-TE tunnel. The working LSP is the primary LSP used to route traffic, while the protecting LSP is a backup for a working LSP. If the working LSP fails, traffic is switched to the protecting LSP until the working LSP is restored, at which time traffic forwarding reverts back to the working LSP.

When FRR is not enabled on a tunnel, and when GAL-BFD and/or Fault OAM is enabled on an associated bidirectional co-routed LSP, path-protection is activated by the FIB running on the line card that hosts the working LSP. The failure on the working LSP can be detected using BFD or Fault OAM.

Configure Path Protection for Associated Bidirectional LSPs, on page 159 provides procedural details.

You can use the **show mpls traffic-eng fast-reroute log** command to confirm whether protection switching has been activated by FIB.

Configure Path Protection for Associated Bidirectional LSPs

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **bfd** {fast-detect | encap-mode}
5. **destination** *ip-address*

6. **bidirectional**
7. **bidirectional association** {**id** <0-65535> | **source-address** <IP address>} [**global-id** <0-4294967295>
8. **association type co-routed**
9. **path-protection**
10. **path-option** *preference - priority* **{dynamic | explicit}**
11. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RSP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.

Step 4	**bfd** {fast-detect | encap-mode}
	Example:
	`RP/0/RSP0/CPU0:IMC0(config-if)#bfd`
	`RP/0/RSP0/CPU0:IMC0(config-if-tunte-bfd)#fast-detect`
	`RP/0/RSP0/CPU0:IMC0(config-if-tunte-bfd)#encap-mode gal`
		Specify if you want BFD enabled for the LSP over a Generic Associated Channel (G-ACh) or over a IP channel. IP channel is the default.

Step 5	**destination** *ip-address* **Example:** `RP/0/RSP0/CPU0:router(config-if)# destination 49.49.49.2`	Assigns a destination address on the new tunnel. The destination address is the remote node's MPLS-TE router ID.
Step 6	**bidirectional** **Example:** `Router(config-if)# bidirectional`	Configure the ingress router for the LSP and include the bidirectional statement to specify that the LSP be established as a bidirectional LSP.
Step 7	**bidirectional association** {**id** <0-65535> | **source-address** <IP address>} [**global-id** <0-4294967295> **Example:** `Router(config-if-bidir)# association id 1 source-address 11.0.0.1`	Set the association ID that uniquely identifies the association of LSPs, which is the tunnel ID of the bound LSP or the tunnel ID of the binding LSP. Also, set the source address to the tunnel sender address of the bound LSP or the tunnel sender address of the binding LSP. Also, set the ID for associating the global source.

	Command or Action	Purpose
		Note Association ID, association source and optional global-id must be configured identically on both the endpoints.
Step 8	**association type co-routed** **Example:** `Router(config-if-bidir)#association type co-routed`	Specify that the LSP be established as a associated co-routed bidirectional LSP.
Step 9	**path-protection** **Example:** `RP/0/RSP0/CPU0:IMC0(config-if-bidir-co-routed)#path-protection`	Enable path protection.
Step 10	**path-option** *preference - priority* **{dynamic | explicit}** **Example:** `RP/0/RSP0/CPU0:router(config-if)# path-option 1 dynamic`	Sets the path option and assigns the path-option ID. Both sides of the co-routed bidirectional LSPs must use dynamic or matching co-routed strict-hop explicit path-option.
Step 11	**commit**	

Example

Here is a sample configuration with path protection defined for the Associated Bidirectional LSP.

```
RP/0/RSP0/CPU0:IMC0#config
RP/0/RSP0/CPU0:IMC0(config)#interface tunnel-te 1
RP/0/RSP0/CPU0:IMC0(config-if)#ipv4 unnumbered loopback0
RP/0/RSP0/CPU0:IMC0(config-if)#destination 49.49.49.2
RP/0/RSP0/CPU0:IMC0(config-if)#bidirectional
RP/0/RSP0/CPU0:IMC0(config-if-bidir)#association id 100 source-address 49.49.4$
RP/0/RSP0/CPU0:IMC0(config-if-bidir)#association type co-routed
RP/0/RSP0/CPU0:IMC0(config-if-bidir-co-routed)#path-protection
RP/0/RSP0/CPU0:IMC0(config-if)#path-option 1  dynamic
RP/0/RSP0/CPU0:IMC0(config-if)#commit
```

OAM Support for Associated Bidirectional LSPs

You can opt to configure operations, administration and management (OAM) support for Associated Bidirectional LSPs in the following areas:

- **Continuity check:** You can configure bidirectional forwarding detection (BFD) over a Generic Associated Channel (G-ACh) with hardware assist. This allows for BFD Hello packets to be generated and processed in hardware making smaller Hello intervals such as 3.3 ms feasible. For more information on BFD and BFD hardware offload see *Implementing BFD* module in the *Cisco ASR 9000 Series Aggregation Services Router Routing Configuration Guide* .
- **Fault notification:** You can run Fault OAM over associated bidirectional co-routed LSPs to convey fault notification from mid-point to end-point of the LSP. The following fault OAM messages are supported:

- Link Down Indication (LDI): generated when an interface goes down (for example, to fiber-cut) at mid-point.
- Lock Report (LKR): generated when an interface is shutdown at mid-point.

  You can configure fault OAM to generate OAM message at mid-point or enable protection switching due to fault OAM at end-point. Generate Fault OAM Messages at Mid-point, on page 162 and Generate Fault OAM Messages at End-point, on page 162provides procedural details.

- **Fault diagnostics:** You can use the ping and traceroute features as a means to check connectivity and isolate failure points for both co-routed and non-co-routed bidirectional TE tunnels. *MPLS Network Management with MPLS LSP Ping and MPLS SP Traceroute* provides details.

Generate Fault OAM Messages at Mid-point

To program all bi-directional LSPs to generate fault OAM message at mid-point use the following steps:

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **fault-oam**
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:IMO(config)# mpls traffic-eng`	Configures an MPLS-TE tunnel interface.
Step 3	**fault-oam** **Example:** `RP/0/RSP0/CPU0:IMC0(config-mpls-te)#fault-oam`	Enable fault OAM for an associated bidirectional LSP.
Step 4	**commit**	

Generate Fault OAM Messages at End-point

In order to enable protection switching due to fault OAM at end-point use the following steps:

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **bidirectional association type co-routed fault-oam**
4. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RSP0/CPU0:IMC0(config)#interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**bidirectional association type co-routed fault-oam** **Example:** `RP/0/RSP0/CPU0:IMC0(config-if)#bidirectional association type co-routed fault-oam`	Enable fault OAM for an associated co-routed bidirectional LSP.
Step 4	**commit**	

Pseudowire Call Admission Control

You can use the Pseudowire Call Admission Control (PW CAC) process to check for bandwidth constraints and ensure that once the path is signaled, the links (pseudowires) participating in the bidirectional LSP association have the required bandwidth. Only pseudowires with sufficient bandwidth are admitted in the bidirectional LSP association process. *Configure Pseudowire Bandwidth* in the *Cisco ASR 9000 Series Aggregation Services Router L2VPN and Ethernet Services Configuration Guide* provides procedural details.

Configure Named Tunnel and Named Path Option

Perform this task to uniquely name TE (Traffic Engineering) tunnels in a network and their path options using STRING names.

SUMMARY STEPS

1. **configure**
2. **mpls traffic-eng**
3. **named-tunnels**
4. **tunnel-te** *tunnel-name*
5. **destination** *address*
6. **path-option** *path-name*
7. **preference** *value*
8. **computation** { **explicit** *explicit-path-name* | **dynamic** }
9. **root**
10. **ipv4 unnumbered mpls traffic-engloopback** *loopback-number*
11. **commit**

DETAILED STEPS

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RSP0/CPU0:router# configure`	Enters global configuration mode.
Step 2	**mpls traffic-eng** **Example:** `RP/0/RSP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**named-tunnels** **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te)# named-tunnels`	Enters the named tunnels configuration sub-mode.
Step 4	**tunnel-te** *tunnel-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-named-tunnels)# tunnel-te FROM-NY-TO-LA`	Specifies the TE tunnel name using STRING characters. The STRING limit is 59.
Step 5	**destination** *address* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-tunnel-name)# destination 192.168.0.1`	Assigns a destination address to the new tunnel.
Step 6	**path-option** *path-name* **Example:** `RP/0/RSP0/CPU0:router(config-mpls-te-tunnel-name)# path-option VIA_DC`	Specifies the path option name.
Step 7	**preference** *value* **Example:** `RP/0/RSP0/CPU0:router(config-path-option-name)# preference 10`	Specifies the path option preference. The range is from 1 to 4294967295. Lower values have a higher preference.

	Command or Action	Purpose
Step 8	**computation** { **explicit** *explicit-path-name* | **dynamic** } **Example:** `RP/0/RSP0/CPU0:router(config-path-option-name)# computation explicit MY_EXPLICIT_PATH`	Sets the path computation method as explicit (Computation is based on the preconfigured path). **Note** You can use the *dynamic* option as the path computation method, where the path is dynamically calculated.
Step 9	**root**	
Step 10	**ipv4 unnumbered mpls traffic-engloopback** *loopback-number* **Example:** `RP/0/RSP0/CPU0:router(config)# ipv4 unnumbered mpls traffic-eng loopback 0`	Enables IPv4 processing without an explicit address.
Step 11	**commit**	

Verify Named Tunnel and Named Path Option Configuration: Example

Use the **show mpls traffic-eng tunnels name** *tunnel-name* command to verify the named tunnel configuration. The following example shows sample output for this command:

```
show mpls traffic-eng tunnels name FROM-NY-TO-LA

Name: FROM-NY-TO-LA  Destination: 192.168.0.1  Ifhandle:0x580
  Tunnel-ID: 32769
  Status:
    Admin:    up Oper: down   Path: valid   Signalling: connected

    path option VIA_DC, preference 10,  type explicit MY_EXPLICIT_PATH

    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Fri Jun 10 15:32:00 2016 (00:36:10 ago)
  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
    Metric Type: TE (global)
    Path Selection:
      Tiebreaker: Min-fill (default)
    Hop-limit: disabled
    Cost-limit: disabled
    Path-invalidation timeout: 10000 msec (default), Action: Tear (default)
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forward class: 0 (default)
    Forwarding-Adjacency: disabled
    Autoroute Destinations: 0
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Disabled, Protection Desired: None
    Path Protection: Not Enabled
    BFD Fast Detection: Disabled
    Reoptimization after affinity failure: Enabled
    Soft Preemption: Disabled
```

```
Displayed 1 (of 3) heads, 0 (of 0) midpoints, 0 (of 0) tails
Displayed 0 up, 1 down, 0 recovering, 0 recovered head
```

Enable per-application accounting for interfaces

The following configurations helps enable per-application accounting for MPLS RSVP-TE IPv4 traffic and segment routing with MPLS IPv4 traffic on the interfaces respectively.

Example 1: Enable per-application accounting for MPLS RSVP-TE IPv4 traffic on the interfaces

```
RP/0/RSP0/CPU0:router# config
RP/0/RSP0/CPU0:router(config)# accounting
RP/0/RSP0/CPU0:router(config-acct)# interfaces
RP/0/RSP0/CPU0:router(config-acct-if)# mpls
RP/0/RSP0/CPU0:router(config-acct-if-mpls)# ipv4 rspv-te
```

Example 2: Enable per-application accounting for segment routing MPLS IPv4 traffic on the interfaces

```
RP/0/RSP0/CPU0:router# config
RP/0/RSP0/CPU0:router(config)# accounting
RP/0/RSP0/CPU0:router(config-acct)# interfaces
RP/0/RSP0/CPU0:router (config-acct-if)# segment-routing mpls ipv4
```

Configure RSVP-TE bandwidth accounting

Perform these steps to enable RSVP-TE bandwidth accounting and dark bandwidth advertisement for all MPLS-TE enabled links:

Before you begin

Make sure that the Enable per-application accounting for interfaces feature is enabled on the router.

Procedure

Step 1 **configure**

Example:

```
RP/0/RSP0/CPU0:router# configure
```

Enters global configuration mode.

Step 2 **mpls traffic-eng**

Example:

```
RP/0/RSP0/CPU0:router(config)# mpls traffic-eng
```

Enters MPLS TE configuration mode.

Step 3 **bandwidth-accounting**

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te)# bandwidth-accounting
```

Enables RSVP-TE dark bandwidth accounting and enters bandwidth accounting configuration mode.

Step 4 **application interval** *seconds*

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te-bw-account)# application interval 90
```

Configures the length of the application interval in seconds. At the end of application interval, dark bandwidth rates are computed and applied to all RSVP-TE enabled interfaces.

Note
Model-driven telemetry supports dark bandwidth. The telemetry polling interval is reduced to 10 seconds.

If the interval is reconfigured while the timer is running, the new value is compared to the time remaining for the running timer. The timer is adjusted so that the lower of these two values is used for this interval. The subsequent interval will use the newly configured value.

Note
TE stores sample history for the current and previous application intervals. If the application interval is lowered, TE may discard the sample history.

Range is from 90 to 1800. The default value is 180.

Step 5 **application enforced**

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te-bw-account)# application enforced
```

Enables enforcement of the calculated effective maximum reservable bandwidth rate. This configuration is mandatory for the dark bandwidth accounting feature to work properly.

Step 6 **adjustment-factor** *percentage*

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te-bw-account)# adjustment-factor 85
```

Configures TE to over-book (>100%) or under-book (<100%) the effective maximum reservable bandwidth. The measured dark-bandwidth will be scaled based on the adjustment factor. Range is from 0 to 200. The default value is 100.

Step 7 **sampling-interval** *seconds*

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te-bw-account)# sampling-interval 30
```

Configures the length of the sampling interval in seconds. The bandwidth rate is collected from the statistics collector process (statsD) at the end of each sampling interval for each TE link.

If the interval is reconfigured while the timer is running, the new value is compared to the time remaining for the running timer. The timer is adjusted so that the lower of these two values is used for this interval. The subsequent interval will use the newly configured value.

Range is from 30 to 600. The default is 60.

Step 8 **flooding threshold** { **up** | **down** } *percentage*

Example:

```
RP/0/RSP0/CPU0:router(config-mpls-te-bw-account)# flooding threshold up 30 down 30
```

Configures the reserved bandwidth thresholds. When bandwidth crosses one of these thresholds, flooding is triggered. Range is from 0 to 100. The default value is 10.

Step 9 **commit**

Step 10 **show mpls traffic-eng link-management summary**

Example:

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng link-management summary
```

(Optional)

Displays a summary of link management information, including bandwidth accounting information.

Step 11 **show mpls traffic-eng link-management advertisements**

Example:

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng link-management advertisements
```

(Optional)

Displays local link information that MPLS-TE link management is currently flooding into the global TE topology.

Step 12 **show mpls traffic-eng link-management interfaces** [*type interface-path-id*]

Example:

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng link-management interfaces gig0/1/1/1 detail
```

(Optional)

Displays bandwidth accounting and utilization details and link management information.

Configure Autoroute Tunnel as Designated Path

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
Autoroute Tunnel as Designated Path	Release 7.6.2	We now provide you the flexibility to simplify the path selection for a traffic class and split traffic among multiple TE tunnels. To split traffic, you can specify an autoroute tunnel to forward traffic to a particular tunnel destination address without considering the IS-IS metric for traffic path selection. IS-IS metric provides the shortest IGP path to a destination based only on link costs along the path. However, you may want to specify a tunnel interface to carry traffic regardless of IGP cost to meet your specific organizational requirements. Earlier, MPLS-TE considered either the Forwarding Adjacency (FA) or Autoroute (AA) tunnel for forwarding traffic based only on the IS-IS metric. The feature introduces the **mpls traffic-eng tunnel restricted** command.

MPLS-TE builds a unidirectional tunnel from a source to a destination using label switched path (LSP) to forward traffic.

To forward the traffic through MPLS tunneling, you can use autoroute, forwarding adjacency, or static routing:

- Autoroute (AA) functionality allows to insert the MPLS TE tunnel in the Shortest Path First (SPF) tree for the tunnel to transport all the traffic from the headend to all destinations behind the tail-end. AA is only known to the tunnel headend router.
- Forwarding Adjacency (FA) allows the MPLS-TE tunnel to be advertised as a link in an IGP network with the cost of the link associated with it. Routers outside of the TE domain can see the TE tunnel and use it to compute the shortest path for routing traffic throughout the network.
- Static routing allows you to inject static IP traffic into a tunnel as the output interface for the routing decision.

Prior to this release, by default, MPLS-TE considers FA or AA tunnels to forward traffic based on the IS-IS metric. The lower metric is always used to forward traffic. There was no mechanism to forward traffic to a specific tunnel interface.

For certain prefixes to achieve many benefits such as security and service-level agreements, there might be a need to forward traffic to a specific tunnel interface that has a matching destination address.

With this feature, you can exclusively use AA tunnels to forward traffic to their tunnel destination address irrespective of IS-IS metric. Traffic steering is performed based on the prefixes and not metrics. Traffic to other prefixes defaults to the forwarding-adjacency (FA) tunnels.

To enable this feature, use the **mpls traffic-eng tunnel restricted** command.

Also, you may require more than one AA tunnel to a particular remote PE and use ECMP to forward traffic across AA tunnels. You can configure a loopback interface with one primary address and multiple secondary addresses on the remote PE, using one IP for the FA tunnel destination, and others for the AA tunnels destinations. Multiple IP addresses are advertised in the MPLS TE domain using the typed length value (TLV) 132 in IS-IS. A TLV-encoded data stream contains code related to the record type, the record length of the value, and value. TLV 132 represents the IP addresses of the transmitting interface.

Feature Behavior

When MPLS-TE tunnel restricted is configured, the following is the behavior:

- A complete set of candidate paths is available for selection on a per-prefix basis during RIB update as the first hop computation includes all the AA tunnels terminating on a node up to a limit of 64 and the lowest cost forwarding-adjacency or native paths terminating on the node or inherited from the parent nodes in the first hops set for the node.
- During per-prefix computation, AA tunnel first hops are used for traffic sent to their tunnel destination address even if FA tunnel or native first hops have a better metric. AA tunnel first-hops are not used for any other prefixes.
- ECMP is used when multiple AA tunnel first hops have the same destination address and metric.
- During per-prefix computation, AA tunnel first hops are used for traffic sent to their tunnel destination address, and for all other destinations on the tunnel tail node or behind it, even if a native path has a better metric.

  Adding **mpls traffic-eng tunnel preferred** configuration has no effect when the tunnel restricted is already configured.
- If there's no AA tunnel or if the tunnel is down, then native paths are used for all other destinations on the tunnel tail node or behind it.

  The route metric for a prefix reflects the chosen first-hop, not necessarily the lowest cost SPF distance to the node.

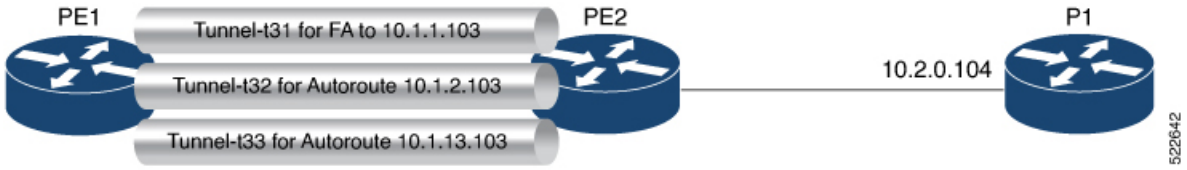
Restrictions for Configure Autoroute Tunnel as Designated Path

- The total number of interface addresses to the number that can be contained in 255 bytes is 63 for IPv4 and 15 for IPv6.
- When this feature is enabled, a maximum of 64 tunnels can terminate on the tail node.

Configure Autoroute Tunnel as Designated Path

Let's understand how to configure the feature using the following topology:

Figure 17: Topology



Consider the topology where PE1 has three MPLS tunnels connecting to PE2.

- Tunnel-t31: Forwarding adjacency (FA) is configured to the primary address of Loopback 0 on PE2 (10.1.1.103).
- Tunnel- t32: Autoroute announce (AA) is configured to a secondary address of Loopback 0 on PE2 (10.1.2.103).
- Tunnel-t33: Autoroute announce (AA) is configured to a secondary address of Loopback 0 on PE2 (10.1.3.103).

This feature is not enabled by default. When this feature is not enabled, traffic is load balanced over all AA tunnels towards the same remote PE provided the tunnel metric is the same:

```
Router# show routes
i L2 10.1.1.103/32 [115/40] via 10.1.2.103, 00:00:30, tunnel-t32
                   [115/40] via 10.1.3.103, 00:00:30, tunnel-t33
i L2 10.1.2.103/32 [115/40] via 10.1.2.103, 00:00:30, tunnel-t32
                   [115/40] via 10.1.3.103, 00:00:30, tunnel-t33
i L2 10.1.3.103/32 [115/40] via 10.1.2.103, 00:00:30, tunnel-t32
                   [115/40] via 10.1.3.103, 00:00:30, tunnel-t33
i L2 10.2.0.103/32 [115/40] via 10.1.2.103, 00:00:30, tunnel-t32
                   [115/40] via 10.1.3.103, 00:00:30, tunnel-t33
 10.2.0.104/32 [115/50] via 10.1.2.103, 00:00:30, tunnel-t32
                   [115/50] via 10.1.3.103, 00:00:30, tunnel-t33
```

Configuration Example

You can configure the feature using the **mpls traffic-eng tunnel restricted** command.

```
RP/0/RSP0/CPU0:ios# configure
RP/0/RSP0/CPU0:ios(config)# router isis 1
RP/0/RSP0/CPU0:ios(config-isis)# address-family ipv4 unicast
RP/0/RSP0/CPU0:ios(config-isis-af# mpls traffic-eng tunnel restricted
```

Running Configuration

The following example shows the AA tunnel metric running configuration:

```
router isis 1
 address-family ipv4 unicast
  mpls traffic-eng tunnel restricted
 !
!
end
```

Verification

When you enable the feature, traffic towards a particular prefix is sent only over the tunnel that has that IP address as destination.

```
Router# show route
i L2 10.1.1.103/32 [115/40] via 10.1.1.103, 00:00:04, tunnel-t31
i L2 10.1.2.103/32 [115/40] via 10.1.2.103, 00:00:04, tunnel-t32
i L2 10.1.3.103/32 [115/40] via 10.1.3.103, 00:00:04, tunnel-t33
i L2 10.2.0.103/32 [115/40] via 10.1.1.103, 00:00:04, tunnel-t31
i L2 10.2.0.104/32 [115/50] via 10.1.1.103, 00:00:04, tunnel-t31
```

When multiple restricted AA tunnels are created towards the same destination IP address, router load balances traffic across all those tunnels:

```
Router# show route
i L2 10.1.1.103/32 [115/40] via 10.1.1.101, 00:00:08, GigabitEthernet0/0/0/2
                   [115/40] via 10.1.3.101, 00:00:08, GigabitEthernet0/0/0/3
i L2 10.1.2.103/32 [115/40] via 10.1.2.103, 00:00:08, tunnel-t32
                   [115/40] via 10.1.2.103, 00:00:30, tunnel-t34
i L2 10.1.3.103/32 [115/40] via 10.1.3.103, 00:00:08, tunnel-t33
i L2 10.2.0.103/32 [115/40] via 10.1.1.101, 00:00:08, GigabitEthernet0/0/0/2
                   [115/40] via 10.1.3.101, 00:00:08, GigabitEthernet0/0/0/3
i L2 10.2.0.104/32 [115/50] via 10.1.1.101, 00:00:08, GigabitEthernet0/0/0/2
                   [115/50] via 10.1.3.101, 00:00:08, GigabitEthernet0/0/0/3
```

Configuration Examples for Cisco MPLS-TE

These configuration examples are used for MPLS-TE:

Build MPLS-TE Topology and Tunnels: Example

The following examples show how to build an OSPF and IS-IS topology:

```
(OSPF)
...
configure
  mpls traffic-eng
  interface pos 0/6/0/0
  router id loopback 0
  router ospf 1
  router-id 192.168.25.66
  area 0
  interface pos 0/6/0/0
  interface loopback 0
  mpls traffic-eng router-id 192.168.70.1
  mpls traffic-eng area 0
  rsvp
  interface pos 0/6/0/0
  bandwidth 100
  commit
show mpls traffic-eng topology
show mpls traffic-eng link-management advertisement
!
(IS-IS)
...
configure
  mpls traffic-eng
  interface pos 0/6/0/0
```

```
  router id loopback 0
  router isis lab
  address-family ipv4 unicast
  mpls traffic-eng level 2
  mpls traffic-eng router-id 192.168.70.2
  !
  interface POS0/0/0/0
  address-family ipv4 unicast
!
```

The following example shows how to configure tunnel interfaces:

```
interface tunnel-te1
  destination 192.168.92.125
  ipv4 unnumbered loopback 0
  path-option l dynamic
  bandwidth 100
  commit
show mpls traffic-eng tunnels
show ipv4 interface brief
show mpls traffic-eng link-management admission-control
!
interface tunnel-te1
  autoroute announce
  route ipv4 192.168.12.52/32 tunnel-te1
  commit
ping 192.168.12.52
show mpls traffic autoroute
!
interface tunnel-te1
  fast-reroute
  mpls traffic-eng interface pos 0/6/0/0
  backup-path tunnel-te 2
  interface tunnel-te2
  backup-bw global-pool 5000
  ipv4 unnumbered loopback 0
  path-option l explicit name backup-path
  destination 192.168.92.125
 commit
show mpls traffic-eng tunnels backup
show mpls traffic-eng fast-reroute database
!
rsvp
  interface pos 0/6/0/0
  bandwidth 100 150 sub-pool 50
  interface tunnel-te1
  bandwidth sub-pool 10
commit
```

Related Topics

Building MPLS-TE Topology, on page 61
Creating an MPLS-TE Tunnel, on page 63
How MPLS-TE Works, on page 5

Configure IETF DS-TE Tunnels: Example

The following example shows how to configure DS-TE:

```
rsvp
 interface pos 0/6/0/0
 bandwidth rdm 100 150 bc1 50
 mpls traffic-eng
 ds-te mode ietf
 interface tunnel-te 1
 bandwidth 10 class-type 1
 commit

configure
 rsvp interface 0/6/0/0
 bandwidth mam max-reservable-bw 400 bc0 300 bc1 200
 mpls traffic-eng
 ds-te mode ietf
 ds-te model mam
 interface tunnel-te 1bandwidth 10 class-type 1
 commit
```

```
rsvp
 interface pos 0/6/0/0
 bandwidth rdm percentage bc0 100 bc1 50
 bandwidth 10 class-type 1
 commit

configure
 rsvp interface 0/6/0/0
 bandwidth mam percentage bc0 100 bc1 50
 ds-te mode ietf
 ds-te model mam
 bandwidth 10 class-type 1
 commit
```

Related Topics

Configuring a Prestandard DS-TE Tunnel, on page 76
Prestandard DS-TE Mode, on page 10

Configure MPLS-TE and Fast-Reroute on OSPF: Example

CSPF areas are configured on a per-path-option basis. The following example shows how to use the traffic-engineering tunnels (tunnel-te) interface and the active path for the MPLS-TE tunnel:

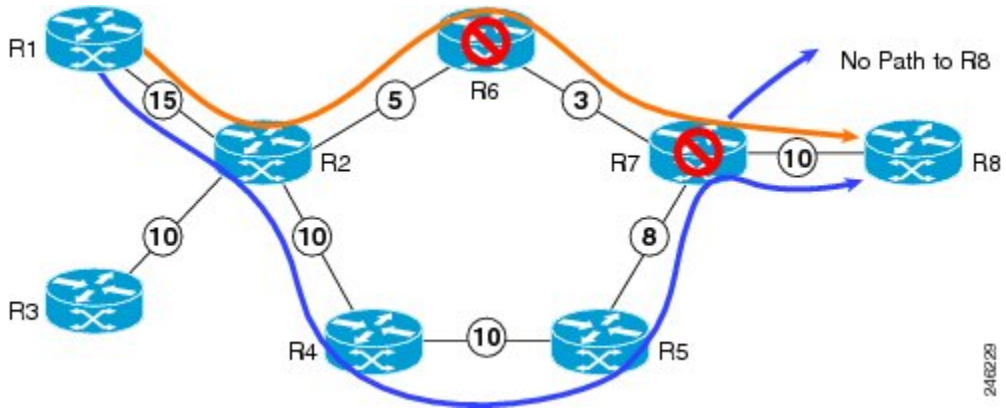
```
configure
 interface tunnel-te 0
  path-option 1 explicit id 6 ospf 126 area 0
  path-option 2 explicit name 234 ospf 3 area 7 verbatim
  path-option 3 dynamic isis mtbf level 1 lockdown
  commit
```

Configure the Ignore IS-IS Overload Bit Setting in MPLS-TE: Example

This example shows how to configure the IS-IS overload bit setting in MPLS-TE:

This figure illustrates the IS-IS overload bit scenario:

Figure 18: IS-IS overload bit



Consider a MPLS TE topology in which usage of nodes that indicated an overload situation was restricted. In this topology, the router R7 exhibits overload situation and hence this node can not be used during TE CSPF. To overcome this limitation, the IS-IS overload bit avoidance (OLA) feature was introduced. This feature allows network administrators to prevent RSVP-TE label switched paths (LSPs) from being disabled when a router in that path has its Intermediate System-to-Intermediate System (IS-IS) overload bit set.

The IS-IS overload bit avoidance feature is activated at router R1 using this command:

```
mpls traffic-eng path-selection ignore overload
```

```
  configure
   mpls traffic-eng
    path-selection ignore overload
     commit
```

Related Topics

Configuring the Ignore Integrated IS-IS Overload Bit Setting in MPLS-TE, on page 84
Ignore Intermediate System-to-Intermediate System Overload Bit Setting in MPLS-TE, on page 14

Configure Flexible Name-based Tunnel Constraints: Example

The following configuration shows the three-step process used to configure flexible name-based tunnel constraints.

```
  R2
  line console
   exec-timeout 0 0
   width 250
  !
  logging console debugging
  explicit-path name mypath
   index 1 next-address loose ipv4 unicast 192.168.0.1 !
  explicit-path name ex_path1
   index 10 next-address loose ipv4 unicast 172.16.0.1  index 20 next-address loose ipv4
unicast 192.168.0.1 !
  interface Loopback0
   ipv4 address 10.22.22.22 255.255.255.255 !
```

```
interface tunnel-te1
 ipv4 unnumbered Loopback0
 signalled-bandwidth 1000000
 destination 192.168.0.1
 affinity include green
 affinity include yellow
 affinity exclude indigo
 affinity exclude orange
 path-option 1 dynamic
!
router isis 1
 is-type level-1
 net 47.0001.0000.0000.0001.00
 nsf cisco
 address-family ipv4 unicast
  metric-style wide
  mpls traffic-eng level-1
  mpls traffic-eng router-id 192.168.70.1
 !
 interface Loopback0
  passive
  address-family ipv4 unicast
  !
 !
 interface GigabitEthernet0/1/0/0
  address-family ipv4 unicast
  !
 !
 interface GigabitEthernet0/1/0/1
  address-family ipv4 unicast
  !
 !
 interface GigabitEthernet0/1/0/2
  address-family ipv4 unicast
  !
 !
 interface GigabitEthernet0/1/0/3
  address-family ipv4 unicast
  !
 !
!
rsvp
 interface GigabitEthernet0/1/0/0
  bandwidth 1000000 1000000
 !
 interface GigabitEthernet0/1/0/1
  bandwidth 1000000 1000000
 !
 interface GigabitEthernet0/1/0/2
  bandwidth 1000000 1000000
 !
 interface GigabitEthernet0/1/0/3
  bandwidth 1000000 1000000
 !
!
mpls traffic-eng
 interface GigabitEthernet0/1/0/0
  attribute-names red purple
 !
 interface GigabitEthernet0/1/0/1
  attribute-names red orange
 !
 interface GigabitEthernet0/1/0/2
  attribute-names green purple
```

```
 !
 interface GigabitEthernet0/1/0/3
  attribute-names green orange
 !
 affinity-map red 1
 affinity-map blue 2
 affinity-map teal 80
 affinity-map green 4
 affinity-map indigo 40
 affinity-map orange 20
 affinity-map purple 10
 affinity-map yellow 8
!
```

Related Topics

Assigning Color Names to Numeric Values, on page 85
Associating Affinity-Names with TE Links, on page 86
Associating Affinity Constraints for TE Tunnels, on page 87
Flexible Name-based Tunnel Constraints, on page 15

Configure an Interarea Tunnel: Example

The following configuration example shows how to configure a traffic engineering interarea tunnel. .

Note Specifying the tunnel tailend in the loosely routed path is optional.

```
configure
  interface Tunnel-te1
    ipv4 unnumbered Loopback0
    destination 192.168.20.20
    signalled-bandwidth 300
    path-option 1 explicit name path-tunnel1

explicit-path name path-tunnel1
  index 10 next-address loose ipv4 unicast 192.168.40.40
  index 20 next-address loose ipv4 unicast 192.168.60.60
  index 30 next-address loose ipv4 unicast 192.168.20.20
```

The following configuration example shows how to configure loose-path retry period (range is 30 to 600 seconds) on headend router.

```
config
 mpls traffic-eng
  timers loose-path retry-period 120
```

The following configuration example shows the global configuration for loose hop expansion affinity or metric on ABR.

```
config
 mpls traffic-eng path-selection loose-expansion affinity 0xff
 mpls traffic-eng path-selection loose-expansion metric te class-type 5
```

Configure Forwarding Adjacency: Example

The following configuration example shows how to configure an MPLS-TE forwarding adjacency on tunnel-te 68 with a holdtime value of 60:

```
configure
 interface tunnel-te 68
 forwarding-adjacency holdtime 60
 commit
```

Related Topics

Configuring MPLS-TE Forwarding Adjacency, on page 91
MPLS-TE Forwarding Adjacency Benefits, on page 19

Configure PCE: Example

The following configuration example illustrates a PCE configuration:

```
configure
mpls traffic-eng
  interface pos 0/6/0/0
  pce address ipv4 192.168.25.66
  router id loopback 0
  router ospf 1
  router-id 192.168.25.66
  area 0
  interface pos 0/6/0/0
  interface loopback 0
  mpls traffic-eng router-id 192.168.70.1
  mpls traffic-eng area 0
  rsvp
  interface pos 0/6/0/0
  bandwidth 100
  commit
```

The following configuration example illustrates PCC configuration:

```
configure
  interface tunnel-te 10
  ipv4 unnumbered loopback 0
  destination 10.2.3.4
  path-option 1 dynamic pce
  mpls traffic-eng
  interface pos 0/6/0/0
  router id loopback 0
  router ospf 1
  router-id 192.168.25.66
  area 0
  interface pos 0/6/0/0
  interface loopback 0
  mpls traffic-eng router-id 192.168.70.1
  mpls traffic-eng area 0
  rsvp
  interface pos 0/6/0/0
  bandwidth 100
```

```
commit
```

Related Topics

Configuring a Path Computation Client, on page 92
Configuring a Path Computation Element Address, on page 93
Configuring PCE Parameters, on page 94
Path Computation Element, on page 20

Configure Fast Repair: Example

The following example shows how to configure fast repair:

```
configure
 mpls traffic-eng
  pce
   stateful-client
    fast-repair
   !
  !
 !
```

Enable PCEP Cisco Extension: Example

The following example shows how to enable PCEP Cisco extension:

```
configure
 mpls traffic-eng
  pce
   stateful-client
    cisco-extension
   !
  !
 !
```

Configure PBTS for IPv4: Examples

These examples show how to configure PBTS for IPv4.

Create rules to classify the ingress packets such as ACL, DSCP, TOS, or EXP to different classes. Associate a forward-class to each type of ingress traffic.

Configure Access List

```
ipv4 access-list prec1
10 permit ipv4 any any precedence priority
!
ipv4 access-list prec2
10 permit ipv4 any any precedence immediate
!
```

Configure Class Map

The following example shows how to configure a classmap using ACL

```
class-map type traffic match-any prec1
match access-group ipv4 prec1
end-class-map
!
class-map type traffic match-any prec2
match access-group ipv4 prec2
end-class-map
!
```

Configure Policy Map

The following example shows how to configure a policy map:

```
policy-map type pbr prec
class type traffic prec1
  set forward-class 1
!
class type traffic prec3
  set forward-class 3
!
class type traffic class-default
!
end-policy-map
!
```

Configure Tunnel Interface

The following example shows how to configure an MPLS TE tunnel interface:

Set up one or more egress MPLS-TE to the destination. Associate the egress MPLS-TE to a forward-class.

```
interface tunnel-te61
ipv4 unnumbered Loopback0
signalled-bandwidth 1000
autoroute announce
destination 6.6.6.6
record-route
forward-class 1
path-option 1 explicit identifier 61
!
```

Configure Policy on a Interface

Enable PBTS on the ingress interface, by applying the service policy (Use already configured classification rules)

```
interface GigabitEthernet0/0/0/1.1
service-policy type pbr input prec
ipv4 address 22.1.1.1 255.255.255.0
encapsulation dot1q 1
!
```

Note

- Only one forward-class can be associated with a TE tunnel at any time.
- The router supports eight unique forwarding class values.
- Forwarding class zero is the default forwarding class and it doesn't require explicit configuration.

Configure PBTS for IPv6: Examples

These examples show how to configure PBTS for IPv6.

Configure Tunnel Interface: Example

The following example shows how to configure MPLS TE tunnel interface:

```
interface tunnel-te5500
 ipv4 unnumbered Loopback0
 ipv6 enable
 destination 19.0.0.1
 fast-reroute
 record-route
 forward-class 1
 forwarding-adjacency
  include-ipv6
 !
 path-option 1 explicit name pri
!
```

Configure Policy on Interface: Example

The following example shows how to configure policy on an interface:

```
interface HundredGigE0/0/0/1
 service-policy type pbr input dscp
 ipv4 address 111.111.1.1 255.255.255.0
 ipv4 unreachables disable
 ipv6 address 2001:111::1/64
 ipv6 unreachables disable
!
```

Configure Policy Map: Example

The following example shows how to configure policy map:

```
policy-map type pbr dscp
 class type traffic ef
  set forward-class 1
 !
 class type traffic af11
  set forward-class 2
 !
 class type traffic ipv6-ef
  set forward-class 1
 !
 class type traffic af21
  set forward-class 3
 !
 class type traffic af31
  set forward-class 4
 !
 class type traffic af41
  set forward-class 5
 !
 class type traffic class-default
```

```
 !
 end-policy-map
!
```

Configure Classmap: Example

The following example shows how to configure classmap using ACL and non ACL:

```
class-map type traffic match-any ef
 match access-group ipv4 acl1
 end-class-map
!
class-map type traffic match-any a11
 match dscp af11
 end-class-map
!

Access-List
ipv4 access-list acl1
 10 permit ipv4 any any dscp ef
!
```

Configure Tunnels for Path Protection: Example

The path protection feature is configured on only the source router. The dynamic path option is a prerequisite to configure a path protection.

```
interface tunnel-te150
 ipv4 unnumbered Loopback150
 autoroute announce
 destination 151.151.151.151
 affinity 11 mask 11
 path-protection
 path-option 2 explicit name p2mp3-p2mp4-p2mp5_1
 path-option 10 dynamic
```

Related Topics

Enabling Path Protection for an Interface, on page 100
Assigning a Dynamic Path Option to a Tunnel, on page 101
Forcing a Manual Switchover on a Path-Protected Tunnel, on page 102
Configuring the Delay the Tunnel Takes Before Reoptimization, on page 103
Path Protection, on page 30
Pre-requisites for Path Protection, on page 30
Restrictions for Path Protection, on page 31

Configure Automatic Bandwidth: Example

The following configuration example illustrates an automatic bandwidth configuration:

```
  configure
   interface tunnel-te6
    auto-bw
     bw-limit min 10000 max 500000
```

```
 overflow threshold 50 min 1000 limit 3
 adjustment-threshold 20 min 1000
 application 180
```

Related Topics

Configuring the Collection Frequency, on page 104
Configuring the Automatic Bandwidth Functions, on page 106
MPLS-TE Automatic Bandwidth Overview, on page 31

Configure the MPLS-TE Shared Risk Link Groups: Example

The following configuration example shows how to specify the SRLG value of each link that has a shared risk with another link:

```
config t
srlg
    interface POS0/4/0/0
         value 10
         value 11
    |
    interface POS0/4/0/1
         value 10
    |
```

The following example shows the SRLG values configured on a specific link.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng topology brief
My_System_id: 100.0.0.2 (OSPF 0 area 0)
My_System_id: 0000.0000.0002.00 (IS-IS 1 level-1)
My_System_id: 0000.0000.0002.00 (IS-IS 1 level-2)
My_BC_Model_Type: RDM

Signalling error holddown: 10 sec Global Link Generation 389225

IGP Id: 0000.0000.0002.00, MPLS TE Id: 100.0.0.2 Router Node  (IS-IS 1 level-1)

IGP Id: 0000.0000.0002.00, MPLS TE Id: 100.0.0.2 Router Node  (IS-IS 1 level-2)

    Link[1]:Broadcast, DR:0000.0000.0002.07, Nbr Node Id:21, gen:389193
      Frag Id:0, Intf Address:51.2.3.2, Intf Id:0
      Nbr Intf Address:51.2.3.2, Nbr Intf Id:0
      TE Metric:10, IGP Metric:10, Attribute Flags:0x0
      Attribute Names:
      SRLGs: 1, 4, 5
      Switching Capability:, Encoding:
      BC Model ID:RDM
      Physical BW:1000000 (kbps), Max Reservable BW Global:10000 (kbps)
      Max Reservable BW Sub:10000 (kbps)
```

The following example shows the configured tunnels and associated SRLG values.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels
```

```
<snip>
Signalling Summary:
              LSP Tunnels Process:  running
                     RSVP Process:  running
                       Forwarding:  enabled
          Periodic reoptimization:  every 3600 seconds, next in 1363 seconds
           Periodic FRR Promotion:  every 300 seconds, next in 181 seconds
          Auto-bw enabled tunnels:  0 (disabled)

Name: tunnel-te1  Destination: 100.0.0.3
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: recovered

    path option 1,  type explicit path123 (Basis for Setup, path weight 2)
          OSPF 0 area 0
    G-PID: 0x0800 (derived from egress interface properties)
    SRLGs excluded: 2,3,4,5
                    6,7,8,9
    Bandwidth Requested: 0 kbps  CT0
<snip>
```

The following example shows all the interfaces associated with SRLG.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng topo srlg
My_System_id: 100.0.0.5 (OSPF 0 area 0)
My_System_id: 0000.0000.0005.00 (IS-IS 1 level-2)
My_System_id: 0000.0000.0005.00 (IS-IS ISIS-instance-123 level-2)

      SRLG      Interface Addr  TE Router ID    IGP Area  ID
_________       _____________   ____________    _____________
        10      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
        11      50.2.3.3        100.0.0.3       IS-IS 1 level-2
        12      50.2.3.3        100.0.0.3       IS-IS 1 level-2
        30      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
        77      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
        88      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
      1500      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
  10000000      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
4294967290      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
4294967295      50.4.5.5        100.0.0.5       IS-IS ISIS-instance-123 level-2
```

The following example shows the NHOP and NNHOP backup tunnels with excluded SRLG values.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng topology path dest 100.0.0.5 exclude-srlg
ipaddr
Path Setup to 100.0.0.2:
bw 0 (CT0), min_bw 0, metric: 30
setup_pri 7, hold_pri 7
affinity_bits 0x0, affinity_mask 0xffff
Exclude SRLG Intf Addr : 50.4.5.5
SRLGs Excluded :  10, 30, 1500, 10000000, 4294967290, 4294967295
Hop0:50.5.1.5
Hop1:50.5.1.1
Hop2:50.1.3.1
Hop3:50.1.3.3
Hop4:50.2.3.3
Hop5:50.2.3.2
Hop6:100.0.0.2
```

The following example shows an extract of explicit-path set to protect a specific interface.

```
RP/0/RSP0/CPU0:router#sh mpls traffic-eng topology path dest 10.0.0.5 explicit-path name
name

Path Setup to 100.0.0.5:
bw 0 (CT0), min_bw 9999, metric: 2
setup_pri 7, hold_pri 7
affinity_bits 0x0, affinity_mask 0xffff
SRLGs Excluded: 10, 30, 77, 88, 1500, 10000000
                4294967290, 4294967295

Hop0:50.3.4.3
Hop1:50.3.4.4
Hop2:50.4.5.4
Hop3:50.4.5.5
Hop4:100.0.0.5
```

Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 108
Creating an Explicit Path With Exclude SRLG, on page 110
Using Explicit Path With Exclude SRLG, on page 111
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 113
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 116
MPLS Traffic Engineering Shared Risk Link Groups, on page 39
Explicit Path, on page 39
Fast ReRoute with SRLG Constraints, on page 40
Importance of Protection, on page 41
Delivery of Packets During a Failure, on page 42
Multiple Backup Tunnels Protecting the Same Interface , on page 42
Weighted-SRLG Auto-backup Path Computation, on page 42
SRLG Limitations, on page 43
MPLS TE SRLG Scale Enhancements, on page 43

Configure BFD and SRLG Diverse Path-Protection Under Named TE Tunnels

Table 5: Feature History Table

Feature Name	Release Information	Feature Description
Configure BFD and SRLG Diverse Path-Protection Under Named TE Tunnels	Release 7.6.1	Instead of using number IDs, you can now use a string to name MPLS-TE tunnels while configuring Bidirectional Forwarding Detection (BFD) and Shared Risk Link Group (SRLG) diverse path protection. Unlike number IDs, tunnel names are unique across all the routers in your network. This facilitates faster troubleshooting as you use the **show mpls traffic-eng named-tunnels** command to check that the BFD and SRLG configurations meet specified performance requirements.

The following example shows how to configure BFD and SRLG diverse path-protection under named TE tunnels:

```
RP/0/RP0/CPU0:router#config
Wed Feb 16 10:30:55.346 -07
RP/0/RP0/CPU0:router(config)#mpls traffic-eng
RP/0/RP0/CPU0:router(config-mpls-te)# named-tunnels
RP/0/RP0/CPU0:router(config-te-named-tunnels)#tunnel-te TUNNEL-NY-TO-LA
RP/0/RP0/CPU0:router(config-te-tun-name)#destination 202.158.0.1
RP/0/RP0/CPU0:router(config-te-tun-name)#path-protection srlg-diverse
RP/0/RP0/CPU0:router(config-te-tun-name)#bfd
RP/0/RP0/CPU0:router(config-mpls-te-tun-bfd)#multiplier 3
RP/0/RP0/CPU0:router(config-mpls-te-tun-bfd)#fast-detect
RP/0/RP0/CPU0:router(config-mpls-te-tun-bfd)#minimum-interval 300
RP/0/RP0/CPU0:router(config-mpls-te-tun-bfd)#path-option BEST
RP/0/RP0/CPU0:router(config-po-name)#preference 10
RP/0/RP0/CPU0:router(config-po-name)#computation dynamic
```

Verification

This log displays the configured BFD and SRLG diverse path protection for named tunnels:

```
RP/0/RP0/CPU0:router(config)#show mpls traffic-eng named-tunnels
    tunnel-te TUNNEL-NY-TO-LA
      bfd
       multiplier 3
       fast-detect
       minimum-interval 300
    path-option BEST
       preference 10
       computation dynamic
     destination 202.158.0.1
```

```
    path-protection
      srlg-diverse
end
```

Configure the MPLS-TE Auto-Tunnel Backup: Example

Table 6: Feature History Table

Feature Name	Release Information	Feature Description
Bandwidth Protection Functions to Enhance auto-tunnel backup Capabilities	Release 7.5.1	This feature introduces bandwidth protection functions for auto-tunnel backups, such as signaled bandwidth, bandwidth protection, and soft-preemption. These functions provide better bandwidth usage and prevent traffic congestion and traffic loss. In earlier releases, auto-tunnel backups provided only link protection and node protection. Backup tunnels were signaled with zero bandwidth, causing traffic congestion when FRR went active. This feature introduces the following commands and keywords: • **bandwidth-protection maximum-aggregate** • **signalled-bandwidth** • **soft-preemption**

The following example shows the auto-tunnel backup configuration for core or edge routers.

```
RP/0/RSP0/CPU0:router(config)#
mpls traffic-eng
    auto-tunnel backup
        tunnel-id min 60000 max 61000

    interface pos 0/1/0/0
       auto-tunnel backup
          attribute-set ab
```

The following example shows the protection (NNHOP and SRLG) that was set on the auto-tunnel backup.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 1
Signalling Summary:
             LSP Tunnels Process:  running
```

```
                    RSVP Process:  running
                      Forwarding:  enabled
          Periodic reoptimization:  every 3600 seconds, next in 2524 seconds
           Periodic FRR Promotion:  every 300 seconds, next in 49 seconds
          Auto-bw enabled tunnels:  1

Name: tunnel-te1  Destination: 200.0.0.3 (auto backup)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10,  type explicit (autob_nnhop_srlg_tunnel1) (Basis for Setup, path weight
 11)
    path option 20,  type explicit (autob_nnhop_tunnel1)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Fri Jul 10 01:53:25.581 PST  (1h 25m 17s ago)

  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
    Metric Type: TE (default)
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Disabled, Protection Desired: None
    Path Protection: Not Enabled
  Auto Backup:
     Protected LSPs: 4
     Protected S2L Sharing Families: 0
     Protected S2Ls: 0
     Protected i/f: Gi0/1/0/0     Protected node: 20.0.0.2
     Protection: NNHOP+SRLG
     Unused removal timeout: not running
  History:
    Tunnel has been up for: 00:00:08
    Current LSP:
      Uptime: 00:00:08
    Prior LSP:
      ID: path option 1 [545]
      Removal Trigger: configuration changed

  Path info (OSPF 0 area 0):
  Hop0: 10.0.0.2
  Hop1: 100.0.0.2
  Hop2: 100.0.0.3
  Hop3: 200.0.0.3
```

The following example shows automatically created path options for this backup auto-tunnel.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels 1 detail
Signalling Summary:
              LSP Tunnels Process:  running
                    RSVP Process:  running
                      Forwarding:  enabled
          Periodic reoptimization:  every 3600 seconds, next in 2524 seconds
           Periodic FRR Promotion:  every 300 seconds, next in 49 seconds
          Auto-bw enabled tunnels:  1

Name: tunnel-te1  Destination: 200.0.0.3 (auto backup)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected
```

```
   path option 10,  type explicit (autob_nnhop_srlg_tunnel1) (Basis for Setup, path weight
11)
   path option 20,  type explicit (autob_nnhop_tunnel1)
   G-PID: 0x0800 (derived from egress interface properties)
   Bandwidth Requested: 0 kbps  CT0
   Creation Time: Fri Jul 10 01:53:25.581 PST  (1h 25m 17s ago)

 Config Parameters:
   Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
   Metric Type: TE (default)
   AutoRoute: disabled  LockDown: disabled   Policy class: not set
   Forwarding-Adjacency: disabled
   Loadshare:          0 equal loadshares
   Auto-bw: disabled
   Fast Reroute: Disabled, Protection Desired: None
   Path Protection: Not Enabled
 Auto Backup (NNHOP+SRLG):
    Protected LSPs: 4
    Protected S2L Sharing Families: 0
    Protected S2Ls: 0
    Protected i/f: Gi0/1/0/0     Protected node: 20.0.0.2
    Protection: NNHOP+SRLG
    Unused removal timeout: not running

    Path Options Details:
     10: Explicit Path Name: (autob_nnhop_srlg_te1)
       1: exclude-srlg 50.0.0.1
       2: exclude-address 50.0.0.2
       3: exclude-node 20.0.0.2
     20: Explicit Path Name: (autob_nnhop_te1)
       1: exclude-address 50.0.0.1
       2: exclude-address 50.0.0.2
       3: exclude-node 20.0.0.2
 History:
   Tunnel has been up for: 00:00:08
   Current LSP:
     Uptime: 00:00:08
   Prior LSP:
     ID: path option 1 [545]
     Removal Trigger: configuration changed

 Path info (OSPF 0 area 0):
 Hop0: 10.0.0.2
 Hop1: 100.0.0.2
 Hop2: 100.0.0.3
 Hop3: 200.0.0.3
```

This example shows the automatically created backup tunnels.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels brief

           TUNNEL NAME         DESTINATION      STATUS  STATE
             tunnel-te0           200.0.0.3          up  up
             tunnel-te1           200.0.0.3          up  up
             tunnel-te2           200.0.0.3          up  up
           tunnel-te50          200.0.0.3          up  up
           *tunnel-te60           200.0.0.3          up  up
           *tunnel-te70           200.0.0.3          up  up
           *tunnel-te80           200.0.0.3          up  up

RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels tabular
           Tunnel    LSP     Destination          Source             FRR    LSP  Path
```

```
              Name     ID         Address         Address   State   State   Role  Prot
------------------ ------ --------------- --------------- ------- ------- ------ -----
        tunnel-te0    549       200.0.0.3       200.0.0.1      up   Inact   Head InAct
        tunnel-te1    546       200.0.0.3       200.0.0.1      up   Inact   Head InAct
        tunnel-te2      6       200.0.0.3       200.0.0.1      up   Inact   Head InAct
      tunnel-te50       6       200.0.0.3       200.0.0.1      up  Active   Head InAct
      tunnel-te60       4       200.0.0.3       200.0.0.1      up  Active   Head InAct
      tunnel-te70       4       200.0.0.3       200.0.0.1      up  Active   Head InAct
      tunnel-te80       3       200.0.0.3       200.0.0.1      up  Active   Head InAct
```

This example shows the auto-tunnel backup details.

```
RP/0/RSP0/CPU0:router#  show mpls traffic-eng tunnels auto-tunnel backup detail

Name: tunnel-te400  Destination: 10.0.0.1 (auto-tunnel backup)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 20,  type explicit (autob_nnhop_te400) (Basis for Setup, path weight 2)
    path option 10,  type explicit (autob_nnhop_srlg_te400) [disabled]
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Thu Aug 16 18:30:41 2012 (00:01:28 ago)
  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
    Metric Type: TE (default)
    Metric Type: TE (default)
    Hop-limit: disabled
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Disabled, Protection Desired: None
    Path Protection: Not Enabled
    Soft Preemption: Disabled
  Auto Backup:
    Protected LSPs: 1
    Protected S2L Sharing Families: 0
    Protected S2L: 0
    Protected i/f: Gi0/1/0/3    Protected node: 192.168.0.1
    Attribute-set: ab1
    Protection: NNHOP
    Unused removal timeout: not running
    Path Option Details:
      10: Explicit Path Name: (autob_nnhop_srlg_te400)
        1: exclude-srlg 34.9.0.4
        2: exclude-address 34.9.0.3
        3: exclude-node 192.168.0.1
      20: Explicit Path Name: (autob_nnhop_te400)
        1: exclude-address 34.9.0.4
        2: exclude-address 34.9.0.3
        3: exclude-node 192.168.0.1
  SNMP Index: 221
  History:
    Tunnel has been up for: 00:00:34 (since Thu Aug 16 18:31:35 EST 2012)
    Current LSP:
      Uptime: 00:00:34 (since Thu Aug 16 18:31:35 EST 2012)
  Current LSP Info:
    Instance: 2, Signaling Area: OSPF 100 area 10.2.3.4
    Uptime: 00:00:34 (since Thu Aug 16 18:31:35 EST 2012)
    Outgoing Interface: GigabitEthernet0/1/0/2, Outgoing Label: 16000
    Router-IDs: local      209.165.201.1
                downstream 172.16.0.1
    Soft Preemption: None
```

```
    Path Info:
      Outgoing:
        Explicit Route:
          Strict, 24.9.0.2
          Strict, 12.9.1.1
          Strict, 10.0.0.1

      Record Route: Empty
      Tspec: avg rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
      Session Attributes: Local Prot: Not Set, Node Prot: Not Set, BW Prot: Not Set
                          Soft Preemption Desired: Not Set
    Resv Info:
      Record Route:
        IPv4 24.9.0.2, flags 0x0
        IPv4 12.9.1.1, flags 0x0
      Fspec: avg rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
Displayed 1 (of 104) heads, 0 (of 0) midpoints, 0 (of 201) tails
Displayed 1 up, 0 down, 0 recovering, 0 recovered heads
```

This example shows the automatically created backup tunnels.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels auto-tunnel backup tabular

           Tunnel   LSP     Destination          Source    Tun    FRR  LSP  Path
             Name    ID         Address         Address  State  State Role  Prot
----------------- ----- --------------- --------------- ------ ------ ---- -----
    *tunnel-te400     2         10.0.0.1         209.165.201.1     up  Inact Head Inact
    *tunnel-te401     2         192.168.0.1         209.165.201.1     up  Inact Head Inact
* = automatically created backup tunnel

RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels auto-tunnel backup brief
           TUNNEL NAME         DESTINATION      STATUS  STATE
         *tunnel-te400            10.0.0.1          up  up
         *tunnel-te401            192.168.0.1          up  up
* = automatically created backup tunnel
Displayed 2 (of 104) heads, 0 (of 0) midpoints, 0 (of 201) tails
Displayed 2 up, 0 down, 0 recovering, 0 recovered heads
```

This example shows the attribute-set for auto-backup tunnels.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng attribute-set auto-backup

Attribute Set Name: ab (Type: auto-backup)
  Number of affinity constraints: 2
     Include bit map       : 0x4
     Include name          : blue
     Exclude bit map       : 0x2
     Exclude name          : red
  Priority: 7 7 (Default)
  Record-route: Enabled
  Policy-class: 1
  Logging: reoptimize, state
  List of protected interfaces (count 1)
      POS0_3_0_1
  List of tunnel IDs (count 1)
    3000
```

This example shows the attribute-set for auto-mesh tunnels.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng attribute-set auto-mesh

Attribute Set Name: am (Type: auto-mesh)
```

```
  Bandwidth: 100 kbps (CT0)
  Number of affinity constraints: 2
     Include bit map       : 0x8
     Include name          : yellow
     Exclude bit map       : 0x2
     Exclude name          : red
  Priority: 2 2
  Interface Bandwidth: 0 kbps (Default)
  AutoRoute Announce: Disabled
  Auto-bw: Disabled
  Soft Preemption: Disabled
  Fast Reroute: Enabled, Protection Desired: Node, Bandwidth
  Record-route: Enabled
  Policy-class: 0 (Not configured)
  Logging: None
  List of Mesh Groups (count 1)
    1
```

This example shows the details about the tunnel that is using auto-backup type of attribute-set.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels attribute-set auto-backup ab

Name: tunnel-te3000  Destination: 10.0.0.1 (auto-tunnel backup)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 20,  type explicit (autob_nhop_te3000) (Basis for Setup, path weight 2)
    path option 10,  type explicit (autob_nhop_srlg_te3000) [disabled]
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Tue Aug 14 23:24:27 2012 (00:05:28 ago)
  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7
    Number of affinity constraints: 2
       Include bit map       : 0x4
       Include name          : blue
       Exclude bit map       : 0x2
       Exclude name          : red

    Metric Type: TE (default)
    Hop-limit: disabled
    AutoRoute: disabled  LockDown: disabled   Policy class: 1
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Disabled, Protection Desired: None
    Path Protection: Not Enabled
    Soft Preemption: Disabled
  Auto Backup:
    Protected LSPs: 2
    Protected S2L Sharing Families: 0
    Protected S2L: 0
    Protected i/f: PO0/3/0/1
    Attribute-set: ab
    Protection: NHOP
    Unused removal timeout: not running
  History:
    Tunnel has been up for: 00:04:57 (since Tue Aug 14 23:24:58 EST 2012)
    Current LSP:
      Uptime: 00:04:57 (since Tue Aug 14 23:24:58 EST 2012)

  Path info (OSPF 100 area 16909060):
  Node hop count: 2
  Hop0: 23.9.0.2
```

```
  Hop1: 12.9.0.2
  Hop2: 12.9.0.1
  Hop3: 10.0.0.1
Displayed 1 (of 7) heads, 0 (of 3) midpoints, 0 (of 0) tails Displayed 1 up, 0 down, 0
recovering, 0 recovered heads
```

This example shows the protected interface for auto-backup auto-tunnels.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels backup protected-interface

Interface: Gi0/2/0/1 (auto-tunnel backup)
  SRLG: N/A, NHOP-only: No
  Attribute-set: Not configured
  Auto-tunnel backup recreate time remaining:  timer not running
    No backup tunnel found

Interface: Gi0/2/0/3
     tunnel-te340   PROTECTED : out i/f:   PO0/3/0/2   Admin:   up  Oper:   up

Interface: PO0/3/0/1 (auto-tunnel backup)
  SRLG: N/A, NHOP-only: No
  Attribute-set: ab
  Auto-tunnel backup recreate time remaining:  timer not running
    *tunnel-te3000        NHOP : out i/f:   Gi0/2/0/2   Admin:   up  Oper:   up

 * = automatically created backup tunnel
```

This example shows the details about all the tunnels that are using auto-mesh type of attribute-set.

```
RP/0/RSP0/CPU0:router# show mpls traffic-eng tunnels attribute-set auto-mesh all

Name: tunnel-te3501  Destination: 10.0.0.1 (auto-tunnel mesh)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10,  type dynamic  (Basis for Setup, path weight 2)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 100 kbps  CT0
    Creation Time: Tue Aug 14 23:25:41 2012 (00:06:13 ago)
  Config Parameters:
    Bandwidth:      100 kbps (CT0) Priority:  2  2
    Number of affinity constraints: 2
       Include bit map       : 0x8
       Include name          : yellow
       Exclude bit map       : 0x2
       Exclude name          : red

    Metric Type: TE (default)
    Hop-limit: disabled
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Enabled, Protection Desired: Node, Bandwidth
    Path Protection: Not Enabled
    Attribute-set: am (type auto-mesh)
    Soft Preemption: Disabled
  Auto-tunnel Mesh:
    Group ID: 1
    Destination list: blah
    Unused removal timeout: not running
  History:
    Tunnel has been up for: 00:06:13 (since Tue Aug 14 23:25:41 EST 2012)
    Current LSP:
```

```
      Uptime: 00:06:13 (since Tue Aug 14 23:25:41 EST 2012)

  Path info (OSPF 100 area 16909060):
  Node hop count: 2
  Hop0: 23.9.0.2
  Hop1: 12.9.0.2
  Hop2: 12.9.0.1
  Hop3: 10.0.0.1

Name: tunnel-te3502  Destination: 172.16.0.1 (auto-tunnel mesh)
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10,  type dynamic  (Basis for Setup, path weight 1)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 100 kbps  CT0
    Creation Time: Tue Aug 14 23:25:41 2012 (00:06:13 ago)
  Config Parameters:
    Bandwidth:      100 kbps (CT0) Priority:  2  2
    Number of affinity constraints: 2
       Include bit map       : 0x8
       Include name          : yellow
       Exclude bit map       : 0x2
       Exclude name          : red

    Metric Type: TE (default)
    Hop-limit: disabled
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Enabled, Protection Desired: Node, Bandwidth
    Path Protection: Not Enabled
    Attribute-set: am (type auto-mesh)
    Soft Preemption: Disabled
  Auto-tunnel Mesh:
    Group ID: 1
    Destination list: blah
    Unused removal timeout: not running
  History:
    Tunnel has been up for: 00:06:13 (since Tue Aug 14 23:25:41 EST 2012)
    Current LSP:
      Uptime: 00:06:13 (since Tue Aug 14 23:25:41 EST 2012)

  Path info (OSPF 100 area 16909060):
  Node hop count: 1
  Hop0: 23.9.0.2
  Hop1: 172.16.0.1

Name: tunnel-te3503  Destination: 209.165.201.1 (auto-tunnel mesh)
  Status:
    Admin:    up Oper: down   Path: not valid   Signalling: Down

    path option 10,  type dynamic
    Last PCALC Error: Tue Aug 14 23:31:26 2012
      Info: No path to destination, 209.165.201.1 (affinity)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 100 kbps  CT0
    Creation Time: Tue Aug 14 23:25:41 2012 (00:06:13 ago)
  Config Parameters:
    Bandwidth:      100 kbps (CT0) Priority:  2  2
    Number of affinity constraints: 2
       Include bit map       : 0x8
       Include name          : yellow
```

```
       Exclude bit map       : 0x2
       Exclude name          : red

    Metric Type: TE (default)
    Hop-limit: disabled
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forwarding-Adjacency: disabled
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Fast Reroute: Enabled, Protection Desired: Node, Bandwidth
    Path Protection: Not Enabled
    Attribute-set: am (type auto-mesh)
    Soft Preemption: Disabled
  Auto-tunnel Mesh:
    Group ID: 1
    Destination list: blah
    Unused removal timeout: not running
Displayed 3 (of 7) heads, 0 (of 3) midpoints, 0 (of 0) tails Displayed 2 up, 1 down, 0
recovering, 0 recovered heads
```

Bandwidth Protection Functions to Enhance auto-tunnel backup Capabilities

Without bandwidth protection, auto-tunnel backups provide only link protection and node protection (per next-next-hop), and backup tunnels are signalled with zero bandwidth. This causes traffic congestion when FRR goes active, since the backup tunnels might be protecting huge amount of data, such as LSPs with large bandwidth or multiple LSPs.

To address the congestion issue, bandwidth protection capabilities are added for auto-tunnel backups. Bandwidth protection, signalled bandwidth, and soft-preemption settings are provided. Details:

- *Bandwidth protection* – A link or node protection backup might not provide bandwidth protection. But with this setting (**bandwidth-protection maximum-aggregate**), you can set the maximum bandwidth value that an auto-tunnel can protect.
- *Signalled bandwidth* – Without bandwidth protection, auto-tunnel backups are signaled with zero bandwidth too, with no guarantee that at least some bandwidth is backed up. So, the backup tunnels might be setup on links that are highly utilized, causing congestion drops when the backup tunnels start to transmit traffic after FRR is triggered.

  This setting (**signalled-bandwidth**) addresses the issue, since you can set the signalled bandwidth of the tunnel (and reserve minimal bandwidth for an auto-tunnel backup). When you set the signal bandwidth value for auto-backup tunnels, congestion over backup links reduces.
- *Soft-preemption* – Since bandwidth can be reserved for autobackup tunnels, a setting (**soft-preemption**) is provided for soft-preemption of the reserved bandwidth, if it is needed for a higher-priority tunnel.

Configurations

```
/*Enable Bandwidth Protection On a TE Auto-Tunnel Backup*/

Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# interface GigabitEthernet 0/2/0/0 auto-tunnel backup
Router(config-te-if-auto-backup)# bandwidth-protection maximum-aggregate 100000
Router(config-te-if-auto-backup)# commit

/*Enable Signalled Bandwidth On a TE Auto-Tunnel Backup*/

Router# configure
Router(config)# mpls traffic-eng attribute-set auto-backup MyBackupConfig
```

```
Router(config-te-attribute-set)# signalled-bandwidth 700000
Router(config-te-attribute-set)# commit
```

After creating the auto backup attribute-set (**MyBackupConfig** in this case), associate with the auto-tunnel backup interface.

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# interface GigabitEthernet 0/2/0/0 auto-tunnel backup
Router(config-te-if-auto-backup)# attribute-set MyBackupConfig
Router(config-te-if-auto-backup)# auto-tunnel backup tunnel-id min 6000 max 6500
Router(config-mpls-te)# commit

/*Enable Soft-Preemption Bandwidth On a TE Auto-Tunnel Backup*/

Router# configure
Router(config)# mpls traffic-eng attribute-set auto-backup MyBackupConfig
Router(config-te-attribute-set)# soft-preemption
Router(config-te-attribute-set)# commit
```

Verification

```
/*Verify Auto-Tunnel Backup Configuration*/
```

In the output, bandwidth protection details are displayed, as denoted by *BW*.

```
Router# show mpls traffic-eng auto-tunnel backup

AutoTunnel Backup Configuration:
    Interfaces count: 1
    Unused removal timeout: 1h 0m 0s
    Configured tunnel number range: 6000-6500

AutoTunnel Backup Summary:
    AutoTunnel Backups:
              0 created, 0 up, 0 down, 0 unused
            0 NHOP, 0 NNHOP, 0 SRLG strict, 0 SRLG preferred, 0 SRLG weighted, 0 BW protected

  Protected LSPs:
              0 NHOP, 0 NHOP+SRLG, 0 NHOP+BW, 0 NHOP+BW+SRLG
              0 NNHOP, 0 NNHOP+SRLG, 0 NNHOP+BW, 0 NNHOP+BW+SRLG
    Protected S2L Sharing Families:
              0 NHOP, 0 NHOP+SRLG, 0 NNHOP+BW, 0 NNHOP+BW+SRLG
              0 NNHOP, 0 NNHOP+SRLG, 0 NNHOP+BW, 0 NNHOP+BW+SRLG
    Protected S2Ls:
              0 NHOP, 0 NHOP+SRLG, 0 NNHOP+BW, 0 NNHOP+BW+SRLG
              0 NNHOP, 0 NNHOP+SRLG, 0 NNHOP+BW, 0 NNHOP+BW+SRLG

 Cumulative Counters (last cleared 00:08:47 ago):
                         Total   NHOP  NNHOP
    Created:               0       0      0
    Connected:             0       0      0
    Removed (down):        0       0      0
    Removed (unused):      0       0      0
    Removed (in use):      0       0      0
    Range exceeded:        0       0      0
```

Related Topics

Enabling an AutoTunnel Backup, on page 72
Removing an AutoTunnel Backup, on page 73
Establishing MPLS Backup AutoTunnels to Protect Fast Reroutable TE LSPs, on page 74
Establishing Next-Hop Tunnels with Link Protection, on page 75
Backup AutoTunnels, on page 6

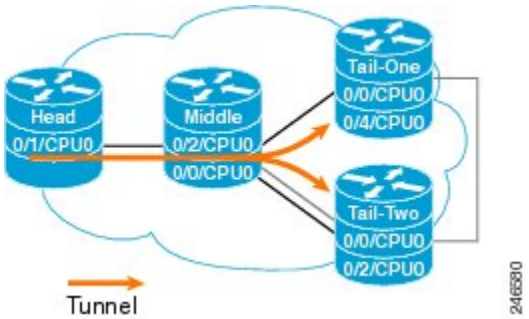
Configure Point-to-Multipoint TE: Examples

These configuration examples show how to configure Point-to-Multipoint TE:

P2MP Topology Scenario: Example

This section describes a typical scenario of point-to-multipoint traffic engineering toplogy. This figure illustrates the P2MP toplogy.

Figure 19: P2MP Topology



This head router describes the configuration at head node. This router does the imposition of MPLS at head node.

```
interface tunnel-mte1
 ipv4 unnumbered Loopback0
 destination 10.0.0.1
  path-option 1 explicit name path-to-tail1
 !
 destination 172.16.0.1
  path-option 1 explicit name path-to-tail2
 !
 fast-reroute

mpls traffic-eng
 interface GigabitEthernet0/1/3/0
!
 interface GigabitEthernet0/1/3/7
 !

multicast-routing
 address-family ipv4
  nsf
  interface all enable
 !
 address-family ipv6
  nsf
  interface all enable
 !
!
 !
router igmp
 vrf default
  interface tunnel-mte1
   static-group 232.0.0.1 192.168.10.1
  !
```

This mid router describes the configuration at mid node. This router performs the role of MPLS label replication at mid node.

```
mpls traffic-eng
 interface POS0/2/0/0
 !
 interface POS0/2/0/1
  backup-path tunnel-te 1000
 !
 interface TenGigE0/3/0/3
 !
 interface GigabitEthernet0/2/5/0
 !
!
```

This tail router describes the configuration at tail node. This router performs the role of MPLS disposition at tail node.

```
mpls traffic-eng
 interface POS0/0/3/0
 !

!


multicast-routing
 address-family ipv4
  interface all enable
 !
 core-tree-protocol rsvp-te group-list lsm
  static-rpf 192.168.10.1 32 mpls 5.5.5.5
 !
!
```

This configuration describes the Fast Reroute configuration in the MPLS network.

```
explicit-path name backup-path-to-tail1
 index 1 next-address strict 198.1.1.2
 index 2 next-address strick 198.1.2.2
!

interface tunnel-te1000 <<< backup p2p tunnel
 ipv4 unnumbered Loopback0
 destination 140.140.140.140
 path-option 1 explicit name backup-path-to-tail1
!
mpls traffic-eng
 interface POS0/2/0/0
 !
 interface POS0/2/0/1
  backup-path tunnel-te 1000
 !
 interface TenGigE0/5/0/4
!
```

Configure Point-to-Multipoint for the Source: Example

At the source, multicast routing must be enabled on both the tunnel-mte interface and customer-facing interface. Then, the static-group must be configured on the tunnel-mte interface to forward specified multicast traffic over P2MP LSP.

Note The multicast group address, which is in Source-Specific Multicast (SSM) address range (ff35::/16), must be used on the static-group configuration because Cisco IOS XR software supports only SSM for Label Switch Multicast (LSM). Additionally, the customer-facing interface must have an IPv6 address.

```
multicast-routing
  address-family ipv6
   interface tunnel-mte 1
    enable
   !
   interface GigabitEthernet0/2/0/3
    enable
   !
  !
 !
 router mld
  vrf default
   interface tunnel-mte 1
    static-group ff35::1 2000::1 3eFF::A
   !
  !
 !
 interface tunnel-mte 1
    ipv4 unnumbered Loopback0
    destination 192.168.0.1
       path-option 1 dynamic
    destination 209.165.201.1
       path-option 1 dynamic
 !
!
```

Related Topics

Point-to-Multipoint Traffic-Engineering Overview, on page 34
Point-to-Multipoint RSVP-TE , on page 35

Configure the Point-to-Multipoint Tunnel: Example

There is no difference between logging events at the tunnel level for both P2P and P2MP. The P2MP tunnel reoptimizes only at the per tunnel level.

```
interface tunnel-mte1
      ipv4 unnumbered Loopback0
      destination 60.60.60.60
      logging events lsp-status state
      logging events lsp-status reroute
      path-option 10 explicit name toR6_via_R2andR3
     !
     logging events lsp-status reoptimize
     logging events lsp-status state
     logging events lsp-status reroute
     fast-reroute
     record-route
    !
explicit-path name PATH7
     index 1 next-address strict ipv4 unicast 192.168.7.2
     index 2 next-address strict ipv4 unicast 192.168.7.1
     index 3 next-address strict ipv4 unicast 192.168.16.1
```

```
    index 4 next-address strict ipv4 unicast 192.168.16.2
    !
```

Related Topics

Path Option for Point-to-Multipoint RSVP-TE, on page 37
Point-to-Multipoint Traffic-Engineering Overview, on page 34

Disable a Destination: Example

From the tunnel-mte interface, you can disable the destination.

```
interface tunnel-mte101
 ipv4 unnumbered Loopback0
 destination 150.150.150.150
  disable
  path-option 10 dynamic
 !
 destination 150.150.150.150
  path-option 2 dynamic
 !
!
```

Related Topics

Point-to-Multipoint Traffic-Engineering Overview, on page 34

Configure the Point-to-Multipoint Solution: Example

Requirements for MPLS-TE Configuration

Before the Point-to-Multipoint (P2MP) tunnel is defined, these MPLS-TE requirements must be configured:

- Multiprotocol Label Switching traffic engineering (MPLS-TE)
- Resource ReSerVation Protocol (RSVP)
- Open Shortest Path First (OSPF)

This example shows the entire P2MP solution:

- Source is the location where the P2MP-TE tunnel interface is created.
- Tunnel contains multiple destinations. For example, the P2MP-TE tunnel is configured with two leaf node destinations by using the dynamic and explicit path options.
- Fast-Reroute (FRR) is specified on the P2MP tunnel.
- All regular TE tunnel options such as affinity or bandwidth are configured.
- Static mapping of the group address to the P2MP tunnel is done in IGMP.

  Internet Group Management Protocol (IGMP).
- The P2MP-TE midpoint configuration requires only TE and Interior Gateway Protocol (IGP) information.
- The P2MP-TE receiver configuration requires a static group and RPF map.

```
!
explicit-path name g2-r2-r1
 index 1 next-address strict ipv4 unicast 10.2.15.1
```

```
!
explicit-path name g2-r2-r3
 index 1 next-address strict ipv4 unicast 10.2.25.1
 index 2 next-address strict ipv4 unicast 10.2.23.2
!
explicit-path name g2-r2-r4
 index 1 next-address strict ipv4 unicast 10.2.25.1
 index 2 next-address strict ipv4 unicast 10.2.24.2
!
ipv4 access-list ssm
 10 permit ipv4 232.1.0.0/16 any
 20 permit ipv4 232.3.0.0/16 any
 30 permit ipv4 232.4.0.0/16 any
!
ipv4 access-list ssm-test
 10 permit ipv4 235.0.0.0/8 any
!
interface Loopback0
 ipv4 address 192.168.1.2 255.255.255.255
!
interface tunnel-mte221
 ipv4 unnumbered Loopback0
 destination 192.168.1.1
  path-option 1 dynamic
 !
 destination 192.168.1.3
  path-option 1 dynamic
 !
 destination 192.168.1.4
  path-option 1 dynamic
 !
!
interface tunnel-mte222
 ipv4 unnumbered Loopback0
 destination 192.168.1.1
  path-option 1 explicit name g2-r2-r1
 !
 destination 192.168.1.3
  path-option 1 explicit name g2-r2-r3
 !
 destination 192.168.1.4
  path-option 1 explicit name g2-r2-r4
 !
 signalled-bandwidth 1000
!
interface MgmtEth0/RP0/CPU0/0
 ipv4 address 172.20.163.12 255.255.255.128
!
interface MgmtEth0/RP1/CPU0/0
 shutdown
!
interface GigabitEthernet0/0/0/0
 ipv4 address 172.2.1.2 255.255.255.0
 load-interval 30
!
interface GigabitEthernet0/0/0/1
 ipv4 address 10.1.15.2 255.255.255.0
!
interface GigabitEthernet0/0/0/1.2
 ipv4 address 10.2.15.2 255.255.255.0
 encapsulation dot1q 2
!
interface GigabitEthernet0/0/0/2
 ipv4 address 10.1.25.2 255.255.255.0
```

```
!
interface GigabitEthernet0/0/0/2.2
 ipv4 address 10.2.25.2 255.255.255.0
 encapsulation dot1q 2
!
interface GigabitEthernet0/0/0/3
 shutdown
!
interface GigabitEthernet0/0/0/4
 shutdown
!
interface GigabitEthernet0/0/0/5
 shutdown
!
interface GigabitEthernet0/0/0/6
 shutdown
!
interface GigabitEthernet0/0/0/7
 shutdown
!
router static
 address-family ipv4 unicast
  0.0.0.0/0 1.56.0.1
  0.0.0.0/0 172.20.163.1
 !
!
router ospf 100
 nsr
 router-id 192.168.70.1
 area 0
  mpls traffic-eng
  interface Loopback0
  !
  interface GigabitEthernet0/0/0/0
  !
  interface GigabitEthernet0/0/0/1
  !
  interface GigabitEthernet0/0/0/1.2
  !
  interface GigabitEthernet0/0/0/2
  !
  interface GigabitEthernet0/0/0/2.2
  !
 !
 mpls traffic-eng router-id 192.168.70.1
!
mpls oam
!
rsvp
 interface GigabitEthernet0/0/0/0
  bandwidth 20000
 !
 interface GigabitEthernet0/0/0/1
  bandwidth 20000
 !
 interface GigabitEthernet0/0/0/2
  bandwidth 20000
 !
 interface GigabitEthernet0/0/0/1.2
  bandwidth 20000
 !
 interface GigabitEthernet0/0/0/2.2
  bandwidth 20000
 !
```

```
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0
 !
 interface GigabitEthernet0/0/0/1
 !
 interface GigabitEthernet0/0/0/2
 !
 interface GigabitEthernet0/0/0/1.2
 !
 interface GigabitEthernet0/0/0/2.2
 !
!
mpls ldp
 router-id 192.168.1.2
 nsr
 graceful-restart
 interface GigabitEthernet0/0/0/0
 !
 interface GigabitEthernet0/0/0/1
 !
 interface GigabitEthernet0/0/0/1.2
 !
 interface GigabitEthernet0/0/0/2
 !
 interface GigabitEthernet0/0/0/2.2
 !
!
multicast-routing
 address-family ipv4
  core-tree-protocol rsvp-te
  ssm range ssm
  static-rpf 172.1.1.1 32 mpls 192.168.1.1
  static-rpf 172.3.1.1 32 mpls 192.168.1.3
  static-rpf 172.4.1.1 32 mpls 192.168.1.4
  interface all enable
 !
!
router igmp
 !
 interface tunnel-mte221
  static-group 232.2.2.1 172.2.1.1
 !
 interface tunnel-mte222
  static-group 232.2.2.2 172.2.1.1
 !
 interface GigabitEthernet0/0/0/0
  static-group 232.1.2.1 172.1.1.1
  static-group 232.1.2.2 172.1.1.1
  static-group 232.3.2.1 172.3.1.1
  static-group 232.3.2.2 172.3.1.1
  static-group 232.4.2.1 172.4.1.1
  static-group 232.4.2.2 172.4.1.1
 !
!
end
```

Related Topics

Point-to-Multipoint Traffic-Engineering Overview, on page 34
Point-to-Multipoint RSVP-TE , on page 35
Path Option for Point-to-Multipoint RSVP-TE, on page 37

Configure MPLS TE Path-selection Cost Limit: Example

This example shows how to set the path-selection cost limit for MPLS TE tunnels at global, TE tunnel interface, and path-option attribute-set levels. By default, the cost-limit set at path-option attribute set takes the priority, if all options are configured and per tunnel interface level takes priority over global cost-limit. At per tunnel interface level, the global cost-limit takes the priority.

```
interface tunnel-te1
 path-selection cost-limit 2
!
mpls traffic-eng
 attribute-set path-option PO3AttrSet
  path-selection cost-limit 3
 !
 path-selection cost-limit 1
!
!
```

Configuring Performance Measurement

Network performance metrics such as packet loss, delay, delay variation, and bandwidth utilization is a critical measure for traffic engineering (TE) in service provider networks. These network performance metrics provide network operators information about the performance characteristics of their networks for performance evaluation and helps to ensure compliance with service level agreements. The service-level agreements (SLAs) of service providers depend on the ability to measure and monitor these network performance metrics. Network operators can use performance measurement (PM) feature to monitor the network metrics for links as well as end-to-end TE label switched paths (LSPs).

Path Calculation Metric Type

To configure the metric type to be used for path calculation for a given tunnel, use the **path-selection metric** command in either the MPLS-TE configuration mode or under the tunnel interface configuration mode.

The metric type specified per interface takes the highest priority, followed by the MPLS-TE global metric type.

Note If the delay metric is configured, CSPF finds a path with optimized*minimum* link delay metric. See the *Configuring Performance Measurement* chapter in the Segment Routing Configuration Guide for information on configuring interface performance delay measurement.

Configuration Example

The following example shows how to set the path-selection metric to use the IGP metric under a specific tunnel interface:

```
Router# configure
Router(config)# interface tunnel-te 1
Router(config-if)# path-selection metric igp
Router(config-if)# commit
```

The following example shows how to set the path-selection metric to use the delay metric under the MPLS-TE configuration mode:

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# path-selection metric delay
Router(config-mpls-te)# commit
```

Path-Selection Delay Limit

Apply the **path-selection delay-limit** configuration to set the upper limit on the path aggregate delay when computing paths for MPLS-TE LSPs. After you configure the **path-selection delay-limit** value, if the sum of minimum-delay metric from all links that are traversed by the path exceeds the specified delay-limit, CSPF will not return any path. The periodic path verification checks if the delay-limit is crossed.

The **path-selection delay-limit** value can be configured at the global MPLS-TE, per-interface tunnel, and per path-option attribute set. The path-selection delay-limit per path-option attribute set takes the highest priority, followed by per-interface, and then the MPLS-TE global path-selection delay-limit values.

The delay limit range is a value from 1 to 4294967295 microseconds.

Note See the *Configuring Performance Measurement* chapter in the Segment Routing Configuration Guide for information on configuring interface performance delay measurement.

Configuration Example

The following example shows how to set the path-selection delay limit under a specific tunnel interface:

```
Router# configure
Router(config)# interface tunnel-te2000
Router(config-if)# path-selection metric delay
Router(config-if)# path-selection delay-limit 200
Router(config-if)# commit
```

The following example shows how to set the path-selection delay limit under a path-option attribute set:

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# attribute-set path-option test
Router(config-te-attribute-set)# path-selection delay-limit 300
Router(config-te-attribute-set)# root
Router(config)# interface tunnel-te1000
Router(config-if)# path-option 10 dynamic attribute-set test
Router(config-if)# commit
```

The following example shows how to set the path-selection delay limit under the global MPLS-TE configuration mode:

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# path-selection metric delay
Router(config-mpls-te)# path-selection delay-limit 150
Router(config-mpls-te)# commit
```

Additional References

For additional information related to implementing MPLS-TE, refer to the following references:

Related Documents

Related Topic	Document Title
MPLS-TE commands	*MPLS Traffic Engineering Commands* module in *MPLS Command Reference for Cisco ASR 9000 Series Routers*.

Standards

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

MIBs

MIBs	MIBs Link
—	To locate and download MIBs using Cisco IOS XR software, use the Cisco MIB Locator found at the following URL and choose a platform under the Cisco Access Products menu: http://cisco.com/public/sw-center/netmgmt/cmtk/mibs.shtml

RFCs

RFCs	Title
RFC 4124	*Protocol Extensions for Support of Diffserv-aware MPLS Traffic Engineering*, F. Le Faucheur, Ed. June 2005. (Format: TXT=79265 bytes) (Status: PROPOSED STANDARD)
RFC 4125	*Maximum Allocation Bandwidth Constraints Model for Diffserv-aware MPLS Traffic Engineering*, F. Le Faucheur, W. Lai. June 2005. (Format: TXT=22585 bytes) (Status: EXPERIMENTAL)
RFC 4127	*Russian Dolls Bandwidth Constraints Model for Diffserv-aware MPLS Traffic Engineering*, F. Le Faucheur, Ed. June 2005. (Format: TXT=23694 bytes) (Status: EXPERIMENTAL)

Technical Assistance

Description	Link
The Cisco Technical Support website contains thousands of pages of searchable technical content, including links to products, technologies, solutions, technical tips, and tools. Registered Cisco.com users can log in from this page to access even more content.	http://www.cisco.com/techsupport