Implementing MPLS Traffic Engineering

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 5.0.0	This feature was introduced.
Release 5.2.1	Support was added for these features: • Point-to-Multipoint Traffic-Engineering • Policy-Based Tunnel Selection
Release 5.2.5	Interarea P2MP Path Expansion within a Domain 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.

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.
- To configure Point-to-Multipoint (P2MP)-TE, a base set of RSVP and TE configuration parameters on ingress, midpoint, and egress nodes in the MPLS network is required. In addition, Point-to-Point (P2P) parameters are required.

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.

Related Topics

Configuring Forwarding over the MPLS-TE Tunnel , on page 39

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 34
Creating an MPLS-TE Tunnel, on page 37
Build MPLS-TE Topology and Tunnels: Example, on page 102

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 44
Removing an AutoTunnel Backup, on page 45
Establishing MPLS Backup AutoTunnels to Protect Fast Reroutable TE LSPs, on page 46

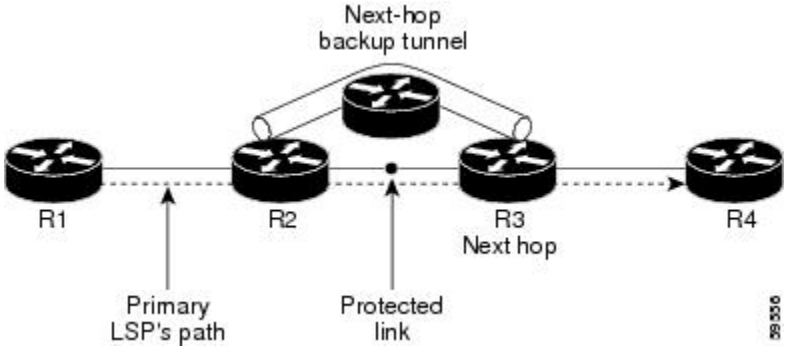
Establishing Next-Hop Tunnels with Link Protection, on page 47

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

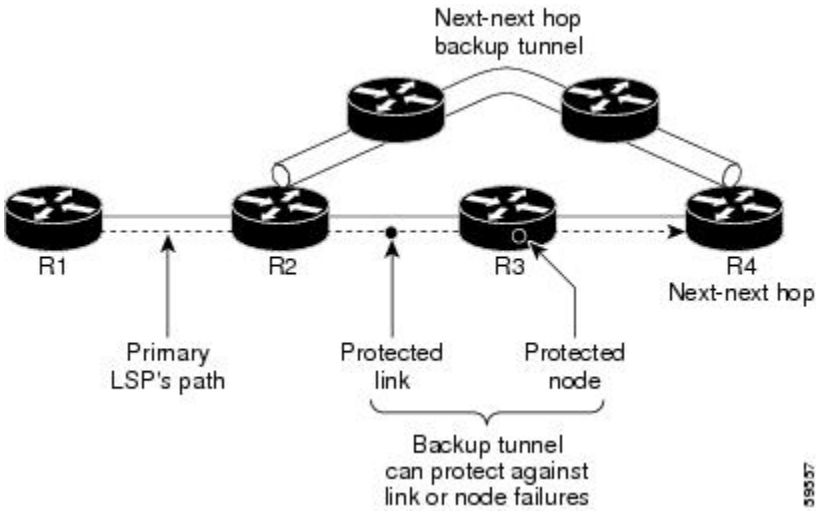


Node Protection

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 48
Configure IETF DS-TE Tunnels: Example, on page 103

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 51

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 49

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 40

MPLS-TE and Fast Reroute over Link Bundles

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,).

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 NCS 6000 Series Routers*.

Related Topics

Configuring the Ignore Integrated IS-IS Overload Bit Setting in MPLS-TE, on page 55
Configure the Ignore IS-IS Overload Bit Setting in MPLS-TE: Example, on page 104

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 56
Associating Affinity-Names with TE Links, on page 57
Associating Affinity Constraints for TE Tunnels, on page 58
Configure Flexible Name-based Tunnel Constraints: Example, on page 105

MPLS Traffic Engineering Interarea Tunneling

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

Interarea Support

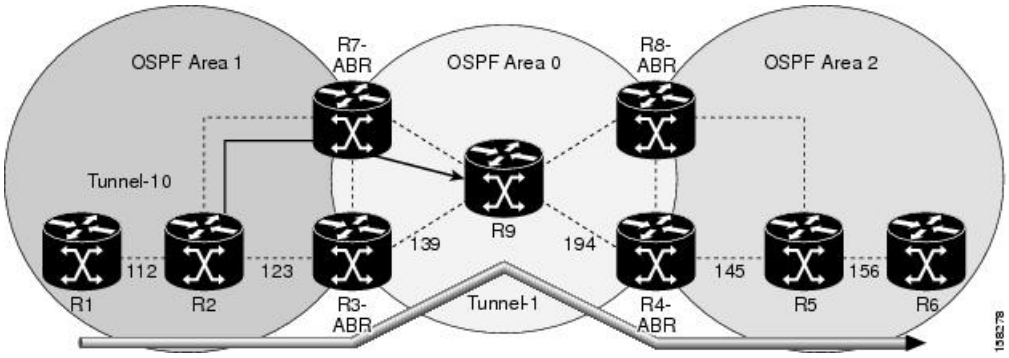
The MPLS-TE interarea tunneling feature allows you to establish P2P tunnels spanning multiple Interior Gateway Protocol (IGP) areas and levels, thereby eliminating the requirement that headend and tailend routers reside in a single area.

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.



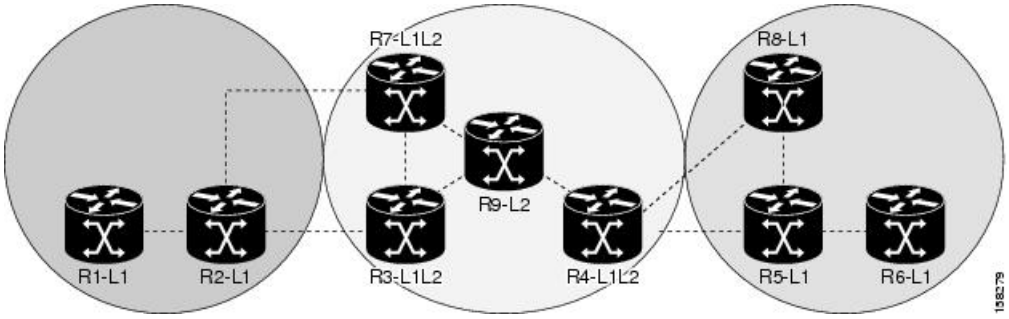
Multiarea Support

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.

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 40

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 62
Configure Forwarding Adjacency: Example, on page 107

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)

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)

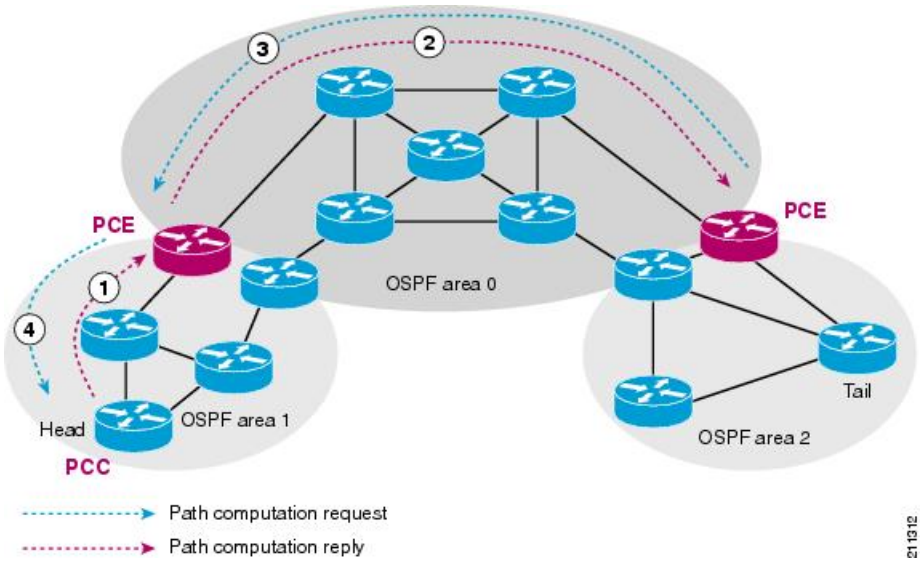
Represents a software module running on a router that is capable of sending and receiving path computation requests and responses to and from PCEs. The PCC is typically an LSR (Label Switching Router).

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 63
Configuring a Path Computation Element Address, on page 64
Configuring PCE Parameters, on page 64
Configure PCE: Example, on page 108

Policy-Based Tunnel Selection

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

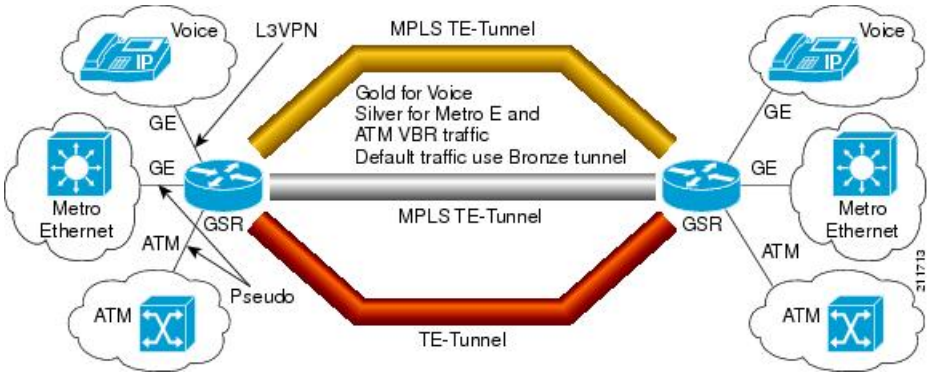
Policy-Based Tunnel Selection

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), or type of service (ToS) field in the packet.

Figure 6: Policy-Based Tunnel Selection Implementation

This figure illustrates a PBTS implementation.



PBTS is supported on the ingress interface and any of the L3 interfaces (physical, sub-interface, and bundle interface).

PBTS supports modification of the class-map and forward-group to TE association.

Related Topics

Configuring Policy-based Tunnel Selection, on page 67

Policy-Based Tunnel Selection Functions

The following PBTS functions are supported:

- IPv4 traffic arrives unlabeled on the VRF interface and the non-VRF interface.
- MPLS traffic is supported on the VRF interface and the non-VRF interface.
- Load balancing across multiple TE tunnels with the same traffic class attribute is supported.
- Selected TE tunnels are used to service the lowest tunnel class as default tunnels.
- LDP over TE tunnel and single-hop TE tunnel are supported.
- Both Interior Gateway Protocol (IGP) and Label Distribution Protocol (LDP) paths are used as the default path for all traffic that belongs to a class that is not configured on the TE tunnels.
- According to the quality-of-service (QoS) policy, tunnel selection is based on the outgoing experimental (EXP) value and the remarked EXP value.

Related Topics

Configuring Policy-based Tunnel Selection, on page 67

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.

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

Function	Command	Description	Default Value
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 68
Configuring the Automatic Bandwidth Functions, on page 70
Configure Automatic Bandwidth: Example, on page 109

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.

Source-to-Leaf (S2L) SubLSP

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

Note Cisco NCS 6000 Series Routers supports only P2MP TE mid-point functionality. The MPLS and the multicast packages are required the mid point router for the P2MP TE feature to work.

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 on the Head-end.
- P2MP tunnel setup is supported with label replication.
- Fast-Reroute (FRR) 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 on the Head-end.

- 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 on the Head-end.

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

Point-to-Multipoint RSVP-TE , on page 23

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

Point-to-Multipoint Fast Reroute, on page 24

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 21
Point-to-Multipoint RSVP-TE , on page 23

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.

Interarea P2MP Path Expansion within a Domain

Interarea P2MP (Point-to-Multipoint) path expansion within a domain feature matches the domain of the subsequent auto-discovered ABR (Area Border Router) with the domain of the incoming interface where the Path message is received. This feature restricts the ERO (Explicit Route Object) expansion using the same

domain as associated with the incoming interface where the Path message is received. This restriction applies to both loose-hop ABR and dynamically discovered ABR.

Configure this feature using the **path-selection loose-expansion domain-match** command in MPLS-TE configuration.

Interarea P2MP path expansion within a domain configuration applies to:

- All interarea TE (Traffic Engineering) path expansions on the ABR node
- Both P2P (Point-to-Point) and P2MP interarea TE LSPs
- Midpoint nodes

Limitation

The ERO expansion domain-match is not supported for multiple incoming IGPs.

MPLS Traffic Engineering Shared Risk Link Groups

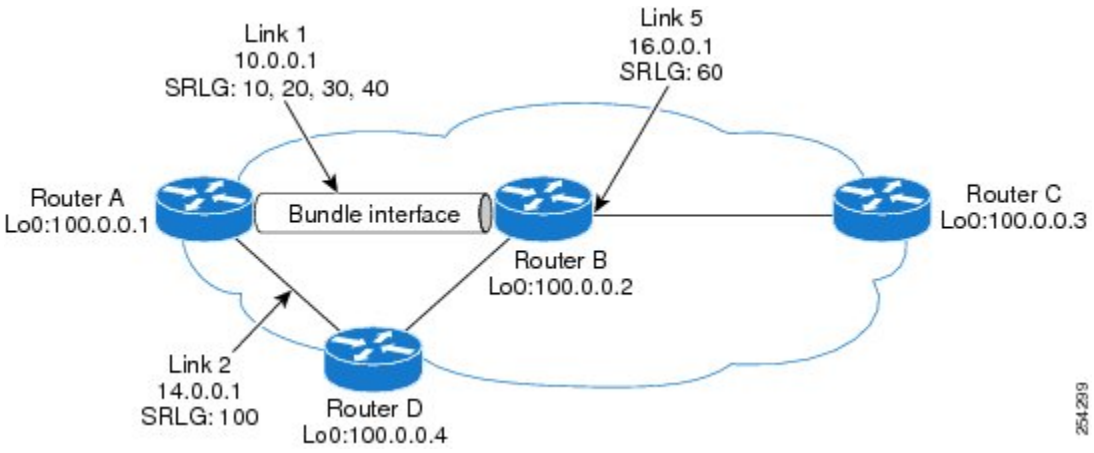
Shared Risk Link Groups (SRLG) in MPLS traffic engineering refer to situations in which links in a network share a common fiber (or a common physical attribute). These links have a shared risk, and that is when one link fails, other links in the group might fail too.

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

Figure 7: Shared Risk Link Group



Related Topics

Configuring the SRLG Values of Each Link that has a Shared Risk with Another Link, on page 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75

Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 77
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 79
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
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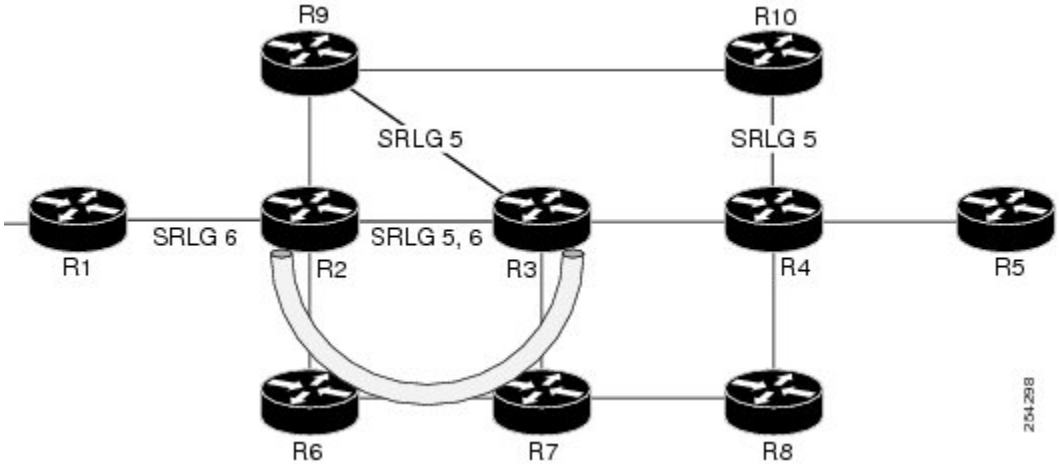
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 8: NHOP Backup Tunnel with SRLG constraint illustrates an NHOP backup tunnel.

Figure 8: NHOP Backup Tunnel with SRLG constraint

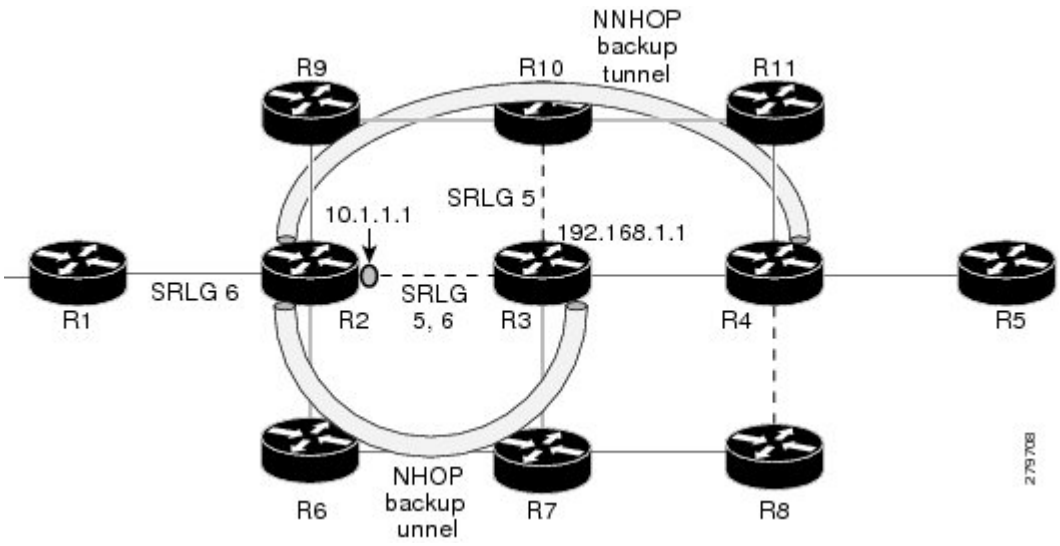


In the topology shown in the above figure, the backup tunnel path computation can be performed in this manner:

- 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 9: NNHOP Backup Tunnel with SRLG constraint illustrates an NNHOP backup tunnel.

Figure 9: 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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 77
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 79
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 77
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Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
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Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 72
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Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 77
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 79
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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 82
Enabling Soft-Preemption on a Tunnel, on page 83

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 84

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 84

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 84

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 84

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 84

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 85
Configuring Auto-tunnel Mesh Unused Timeout, on page 86
Configuring Auto-Tunnel Mesh Group, on page 87
Configuring Tunnel Attribute-Set Templates, on page 88
Enabling LDP on Auto-Tunnel Mesh, on page 90

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:100.1.1.1 Router Node  (ISIS 1 level-2)
IGP Id: 0001.0000.0011.00, MPLS TE Id:100.2.2.2 Router Node  (ISIS 1 level-2)
IGP Id: 0001.0000.0012.00, MPLS TE Id:100.3.3.3 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 100.0.0.0 with wildcard 0.255.255.255, then all 100.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, 100.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 85
Configuring Auto-tunnel Mesh Unused Timeout, on page 86
Configuring Auto-Tunnel Mesh Group, on page 87
Configuring Tunnel Attribute-Set Templates, on page 88
Enabling LDP on Auto-Tunnel Mesh, on page 90

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.

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

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 3	**interface** *type interface-path-id*
	Example:
	`RP/0/RP0/CPU0:router(config-mpls-te)#interface POS0/6/0/0`
	`RP/0/RP0/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/RP0/CPU0:router(config-mpls-te-if)# exit`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Exits the current configuration mode.

Step 5	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config)#`	
Step 6	**router ospf** *process-name* **Example:** `RP/0/RP0/CPU0:router(config)# router ospf 1`	Enters a name for the OSPF process.
Step 7	**area** *area-id* **Example:** `RP/0/RP0/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:
	`RP/0/RP0/CPU0:router(config-ospf-ar)# exit`
	`RP/0/RP0/CPU0:router(config-ospf)#`
		Exits the current configuration mode.

Step 9	**mpls traffic-eng router-id** *ip-address* **Example:** `RP/0/RP0/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/RP0/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/RP0/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 3
Build MPLS-TE Topology and Tunnels: Example, on page 102

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**destination** *ip-address* **Example:** `RP/0/RP0/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.

	Command or Action	Purpose
Step 4	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/CPU0:router(config-if)# path-option 1 dynamic`	Sets the path option to dynamic and assigns the path ID.
Step 6	**signalled- bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/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 3
Build MPLS-TE Topology and Tunnels: Example, on page 102
Building MPLS-TE Topology, on page 34

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.

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 1`	Enters MPLS-TE interface configuration mode.
Step 3	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/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:** `RP/0/RP0/CPU0:router(config-if)# autoroute announce`	Enables messages that notify the neighbor nodes about the routes that are forwarding.

	Command or Action	Purpose
Step 5	**exit** **Example:** `RP/0/RP0/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/RP0/CPU0:router(config)# router static address-family ipv4 unicast 2.2.2.2/32 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/RP0/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/RP0/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 2
Creating an MPLS-TE Tunnel, on page 37

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router# interface tunnel-te 1`	Configures an MPLS-TE tunnel interface.
Step 3	**fast-reroute** **Example:** `RP/0/RP0/CPU0:router(config-if)# fast-reroute`	Enables fast reroute.

	Command or Action	Purpose
Step 4	**exit** **Example:** `RP/0/RP0/CPU0:router(config-if)# exit`	Exits the current configuration mode.

Step 5	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 6	**interface** *type interface-path-id*
	Example:
	`RP/0/RP0/CPU0:router(config-mpls-te)# interface pos0/6/0/0`
	`RP/0/RP0/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/RP0/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/RP0/CPU0:router(config-mpls-te-if)# exit`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Exits the current configuration mode.

Step 9	**exit**
	Example:
	`RP/0/RP0/CPU0:router(config-mpls-te)# exit`
	`RP/0/RP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 10	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 11	**backup-bw** {*backup bandwidth* | **sub-pool** {*bandwidth* | **unlimited**} | **global-pool** {*bandwidth* | **unlimited**} }	Sets the CT0 bandwidth required on this interface.

	Command or Action	Purpose
	Example: `RP/0/RP0/CPU0:router(config-if)#backup-bw global-pool 5000`	**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/RP0/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/RP0/CPU0:router(config-if)# path-option l 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/RP0/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/RP0/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/RP0/CPU0:router# show mpls traffic-eng tunnels protection frr`	Displays the tunnel protection information for Fast-Reroute (FRR).

	Command or Action	Purpose
Step 18	(Optional) **show mpls traffic-eng fast-reroute database** **Example:** `RP/0/RP0/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 10
Fast Reroute Node Protection, on page 15
Creating an MPLS-TE Tunnel, on page 37
Configuring Forwarding over the MPLS-TE Tunnel , on page 39

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**ipv4 unnumbered mpls traffic-eng Loopback** *0* **Example:** `RP/0/RP0/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.
Step 3	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
Step 4	**auto-tunnel backup timers removal unused** *frequency* **Example:** `RP/0/RP0/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/RP0/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/RP0/CPU0:router# show mpls traffic-eng auto-tunnel backup summary	Displays information about configured MPLS-TE backup autotunnels.

Related Topics

Backup AutoTunnels, on page 4

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

	Command or Action	Purpose
Step 1	**clear mpls traffic-eng auto-tunnel backup unused** { **all**	**tunnel-te***number*} **Example:** `RP/0/RP0/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:**	Displays information about MPLS-TE autotunnels including the ones removed.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router# show mpls traffic-eng auto-tunnel summary`	

Related Topics

Backup AutoTunnels, on page 4

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. **commit**
6. **show mpls traffic-eng auto-tunnel backup summary**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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	**commit**	
Step 6	**show mpls traffic-eng auto-tunnel backup summary** **Example:** `RP/0/RP0/CPU0:router# show mpls traffic auto-tunnel backup summary`	Displays information about configured MPLS-TE backup autotunnels.

Related Topics

Backup AutoTunnels, on page 4

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. **commit**
7. **show mpls traffic-eng tunnels** *number* **detail**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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/RP0/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	**commit**	
Step 7	**show mpls traffic-eng tunnels** *number* **detail** **Example:** `RP/0/RP0/CPU0:router# show mpls traffic-eng tunnels 1 detail`	Displays information about configured NHOP tunnels and SRLG information.

Related Topics

Backup AutoTunnels, on page 4

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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.

	Command or Action	Purpose

Step 4	**exit**
	Example:
	`RP/0/RP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RP0/CPU0:router(config-rsvp)#`
		Exits the current configuration mode.

Step 5	**exit**
	Example:
	`RP/0/RP0/CPU0:router(config-rsvp)# exit`
	`RP/0/RP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 6	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/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/RP0/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 8
Configure IETF DS-TE Tunnels: Example, on page 103

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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/RP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RP0/CPU0:router(config-rsvp)`
		Exits the current configuration mode.

Step 5	**exit**
	Example:
	`RP/0/RP0/CPU0:router(config-rsvp) exit`
	`RP/0/RP0/CPU0:router(config)`
		Exits the current configuration mode.

Step 6	**mpls traffic-eng** **Example:**	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng` `RP/0/RP0/CPU0:router(config-mpls-te)#`	
Step 7	**ds-te mode ietf** **Example:** `RP/0/RP0/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/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.

Step 9	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RP0/CPU0:router(config)# interface tunnel-te 4`
	`RP/0/RP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface.

Step 10	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RP0/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 9

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**rsvp interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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/RP0/CPU0:router(config-rsvp-if)# exit`
	`RP/0/RP0/CPU0:router(config-rsvp)#`
		Exits the current configuration mode.

	Command or Action	Purpose

Step 5	**exit**
	Example:
	`RP/0/RP0/CPU0:router(config-rsvp)# exit`
	`RP/0/RP0/CPU0:router(config)#`
		Exits the current configuration mode.

Step 6	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 7	**ds-te mode ietf** **Example:** `RP/0/RP0/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/RP0/CPU0:router(config-mpls-te)# ds-te bc-model mam`	Enables the MAM bandwidth constraint model globally.
Step 9	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.

Step 10	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RP0/CPU0:router(config)# interface tunnel-te 4`
	`RP/0/RP0/CPU0:router(config-if)#`
		Configures an MPLS-TE tunnel interface.

Step 11	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*} **Example:** `RP/0/RP0/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).

	Command or Action	Purpose
Step 12	**commit**	

Related Topics

Configuring Traffic Engineering Tunnel Bandwidth
Maximum Allocation Bandwidth Constraint Model, on page 8

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

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RP0/CPU0:router(config)# interface tunnel-te 1`
	`RP/0/RP0/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*}	Configures an explicit path option for an MPLS-TE tunnel. OSPF is limited to a single OSPF instance and area.

	Command or Action	Purpose
	] [**ospf** *instance name* {**area** *area ID*}]] [**verbatim**] [**lockdown**] **Example:** `RP/0/RP0/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/RP0/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/RP0/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

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/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/RP0/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 11
Configure the Ignore IS-IS Overload Bit Setting in MPLS-TE: Example, on page 104

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 56
2. Associating Affinity-Names with TE Links, on page 57
3. Associating Affinity Constraints for TE Tunnels, on page 58

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:**	Enters MPLS-TE configuration mode.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng` `RP/0/RP0/CPU0:router(config-mpls-te)#`	
Step 3	**affinity-map** *affinity name* {*affinity value* | **bit-position** *value*} **Example:** `RP/0/RP0/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 12
Configure Flexible Name-based Tunnel Constraints: Example, on page 105

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

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# interface tunnel-te 2`	Enables MPLS-TE on an interface and enters MPLS-TE interface configuration mode.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config-mpls-te-if)#`	
Step 4	**attribute-names** *attribute name* **Example:** `RP/0/RP0/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 12
Configure Flexible Name-based Tunnel Constraints: Example, on page 105
Assigning Color Names to Numeric Values, on page 56

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

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/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/RP0/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 12
Configure Flexible Name-based Tunnel Constraints: Example, on page 105

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. **metric-style wide**
6. **mpls traffic-eng** *level*
7. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**router isis** *instance-id* **Example:**	Enters an IS-IS instance.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config)# router isis 1`	
Step 3	**net** *network-entity-title* **Example:** `RP/0/RP0/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/RP0/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	**metric-style wide** **Example:** `RP/0/RP0/CPU0:router(config-isis-af)# metric-style wide`	Enters the new-style type, length, and value (TLV) objects.
Step 6	**mpls traffic-eng** *level* **Example:** `RP/0/RP0/CPU0:router(config-isis-af)# mpls traffic-eng level-1-2`	Enters the required MPLS-TE level or levels.
Step 7	**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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**router ospf** *process-name* **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/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

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**explicit-path name** *name* **Example:** `RP/0/RP0/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/RP0/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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 1`	Enters MPLS-TE interface configuration mode.
Step 3	**forwarding-adjacency holdtime** *value* **Example:** `RP/0/RP0/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 16
Configure Forwarding Adjacency: Example, on page 107

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 63
- Configuring a Path Computation Element Address, on page 64
- Configuring PCE Parameters, on page 64

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/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/RP0/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 16
Configure PCE: Example, on page 108

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters the MPLS-TE configuration mode.
Step 3	**pce address ipv4** *address* **Example:** `RP/0/RP0/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 16
Configure PCE: Example, on page 108

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**pce address ipv4** *address* **Example:** `RP/0/RP0/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/RP0/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/RP0/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.

	Command or Action	Purpose
Step 6	**pce deadtimer** *value* **Example:** `RP/0/RP0/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/RP0/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.
Step 8	**pce request-timeout** *value* **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/CPU0:router# show mpls traffic-eng pce tunnels`	Displays the status of the PCE tunnels.

Related Topics

Path Computation Element, on page 16
Configure PCE: Example, on page 108

Configuring Policy-based Tunnel Selection

Perform this task to configure policy-based tunnel selection (PBTS).

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **signalled-bandwidth** {*bandwidth* [**class-type** *ct*] | **sub-pool** *bandwidth*}
5. **autoroute announce**
6. **destination** *ip-address*
7. **policy-class** {*1 - 7*} | {**default**}
8. **path-option** *preference-priority* {**explicit name** *explicit-path-name*}
9. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/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	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address so that forwarding can be performed on the new tunnel.
Step 4	**signalled-bandwidth** {*bandwidth* [**class-type** *ct*]	**sub-pool** *bandwidth*} **Example:** `RP/0/RP0/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 5	**autoroute announce** **Example:** `RP/0/RP0/CPU0:router(config-if)# autoroute announce`	Enables messages that notify the neighbor nodes about the routes that are forwarding.

	Command or Action	Purpose
Step 6	**destination** *ip-address* **Example:** `RP/0/RP0/CPU0:router(config-if)# destination 10.1.1.1`	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.
Step 7	**policy-class** {*1 - 7*} | {**default**} **Example:** `RP/0/RP0/CPU0:router(config-if)# policy-class 1`	Configures PBTS to direct traffic into specific TE tunnels or default class.
Step 8	**path-option** *preference-priority* {**explicit name** *explicit-path-name*} **Example:** `RP/0/RP0/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 9	**commit**	

Related Topics

Policy-Based Tunnel Selection Functions, on page 18
Policy-Based Tunnel Selection, on page 18

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

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose

Step 2	**mpls traffic-eng**
	Example:
	`RP/0/RP0/CPU0:router(config)# mpls traffic-eng`
	`RP/0/RP0/CPU0:router(config-mpls-te)#`
		Enters MPLS-TE configuration mode.

Step 3	**auto-bw collect frequency** *minutes* **Example:** `RP/0/RP0/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/RP0/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 19
Configure Automatic Bandwidth: Example, on page 109

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

	Command or Action	Purpose
Step 1	**mpls traffic-eng auto-bw apply** {**all** | **tunnel-te** *tunnel-number*} **Example:** `RP/0/RP0/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.
Step 2	**commit**	
Step 3	**show mpls traffic-eng tunnels** [**auto-bw**] **Example:** `RP/0/RP0/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

	Command or Action	Purpose
Step 1	**configure**	

Step 2	**interface tunnel-te** *tunnel-id*
	Example:
	`RP/0/RP0/CPU0:router(config)# interface tunnel-te 6`
	`RP/0/RP0/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/RP0/CPU0:router(config-if)# auto-bw`
	`RP/0/RP0/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/RP0/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/RP0/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/RP0/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.

	Command or Action	Purpose
		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.
Step 7	**overflow threshold** *percentage* [**min** *bandwidth*] **limit** *limit* **Example:** `RP/0/RP0/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/RP0/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 19
Configure Automatic Bandwidth: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**srlg** **Example:** `RP/0/RP0/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/RP0/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/RP0/CPU0:router(config-srlg-if)# value 100`
	`RP/0/RP0/CPU0:router (config-srlg-if)# value 200`
	`RP/0/RP0/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/RP0/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/RP0/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 25

Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28
Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**explicit-path {identifier number [disable | index]}{ name** *explicit-path-name*} **Example:** `RP/0/RP0/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/RP0/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/RP0/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 25
Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28

Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RP0/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:** `RP/0/RP0/CPU0:router(config-mpls-te)# backup-path tunnel-te 2`	Configures an MPLS TE backup path for a specific interface.
Step 5	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.

	Command or Action	Purpose
Step 6	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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. **Note** You can use the dynamic option to dynamically assign a path.
Step 10	**destination** *ip-address* **Example:** `RP/0/RP0/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/RP0/CPU0:router(config-if)# exit	Exits the current configuration mode.
Step 12	**commit**	
Step 13	**show run explicit-path name** *name* **Example:** `RP/0/RP0/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:**	Displays the SRLG values that are configured for the link.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router#show mpls traffic-eng topology path destination 192.168.92.125 explicit-path backup-srlg`	

Related Topics

MPLS Traffic Engineering Shared Risk Link Groups, on page 25
Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28
Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.
Step 6	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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* **Example:** `RP/0/RP0/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.

	Command or Action	Purpose
Step 11	**exit** **Example:** RP/0/RP0/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/RP0/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/RP0/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/RP0/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 25
Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28
Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**interface** *type interface-path-id* **Example:** `RP/0/RP0/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/RP0/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/RP0/CPU0:router(config-mpls-te-if)# exit`	Exits the current configuration mode.
Step 6	**exit** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# exit`	Exits the current configuration mode.
Step 7	**interface tunnel-te***tunnel-id* **Example:** `RP/0/RP0/CPU0:router(config)# interface tunnel-te 2`	Configures an MPLS-TE tunnel interface.
Step 8	**ipv4 unnumbered** *type interface-path-id* **Example:** `RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered Loopback0`	Assigns a source address to set up forwarding on the new tunnel.

	Command or Action	Purpose
Step 9	**path-option** *preference-priority*{ **dynamic | explicit {identifier | name** *explicit-path-name*}} **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/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:** `RP/0/RP0/CPU0:router:router(config-if)# index 1 exclude-address 192.168.92.1`	Specifies the protected node IP address to be excluded from the explicit path.
Step 14	**index 2 exclude-srlg** *192.168.92.2* **Example:** `RP/0/RP0/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/RP0/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 25
Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28
Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29
Configure the MPLS-TE Shared Risk Link Groups: Example, on page 109

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**soft-preemption** **Example:** `RP/0/RP0/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:**	Specifies the timeout for the soft-preempted LSP, in seconds. The range is from 1 to 300.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config-soft-preemption)# timeout 20`	
Step 5	**commit**	

Related Topics

Soft-Preemption, on page 30

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**interface tunnel-te** *tunnel-id* **Example:** `RP/0/RP0/CPU0:router# interface tunnel-te 10`	Configures an MPLS-TE tunnel interface.
Step 3	**soft-preemption** **Example:** `RP/0/RP0/CPU0:router(config-if)# soft-preemption`	Enables soft-preemption on a tunnel. 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.

	Command or Action	Purpose
Step 4	**commit**	

Related Topics

Soft-Preemption, on page 30

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**attribute-set path-option** *attribute-set-name* **Example:** `RP/0/RP0/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/RP0/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/RP0/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.**

	Command or Action	Purpose
Step 6	**commit**	
Step 7	**show mpls traffic-eng attribute-set** **Example:** `RP/0/RP0/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/RP0/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 30
Configuration Hierarchy of Path Option Attributes, on page 30
Traffic Engineering Bandwidth and Bandwidth Pools, on page 31
Path Option Switchover, on page 32
Path Option and Path Protection, on page 32

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RP0/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.

	Command or Action	Purpose
Step 4	**tunnel-id min** *value* **max** *value* **Example:** `RP/0/RP0/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 33
Destination List (Prefix-List), on page 33

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# auto-tunnel mesh`	Enables auto-tunnel mesh groups globally.
Step 4	**timer removal unused** *timeout* **Example:** `RP/0/RP0/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

	Command or Action	Purpose
		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 33
Destination List (Prefix-List), on page 33

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**auto-tunnel mesh** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# auto-tunnel mesh`	Enables auto-tunnel mesh groups globally.
Step 4	**group** *value* **Example:** `RP/0/RP0/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.

	Command or Action	Purpose
Step 5	**disable** **Example:** `RP/0/RP0/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/RP0/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/RP0/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.
Step 8	**commit**	

Related Topics

Auto-Tunnel Mesh, on page 33
Destination List (Prefix-List), on page 33

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

	Command or Action	Purpose
Step 1	**configure**	

	Command or Action	Purpose
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**attribute-set auto-mesh** *attribute-set-name* **Example:** `RP/0/RP0/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/RP0/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.
Step 5	**signalled-bandwidth** *kbps* **class-type** *class-type number* **Example:** `RP/0/RP0/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/RP0/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/RP0/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/RP0/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:**	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.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config-te-attribute-set)# logging events lsp-status state`	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 33
Destination List (Prefix-List), on page 33

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

	Command or Action	Purpose
Step 1	**configure**	
Step 2	**mpls ldp** **Example:** `RP/0/RP0/CPU0:router(config-ldp)# mpls ldp`	Enters MPLS LDP configuration mode.
Step 3	**traffic-eng auto-tunnel mesh** **Example:** `RP/0/RP0/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/RP0/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 33
Destination List (Prefix-List), on page 33

Implementing Associated Bidirectional Label Switched Paths

This section describes how to configure MPLS Traffic Engineering Associated Bidirectional Label Switched Paths (MPLS-TE LSPs).

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.

Signaling Methods and Object Association for Bidirectional LSPs, on page 91 ,Associated Bidirectional Non Co-routed and Co-routed LSPs, on page 92 provides details.

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.

Path Protection, on page 96 provides details.

Signaling Methods and Object Association for Bidirectional LSPs

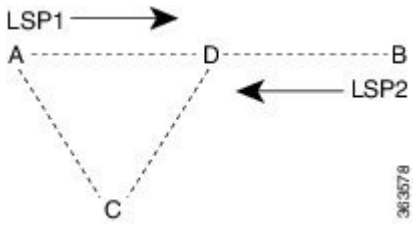
This section provides an overview of the association signaling methods for the bidirectional LSPs. Two unidirectional LSPs can be bound to form an associated bidirectional LSP in the following scenarios:

- 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.

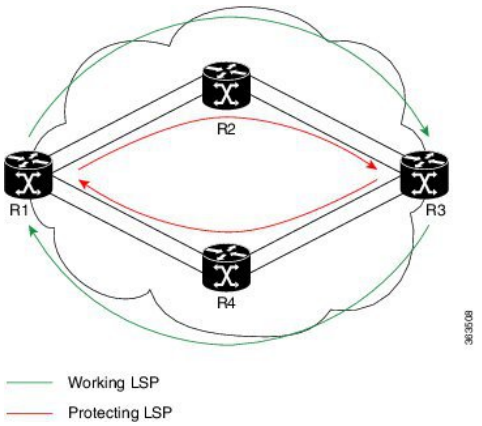
Configure Associated Bidirectional Co-routed LSPs, on page 94 describes the procedure to create associated bidirectional co-routed LSPs.

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.



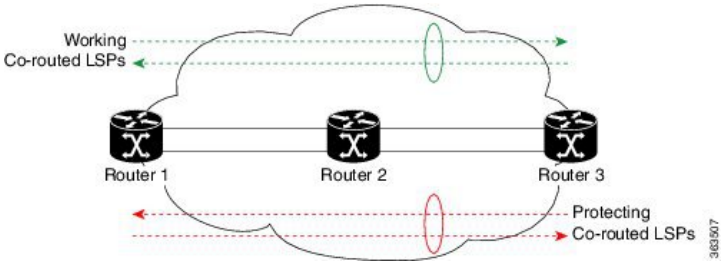
In the above topology:

- 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 94 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

	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.

	Command or Action	Purpose
		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 96 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

	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/RP0/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	**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/RP0/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. **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/RP0/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 98 and Generate Fault OAM Messages at End-point, on page 99provides 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

	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

	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

	Command or Action	Purpose
Step 1	**configure** **Example:** `RP/0/RP0/CPU0:router# configure`	Enters global configuration mode.
Step 2	**mpls traffic-eng** **Example:** `RP/0/RP0/CPU0:router(config)# mpls traffic-eng`	Enters MPLS-TE configuration mode.
Step 3	**named-tunnels** **Example:** `RP/0/RP0/CPU0:router(config-mpls-te)# named-tunnels`	Enters the named tunnels configuration sub-mode.
Step 4	**tunnel-te** *tunnel-name* **Example:** `RP/0/RP0/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:**	Assigns a destination address to the new tunnel.

	Command or Action	Purpose
	`RP/0/RP0/CPU0:router(config-mpls-te-tunnel-name)# destination 192.168.0.1`	
Step 6	**path-option** *path-name* **Example:** `RP/0/RP0/CPU0:router(config-mpls-te-tunnel-name)# path-option VIA_DC`	Specifies the path option name.
Step 7	**preference** *value* **Example:** `RP/0/RP0/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.
Step 8	**computation** { **explicit** *explicit-path-name* | **dynamic** } **Example:** `RP/0/RP0/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/RP0/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
```

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 34
Creating an MPLS-TE Tunnel, on page 37
How MPLS-TE Works, on page 3

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
```

Related Topics

Configuring a Prestandard DS-TE Tunnel, on page 48
Prestandard DS-TE Mode, on page 8

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:

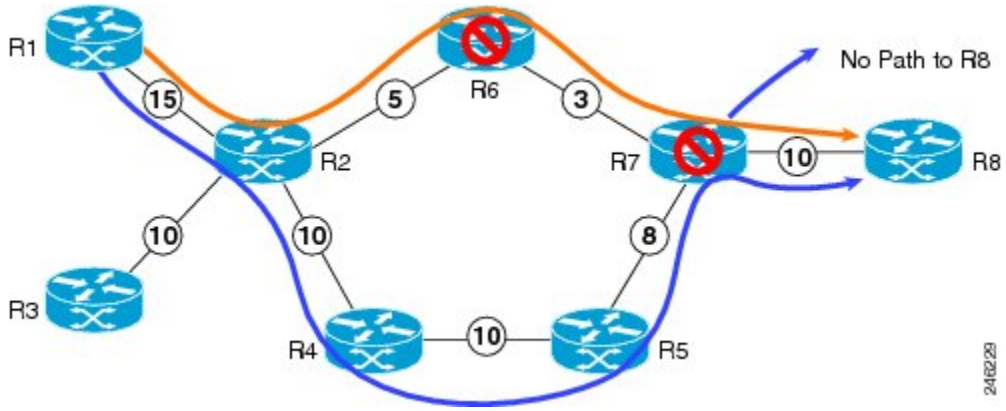
```
configure
 interface tunnel-te 0
  path-option 1 explicit id 6 ospf 126 area 0
  path-option 2 explicit name 234 ospf 3 area 7 verbatim
  path-option 3 dynamic isis mtbf level 1 lockdown
  commit
```

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 10: 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 55
Ignore Intermediate System-to-Intermediate System Overload Bit Setting in MPLS-TE, on page 11

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 3.3.3.3 !
explicit-path name ex_path1
 index 10 next-address loose ipv4 unicast 2.2.2.2  index 20 next-address loose ipv4 unicast
3.3.3.3 !
interface Loopback0
 ipv4 address 22.22.22.22 255.255.255.255 !
interface tunnel-te1
 ipv4 unnumbered Loopback0
```

```
 signalled-bandwidth 1000000
 destination 3.3.3.3
 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 56
Associating Affinity-Names with TE Links, on page 57
Associating Affinity Constraints for TE Tunnels, on page 58
Flexible Name-based Tunnel Constraints, on page 12

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
```

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 62
MPLS-TE Forwarding Adjacency Benefits, on page 16

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 1.2.3.4
  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 63
Configuring a Path Computation Element Address, on page 64
Configuring PCE Parameters, on page 64
Path Computation Element, on page 16

Configure Policy-based Tunnel Selection: Example

The following configuration example illustrates a PBTS configuration:

```
configure
 interface tunnel-te0
```

```
ipv4 unnumbered Loopback3
signalled-bandwidth 50000
autoroute announce
destination 1.5.177.2
policy-class 2
path-option 1 dynamic
```

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 68
Configuring the Automatic Bandwidth Functions, on page 70
MPLS-TE Automatic Bandwidth Overview, on page 19

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/RP0/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/RP0/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/RP0/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/RP0/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/RP0/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 72
Creating an Explicit Path With Exclude SRLG, on page 74
Using Explicit Path With Exclude SRLG, on page 75
Creating a Link Protection on Backup Tunnel with SRLG Constraint, on page 77
Creating a Node Protection on Backup Tunnel with SRLG Constraint, on page 79
MPLS Traffic Engineering Shared Risk Link Groups, on page 25
Explicit Path, on page 26
Fast ReRoute with SRLG Constraints, on page 26
Importance of Protection, on page 28
Delivery of Packets During a Failure, on page 29
Multiple Backup Tunnels Protecting the Same Interface , on page 29
SRLG Limitations, on page 29

Configure Entropy Labels for MPLS TE Networks

Most MPLS networks use load balancing techniques for traffic engineering. What causes latency in such widespread networks is the time taken to inspect the label stack at each transit Label Switching Router (LSR) to determine the next hop or path.

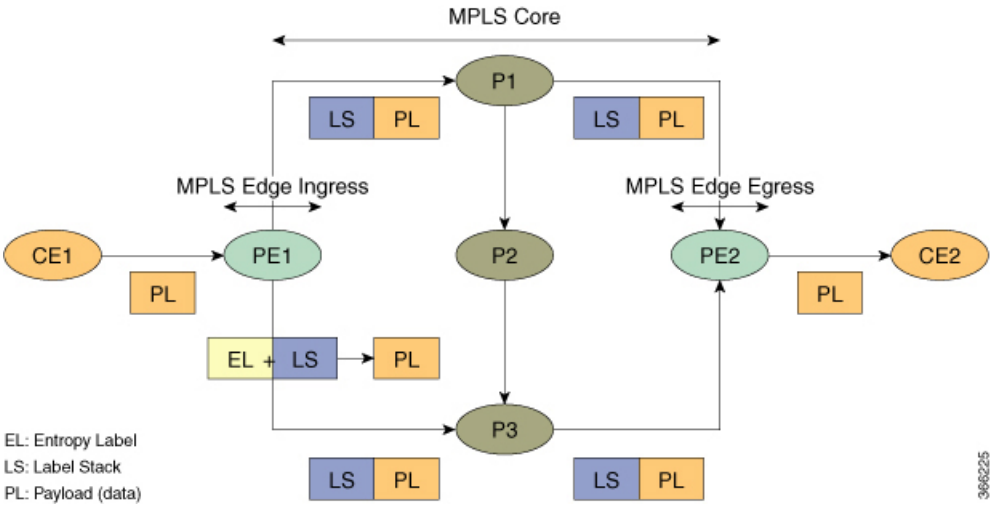
The latency can be reduced by inserting a label known as the *entropy label* on top of the label stack at the ingress LSR. The entropy label contains the keys required by the load balancing function, and thus eliminates the need for deep packet inspection at transit LSRs. The ingress LSR, which has all the information about incoming packets, extracts the load balancing keys from the entropy label and decides the optimum paths for the packets. The transit LSRs use the rest of the label stack to forward the packets along the pre-determined paths.

The advantages of using entropy labels in MPLS networks are:

- Ingress LSRs operate at lower bandwidths than transit LSRs, and are hence the ideal choice for load balancing.
- Transit LSRs do not need to perform deep packet inspection and can effectively load balance the packets as decided by the Ingress LSRs.
- Transit LSRs are spared from the problem of misinterpreting the protocol denoted in the label stack and thereby causing inequitable distribution of traffic across equal cost paths exiting from the LSR.

The following illustration shows the transit of a packet through the MPLS network. The entropy label is attached at the ingress router for load balancing. When the optimum path is determined for the packet, which contains the payload (data) and the label stack, the entropy label is no longer required.

Figure 11: Transit of an MPLS Packet with an Entropy Label



Configuration

1. To configure an MPLS entropy label, use the following configuration.

```
RP/0/RP0/CPU0:router(config)# mpls ldp
RP/0/RP0/CPU0:router(config-ldp)# entropy-label
```

```
RP/0/RP0/CPU0:router(config-ldp)# commit
RP/0/RP0/CPU0:router(config-ldp)# end
```

2. Locate the route that needs to use the entropy label for load balancing.

```
RP/0/RP0/CPU0:router# show cef exact-route 10.1.6.1 10.1.1.1

10.1.1.1/32, version 40, internal 0x1000001 0x0 (ptr 0x8d42b4d8) [1], 0x0 (0x8d5c5020),
 0xa20 (0x8e1c0098)
...
Prefix Len 32, traffic index 0, precedence n/a, priority 4
   via Bundle-Ether613
   via 11.1.5.1/32, Bundle-Ether613, 2 dependencies, weight 0, class 0 [flags 0x0]
    path-idx 2 NHID 0x0 [0x8dd02920 0x8dd02810]
    next hop 11.1.5.1/32
    local adjacency
     local label 24002      labels imposed {ImplNull}
```

3. Use the route to pass the entropy label for load balancing.

   You are prompted for the option of entering the entropy label for multiple source-destination pairs.

```
RP/0/RP0/CPU0:router# bundle-hash bundle-Ether 613
Specify load-balance configuration (L3/3-tuple or L4/7-tuple) (L3,L4): L3
Single SA/DA pair (IPv4,IPv6) or range (IPv4 only) or Entropy Label (MPLS only): S/R/E
[S]: E

Enter Entropy Label(in network byte order): 14001

Entropy Label 14001 -- Link hashed to is TenGigE0/1/0/8/8

Another? [y]:
```

4. Verify if traffic is getting load balanced with the MPLS entropy label configuration.

```
RP/0/RP0/CPU0:router# show mpls forwarding exact-route label 24002 entropy-label 14001

Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
24002  24010    10.1.1.1/32        BE613        11.1.5.1/32       N/A
     Via: BE613, Next Hop: 11.1.5.1/32
     Label Stack (Top -> Bottom): { 24010 }
     NHID: 0x0, Encap-ID: N/A, Path idx: 0, Backup path idx: 0, Weight: 0
     MAC/Encaps: 0/4, MTU: 1500
```

You have successfully configured an MPLS entropy label in your network.

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 NCS 6000 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