JUNIPER NETWORKS

Network Configuration Example

Configuring the Path Computation Element Protocol for MPLS RSVP-TE

Published: 2014-01-10

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Network Configuration Example Configuring the Path Computation Element Protocol for MPLS RSVP-TE
NCE0108
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Table of Contents

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Introduction

This document provides a step-by-step procedure for configuring external path computing by a Path Computation Element (PCE) for traffic engineered label-switched paths (TE LSPs) on a Path Computation Client (PCC) using the Path Computation Element Protocol (PCEP).

Use Case for Configuring the Path Computation Element Protocol

There is a great need for MPLS traffic engineering (TE) capabilities in large service provider IP networks. These capabilities can be implemented on the label switched routers (LSRs) from different vendors that interoperate using a common signaling and label distribution protocol. The Resource Reservation Protocol with traffic-engineering extensions (RSVP-TE) is one such label distribution protocol that enables label binding and explicit route capability.

Although traffic engineered label-switched paths (TE LSPs) provide bandwidth and class-of-service (CoS) guarantees, such as minimal latency while avoiding high-cost links, computing end-to-end TE LSPs through an MPLS RSVP-TE network can be quite complex. It becomes even more complex when the TE-LSPs cross different routing domains and autonomous systems (ASs) or in a multi-layer network where part of the path might include an MPLS-unaware technology such as optical switching. Adding complex path computation can overwhelm the bandwidth resources on a networking device.

As a result, the ability to compute shortest constrained TE LSP in an MPLS RSVP-TE network has been identified as a key requirement for point-to-point and point-to-multipoint scenarios. Implementing the stateful Path Computation Element (PCE) architecture in the MPLS RSVP-TE network overcomes the limitations of constraint-based routing by providing external offline path computations.

The Path Computation Element Protocol (PCEP) is a software-defined networking (SDN) protocol that enables large service providers to get the best from technology with the maximum flexibility. The central concept of SDN is to provide a separation of the control plane from the physical network for visibility, programmability, and granular control. The stateful PCE architecture simplifies path computation by separating network topology determination from path creation. Both tasks have traditionally been done by the provider edge (PE) device that receives the customer path request.

Implementing SDN might require upgrading or replacing all existing routers and switches with compliant units. Upgrading the entire MPLS network is extremely expensive and disruptive. PCE presents an evolutionary approach as it requires upgrading only the ingress LSRs, called the Path Computation Client (PCC).

Configuring PCEP enables large service providers to optimize network utilization and provide increased revenue by minimizing link utilization while also minimizing end-to-end delay and the cost of point-to-multipoint networks. This enables large service providers to exceed the most stringent service-level agreements (SLAs) and resiliency requirements.

A PCE plays a vital role in emerging SDN architectures, especially in service provider networks. Applications such as VoIP, video, and collaboration depend on strict quality-of-service (QoS) compliance. Increasing use of these applications, along with the continuing need to minimize costs, adds incentives to implement the stateful PCE architecture.

Related Documentation

- Support of the Path Computation Element Protocol for RSVP-TE Overview on page 2
- Example: Configuring the Path Computation Element Protocol for MPLS RSVP-TE on page 12

Support of the Path Computation Element Protocol for RSVP-TE Overview

This section contains the following topics:

Understanding MPLS RSVP-TE

Traffic engineering (TE) deals with performance optimization of operational networks, mainly mapping traffic flows onto an existing physical topology. Traffic engineering provides the ability to move traffic flow away from the shortest path selected by the interior gateway protocol (IGP) and onto a potentially less congested physical path across a network.

For traffic engineering in large dense networks, MPLS capabilities can be implemented, because they potentially provide most of the functionality available from an overlay model, in an integrated manner, and at a lower cost than the currently competing alternatives. The primary reason for implementing MPLS traffic engineering is to control paths along which traffic flows through a network. The main advantage of implementing MPLS traffic engineering is that it provides a combination of the traffic engineering capabilities of ATM along with the class-of-service (CoS) differentiation of IP.

In an MPLS network, data plane information is forwarded using label switching. A packet arriving on a provider edge (PE) router from the customer edge (CE) router has labels applied to it and it is then forwarded to the egress PE router. The labels are removed at the egress router and forwarded out to the appropriate destination as an IP packet. The label switch routers (LSRs) in the MPLS domain use label distribution protocols to

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communicate the meaning of labels used to forward traffic between and through the LSRs. RSVP-TE is one such label distribution protocol that enables an LSR peer to learn about the label mappings of other peers.

When both MPLS and RSVP are enabled on a router, MPLS becomes a client of RSVP. The primary purpose of the Junos® operating system (Junos OS) RSVP software is to support dynamic signaling within label-switched paths (LSPs). RSVP reserves resources, such as for IP unicast and multicast flows, and requests quality-of-service (QoS) parameters for applications. The protocol is extended in MPLS traffic engineering to enable RSVP to set up LSPs that can be used for traffic engineering in MPLS networks.

When MPLS and RSVP are combined, labels are associated with RSVP flows. Once an LSP is established, the traffic through the path is defined by the label applied at the ingress node of the LSP. The mapping of label to traffic is accomplished using different criteria. The set of packets that are assigned the same label value by a specific node belong to the same forwarding equivalence class (FEC), and effectively define the RSVP flow. When traffic is mapped onto an LSP in this way, the LSP is called an LSP tunnel.

LSP tunnels are a way to establish unidirectional label-switched paths. RSVP-TE builds on the RSVP core protocol by defining new objects and modifying existing objects used in the PATH and RESV objects for LSP establishment. The new objects—LABEL-REQUEST object (LRO), RECORD-ROUTE object (RRO), LABEL object, and EXPLICIT-ROUTE object (ERO)—are optional with respect to the RSVP protocol, except for the LRO and LABEL objects, which are both mandatory for establishing LSP tunnels.

In general, RSVP-TE establishes a label-switched path that ensures frame delivery from ingress to egress router. However, with the new traffic engineering capabilities, the following functions are supported in an MPLS domain:

- Possibility to establish a label-switched path using either a full or partial explicit route (RFC 3209).
- Constraint-based LSP establishment over links that fulfill requirements, such as bandwidth and link properties.
- End-point control, which is associated with establishing and managing LSP tunnels at the ingress and egress routers.
- Link management, which manages link resources to do resource-aware routing of TE LSPs and to program MPLS labels.
- MPLS fast reroute (FRR), which manages the LSPs that need protection and assigns backup tunnel information to these LSPs.

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Current MPLS RSVP-TE Limitations

Although the RSVP extensions for traffic engineering enable better network utilization and meet requirements of classes of traffic, today's MPLS RSVP-TE protocol suite has several issues inherent to its distributed nature. This causes a number of issues during contention for bisection capacity, especially within an LSP priority class where a subset of LSPs share common setup and hold priority values. The limitations of RSVP-TE include:

- Lack of visibility of individual per-LSP, per-device bandwidth demands—The ingress routers in an MPLS RSVP-TE network establish LSPs without having a global view of the bandwidth demand on the network. Information about network resource utilization is only available as total reserved capacity by traffic class on a per interface basis. Individual LSP state is available locally on each label edge router (LER) for its own LSPs only. As a result, a number of issues related to demand pattern arise, particularly within a common setup and hold priority.
- Asynchronous and independent nature of RSVP signaling—In RSVP-TE, the constraints for path establishment are controlled by an administrator. As such, bandwidth reserved for an LSP tunnel is set by the administrator and does not automatically imply any limit on the traffic sent over the tunnel. Therefore, bandwidth available on a traffic engineering link is the bandwidth configured for the link excluding the sum of all reservations made on the link. Thus, the unsignaled demands on an LSP tunnel lead to service degradation of the LSP requiring excess bandwidth, as well as the other LSPs that comply with the bandwidth requirements of the traffic engineering link.
- LSPs established based on dynamic or explicit path options in the order of preference—The ingress routers in an MPLS RSVP-TE network establish LSPs for demands based on the order of arrival. Because the ingress routers do not have a global view of the bandwidth demand on the network, using the order of preference to establish LSPs can cause traffic to be dropped or LSPs from not being established at all when there is an excess of bandwidth demand.

As an example, Figure 1 on page 5 is configured with MPLS RSVP-TE, in which A and G are the label edge routers (LERs). These ingress routers establish LSPs independently based on the order of demands and have no knowledge or control over each other's LSPs. Routers B, C, and D are intermediate or transit routers that connect to the egress routers E and F.

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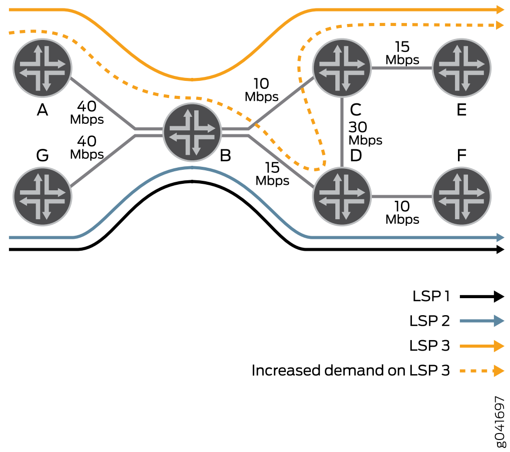
Figure 1: Example MPLS Traffic Engineering



The ingress routers establish LSPs based on the order in which the demands arrive. If Router G receives two demands of capacity 5 Mbps each for G-F, then G signals two LSPs – LSP1 and LSP2 – through G-B-D-F. In the same way, when Router A receives the third demand of capacity 10 Mbps for A-E, then it signals an LSP, LSP3, through A-B-C-E. However, if the demand on the A-E LSP increases from 10 Mbs to 15 Mbps, Router A cannot signal LSP3 using the same (A-B-C-E) path, because the B-C link has a lower capacity.

Router A should have signaled the increased demand on LSP3 using the A-B-D-C-E path. However, because LSP1 and LSP2 have utilized the B-D link based on the order of demands received, LSP3 is not signaled.

Thus, although adequate max-flow bandwidth is available for all the LSPs, LSP3 is subject to potentially prolonged service degradation. This is due to Router A's lack of global demand visibility and the lack of systemic coordination in demand placement by the ingress routers A and G.

Use of an External Path Computing Entity

As a solution to the current limitations found in the MPLS RSVP-TE path computation, an external path computing entity with a global view of per-LSP, per-device demand in the network independent of available capacity is required.

Currently, only online and real-time constraint-based routing path computation is provided in an MPLS RSVP-TE network. Each router performs constraint-based routing calculations independent of the other routers in the network. These calculations are based on currently available topology information—information that is usually recent, but not completely accurate. LSP placements are locally optimized, based on current network status. The MPLS RSVP-TE tunnels are set up using the CLI. An operator configures the TE LSP, which is then signaled by the ingress router.

In addition to the existing traffic engineering capabilities, the MPLS RSVP-TE functionality is extended to include an external path computing entity, called the Path Computation

Element (PCE). The PCE computes the path for the TE LSPs of ingress routers that have been configured for external control. The ingress router that connects to a PCE is called a Path Computation Client (PCC). The PCC is configured with the Path Computation Client Protocol (PCEP) to facilitate external path computing by a PCE.

For more information, see "Components of External Path Computing" on page 6.

To enable external path computing for a PCC's TE LSPs, include the **lsp-external-controller *pccd*** statement at the **[edit mpls]** and **[edit mpls lsp *lsp-name*]** hierarchy levels.

Components of External Path Computing

The components that make up an external path computing system are:

- Path Computation Element on page 6
- Path Computation Client on page 7
- Path Computation Element Protocol on page 7

Path Computation Element

A Path Computation Element (PCE) can be any entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints. However, a PCE can compute the path for only those TE LSPs of a PCC that have been configured for external control.

A PCE can either be stateful or stateless.

- Stateful PCE—A stateful PCE maintains strict synchronization between the PCE and network states (in terms of topology and resource information), along with the set of computed paths and reserved resources in use in the network. In other words, a stateful PCE utilizes information from the traffic engineering database as well as information about existing paths (for example, TE LSPs) in the network when processing new requests from the PCC.

  A stateful PCE is of two types:

  - Passive stateful PCE—Maintains synchronization with the PCC and learns the PCC LSP states to better optimize path calculations, but does not have control over them.
  - Active stateful PCE—Actively modifies the PCC LSPs, in addition to learning about the PCC LSP states.

NOTE: In a redundant configuration with main and backup active stateful PCEs, the backup active stateful PCE cannot modify the attributes of delegated LSPs until it becomes the main PCE at the time of a failover. There is no preempting of PCEs in the case of a switchover. The main PCE is backed by a backup PCE, and when the main PCE goes down, the backup PCE assumes the role of the main PCE and remains the main PCE even after the PCE that was previously the main PCE is operational again.

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A stateful PCE provides the following functions:

- Offers offline LSP path computation.
- Triggers LSP re-route when there is a need to re-optimize the network.
- Changes LSP bandwidth when there is an increase in bandwidth demand from an application.
- Modifies other LSP attributes on the router, such as ERO, setup priority, and hold priority.

A PCE has a global view of the bandwidth demand in the network and maintains a traffic-engineered database to perform path computations. It performs statistics collection from all the routers in the MPLS domain using SNMP and NETCONF. This provides a mechanism for offline control of PCC's TE LSPs. Although an offline LSP path computation system can be embedded in a network controller, the PCE acts like a full-fledged network controller that provides control over the PCC's TE LSPs, in addition to computing paths.

Although a stateful PCE allows for optimal path computation and increased path computation success, it requires reliable state synchronization mechanisms, with potentially significant control plane overhead and the maintenance of a large amount of data in terms of states, as in the case of a full mesh of TE LSPs.

- Stateless PCE—A stateless PCE does not remember any computed path, and each set of requests is processed independently of each other (RFC 5440).

Path Computation Client

A Path Computation Client (PCC) is any client application requesting a path computation to be performed by a PCE.

A PCC can connect to a maximum of 10 PCEs at one time. The PCC-to-PCE connection can be a configured static route or a TCP connection that establishes reachability. The PCC assigns each connected PCE a priority number. It sends a message to all the connected PCEs with information about its current LSPs, in a process called LSP state synchronization. For the TE LSPs that have external control enabled, the PCC delegates those LSPs to the main PCE. The PCC elects, as the main PCE, a PCE with the lowest priority number, or the PCE that it connects to first in the absence of a priority number.

The PCC re-signals an LSP based on the computed path it receives from a PCE. When the PCEP session with the main PCE is terminated, the PCC elects a new main PCE, and all delegated LSPs to the previously main PCE are delegated to the newly available main PCE.

Path Computation Element Protocol

The Path Computation Element Protocol (PCEP) is used for communication between PCC and PCE (as well as between two PCEs) (RFC 5440). PCEP is a TCP-based protocol defined by the IETF PCE Working Group, and defines a set of messages and objects used to manage PCEP sessions and to request and send paths for multidomain TE LSPs. The PCEP interactions include PCC messages as well as notifications of specific states related

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to the use of a PCE in the context of MPLS RSVP-TE. When PCEP is used for PCE-to-PCE communication, the requesting PCE assumes the role of a PCC.

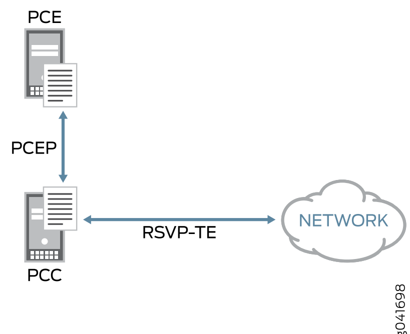
Thus, the PCEP functions include:

- LSP tunnel state synchronization between PCC and a stateful PCE.
- Delegation of control over LSP tunnels to a stateful PCE.

Interaction Between a PCE and a PCC Using PCEP

Figure 2 on page 8 illustrates the relationship between a PCE, PCC, and the role of PCEP in the context of MPLS RSVP-TE.

Figure 2: PCC and RSVP-TE



The PCE-to-PCC communication is enabled by the TCP-based PCEP. The PCC initiates the PCEP session and stays connected to a PCE for the duration of the PCEP session.

Once the PCEP session is established, the PCC performs the following tasks:

1. LSP state synchronization—The PCC sends information about all the LSPs (local and external) to all connected PCEs. For external LSPs, the PCC sends information about any configuration change, RRO change, state change, and so on, to the PCE.
2. LSP delegation—The PCC then delegates the external LSPs to one PCE, which is the main active stateful PCE. It is only the main PCE that can set parameters for the external LSP. The parameters that the main PCE modifies include bandwidth, path (ERO), and priority (setup and hold). The parameters specified in the local configuration are overridden by the parameters that are set by the main PCE.

   NOTE: **When the PCEP session with the main PCE is terminated, the PCC elects a new main PCE, and all delegated LSPs to the previously main PCE are delegated to the newly available main PCE.**

3. LSP signaling—On receiving one or more LSP parameters from the main active stateful PCE, the PCC re-signals the TE LSP based on the PCE provided path. If the PCC fails to set up the LSP, it notifies the PCE of the setup failure and waits for the main PCE to provide new parameters for that LSP, and then re-signals it.

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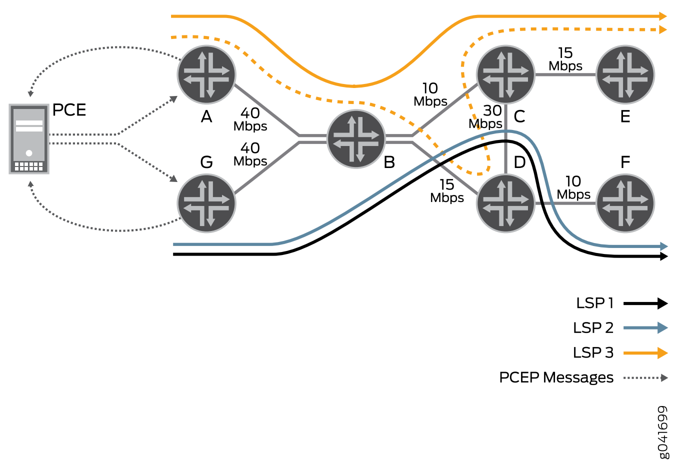
When the PCE specifies a path that is incomplete or has loose hops where only the path endpoints are specified, the PCC does not perform local constraint-based routing to find out the complete set of hops. Instead, the PCC provides RSVP with the PCE provided path, as it is, for signaling, and the path gets set up using IGP hop-by-hop routing.

Considering the topology used in Figure 1 on page 5, Figure 3 on page 9 illustrates the partial client-side PCE implementation in the MPLS RSVP-TE enabled network. The ingress routers A and G are the PCCs that are configured to connect to the external stateful PCE through a TCP connection.

The PCE has a global view of the bandwidth demand in the network and performs external path computations after looking up the traffic engineering database. The active stateful PCE then modifies one or more LSP attributes and sends an update to the PCC. The PCC uses the parameters it receives from the PCE to re-signal the LSP.

Figure 3: Example PCE for MPLS RSVP-TE



In this example, the PCE is aware of the bandwidth requirement of all the externally controlled LSPs of Router A and Router G. Thus, the individual PCCs re-signal the LSPs using the PCE computed paths to meet the following:

- Increase in demand on LSP3 of Router A.
- Establishing LSP1 and LSP2 of Router G.

This way, the stateful PCE provides a cooperative operation of distributed functionality used to address specific challenges of a shortest interdomain constrained path computation. It eliminates congestion scenarios in which traffic streams are inefficiently mapped onto available resources causing over utilization of some subsets of network resources, while other resources remain under utilized.

LSP Behavior with External Computing

LSP Types

In a client-side PCE implementation, there are two types of TE LSPs:

- CLI-controlled LSPs—The LSPs that do not have the **lsp-external-controller** ***pccd*** statement configured are called CLI-controlled LSPs. Although these LSPs are under local control, the PCC updates the connected PCEs with information about the CLI-controlled LSPs during the initial LSP synchronization process. After the initial LSP synchronization, the PCC informs the PCE of any new and deleted LSPs as well.
- PCE-controlled LSPs—The LSPs that have the **lsp-external-controller** ***pccd*** statement configured are called PCE-controlled LSPs. The PCC delegates the PCC-initiated LSPs to the main PCE for external path computation.

  The PCC informs the PCE about the configured parameters of a PCE-controlled LSP, such as bandwidth, ERO, and priorities. It also informs the PCE about the actual values used for these parameters to set up the LSP including the RRO, when available.

  The PCC sends such LSP status reports to the PCE only when a re-configuration has occurred or when there is a change in the ERO, RRO, or status of the PCE-controlled LSPs under external control.

  There are two types of parameters that come from the CLI configuration of an LSP for a PCE:

  - Parameters that are not overridden by a PCE, and that are applied immediately.
  - Parameters that are overridden by a PCE. These parameters include bandwidth, path, and priority (setup and hold values). When the control mode switches from external to local, the CLI-configured values for these parameters are applied at the next opportunity to re-signal the LSP. The values are not applied immediately.

The CLI-controlled LSPs and PCE-controlled LSPs can coexist on a PCC.

LSP Control Mode

In a client-side PCE implementation, there are two types of control modes for a PCC-controlled LSP:

- External—By default, all PCE-controlled LSPs are under external control. When an LSP is under external control, the PCC uses the PCE-provided parameters to set up the LSP.
- Local—A PCE-controlled LSP can come under local control. When the LSP switches from external control to local control, path computation is done using the CLI-configured parameters and constraint-based routing. Such a switchover happens only when there is a trigger to re-signal the LSP. Until then, the PCC uses the PCE-provided parameters to signal the PCE-controlled LSP, although the LSP remains under local control.

A PCE-controlled LSP switches to local control from its default external control mode in cases such as no connectivity to a PCE or when a PCE returns delegation of LSPs back to the PCC.

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For more information about CLI-controlled LSPs and PCE-controlled LSPs, see "LSP Types" on page 10.

Configuration Statements Supported for External Computing

Table 1 on page 11 lists the MPLS and existing LSP configuration statements that apply to a PCE-controlled LSP.

Table 1: Applicability of MPLS and Existing LSP Configurations to a PCE-Controlled LSP

Support for PCE-Controlled LSP	Applicable LSP Configuration Statements	Applicable MPLS Configuration Statements
These configuration statements can be configured along with the PCE configuration. However, they take effect only when the local configuration is in use. During PCE control, these configuration statements remain inactive.	• admin-group • auto-bandwidth • hop-limit • least-fill • most-fill • random	• admin-group • admin-groups • admin-group-extended • hop-limit • no-cspf • smart-optimize-timer
These configuration statements can be configured along with the PCE configuration, but are overridden by the PCE-controlled LSP attributes. However, when the local configuration is in use, the configured values for these configuration statements are applied. NOTE: Changes to the local configuration using the CLI while the LSP is under the control of a stateful PCE does not have any effect on the LSP. These changes come into effect only when the local configuration is applied.	• bandwidth • primary • priority	• priority
These configuration statements cannot be configured along with the PCE configuration.	• p2mp • template	• p2mp-lsp-next-hop

The rest of the LSP configuration statements are applicable in the same way as for existing LSPs. For a PCE-controlled LSP, an MPLS log message is generated to indicate when the parameters of the above configuration statements take effect.

PCE-Controlled LSP Protection

The protection paths, including fast reroute and bypass LSPs, are locally computed by the PCC using constraint-based routing. A stateful PCE specifies the primary path (ERO) only. A PCE can also trigger a non-standby secondary path, even if the local configuration does not have a non-standby secondary path for LSP protection.

Auto-Bandwidth and PCE-Controlled LSP

The auto-bandwidth option does not apply to PCE-controlled LSPs, although LSPs under the control of auto-bandwdith and constraint-based routing can coexist with PCE-controlled LSPs. The statistics collection for auto-bandwidth takes effect only when

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the control mode of a PCE-controlled LSP changes from external to local. This can happen in cases such as no connectivity to a PCE or when a PCE returns delegation of LSPs back to the PCC.

Impact of Client-Side PCE Implementation on Network Performance

The maintenance of a stateful database can be non-trivial. In a single centralized PCE environment, a stateful PCE simply needs to remember all the TE LSPs that the PCE has computed, the TE LSPs that were actually set up (if this can be known), and when the TE LSPs were torn down. However, these requirements cause substantial control protocol overhead in terms of state, network usage and processing, and optimizing links globally across the network. Thus, the concerns of a stateful PCE implementation include:

- Any reliable synchronization mechanism results in significant control plane overhead. PCEs might synchronize state by communicating with each other, but when TE LSPs are set up using distributed computation performed among several PCEs, the problems of synchronization and race condition avoidance become larger and more complex.
- Out-of-band traffic engineering database synchronization can be complex with multiple PCEs set up in a distributed PCE computation model, and can be prone to race conditions, scalability concerns, and so on.
- Path calculations incorporating total network state is highly complex, even if the PCE has detailed information on all paths, priorities, and layers.

In spite of the above concerns, the partial client-side implementation of the stateful PCE is extremely effective in large traffic engineering systems. It provides rapid convergence and significant benefits in terms of optimal resource usage, by providing the requirement for global visibility of a TE LSP state and for ordered control of path reservations across devices within the system being controlled.

Related Documentation

- Use Case for Configuring the Path Computation Element Protocol on page 1
- Example: Configuring the Path Computation Element Protocol for MPLS RSVP-TE on page 12

Example: Configuring the Path Computation Element Protocol for MPLS RSVP-TE

This example shows how to enable external path computing by a Path Computation Element (PCE) for traffic engineered label-switched paths (TE LSPs) on a Path Computation Client (PCC). It also shows how to configure the Path Computation Element Protocol (PCEP) on the PCC to enable PCE-to-PCC communication.

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Requirements

This example uses the following hardware and software components:

- Three routers that can be a combination of M Series Multiservice Edge Routers, MX Series 3D Universal Edge Routers, or T Series Core Routers, one of which is configured as a PCC.
- A TCP connection to an external stateful PCE from the PCC.
- Junos OS Release 12.3 or later running on the PCC along with the JSDN add-on package.

NOTE: The JSDN add-on package is required to be installed along with the core Junos OS installation package.

NOTE: This configuration example has been tested using the software release listed and is assumed to work on all later releases.

Before you begin:

1. Configure the device interfaces.
2. Configure MPLS and RSVP-TE.
3. Configure IS-IS or any other IGP protocol.

Overview

Starting with Junos OS Release 12.3, the MPLS RSVP-TE functionality is extended to provide a partial client-side implementation of the stateful PCE architecture (draft-ietf-pce-stateful-pce) on a PCC.

To enable external path computing by a PCE, include the **lsp-external-controller** statement on the PCC at the **[edit mpls]** and **[edit mpls lsp *lsp-name*]** hierarchy levels.

lsp-external-controller *pccd*;

An LSP configured with the **lsp-external-controller** statement is referred to as a PCE-controlled LSP and is under the external control of a PCE by default. An active stateful PCE can override the parameters set from the CLI, such as bandwidth, path (ERO), and priority, for such PCE-controlled LSPs of the PCC.

To enable PCE-to-PCC communication, configure PCEP on the PCC at the **[edit protocols]** hierarchy level.

pcep { ... }

When configuring PCEP on a PCC, be aware of the following considerations:

- The JSDN add-on package is required to be installed along with the core Junos OS installation package.
- Junos OS Release 12.3 supports only stateful PCEs.
- A PCC can connect to a maximum of 10 stateful PCEs. At any given point in time, there can be only one main PCE (the PCE with the lowest priority value, or the PCE that connects to the PCC first in the absence of a PCE priority) to which the PCC delegates LSPs for path computation.
- For Junos OS Release 12.3, the PCC always initiates the PCEP sessions. PCEP sessions initiated by remote PCEs are not accepted by the PCC.
- Existing LSP features, such as LSP protection and make-before-break, work for PCE-controlled LSPs.
- The auto-bandwidth option is turned off for PCE-controlled LSPs, although LSPs under the control of auto-bandwdith and constraint-based routing can coexist with PCE-controlled LSPs.
- PCE-controlled LSPs can be referred to by other CLI configurations, such as lsp-nexthop to routes, forwarding adjacencies, CCC connections, and logical tunnels.
- PCE-controlled LSPs do not support GRES.
- PCE-controlled LSPs under logical-systems are not supported.
- PCE-controlled LSPs cannot be point-to-multipoint LSPs.
- Bidirectional LSPs are not supported.
- PCE-controlled LSPs cannot have secondary paths without a primary path.
- PCE-controlled LSPs depend on external path computation, which impacts overall setup time, reroutes, and make-before-break features.
- Setup time and convergence time (reroute, MBB) for exisiting LSPs is the same as in previous releases, in the absence of PCE-controlled LSPs. However, a small impact is seen in the presence of PCE-controlled LSPs.
- ERO computation time is expected to be significantly higher than local-CSPF.

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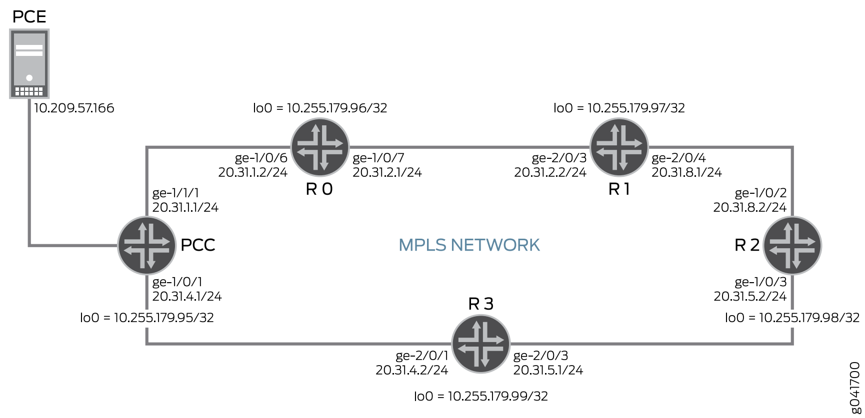
Topology

Figure 4: Configuring PCEP for MPLS RSVP-TE



In this example, PCC is the ingress router that connects to the external active stateful PCE.

The external LSPs of Router PCC are computed as follows:

1. Router PCC receives the LSP tunnel configuration that was set up using the CLI. Assuming that the received configuration is enabled with external path computing, Router PCC becomes aware that some of the LSP attributes – bandwidth, path, and priority – are under the control of the stateful PCE and delegates the LSP to the PCE.

   In this example, the external LSP is called **PCC-to-R2** and it is being set up from Router PCC to Router R2 . The CLI-configured ERO for **PCC-to-R2** is PCC-R0-R1-R2. The bandwidth for **PCC-to-R2** is 10m, and both the setup and hold priority values are 4.

2. Router PCC tries to retrieve the PCE-controlled LSP attributes. To do this, Router PCC sends out a PCRpt message to the stateful PCE stating that the LSP has been configured. The PCRpt message communicates the status of the LSP and contains the local configuration parameters of the LSP.

3. The stateful PCE modifies one or more of the delegated LSP attributes and sends the new LSP parameters to Router PCC through the PCUpd message.

4. On receiving the new LSP parameters, Router PCC sets up a new LSP and re-signals it using the PCE-provided path.

   In this example, the PCE-provided ERO for **PCC-to-R2** is PCC-R3-R2. The bandwidth for **PCC-to-R2** is 8m, and both the setup and hold priority values are 3.

5. Router PCC sends a PCRpt with the new RRO to the stateful PCE.

Configuration

CLI Quick Configuration

To quickly configure this example, copy the following commands, paste them into a text file, remove any line breaks, change any details necessary to match your network configuration, and then copy and paste the commands into the CLI at the **[edit]** hierarchy level.

PCC

```
set interfaces ge-1/0/1 unit 0 family inet address 20.31.4.1/24
set interfaces ge-1/0/1 unit 0 family iso
set interfaces ge-1/0/1 unit 0 family mpls
set interfaces ge-1/1/1 unit 0 family inet address 20.31.1.1/24
set interfaces ge-1/1/1 unit 0 family iso
set interfaces ge-1/1/1 unit 0 family mpls
set interfaces lo0 unit 0 family inet address 10.255.179.95/32
set protocols rsvp interface all
set protocols rsvp interface fxp0.0 disable
set protocols mpls lsp-external-controller pccd
set protocols mpls label-switched-path PCC-to-R2 to 10.255.179.98
set protocols mpls label-switched-path PCC-to-R2 bandwidth 10m
set protocols mpls label-switched-path PCC-to-R2 priority 4 4
set protocols mpls label-switched-path PCC-to-R2 primary to-R2-path
set protocols mpls label-switched-path PCC-to-R2 lsp-external-controller pccd
set protocols mpls path to-R2-path 20.31.1.2 strict
set protocols mpls path to-R2-path 20.31.2.2 strict
set protocols mpls interface all
set protocols mpls interface fxp0.0 disable
set protocols isis level 1 disable
set protocols isis interface all
set protocols isis interface fxp0.0 disable
set protocols isis interface lo0.0
set protocols pcep pce pce1 destination-ipv4-address 10.209.57.166
set protocols pcep pce pce1 destination-port 4189
set protocols pcep pce pce1 pce-type active
set protocols pcep pce pce1 pce-type stateful
```

R0

```
set interfaces ge-1/0/6 unit 0 family inet address 20.31.1.2/24
set interfaces ge-1/0/6 unit 0 family iso
set interfaces ge-1/0/6 unit 0 family mpls
set interfaces ge-1/0/7 unit 0 family inet address 20.31.2.1/24
set interfaces ge-1/0/7 unit 0 family iso
set interfaces ge-1/0/7 unit 0 family mpls
set interfaces lo0 unit 0 family inet address 10.255.179.96/32
set protocols rsvp interface all
set protocols rsvp interface fxp0.0 disable
set protocols mpls interface all
set protocols mpls interface fxp0.0 disable
set protocols isis level 1 disable
set protocols isis interface all
set protocols isis interface fxp0.0 disable
set protocols isis interface lo0.0
```

R1

```
set system ports console log-out-on-disconnect
set interfaces ge-2/0/3 unit 0 family inet address 20.31.2.2/24
set interfaces ge-2/0/3 unit 0 family iso
set interfaces ge-2/0/3 unit 0 family mpls
set interfaces ge-2/0/4 unit 0 family inet address 20.31.8.1/24
set interfaces ge-2/0/4 unit 0 family iso
set interfaces ge-2/0/4 unit 0 family mpls
set interfaces lo0 unit 0 family inet address 10.255.179.97/32
```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```
set protocols rsvp interface all
set protocols rsvp interface fxp0.0 disable
set protocols mpls interface all
set protocols mpls interface fxp0.0 disable
set protocols isis level 1 disable
set protocols isis interface all
set protocols isis interface fxp0.0 disable
set protocols isis interface lo0.0
```

R2

```
set interfaces ge-1/0/2 unit 0 family inet address 20.31.8.2/24
set interfaces ge-1/0/2 unit 0 family iso
set interfaces ge-1/0/2 unit 0 family mpls
set interfaces ge-1/0/3 unit 0 family inet address 20.31.5.2/24
set interfaces ge-1/0/3 unit 0 family iso
set interfaces ge-1/0/3 unit 0 family mpls
set interfaces lo0 unit 0 family inet address 10.255.179.98/32
set protocols rsvp interface all
set protocols rsvp interface fxp0.0 disable
set protocols mpls interface all
set protocols mpls interface fxp0.0 disable
set protocols isis level 1 disable
set protocols isis interface all
set protocols isis interface fxp0.0 disable
set protocols isis interface lo0.0
```

R3

```
set interfaces ge-2/0/1 unit 0 family inet address 20.31.4.2/24
set interfaces ge-2/0/1 unit 0 family iso
set interfaces ge-2/0/1 unit 0 family mpls
set interfaces ge-2/0/3 unit 0 family inet address 20.31.5.1/24
set interfaces ge-2/0/3 unit 0 family iso
set interfaces ge-2/0/3 unit 0 family mpls
set interfaces lo0 unit 0 family inet address 10.255.179.99/32
set protocols rsvp interface all
set protocols rsvp interface fxp0.0 disable
set protocols mpls interface all
set protocols mpls interface fxp0.0 disable
set protocols isis level 1 disable
set protocols isis interface all
set protocols isis interface fxp0.0 disable
set protocols isis interface lo0.0
```

Step-by-Step Procedure

The following example requires you to navigate various levels in the configuration hierarchy. For information about navigating the CLI, see *Using the CLI Editor in Configuration Mode*.

To configure Router PCC:

NOTE: Repeat this procedure for every Juniper Networks ingress router in the MPLS domain, after modifying the appropriate interface names, addresses, and any other parameters for each router.

1. Configure the interfaces.

To enable MPLS, include the protocol family on the interface so that the interface does not discard incoming MPLS traffic.

```
[edit interfaces]
user@PCC# set ge-1/0/1 unit 0 family inet address 20.31.4.1/24
user@PCC# set ge-1/0/1 unit 0 family iso
user@PCC# set ge-1/0/1 unit 0 family mpls

user@PCC# set ge-1/1/1 unit 0 family inet address 20.31.1.1/24
user@PCC# set ge-1/1/1 unit 0 family iso
user@PCC# set ge-1/1/1 unit 0 family mpls

user@PCC# set lo0 unit 0 family inet address 10.255.179.95/32
```

2. Enable RSVP on all interfaces of Router PCC, excluding the management interface.

```
[edit protocols]
user@PCC# set rsvp interface all
user@PCC# set rsvp interface fxp0.0 disable
```

3. Configure the label-switched path (LSP) from Router PCC to Router R2 and enable external control of LSPs by the PCE.

```
[edit protocols]
user@PCC# set mpls lsp-external-controller pccd
user@PCC# set mpls label-switched-path PCC-to-R2 to 10.255.179.98/32
user@PCC# set mpls label-switched-path PCC-to-R2 bandwidth 10m
user@PCC# set protocols mpls label-switched-path PCC-to-R2 priority 4 4
user@PCC# set protocols mpls label-switched-path PCC-to-R2 primary to-R2-path
user@PCC# set protocols mpls label-switched-path PCC-to-R2
  lsp-external-controller pccd
```

4. Configure the LSP from Router PCC to Router R2, which has local control and is overridden by the PCE-provided LSP parameters.

```
[edit protocols]
user@PCC# set mpls path to-R2-path 20.31.1.2/30 strict
user@PCC# set mpls path to-R2-path 20.31.2.2/30 strict
```

5. Enable MPLS on all interfaces of Router PCC, excluding the management interface.

```
[edit protocols]
user@PCC# set mpls interface all
user@PCC# set mpls interface fxp0.0 disable
```

6. Configure IS-IS on all interfaces of Router PCC, excluding the management interface.

```
[edit protocols]
user@PCC# set isis level 1 disable
user@PCC# set isis interface all
user@PCC# set isis interface fxp0.0 disable
user@PCC# set isis interface lo0.0
```

7. Define the PCE that Router PCC connects to, and configure the IP address of the PCE.

```
[edit protocols]
user@PCC# set pcep pce pce1 destination-ipv4-address 10.209.57.166
```


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8. Configure the destination port for Router PCC that connects to a PCE using the TCP-based PCEP.

```
[edit protocols]
user@PCC# set pcep pce pce1 destination-port 4189
```

9. Configure the PCE type.

```
[edit protocols]
user@PCC# set pcep pce pce1 pce-type active
user@PCC# set pcep pce pce1 pce-type stateful
```

Results

From configuration mode, confirm your configuration by entering the **show interfaces** and **show protocols** commands. If the output does not display the intended configuration, repeat the instructions in this example to correct the configuration.

```
user@PCC# show interfaces
ge-1/0/1 {
  unit 0 {
    family inet {
      address 20.31.4.1/24;
    }
    family iso;
    family mpls;
  }
}
ge-1/1/1 {
  unit 0 {
    family inet {
      address 20.31.1.1/24;
    }
    family iso;
    family mpls;
  }
}
lo0 {
  unit 0 {
    family inet {
      address 10.255.179.95/32;
    }
  }
}
```

```
user@PCC# show protocols
rsvp {
  interface all;
  interface fxp0.0 {
    disable;
  }
}
mpls {
  lsp-external-controller pccd;
  label-switched-path PCC-to-R2 {
    to 10.255.179.98;
```

```
        bandwidth 10m;
        priority 4 4;
        primary to-R2-path;
        lsp-external-controller pccd;
    }
    path to-R2-path {
        20.31.1.2 strict;
        20.31.2.2 strict;
    }
    interface all;
    interface fxp0.0 {
        disable;
    }
}
isis {
    level 1 disable;
    interface all;
    interface fxp0.0 {
        disable;
    }
    interface lo0.0;
}
pcep {
    pce pce1 {
        destination-ipv4-address 10.209.57.166;
        destination-port 4189;
        pce-type active stateful;
    }
}
```

If you are done configuring the device, enter **commit** from configuration mode.

Verification

Confirm that the configuration is working properly.

- Verifying the PCEP Session Status on page 20
- Verifying the PCE-Controlled LSP Status When LSP Control Is External on page 21
- Verifying the PCE-Controlled LSP Status When LSP Control Is Local on page 23

Verifying the PCEP Session Status

Purpose Verify the PCEP session status between the PCE and Router PCC when the PCE status is up.

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Action From operational mode, run the **show path-computation-client active-pce** command.

```
user@PCC> show path-computation-client active-pce
PCE pce1
General
    IP address                : 10.209.57.166
    Priority                  : 0
    PCE status                : PCE_STATE_UP
    Session type              : PCE_TYPE_STATEFULACTIVE
    PCE-mastership            : main

Counters
    PCReqs              Total: 0          last 5min: 0           last hour: 0

    PCReps              Total: 0          last 5min: 0           last hour: 0

    PCRpts              Total: 5          last 5min: 5           last hour: 5

    PCUpdates           Total: 1          last 5min: 1           last hour: 1


Timers
    Local             Keepalive timer:        30 [s]   Dead timer:       120 [s]

    Remote            Keepalive timer:        30 [s]   Dead timer:       120 [s]

Errors
    PCErr-recv
    PCErr-sent
    PCE-PCC-NTFS
    PCC-PCE-NTFS
```

Meaning The output displays information about the current active stateful PCE that Router PCC is connected to. The **PCE status** output field indicates the current status of the PCEP session between the PCE and Router PCC.

For **pce1**, the status of the PCEP session is **PCE_STATE_UP**, which indicates that the PCEP session has been established between the PCEP peers.

The statistics of **PCRpts** indicate the number of messages sent by Router PCC to the PCE to report the current status of LSPs. The **PCUpdates** statistics indicate the number of messages received by Router PCC from the PCE. The **PCUpdates** messages include the PCE modified parameters for the PCE-controlled LSPs.

Verifying the PCE-Controlled LSP Status When LSP Control Is External

Purpose Verify the status of the PCE-controlled LSP from Router PCC to Router R2 when the LSP is under external control.

Action From operational mode, run the **show mpls lsp name PCC-to-R2 extensive** command.

```
user@PCC> show mpls lsp name PCC-to-R2 extensive
Ingress LSP: 1 sessions

10.255.179.98
  From: 10.255.183.59, State: Up, ActiveRoute: 0, LSPname: PCC-to-R2
```

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```
  ActivePath: to-R2-path (primary)
  LSPtype: Externally controlled, Penultimate hop popping
  LSP Control Status: Externally controlled
    LoadBalance: Random
  Encoding type: Packet, Switching type: Packet, GPID: IPv4
 *Primary   to-R2-path     State: Up
    Priorities: 3 3
    Bandwidth: 8Mbps
    SmartOptimizeTimer: 180
        No computed ERO.
    Received RRO (ProtectionFlag 1=Available 2=InUse 4=B/W 8=Node 10=SoftPreempt
 20=Node-ID):
          20.31.4.2 20.31.5.2
   21 Mar 11 05:00:56.736 EXTCTRL LSP: Sent Path computation request and LSP
status
   20 Mar 11 05:00:56.736 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   19 Mar 11 05:00:56.735 Selected as active path
   18 Mar 11 05:00:56.734 EXTCTRL LSP: Sent Path computation request and LSP
status
   17 Mar 11 05:00:56.734 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   16 Mar 11 05:00:56.734 Record Route:  20.31.4.2 20.31.5.2
   15 Mar 11 05:00:56.734 Up
   14 Mar 11 05:00:56.713 EXTCTRL LSP: Sent Path computation request and LSP
status
   13 Mar 11 05:00:56.713 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   12 Mar 11 05:00:56.712 Originate Call
   11 Mar 11 05:00:56.712 EXTCTRL_LSP: Received setup parameters :  20.31.4.2
20.31.5.2
   10 Mar 11 05:00:49.283 EXTCTRL LSP: Sent Path computation request and LSP
status
    9 Mar 11 05:00:49.283 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    8 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    7 Mar 11 05:00:20.581 EXTCTRL LSP: Sent Path computation request and LSP
status
    6 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    5 Mar 11 05:00:20.580 EXTCTRL_LSP: Control status became external
    4 Mar 11 05:00:03.716 EXTCTRL_LSP: Control status became local
    3 Mar 11 05:00:03.714 EXTCTRL LSP: Sent Path computation request and LSP
status
    2 Mar 11 05:00:03.714 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    1 Mar 11 05:00:00.279 EXTCTRL LSP: Awaiting external controller connection
  Created: Mon Mar 11 05:00:00 2013
Total 1 displayed, Up 1, Down 0

Egress LSP: 0 sessions
Total 0 displayed, Up 0, Down 0

Transit LSP: 0 sessions
Total 0 displayed, Up 0, Down 0
```

Meaning In the output, the **LSPtype** and **LSP Control Status** output fields show that the LSP is externally controlled. The output also shows a log of the PCEP messages sent between Router PCC and the PCE.

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The PCEP session between the PCE and Router PCC is up, and Router PCC receives the following PCE-controlled LSP parameters:

- ERO (path)—20.31.4.2 and 20.31.5.2
- Bandwidth—8Mbps
- Priorities—3 3 (setup and hold values)

Verifying the PCE-Controlled LSP Status When LSP Control Is Local

Purpose Verify the status of the PCE-controlled LSP from Router PCC to Router R2 when the LSP control becomes local.

Action From operational mode, run the **show mpls lsp name PCC-to-R2 extensive** command.

```
user@PCC> show mpls lsp name PCC-to-R2 extensive
Ingress LSP: 1 sessions

10.255.179.98
  From: 10.255.183.59, State: Up, ActiveRoute: 0, LSPname: PCC-to-R2
  ActivePath: to-R2-path (primary)
  LSPtype: Externally controlled, Penultimate hop popping
  LSP Control Status: Locally controlled
  LoadBalance: Random
  Encoding type: Packet, Switching type: Packet, GPID: IPv4
 *Primary   to-R2-path     State: Up
    Priorities: 4 4 (ActualPriorities 3 3)
    Bandwidth: 10Mbps (ActualBandwidth: 8Mbps)
        SmartOptimizeTimer: 180
        No computed ERO.
    Received RRO (ProtectionFlag 1=Available 2=InUse 4=B/W 8=Node 10=SoftPreempt
 20=Node-ID):
          20.31.4.2 20.31.5.2
   22 Mar 11 05:02:09.618 EXTCTRL_LSP: Control status became local
   21 Mar 11 05:00:56.736 EXTCTRL LSP: Sent Path computation request and LSP
status
   20 Mar 11 05:00:56.736 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   19 Mar 11 05:00:56.735 Selected as active path
   18 Mar 11 05:00:56.734 EXTCTRL LSP: Sent Path computation request and LSP
status
   17 Mar 11 05:00:56.734 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   16 Mar 11 05:00:56.734 Record Route:  20.31.4.2 20.31.5.2
   15 Mar 11 05:00:56.734 Up
   14 Mar 11 05:00:56.713 EXTCTRL LSP: Sent Path computation request and LSP
status
   13 Mar 11 05:00:56.713 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   12 Mar 11 05:00:56.712 Originate Call
   11 Mar 11 05:00:56.712 EXTCTRL_LSP: Received setup parameters :  20.31.4.2
20.31.5.2
   10 Mar 11 05:00:49.283 EXTCTRL LSP: Sent Path computation request and LSP
status
    9 Mar 11 05:00:49.283 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    8 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
```

```
    7 Mar 11 05:00:20.581 EXTCTRL LSP: Sent Path computation request and LSP
status
    6 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    5 Mar 11 05:00:20.580 EXTCTRL_LSP: Control status became external
    4 Mar 11 05:00:03.716 EXTCTRL_LSP: Control status became local
    3 Mar 11 05:00:03.714 EXTCTRL LSP: Sent Path computation request and LSP
status
    2 Mar 11 05:00:03.714 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    1 Mar 11 05:00:00.279 EXTCTRL LSP: Awaiting external controller connection
  Created: Mon Mar 11 05:00:00 2013
Total 1 displayed, Up 1, Down 0

Egress LSP: 0 sessions
Total 0 displayed, Up 0, Down 0

Transit LSP: 0 sessions
Total 0 displayed, Up 0, Down 0
```

Meaning In the output, the **LSP Control Status** output field shows that the LSP is under local control. Although the PCE-controlled LSP is under local control, Router PCC continues to use the PCE-provided parameters, until the next opportunity to re-signal the LSP.

The output now displays the LSP parameters that were configured using the CLI along with the PCE-provided parameters used to establish the LSP as the actual values in use.

- Bandwidth—10Mbps (ActualBandwidth: 8Mbps)
- Priorities—4 4 (ActualPriorities 3 3)

On the trigger to re-signal the LSP, Router PCC uses the local configuration parameters to establish the PCE-controlled LSP.

user@PCC> **show mpls lsp name PCC-to-R2 extensive externally-controlled**

```
Ingress LSP: 1 sessions

10.255.179.98
  From: 10.255.183.59, State: Up, ActiveRoute: 0, LSPname: PCC-to-R2
  ActivePath: to-R2-path (primary)
  LSPtype: Externally controlled, Penultimate hop popping
  LSP Control Status: Locally controlled
  LoadBalance: Random
  Encoding type: Packet, Switching type: Packet, GPID: IPv4
 *Primary   to-R2-path     State: Up
  Priorities: 4 4
  Bandwidth: 10Mbps
    SmartOptimizeTimer: 180
    Computed ERO (S [L] denotes strict [loose] hops): (CSPF metric: 30)
 20.31.1.2 S 20.31.2.2 S 20.31.8.2 S
    Received RRO (ProtectionFlag 1=Available 2=InUse 4=B/W 8=Node 10=SoftPreempt
 20=Node-ID):
          20.31.1.2 20.31.2.2 20.31.8.2
   28 Mar 11 05:02:51.787 Record Route:  20.31.1.2 20.31.2.2 20.31.8.2
   27 Mar 11 05:02:51.787 Up
   26 Mar 11 05:02:51.697 EXTCTRL_LSP: Applying local parameters with this
signalling attempt
   25 Mar 11 05:02:51.697 Originate Call
   24 Mar 11 05:02:51.696 Clear Call
   23 Mar 11 05:02:51.696 CSPF: computation result accepted  20.31.1.2 20.31.2.2
```

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```
 20.31.8.2
   22 Mar 11 05:02:09.618 EXTCTRL_LSP: Control status became local
   21 Mar 11 05:00:56.736 EXTCTRL LSP: Sent Path computation request and LSP
status
   20 Mar 11 05:00:56.736 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   19 Mar 11 05:00:56.735 Selected as active path
   18 Mar 11 05:00:56.734 EXTCTRL LSP: Sent Path computation request and LSP
status
   17 Mar 11 05:00:56.734 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   16 Mar 11 05:00:56.734 Record Route:  20.31.4.2 20.31.5.2
   15 Mar 11 05:00:56.734 Up
   14 Mar 11 05:00:56.713 EXTCTRL LSP: Sent Path computation request and LSP
status
   13 Mar 11 05:00:56.713 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
   12 Mar 11 05:00:56.712 Originate Call
   11 Mar 11 05:00:56.712 EXTCTRL_LSP: Received setup parameters :  20.31.4.2
20.31.5.2
   10 Mar 11 05:00:49.283 EXTCTRL LSP: Sent Path computation request and LSP
status
    9 Mar 11 05:00:49.283 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    8 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    7 Mar 11 05:00:20.581 EXTCTRL LSP: Sent Path computation request and LSP
status
    6 Mar 11 05:00:20.581 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    5 Mar 11 05:00:20.580 EXTCTRL_LSP: Control status became external
    4 Mar 11 05:00:03.716 EXTCTRL_LSP: Control status became local
    3 Mar 11 05:00:03.714 EXTCTRL LSP: Sent Path computation request and LSP
status
    2 Mar 11 05:00:03.714 EXTCTRL_LSP: Computation request/lsp status contains:
 bandwidth 10000000 priority - setup 4 hold 4 hops:  20.31.1.2 20.31.2.2
    1 Mar 11 05:00:00.279 EXTCTRL LSP: Awaiting external controller connection
  Created: Mon Mar 11 05:00:00 2013
Total 1 displayed, Up 1, Down 0

Egress LSP: 0 sessions
Total 0 displayed, Up 0, Down 0

Transit LSP: 0 sessions
Total 0 displayed, Up 0, Down 0
```

The **Computed ERO** is 20.31.1.2, 20.31.2.2, and 20.31.8.2. The PCE-controlled LSP is established using the local configuration parameters.

Related Documentation

- Use Case for Configuring the Path Computation Element Protocol on page 1
- Support of the Path Computation Element Protocol for RSVP-TE Overview on page 2

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