Implementing RSVP for MPLS-TE

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Implementing RSVP for MPLS-TE

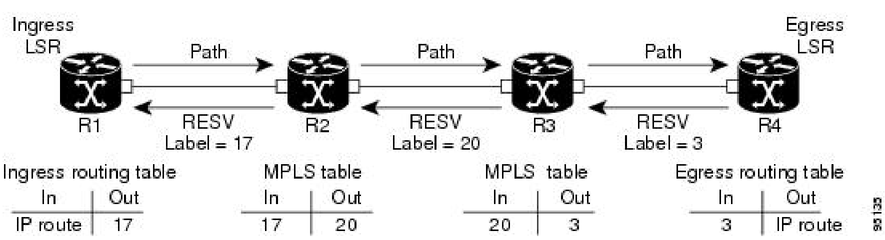
Resource Reservation Protocol (RSVP) is a signaling protocol that enables systems to request resource reservations from the network. RSVP processes protocol messages from other systems, processes resource requests from local clients, and generates protocol messages. As a result, resources are reserved for data flows on behalf of local and remote clients. RSVP creates, maintains, and deletes these resource reservations.

MPLS Traffic Engineering (MPLS-TE) learns the topology and resources available in a network and then maps traffic flows to particular paths based on resource requirements and network resources such as bandwidth. MPLS TE builds a unidirectional tunnel from a source to a destination in the form of a label switched path (LSP), which is then used to forward traffic. MPLS-TE uses RSVP to signal LSPs.

Setting up MPLS LSP Using RSVP

The following figure shows how RSVP sets up a LSP from router R1 through router R4 that can be used for TE in an MPLS environment.

Figure 1: MPLS LSP Using RSVP



The LSP setup is initiated when the LSP head node sends path messages to the tail node. The Path messages reserve resources along the path to each node, and creates path states associated with the session on each node. When the tail node receives a path message, it sends a reservation (RESV) message with a label back to the previous node. The reservation state in each router is considered as a soft state, which means that periodic PATH and RESV messages must be sent at each hop to maintain the state.

When the reservation message arrives at the previous node, it causes the reserved resources to be locked and forwarding entries are programmed with the MPLS label sent from the tail-end node. A new MPLS label is allocated and sent to the next node upstream. When the reservation message reaches the head node, the label is programmed and the MPLS data starts to flow along the path.

Overview of RSVP for MPLS-TE Features

This section provides an overview of the various features of RSVP for MPLS-TE.

RSVP is automatically enabled on interfaces on which MPLS-TE is configured. For MPLS-TE LSPs with bandwidth, the RSVP bandwidth has to be configured on the interfaces. There is no need to configure RSVP, if all MPLS-TE LSPs have zero bandwidth.

RSVP Graceful restart ensures high availability and allows RSVP TE enabled routers to recover RSVP state information from neighbors after a failure in the network.

RSVP requires that the path and reservation state that are set up during LSP signaling must be refreshed by periodically sending refresh messages. Refresh messages are used to synchronize the state between RSVP neighbors and to recover from lost RSVP messages. RSVP refresh reduction feature includes support for reliable messages which are transmitted rapidly when the messages are lost. Summary refresh messages contain information to refresh multiple states and reduces the number of messages required to refresh states.

RSVP messages can be authenticated to ensure that only trusted neighbors can set up reservations.

For detailed information about RSVP for MPLS-TE features, see *RSVP for MPLS-TE Features- Details*.

Configuring RSVP for MPLS-TE

RSVP requires coordination among several routers, establishing exchange of RSVP messages to set up LSPs. To configure RSVP, you need to install the following two RPMs :

- ncs5500-mpls-2.0.0.0-r601.x86_64.rpm-6.0.1
- ncs5500-mpls-te-rsvp-2.0.0.0-r601.x86_64.rpm-6.0.1

Depending on the requirements, RSVP requires some basic configuration described in the following topics:

Configuring RSVP Message Authentication Globally

The RSVP authentication feature permits neighbors in an RSVP network to use a secure hash algorithm to authenticate all RSVP signaling messages digitally. The authentication is accomplished on a per-RSVP-hop basis using an RSVP integrity object in the RSVP message. The integrity object includes a key ID, a sequence number for messages, and keyed message digest.

You can globally configure the values of authentication parameters including the key-chain, time interval that RSVP maintains security associations with other trusted RSVP neighbors (life time) and maximum number of RSVP authenticated messages that can be received out of sequence (window size). These defaults are inherited for each neighbor or interface.

Configuration Example

In this example, authentication parameters are configured globally on a router. The authentication parameters including authentication key-chain, lifetime, and window size are configured. A valid key-chain should be configured before performing this task.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# key chain mpls-keys
```

```
RP/0/RP0/CPU0:router(config-mpls-keys)# exit
RP/0/RP0/CPU0:router(config)# rsvp authentication
RP/0/RP0/CPU0:router(config-rsvp-auth)# key-source key-chain mpls-keys
RP/0/RP0/CPU0:router(config-rsvp-auth)# life-time 2000
RP/0/RP0/CPU0:router(config-rsvp-auth)# window-size 33
```

Verification

Verify the configuration of authentication parameters using the following command.

```
RP/0/RP0/CPU0:router# show rsvp authentication detail

  RSVP Authentication Information:
    Source Address:         3.0.0.1
    Destination Address:    3.0.0.2
    Neighbour Address:      3.0.0.2
    Interface:              HundredGigabitEthernet 0/0/0/3
    Direction:              Send
    LifeTime:               2000 (sec)
    LifeTime left:          1305 (sec)
    KeyType:                Static Global KeyChain
    Key Source:             mpls-keys
    Key Status:             No error
    KeyID:                  1
    Digest:                 HMAC MD5 (16)
    window-size:            33
Challenge:              Not supported
    TX Sequence:            5023969459702858020 (0x45b8b99b00000124)
    Messages successfully authenticated:    245
    Messages failed authentication:         0
```

Related Topics

- Configuring RSVP Authentication for an Interface, on page 3
- Configuring RSVP Authentication on a Neighbor, on page 4
- #unique_45

Configuring RSVP Authentication for an Interface

You can individually configure the values of RSVP authentication parameters including key-chain, life time, and window size on an interface. Interface specific authentication parameters are used to secure specific interfaces between two RSVP neighbors.

Configuration Example

This example configures authentication key-chain, life time for the security association, and window size on an interface. A valid key-chain should be already configured to use it as part of this task.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# rsvp interface HundredGigabitEthernet0/0/0/3
RP/0/RP0/CPU0:router(config-rsvp-if)# authentication
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# key-source key-chain mpls-keys
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# life-time 2000
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# window-size 33
RP/0/RP0/CPU0:router(config)# commit
```

Verification

Verify the configuration of authentication parameters using the following command.

```
RP/0/RP0/CPU0:router# show rsvp authentication detail

  RSVP Authentication Information:
    Source Address:          3.0.0.1
    Destination Address:     3.0.0.2
    Neighbour Address:       3.0.0.2
    Interface:               HundredGigabitEthernet 0/0/0/3
    Direction:               Send
    LifeTime:                2000 (sec)
    LifeTime left:           1305 (sec)
    KeyType:                 Static Global KeyChain
    Key Source:              mpls-keys
    Key Status:              No error
    KeyID:                   1
    Digest:                  HMAC MD5 (16)
    window-size:             33
    Challenge:               Not supported
    TX Sequence:             5023969459702858020 (0x45b8b99b00000124)
    Messages successfully authenticated:    245
    Messages failed authentication:         0
```

Related Topics

- Configuring RSVP Message Authentication Globally, on page 2
- Configuring RSVP Authentication on a Neighbor, on page 4
- #unique_45

Configuring RSVP Authentication on a Neighbor

You can individually configure the values of RSVP authentication parameters including key-chain, life time, and window size on a neighbor.

Configuration Example

This example configures the authentication key-chain, life time for the security association, and window size on a RSVP neighbor. A valid key-chain should be already configured to use it as part of this task.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# rsvp neighbor 10.0.0.1 authentication
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# key-source key-chain mpls-keys
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# life-time 2000
RP/0/RP0/CPU0:router(config-rsvp-if-auth)# window-size 33
RP/0/RP0/CPU0:router(config)# commit
```

Verification

Verify the configuration of authentication parameters using the following command.

```
RP/0/RP0/CPU0:router# show rsvp authentication detail

  RSVP Authentication Information:
    Neighbour Address:       10.0.0.1
    Interface:               HundredGigabitEthernet 0/0/0/3
    Direction:               Send
    LifeTime:                2000 (sec)
    LifeTime left:           1205 (sec)
    KeyType:                 Static Global KeyChain
    Key Source:              mpls-keys
    Key Status:              No error
    KeyID:                   1
    Digest:                  HMAC MD5 (16)
```

```
window-size:            33
Challenge:              Not supported
```

Related Topics

- Configuring RSVP Message Authentication Globally, on page 2
- Configuring RSVP Authentication for an Interface, on page 3
- #unique_45

Configuring Graceful Restart

RSVP graceful restart provides a mechanism to ensure high availability (HA), which allows detection and recovery from failure conditions for systems running cisco IOS XR software and ensures non-stop forwarding services. RSVP graceful restart is based on RSVP hello messages and allows RSVP TE enabled routers to recover RSVP state information from neighbors after a failure in the network. RSVP uses a Restart Cap object (RSVP RESTART) in hello messages in which restart and recovery times are specified to advertise the restart capability of a node. The neighboring node helps a restarting node by sending a Recover Label object to recover the forwarding state of the restarting node.

You can configure standard graceful restart which is based on node-id address based hello messages and also interface-based graceful restart which is interface-address based hello messages.

Configuration Example

In this example, RSVP-TE is already enabled on the router nodes on a network and graceful restart needs to be enabled on the router nodes for failure recovery. Graceful restart is configured globally to enabled node-id address based hello messages and also on a router interface to support interface-address based hello messages.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# rsvp
RP/0/RP0/CPU0:router(config-rsvp)# signalling graceful-restart
RP/0/RP0/CPU0:router(config-rsvp)# interface HundredGigabitEthernet 0/0/0/3
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling graceful-restart
interface-based
RP/0/RP0/CPU0:router(config)# commit
```

Verification

Use the following commands to verify that graceful restart is enabled.

```
RP/0/RP0/CPU0:router# show rsvp graceful-restart
 Graceful restart: enabled Number of global neighbors: 1
 Local MPLS router id: 192.168.55.55
 Restart time: 60 seconds  Recovery time: 120 seconds
 Recovery timer: Not running
 Hello interval: 5000 milliseconds Maximum Hello miss-count: 4
```

```
RP/0/RP0/CPU0:router# show rsvp graceful-restart neighbors detail

 Neighbor: 192.168.77.77 Source: 192.168.55.55 (MPLS)
   Hello instance for application MPLS
     Hello State: UP        (for 00:20:52)
     Number of times communications with neighbor lost: 0
     Reason: N/A
Recovery State: DONE
```

```
Number of Interface neighbors: 1
  address: 192.168.55.0
Restart time: 120 seconds  Recovery time: 120 seconds
Restart timer: Not running
Recovery timer: Not running
Hello interval: 5000 milliseconds  Maximum allowed missed Hello messages: 4
```

Related Topics

- #unique_45

Configuring Refresh Reduction

RSVP Refresh Reduction improves the reliability of Resource Reservation Protocol (RSVP) signaling to enhance network performance and message delivery and it is enabled by default. Refresh reduction is used with a neighbor only if the neighbor supports it. You can also disable refresh reduction on an interface if you want.

Configuration Example

The example shows how to configure the various parameters available for the refresh reduction feature.

The following parameters are configured to change their default values:

- refresh interval
- number of refresh messages a node can miss
- retransmit time
- acknowledgment hold time
- acknowledgment message size
- refresh message summary size

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# rsvp
RP/0/RP0/CPU0:router(config-rsvp)# interface HundredGigabitEthernet 0/0/0/3
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh interval 40
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh missed 6
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh reduction reliable retransmit-time
 2000
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh reduction reliable ack-hold-time
1000
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh reduction reliable ack-max-size
1000
RP/0/RP0/CPU0:router(config-rsvp-if)# signalling refresh reduction summary  max-size 1500
RP/0/RP0/CPU0:router(config)# commit
```

Configuring ACL Based Prefix Filtering

You can configure extended access lists (ACLs) to forward, drop, or perform normal processing on RSVP router-alert (RA) packets. For each incoming RSVP RA packet, RSVP inspects the IP header and attempts to match the source or destination IP addresses with a prefix configured in an extended ACL. If there is no explicit permit or explicit deny, the ACL infrastructure returns an implicit deny by default. By default, RSVP processes the packet if the ACL match yields an implicit (default) deny.

Configuration Example

This example configures ACL based prefix filtering on RSVP RA packets. When RSVP receives a RA packet from source address 10.0.0.1 it is forwarded and packets destined to the IP address 172.16.0.1 are dropped.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# ipv4 access-list rsvpacl
RP/0/RP0/CPU0:router(config-ipv4-acl)# 10 permit ipv4 host 10.0.0.1 any
RP/0/RP0/CPU0:router(config-ipv4-acl)# 20 deny ipv4 any host 172.16.0.1
RP/0/RP0/CPU0:router(config)# rsvp
RP/0/RP0/CPU0:router(config-rsvp)# signalling prefix-filtering access-list rsvp-acl
RP/0/RP0/CPU0:router(config)# commit
```

Verification

Verify the configuration of ACL based prefix filtering

```
RP/0/RP0/CPU0:router# show rsvp counters prefix-filtering access-list rsvp-acl

  ACL:rsvp-acl              Forward          Local          Drop            Total
  Path                        0                0              0               0
  PathTear                    0                0              0               0
  ResvConfirm                 0                0              0               0
  Total                       0                0              0
```

Related Topics

- Configuring RSVP Packet Dropping, on page 7

Configuring RSVP Packet Dropping

You can configure extended access lists (ACLs) to forward, drop, or perform normal processing on RSVP router-alert (RA) packets. By default, RSVP processes the RA packets even if the ACL match yields an implicit deny. You can configure RSVP to drop RA packets when the ACL matches results in an implicit deny.

Configuration Example

This example configures ACL based prefix filtering on RSVP RA packets. When RSVP receives a RA packet from source address 10.0.0.1 it is forwarded and packets destined to the IP address 172.16.0.1 are dropped. RA packets are dropped if the ACL matches results in an implicit deny.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# ipv4 access-list rsvpacl
RP/0/RP0/CPU0:router(config-ipv4-acl)# 10 permit ipv4 host 10.0.0.1 any
RP/0/RP0/CPU0:router(config-ipv4-acl)# 20 deny ipv4 any host 172.16.0.1
RP/0/RP0/CPU0:router(config)# rsvp
RP/0/RP0/CPU0:router(config-rsvp)# signalling prefix-filtering default-deny-action drop
RP/0/RP0/CPU0:router(config)# commit
```

Verification

Verify the configuration of RSVP packet drop using the following command.

```
RP/0/RP0/CPU0:router# show rsvp counters prefix-filtering access-list rsvpacl

  ACL: rsvpacl              Forward          Local          Drop            Total
  Path                        4                1              0               5
  PathTear                    0                0              0               0
```

```
ResvConfirm              0              0              0              0
Total                    4              1              0              5
```

Related Documents

- Configuring ACL Based Prefix Filtering, on page 6

Enabling RSVP Traps

By implementing the RSVP MIB, you can use SNMP to access objects belonging to RSVP. You can also specify two traps (NewFlow and LostFlow) which are triggered when a new flow is created or deleted. RSVP MIBs are automatically enabled when you turn on RSVP, but you need to enable RSVP traps.

Configuration Example

This example shows how to enable RSVP MIB traps when a flow is deleted or created and also how to enable both the traps.

```
RP/0/RP0/CPU0:router# configure
RP/0/RP0/CPU0:router(config)# snmp-server traps rsvp lost-flow
RP/0/RP0/CPU0:router(config)# snmp-server traps rsvp new-flow
RP/0/RP0/CPU0:router(config)# snmp-server traps rsvp all
RP/0/RP0/CPU0:router(config)# commit
```

RSVP for MPLS-TE Features- Details

RSVP Graceful Restart Operation

RSVP graceful restart is based on RSVP hello messages. Hello messages are exchanged between the router and its neighbor nodes. Each neighbor node can autonomously issue a hello message containing a hello request object. A receiver that supports the hello extension replies with a hello message containing a hello acknowledgment (ACK) object. If the sending node supports state recovery, a Restart Cap object that indicates a node's restart capability is also carried in the hello messages. In the Restart Cap object, the restart time and the recovery time is specified. The restart time is the time after a loss in Hello messages within which RSVP hello session can be re-established. The recovery time is the time that the sender waits for the recipient to re-synchronize states after the re-establishment of hello messages.

For graceful restart, the hello messages are sent with an IP Time to Live (TTL) of 64. This is because the destination of the hello messages can be multiple hops away. If graceful restart is enabled, hello messages (containing the restart cap object) are send to an RSVP neighbor when RSVP states are shared with that neighbor. If restart cap objects are sent to an RSVP neighbor and the neighbor replies with hello messages containing the restart cap object, the neighbor is considered to be graceful restart capable. If the neighbor does not reply with hello messages or replies with hello messages that do not contain the restart cap object, RSVP backs off sending hellos to that neighbor. If a hello Request message is received from an unknown neighbor, no hello ACK is sent back.

RSVP Authentication

Network administrators need the ability to establish a security domain to control the set of systems that initiates RSVP requests. The RSVP authentication feature permits neighbors in an RSVP network to use a secure hash to sign all RSVP signaling messages digitally, thus allowing the receiver of an RSVP message to verify the sender of the message without relying solely on the sender's IP address.

The signature is accomplished on a per-RSVP-hop basis with an RSVP integrity object in the RSVP message as defined in RFC 2747. The integrity object includes a key ID, a sequence number for messages, and keyed message digest. This method provides protection against forgery or message modification. However, the receiver must know the security key used by the sender to validate the digital signature in the received RSVP message. Network administrators manually configure a common key for each RSVP neighbor on the shared network. The sending and receiving systems maintain a security association for each authentication key that they share. For detailed information about different security association parameters, see the **Security Association Parameters** table.

You can configure global defaults for all authentication parameters including key, window size, and lifetime. These defaults are inherited when you configure authentication for each neighbor or interface. However, you can also configure these parameters individually on a neighbor or interface basis, in which case the global values (configured or default) are no longer inherited.

Interface and neighbor interface modes unless explicitly configured, inherit the parameters from global configuration mode as follows:

- Window-size is set to 1.
- Lifetime is set to 1800.
- key-source key-chain command is set to none or disabled.

The following situations explain how to choose between global, interface, or neighbor configuration modes:

- Global configuration mode is optimal when a router belongs to a single security domain (for example, part of a set of provider core routers). A single common key set is expected to be used to authenticate all RSVP messages.
- Interface, or neighbor configuration mode, is optimal when a router belongs to more than one security domain. For example, a provider router is adjacent to the provider edge (PE), or a PE is adjacent to an edge device. Different keys can be used but not shared.

A security association (SA) is a collection of information that is required to maintain secure communications with a peer. The following table lists the main parameters that defines a security association

Table 1: Security Association Parameters

Security Association Parameters	Description
src	IP address of the sender.
dst	IP address of the final destination.
interface	Interface of the security association.
direction	Send or receive type of the security association.
Lifetime	Expiration timer value that is used to collect unused security association data.
Sequence Number	Last sequence number that was either sent or accepted (dependent of the direction type).
key-source	Source of keys for the configurable parameter.

Security Association Parameters	Description
keyID	Key number (returned form the key-source) that was last used.
Window Size	Specifies the maximum number of authenticated messages that can be received out of order.
Window	Specifies the last *window size* value sequence number that is received or accepted.

Configuring Midpoint LSP limit (LSP out-of-resource [OOR])

You can limit the RSVP-TE states on an LSR. To achieve this, specify an upper limit on the number of midpoint LSPs, and a limit on the unprotected LSPs on the LSR.

The actions that are triggered when the resource exhaustion happens allows you to fine tune the network to avoid the router in question.

You can specify Yellow and Red thresholds for midpoint LSP limits (overall and unprotected). Each limit has a value for the Yellow threshold and the Red threshold.

When the thresholds are crossed, the actions configured under the LSP-OOR sub-mode take effect. These actions are applied on *all* the interfaces of the LSR. The same timed transition to Green state will also occur when the LSP numbers drop.

The limits do not apply to ingress and egress LSPs as they are driven by explicit configuration. In other words, the configuration determines how many egress or ingress LSPs a given node has. For midpoints, it is different as the number is a function of the topology, the links metrics and links bandwidth.

State Transition Triggers - The LSP-OOR state transition is triggered by checking both the total transit LSP count and the unprotected count. If either count crosses the threshold, then the state transition is triggered. If both counts cross the limit, then the more critical state is chosen.

Low vs High Priority LSPs - when the LSP OOR is in yellow or red state, new high priority LSPs will not pre-empt low priority LSP. Pre-emption can still occur but only for bandwidth reasons. In other words, if the router is in Red state where one of the actions is to reject any new LSP, then new high-priority LSPs will be rejected even if there is already an established low-priority LSP: the low-priority LSP will not be removed to make room for the high-priority one.

Configuration Change - Setting the configured limit to a value that is smaller than the current number of LSPs will not cause existing LSPs to be deleted or pre-empted.

Setting the configured limit to a value that is larger than the current number of LSPs takes the node out of LSP-OOR state.

Path Error - When an LSP cannot be admitted due to LSP-OOR, the path-error is sent to the LER.

Interaction between LSP-OOR and HW-OOR - When both HW-OOR and LSP-OOR are active, the more critical action is done based on the interface in question. For example, if the LSP-OOR is Red and HW-OOR is Yellow for interface A, then TE will apply the Red state actions for all interfaces including interface A. Conversely, if the LSP-OOR is Yellow for the overall LSPs and HW-OOR is Red for interface A, then TE will apply the Yellow state actions for all interfaces except interface A. Instead, TE will apply the Red state actions for interface A.

Configuration Example

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# lsp-oor
Router(config-te-lsp-oor)# yellow
Router(config-te-lsp-oor-state)# transit-all threshold 45000
Router(config-te-lsp-oor-state)# transit-unprotected threshold 15000
Router(config-te-lsp-oor-state)# exit

Router(config-te-lsp-oor)# red
Router(config-te-lsp-oor-state)# transit-all threshold 50000
Router(config-te-lsp-oor-state)# transit-unprotected threshold 20000
Router(config-te-lsp-oor-state)# commit
```

The defaults of the above thresholds are infinite.

When a threshold is crossed, these below actions are applied to all the TE interfaces on the box. When the “accept-reopt” configuration is added it will work for both HW-OOR and LSP-OOR.

```
Router(config-mpls-te)# hw-oor
Router(config-te-hwoor)# green
Router(config-te-hwoor-state)# action flood available-bw 80
Router(config-te-hwoor-state)# recovery-duration 1
Router(config-te-hwoor-state)# action admit lsp-min-bw 1000
Router(config-te-hwoor-state)# action flood te-metric penalty 100
Router(config-te-hwoor-state)# action node-protection disable
Router(config-te-hwoor-state)# exi
Router(config-te-hwoor)# yellow
Router(config-te-hwoor-state)# action flood available-bw 50
Router(config-te-hwoor-state)# action admit lsp-min-bw 5000
Router(config-te-hwoor-state)# action flood te-metric penalty 200
Router(config-te-hwoor-state)# action node-protection disable
Router(config-te-hwoor-state)# exi
Router(config-te-hwoor)# red
Router(config-te-hwoor-state)# action flood available-bw 0
Router(config-te-hwoor-state)# action admit lsp-min-bw 10000
Router(config-te-hwoor-state)# action flood te-metric penalty 1000
Router(config-te-hwoor-state)# action node-protection disable
Router(config-te-hwoor-state)# exi
Router(config-te-hwoor)# commit
```

Verification

```
Router# show mpls traffic-eng lsp-oor summary

Total Transit LSP:

Yellow Threshold: 45000
  Red Threshold:    50000
  Current Count:    23456

Unprotected Transit LSP:

Yellow Threshold: 15000
  Red Threshold:    20000
  Current Count:    14456

LSP OOR Status: Green; Changed last at: Thu Oct 27 16:41:22 2016

Green state recovery actions in effect for: 115 seconds

LSP OOR Green State Parameters:
  Available Bandwidth percentage: 90%
```

```
  TE Metric Penalty: 0
  Minimum LSP Size: 0 kbps
  Transition duration: 2 minutes
  Statistics:
    Transitions 0; LSPs accepted 0, rejected 0;

LSP OOR Yellow State Parameters:
  Available Bandwidth percentage: 50%
  TE Metric Penalty: 10
  Minimum LSP Size: 500000 kbps
  HW OOR Statistics:
    Transitions 0; LSPs accepted 0, rejected 0;

LSP OOR Red State Parameters:
  Available Bandwidth percentage: 5%
  TE Metric Penalty: 50
  Minimum LSP Size: 1000000 kbps
  HW OOR Statistics:
    Transitions 0; LSPs accepted 0, rejected 0;
```

MPLS-TE LSP OOR

The MPLS-TE LSP OOR function adds capability for the RSVP-TE control plane to track the LSP scale of transit routers, so that it can take a specific set of (pre-configured) actions when threshold limits are crossed, and inform other routers in the network. MPLS-TE keeps track of the number of transit LSPs set up through the router. The limits do not apply to ingress and egress LSP routers since they are driven by explicit configuration. In other words, the configuration determines how many egress or ingress LSPs a router has. For midpoint routers, the number is a function of the topology, the links metrics, and links' bandwidth.

State Transition Triggers - The LSP OOR state transition is triggered by checking the total transit LSP count and the unprotected count. If either count crosses the threshold, the state transition is triggered. If both counts cross the limit, the more critical state is chosen. Each limit will have a value for the *Yellow* threshold and a value for the *Red* threshold. When these thresholds are crossed, the configured MPLS-TE LSP OOR actions take effect. Similarly, the transition to *Green* state occurs when the LSP numbers drop.

LSP OOR State Dampening - The reason for LSP OOR State Dampening is that the number of accepted LSPs would be at the threshold and once an LSP is deleted, the state goes back from Red to Yellow, and a new LSP is setup and the state goes back to Red.

The solution is to introduce dampening when there is a state transition from Red to Yellow or from Yellow to Green. Whenever the transit number of LSPs crosses down a threshold, a timer is started for 10 seconds. After the timer expires, the new state is computed and moved to it. The timer is stopped if the transit number threshold is crossed (up) again. The transition from a state to a more severe state is not dampened.

Low and High Priority LSPs - When the LSP OOR is in yellow or red state, new high priority LSPs will not preempt low priority LSPs. Preemption can still occur but only for bandwidth reasons. In other words, if the router is in Red state where one of the actions is to reject any new LSP, the new high-priority LSPs are rejected even if there is an established low-priority LSP. The low-priority LSP is not removed to make room for the high-priority one.

Configuration Limit - Setting the configured limit to a value that is smaller than the current number of LSPs will trigger state transition but will not cause existing LSPs to be deleted or preempted. Setting the configured limit to a value that is larger than the current number of LSPs takes the node out of LSP OOR state. When an LSP cannot be admitted due to LSP OOR, the LSRs send Path Error messages to the LERs.

Event Logging - This is generated when the system transitions across OOR states, such as a resource change into an *yellow* or *red* state. Reporting level for *Red* is critical (1), and for yellow is warning (4). The following example shows that the count has crossed the threshold of 5000.

```
RP/0/RP1/CPU0:May 15 17:05:48 PDT: te_control[1034]: %ROUTING-MPLS_TE-4-LSP_OOR :

Transit LSP resources changed to Yellow.
Total transit: configured threshold 5000; actual count 5001;
Unprotected transit: configured threshold 4294967295; actual count 0
```

When the resource comes out of OOR, it will report as *green*.

Configuration Example

```
mpls traffic-eng
 lsp-oor
  green
   action accept reopt-lsp
   action flood available-bw 20
   recovery-duration
   action admit lsp-min-bw   X   -- > (in kbps, a lower limit than yellow and red state)

  yellow
   transit-all threshold 75000
   action accept reopt-lsp
   action flood available-bw 0
   action admit lsp-min-bw  Y

  red
   transit-all threshold 90000
   action flood available-bw 0
   action admit lsp-min-bw Z
```

The LSP OOR threshold values are set to yellow as 75000 and red as 90000. When these thresholds are crossed, corresponding actions are applied to all the TE interfaces.

Note The default values of the above thresholds are infinite.

When the LSP OOR *yellow* state is reached, the **accept reopt-lsp** action, **flood available-bw 0** action and **admit lsp-min-bw** actions are activated. This allows headend routers to reoptimize existing LSPs through, but doesn't allow new LSPs to get established. Also, MPLS-TE advertises zero bandwidth out of all interfaces, making this transit router less preferable for new LSPs. To handle a sudden burst of new LSPs that get signaled, the **action admit lsp-min-bw** function ensures only a small number of high bandwidth LSPs get provisioned through the affected router. When the red threshold state is crossed, the **flood available-bw 0** and **admit lsp-min-bw** actions prevent any additional or reoptimized transit LSPs from getting set up through the affected router.