Implementing GMPLS UNI

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Table 1: Feature History Table

Feature Name	Release Information	Feature Description

GMPLS User Network Interface (UNI) to Manage Optical Networks	Release 7.11.1	We have improved the dynamic optical transport connection provisioning between IP routers and optical network elements to reduce operational time and administrative overhead needed for new connectivity setup by enabling support for Generalized Multiprotocol Label Switching (GMPLS) User Network Interface (UNI), which enables advanced traffic engineering capabilities.
		This feature introduces the following changes:
		• **CLI**
		  • New **gmpls uni** commands.
		• **YANG Data Model**
		  • New XPaths for `Cisco-IOS-XR-um-mpls-te-cfg.yang` (see GitHub, YANG Data Models Navigator).

Restrictions for Implementing GMPLS UNI

- The total number of configured GMPLS UNI controllers should not exceed the platform scale limit of 500 GMPLS interfaces.
- Each UNI-N (ingress or egress) should be routable from its adjacent UNI-C. The UNI-C nodes need to be routable from the UNI-N nodes too.

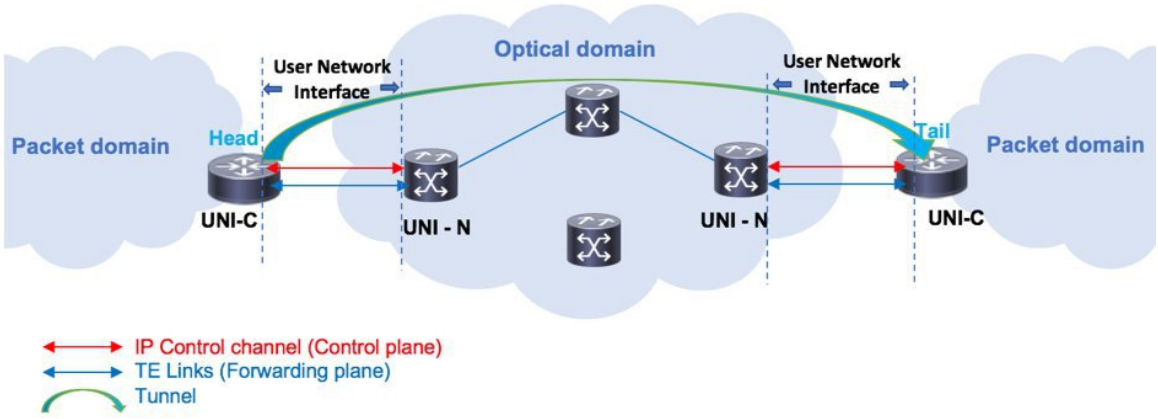
- GMPLS UNI is supported only over DWDM controllers and so, over POS and GigabitEthernet interfaces.

GMPLS UNI and GMPLS NNI

The GMPLS NNI optical network topology is known, and path calculations are performed at the NNI head. The GMPLS UNI optical network topology is unknown to the UNI-C nodes, and path calculations are performed by the UNI-N nodes.

GMPLS UNI Use Case

Figure 1: GMPLS UNI



The UNI components are UNI-N and UNI-C. The GMPLS UNI creates a circuit connection between two clients (UNI-C) of an optical network. This connection is achieved by signaling exchanges between UNI Client (UNI-C) and UNI Network (UNI-N) nodes. The UNI-C nodes are router nodes and UNI-N nodes are optical nodes.The tunnel originates on the headend UNI, depicted in the left part of the image. The tunnel terminates on the tailend UNI, depicted in the right part of the image. Enable the following configurations on the headend UNI and tailend UNI:

- Control plane - IP control channel between the UNI-C and UNI-N router IDs. This creates LMP adjacency over the control channel.
- Forwarding plane - TE Link between UNI-C and UNI-N optical interfaces.
- Tunnel configuration from Head UNI-C to a Tail UNI-C optical interface, over the optical network.

  For each tunnel, you must enable corresponding tunnel and TE link configurations.

Link Management Protocol (LMP) – LMP manages the control channel across the UNIs, verifies TE link connectivity between the UNI interfaces, and performs fault management.

Dynamic LMP – You can enable the Dynamic LMP function which validates LMP configuration consistency across the headend and tailend UNIs. Consistency check examples:

- You have configured one end of a TE link as an unnumbered interface, and the other end with an IP address.
- You have entered the wrong neighbor interface ID when configuring an unnumbered neighbor interface.

Ensure that you enable the preceding configurations correctly.

GMPLS LSP Signaling

The GMPLS overlay model architecture is used for LSP signaling for GMPLS connections. In GMPLS UNI, UNI-C nodes send a request for a connection to UNI-N node. The connection request does not contain an end-to-end path. This is because, as mentioned previously, UNI-C nodes do not have knowledge of the topology of the optical network and therefore cannot determine the end-to-end path. The UNI-C node signals a connection request without an ERO.

The LSP diversity is signaled on a GMPLS UNI tunnel with a path-option. A path-option is permitted on a GMPLS UNI tunnel with a "no ERO" and an optional "XRO" attribute sets to specify LSP diversity requirements. If multiple LSP exclusions are configured in the attribute-set, they can be added to the path message along with an appropriate LSP connection diversity sub-object.

Supported LSP encoding types, and corresponding switching types:

Switching Type	LSP Encoding Type
LSC	Lambda
FSC	EthernetType1, EthernetType2, Fiber
DCSC	EthernetType2

A packet network is switched across a fiber, optic, or data channel network. Enable the LSP encoding and switching types under the GMPLS UNI and LMP configuration modes. Also, enable the Generalized PID (G-PID) under the GMPLS UNI configuration mode. G-PID is an identifier of the type of payload that the LSP carries, and the LSP endpoints (the UNI-C devices) use.

The LSP encoding type, switching type, and G-PID are updated to the GMPLS label.

Path Message without an ERO

In GMPLS UNI, UNI-C nodes send a request for a connection to UNI-N node. The connection request does not contain an end-to-end path, because, UNI-C nodes do not have knowledge of the topology of the optical network and therefore cannot determine the end-to-end path. The UNI-C node signals a connection request without an ERO.

When no ERO is present in a received path message, the UNI-N node calculates a route to the destination and includes that route in an ERO, before forwarding the path message. If no route is found, the UNI-N returns a path error message with an error code and subcode of *24,5 - "No route available toward destination"*.

The destination address of a GMPLS LSP can be either the optical router-id of the tail UNI-C node, or the optical address of the ingress interface to the tail UNI-C node. Supplying the router-id allows the UNI-N to route the tunnel to the tail UNI-C node via any attached UNI-N node; supplying the UNI-C's ingress interface address forces the tunnel's path to traverse the UNI-N node attached to that interface.

Note The optical router-ids and interface addresses may or may not be the same as the packet ones.

XRO Attribute-set

An optional XRO attribute-set can be specified as part of the path-option to specify LSP diversity requirements. An empty XRO attribute set results in the GMPLS tunnel being signaled with no exclusions, and therefore no XRO.

Note A non-existent XRO attribute-set can be configured in the GMPLS UNI tunnel path-option; in this case no attempt will be made to bring up the GMPLS tunnel until the configuration is complete.

Connection Diversity

Connection diversity is required to ensure that GMPLS tunnels can be established without sharing resources, thus, greatly reducing the probability of simultaneous connection failures. For example, an edge-node wishes to establish multiple LSPs towards the same destination edge-node, and these LSPs need to have few or no resources in common.

Connection diversity supports the establishment of a GMPLS LSP which is diverse from the path taken by an existing LSP. An XRO is added to the tunnel's path message with appropriate LSP diversity sub-objects or exclusions. A maximum of 20 connection diversity exclusions per XRO is supported.

GMPLS RSVP VRF Signaling

The Cisco IOS XR software supports a single non-default VRF for the GMPLS RSVP signaling. This allows GMPLS signaling to work even when the only available communication between the UNI-C and UNI-N nodes is through a VRF. This non-default VRF is supported only for GMPLS signaling; whereas the MPLS-TE signaling continues to support only the default VRF.

DWDM Transponder Integration

A GMPLS UNI based solution preserves all the advantages of the integration of the DWDM transponder into the router blade. These advantages include the following:

- Improved CAPEX and OPEX models.
- Component, space and power savings.
- Improved IP availability through pro-active protection.

nLight Enhancements

These topics describe the enhancements made to nLight (also known as GMPLS UNI):

Explicit Route Object

Explicit Route Objects (EROs) limit LSP routing to a specified list of LSRs. Formerly, the UNI Client (UNI-C) node signaled a connection request, without an ERO, to the UNI Network (UNI-N) node. In this IOS XR Software release, the UNI-C node provides support for path message with ERO for GMPLS tunnels. This includes the capability to specify either a strict or a loose ERO to a path option to be included in the path message for processing by the ingress UNI-N.

An ERO in constructed using the strict and loose hops, specified in the explicit path, by the path option.

When a loose hop is configured, it identifies one or more transit LSRs which suggests the preferred path for the LSP. If a suggested path fails, another LSR is tried.

When a strict hop is configured, it identifies an exact path through which the LSP must be routed. Strict hop EROs specify the exact sequence of LSRs in the LSP.

As a result of these operations, a LSP is established from the sender to the destination of the session, following the explicitly routed path specified in the ERO.

Note

- *lockdown* and *verbatim* are mandatory in ERO path option.
- A path option may still be configured to use no ERO.

  In no ERO, *lockdown* is mandatory.

Wavelength Specification

The wavelength (also called label) specification enhancement enables the network planning tool to determine the wavelength, and specify the same at the UNI-C. The UNI-N then accepts the label provided by the UNI-C, or rejects the path entirely. Previously, the wavelength to be used for the GMPLS UNI tunnel was determined by the UNI-N, taking into account the headend UNI-C's capabilities.

The wavelength to be used is added to the path option configuration. This optional configuration allows a fixed wavelength to be specified for the path option.

When signaling using a path option with the specified wavelength takes place, the following changes happen because of the wavelength specification enhancement:

- The configured wavelength is validated against the controller’s capabilities; signaling fails if the wavelength cannot be used by the controller.
- The upstream label is set to the specified wavelength.
- The label-set in the Path message, instead of containing one label for each supported wavelength, contains only the specified wavelength.
- A path-error message with error code 25 and subcode 6 no longer receives special handling. If a suggested label is supplied, it is ignored.

Note A suggested label received in response to signaling with a path option that specifies a different label, is not stored for future use. Other path options, in general, have different constraints and therefore require path calculation to be redone.

Multiple Path Options

Multiple path options are permitted per GMPLS UNI tunnel. The index given to each path option indicates its relative preference level, with lower indices being preferred. This is similar to the existing multiple path option functionality available for packet TE. This allows the provision of multiple path options with, for example, progressively free constraints.

The path-option index is no longer fixed to ten and is now set by the user and distinguishes path options in the same manner as for packet tunnels. In all situations where a tunnel is being brought up or reoptimized, the path-option with the lowest index is tried first; if no LSP can be established with this path option, then subsequent path options are tried in ascending order. This also applies to recovery from failures, unless any recovery path option is specified.

Reoptimization

Reoptimization differs from restoration though the mechanisms involved are similar. Reoptimization occurs without the original connection having failed.

Unlike packet tunnels, reoptimization in GMPLS tunnels is not supposed to be loss free.

Manual Reoptimization

Manual reoptimization of a single GMPLS UNI tunnel can be triggered from the UNI-C node (headend). Use the **mpls traffic-eng optical-uni reoptimize tunnel-id** command to trigger manual reoptimization of a GMPLS UNI tunnel.

The manual trigger for reoptimization causes the currently established LSP to be torn down and signals a new LSP using the normal bring-up process (though the new LSP is same as the current one).

It is not possible to trigger reoptimization for multiple GMPLS UNI tunnels or at the tailend of a tunnel.

SRLG Discovery

Note Shared Risk Link Group (SRLG) discovery, SRLG collection and SRLG recording represent the same function.

The head and tail UNI-C routers have no direct knowledge of the path taken through the optical network by a GMPLS UNI tunnel, or of the properties of that path. All information about the path of a particular GMPLS UNI connection must therefore be explicitly requested and learned during the signaling process.

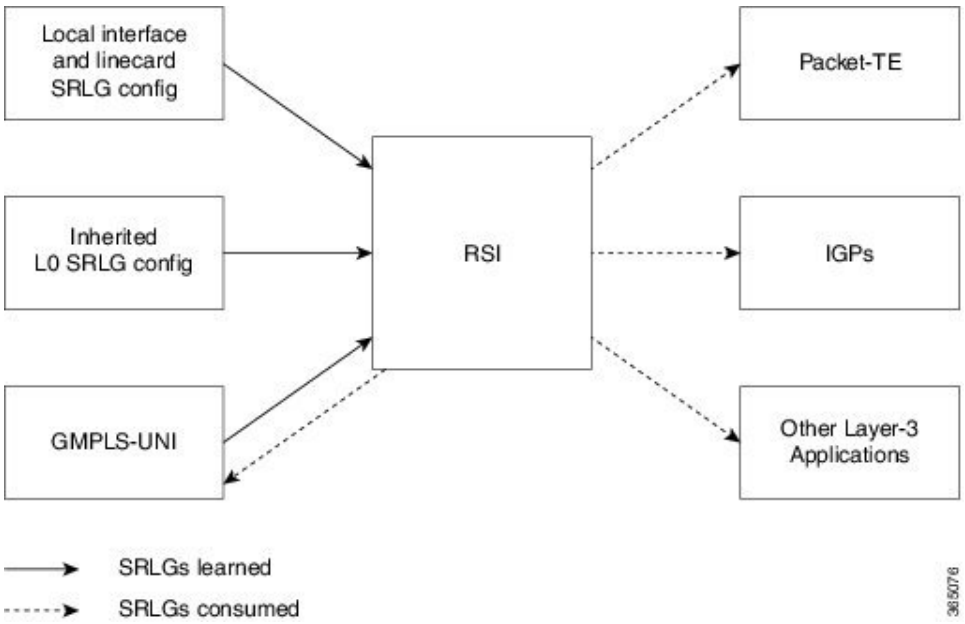
A key property of a GMPLS UNI connection is the set of SRLGs used by the optical links along the connection. It is necessary for the UNI-C routers to learn the set of SRLGs associated with a connection, so that this information can be used, both by GMPLS UNI in the specification of diversity requirements for other connections and by Layer-3 applications for effecting routing and protection decision making.

The learning of SRLGs during GMPLS UNI LSP signaling is done by requesting SRLG collection when LSP signaling is initiated, and by the addition of SRLG RRO sub-objects to the Path and Resv messages during signaling as described in IETF draft *SRLG-collect*. Path message learns egress interfaces from head to tail and Resv message learns egress interfaces from tail to head.

Provision of Discovered SRLGs to RSI

Once the SRLGs used by a GMPLS UNI connection are collected during signaling as in SRLG discovery, they are made available to the Layer-3 processes. This is done through RSI (Router Space Infrastructure), as illustrated in the following diagram:

Figure 2: SRLG Communication



An API is provided by the RSI component to allow SRLGs discovered during GMPLS UNI signaling to be communicated to RSI, as documented in IETF draft *RSI-SRLG*. RSI combines the SRLG sets learned from GMPLS and configuration for an interface and deliver a single set of SRLGs to applications registered as SRLG clients.

The SRLGs discovered during GMPLS UNI signaling are given to RSI for application to the Layer-3 interface of the DWDM controller associated with the GMPLS UNI tunnel. This may be a POS, GigE or an OTN interface.

SRLG Announce

All SRLGs discovered through GMPLS signaling are announced to RSI once the tunnel is up. These SRLGs are withdrawn from RSI when the tunnel goes down.

SRLG Diversity

Note SRLG diversity and SRLG exclusion represent the same function.

Support is added for signaling SRLG based diversity requirements, based on the XRO SRLG sub-object defined in RFC 4874. The use of SRLGs removes the restrictions of LSP based diversity, as SRLGs are flooded throughout the optical network, and by their very nature, reduce the risk of concurrent failure.

SRLG diversity is configured under the XRO attribute-set.

Head UNI-C Behavior

SRLG diversity is configured at the tunnel head. Individual SRLG exclusions are added to an XRO attribute-set; each is specified as either *best-effort* or mandatory (*strict*). Whenever any exclusion is specified, an XRO object is added to the Path message by the head UNI-C. The XRO contains a SRLG sub-object for each specified SRLG. The SRLG exclusions may coexist in the same XRO with LSP exclusions.

The XRO attribute-set is associated with tunnel path options in the same manner as for LSP exclusions.

If a SRLG with a strict exclusion matches an SRLG configured on the local DWDM controller, the bring-up attempt fails.

The SRLG exclusions requested by the head UNI-C are processed by the ingress UNI-N node during path calculation for the tunnel.

Tail UNI-C Behavior

On receiving a Path message containing an XRO, the tail UNI-C inspects each SRLG sub-object. If a SRLG sub-object, with a strict exclusion, matches an SRLG configured on the local DWDM controller, the Path message is rejected and a path-error is generated with error codes. No action is taken if the SRLG sub-object specifies a *best-effort* exclusion.

Multi-Layer Restoration - Optical

Multi-Layer Restoration-Optical (MLR-O) involves restoration from failures in the optical network that can leverage the same router interfaces at both ends.

Optical restoration involves the repair of a failure by the optical network locally. Although the routers may see loss of light until the failure is repaired, there is no signaling involving the routers, and from the routers perspective the GMPLS UNI LSP remains unchanged.

Optical Restoration: Same Wavelength

When a failure occurs on a physical link within the optical network, the routers identify that the link is down and Layer 3 protection mechanisms, such as FRR, are used to minimize the traffic loss. The optical network re-routes the GMPLS connection to an alternative path. This is done without any involvement of the routers.

Limitation - A significant limitation of optical restoration in this case, is that the wavelength in use for the connection cannot be changed. This is because the wavelength must be the same along the entire path and cannot be changed without end-to-end signaling. The constraints imposed on the connection during its initial signaling are also unchanged, which may reduce the chance of finding an alternative path.

Optical Restoration: Wavelength Change

Optical restoration may occur with an associated wavelength change, in the case where the optical network finds an alternative path with the same constraints as were originally signaled, but using a different wavelength. Some signaling is required, since the wavelength (and therefore the labels) used by the GMPLS connection are to change.

Consider a failure within the optical network on the path of a GMPLS UNI LSP. The restoration proceeds as in the previous case (same wavelength), but the new path found, uses a different wavelength. The ingress UNI-N then sends a path-error message indicating the new wavelength to be used; this has error code 24 (routing), sub-error 6 (unacceptable label set) and contains a suggested-label sub-object with the new label to be used. The head UNI-C then signals a new LSP with the new wavelength.

Although the wavelength in use may change in this case, the constraints used in signaling the original LSP remain unchanged.

Configure GMPLS UNI

Configure TE for GMPLS UNI

TE configuration specific to packet tunnels does not affect GMPLS UNI tunnels.

Configure GMPLS UNI Controller

Perform this task to setup a GMPLS tail in MPLS-TE configuration. This task enables GMPLS UNI controller submode to configure controllers for establishing GMPLS UNI tunnels. This is the minimal configuration required at the tunnel tail.

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# gmpls optical-uni
Router(config-te-gmpls)# controller dwdm 0/1/0/1
```

Configure the GMPLS UNI Controller as a Tunnel Head

Perform this task to configure the tunnel properties for a GMPLS UNI controller.

This configuration designates the controller as a tunnel-head, rather than a tunnel tail. After you configure the tunnel properties, the incoming path messages are rejected and any existing tailend tunnel is torn down.

```
Router(config-te-gmpls-cntl)# mtu 9000
Router(config-te-gmpls-cntl)# tunnel-properties
Router(config-te-gmpls-tun)# g-pid 37
Router(config-te-gmpls-tun)# encoding-type lambda
Router(config-te-gmpls-tun)# tunnel-id 100
Router(config-te-gmpls-tun)# logging events lsp-status state
Router(config-te-gmpls-tun)# destination ipv4 unicast 10.10.3.4
Router(config-te-gmpls-tun)# exit
```

This configuration assigns the Lambda switching type for transporting traffic.

```
Router(config-te-gmpls-cntl)# switching-type lsc
```

(Optional) Tunnel Properties

```
Router(config-te-gmpls-cntl)# tunnel-properties
Router(config-te-gmpls-tun)# priority 3 2
Router(config-te-gmpls-tun)# record-route
Router(config-te-gmpls-tun)# signalled-name sign1
Router(config-te-gmpls-tun)# exit
```

Note If you remove the GMPLS UNI and GMPLS UNI controller submodes, all GMPLS UNI tunnels are removed.

Path Options - These configurations specify a path-option for the GMPLS tunnel headend router.

This configures a path option with no ERO.

```
Router(config-te-gmpls-tun)# path-option 30 no-ero lockdown
```

This configures a path option with an ERO for the GMPLS tunnel. You can specify an explicit path in the range 1 to 1000. **lockdown** and **verbatim** are mandatory in an ERO path option.

```
Router(config-te-gmpls-tun)# path-option 10 explicit name explicit_path_a lockdown verbatim
```

This configures a wavelength for the path option. The DWDM channel number range is 1 to 89. The DWDM channel number configured is formulated as 61-channel number. For example, for channel number 42 (in the supported channel list), the configured "DWDM channel number" is 61 - 42 = 19.

```
Router(config-te-gmpls-tun)# path-option 10 explicit name exp_all_loose_hop signaled-label
 dwdm wavelength 10 lockdown verbatim
```

This configures multiple path options for a single tunnel.

```
Router(config-te-gmpls-tun)# path-option 10 explicit name explicit_path_a lockdown verbatim

Router(config-te-gmpls-tun)# path-option 20 explicit name explicit_path_b lockdown verbatim
Router(config-te-gmpls-tun)# path-option 30 no-ero lockdown
```

This configures the LSP diversity function. You can configure an XRO attribute-set as part of the path-option for MPLS-TE, and specify exclusions for an attribute set for LSP diversity.

```
Router(config-te-gmpls-tun)# path-option 10 no-ero xro-attribute-set A01 lockdown
```

This configures the connection diversity function. You can specify exclusions for an attribute set for LSP diversity.

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# attribute-set xro attrset01
Router(config-te-attribute-set)# exclude best-effort lsp source 10.10.1.2 destination
10.20.4.4 tunnel-id 17 extended-tunnel-id 10.20.3.3 lsp-id 17
Router(config-te-attribute-set)# commit
```

Configure LMP for GMPLS UNI

To implement LMP configuration for GMPLS UNI, follow these steps:

LMP Configuration - Configure the optical router ID and LMP neighbor:

```
Router# configure
Router(config)# lmp
Router(config-lmp)# gmpls optical-uni
Router(config-lmp-gmpls-uni)# router-id ipv4 unicast 10.10.4.4
Router(config-lmp-gmpls-uni)# neighbor nbr1
Router(config-lmp-gmpls-uni-nbr1)# dynamic
Router(config-lmp-gmpls-uni-nbr1)# hello 1000 10000
Router(config-lmp-gmpls-uni-nbr-nbr1)# ipcc routed
Router(config-lmp-gmpls-uni-nbr-nbr1)# router-id ipv4 unicast 10.10.4.5
```

LMP Controller Configuration - Configure the LMP link for the GMPLS UNI controller:

```
Router(config-lmp-gmpls-uni)# controller dwdm 0/4/0/0
Router(config-lmp-gmpls-uni-cntl)# neighbor nbr1
Router(config-lmp-gmpls-uni-cntl)# link-id ipv4 unicast 10.2.2.4
Router(config-lmp-gmpls-uni-cntl)# switching-type lsc
Router(config-lmp-gmpls-uni-cntl)# encoding-type Lambda
Router(config-lmp-gmpls-uni-cntl)# neighbor link-id ipv4 unicast 10.2.2.5
Router(config-lmp-gmpls-uni-cntl)# neighbor interface-id unnumbered 17
Router(config-lmp-gmpls-uni-cntl)# commit
```

Configure RSVP Optical Refresh Interval and Missed Count

Perform this task to configure optical refresh interval under the RSVP controller submode and to configure the number of missed refresh messages allowed before optical tunnel states are deleted.

```
Router# configure
Router(config)# rsvp
Router(config-rsvp)# controller dwdm 0/1/0/1
Router(config-rsvp-cntl)# signalling refresh out-of-band interval 200
Router(config-rsvp-cntl)# signalling refresh out-of-band missed 30
Router(config-rsvp-cntl)# commit
```

Configure SRLG

SRLG discovery on the head router of a nLight tunnel.

- SRLG discovery/recording is enabled only on the headend for each tunnel.
- SRLG discovery/recording allows a maximum of 62 SRLGs in RSVP, which is different from the maximum count of 64 in RSI.

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# gmpls optical-uni
Router(config-te-gmpls)# controller dwdm 0/1/0/1
Router(config-te-gmpls-cntl)# tunnel-properties
Router(config-te-gmpls-tun)# logging events lsp-status state
Router(config-te-gmpls-tun)# tunnel-id 100
Router(config-te-gmpls-tun)# record srlg
Router(config-te-gmpls-tun)# destination ipv4 unicast 10.10.3.4
Router(config-te-gmpls-tun)# path-option 10 no-ero lockdown
Router(config-te-gmpls-tun)# exit
```

To announce the discovered SRLGs to the system, use the **announce srlgs** command.

```
Router(config-te-gmpls-cntl)# announce srlgs
Router(config-te-gmpls-cntl)# commit
```

You can configure the attribute-set and SRLG path diversity with the best-effort or strict exclusion function.

```
Router# configure
Router(config)# mpls traffic-eng
Router(config-mpls-te)# attribute-set xro exclude_srlgs
Router(config-te-attribute-set)# exclude best-effort srlg value 21
Router(config-te-attribute-set)# exit
```

Associate the XRO attribute set to the GMPLS UNI tunnel through the path option. The path-option range is 1 to 1000.

```
Router(config-mpls-te)# gmpls optical-uni
Router(config-te-gmpls)# controller dwdm 0/1/0/1
router(config-te-gmpls-cntl)# tunnel-properties
Router(config-te-gmpls-tun)# path-option 10 no-ero xro-attribute-set exclude_srlgs lockdown
```

Verify GMPLS UNI Configurations

Various GMPLS UNI function configurations are displayed in this section:

Explicit Route Object (ERO)

```
Router# show mpls traffic-eng tunnels 1001 detail

Name: GMPLS-UNI-dwdm0_3_0_0 Destination: 172.16.0.1 Signalled-Name: head_ot1001_172.16.0.1

GMPLS UNI tunnel controlling link dwdm0/3/0/0, tunnel-id: 1001
Status:
Admin:    up Oper:   up   Path:  valid   Signalling: connected
path option 10, (LOCKDOWN verbatim) type explicit explicit_path_a (Basis for Setup, path
weight 0)
G-PID: 0x0800 (derived from egress interface properties) Creation Time: Fri Jul 17 08:41:21
 ---- (3d07h ago)
..
Current LSP Info:
  Instance: 20
  Uptime: 00:00:33 (since Mon Jul 20 ---- 15:45:22)

Upstream label:

  Optical label:
  Grid              : DWDM
  Channel spacing   : 50GHz
  Identifier        : 0
```

```
  Channel Number    : 60

Downstream label:

  Optical label:
  Grid              : DWDM
  Channel spacing   : 50GHz
  Identifier        : 0
  Channel Number    : 60

Router-IDs: local   10.0.0.1
downstream          172.16.0.1
Soft Preemption: None
SRLGs: not collected
Path Info:
  Outgoing:
    Explicit Route:
        Strict, 10.10.10.2
        Strict, 10.11.11.3
        Strict, 10.12.12.3
```

Wavelength

The following sequence of examples show how to add a wavelength to a path option for a GMPLS tunnel and verify the outgoing label is set accordingly.

This example shows how to configure a GMPLS tunnel with no ERO path option.

```
gmpls optical-uni
  controller dwdm0/3/0/0
   tunnel-properties
    tunnel-id 1001
    destination ipv4 unicast 172.16.0.1
    path-option 10 no-ero lockdown
   !
```

This example shows how to verify the default values for the outgoing label (UNI-N source, channel number same as Default Channel) and the list of valid wavelengths.

```
Router# show mpls traffic-eng link-management optical-uni controller dwdm 0/3/0/0

Optical interface: dwdm0/3/0/0
  Overview:
    IM state: Up
    Child interface: POS0_3_0_0: IM state Up
    OLM/LMP state: Up
    Optical tunnel state: up
  Connection:
    Tunnel role: Head
    Tunnel-id: 1001, LSP-id 21, Extended tunnel-id 10.0.0.1
    Tunnel source: 10.0.0.1, destination: 172.16.0.1
    Optical router-ids: Local: 10.0.0.1, Remote: 172.16.0.1
    Label source: UNI-N
    Upstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 60
    Downstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
```

```
      Channel Number      : 60
    SRLG discovery: Disabled
    SRLG announcement: None
...
  Optical capabilities:
    Controller type: DWDM
    Channel spacing: 50 GHz
    Default channel: 60
    89 supported channels:
      -28, -27, -26, -25, -24, -23, -22, -21
      -20, -19, -18, -17, -16, -15, -14, -13
      -12, -11, -10, -9, -8, -7, -6, -5
      -4, -3, -2, -1, 0, 1, 2, 3
      4, 5, 6, 7, 8, 9, 10, 11
      12, 13, 14, 15, 16, 17, 18, 19
      20, 21, 22, 23, 24, 25, 26, 27
      28, 29, 30, 31, 32, 33, 34, 35
      36, 37, 38, 39, 40, 41, 42, 43
      44, 45, 46, 47, 48, 49, 50, 51
      52, 53, 54, 55, 56, 57, 58, 59
      60
    Controller SRLGs
      None
```

This example shows how to set valid wavelength 10 (61 - 51) for the current path.

```
gmpls optical-uni
  controller dwdm0/3/0/0
   tunnel-properties
    tunnel-id 1001
    destination ipv4 unicast 172.16.0.1
   path-option 10 explicit name explicit_all_loose_multi_hop signaled-label dwdm wavelength
 10 lockdown verbatim
   !
```

This example shows how to verify that the tunnel is up and the specified wavelength is used (label source is UNI-C and outgoing label is 51).

```
Router# show mpls traffic-eng link-management optical-uni controller dwdm 0/3/0/0

Optical interface: dwdm0/3/0/0
  Overview:
    IM state: Up
    Child interface: POS0_3_0_0: IM state Up
    OLM/LMP state: Up
    Optical tunnel state: up
  Connection:
    Tunnel role: Head
    Tunnel-id: 1001, LSP-id 23, Extended tunnel-id 10.0.0.1
    Tunnel source: 10.0.0.1, destination: 172.16.0.1
    Optical router-ids: Local: 10.0.0.1, Remote: 172.16.0.1
    Label source: UNI-C
    Upstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 51
    Downstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 51
```

```
    SRLG discovery: Disabled
    SRLG announcement: None
...
  Optical capabilities:
    Controller type: DWDM
    Channel spacing: 50 GHz
    Default channel: 60
    89 supported channels:
      -28, -27, -26, -25, -24, -23, -22, -21
      -20, -19, -18, -17, -16, -15, -14, -13
      -12, -11, -10, -9, -8, -7, -6, -5
      -4, -3, -2, -1, 0, 1, 2, 3
      4, 5, 6, 7, 8, 9, 10, 11
      12, 13, 14, 15, 16, 17, 18, 19
      20, 21, 22, 23, 24, 25, 26, 27
      28, 29, 30, 31, 32, 33, 34, 35
      36, 37, 38, 39, 40, 41, 42, 43
      44, 45, 46, 47, 48, 49, 50, 51
      52, 53, 54, 55, 56, 57, 58, 59
      60
    Controller SRLGs
      None
```

This example shows how to verify the upstream label on the tunnel tail.

```
Router# show mpls traffic-eng link-management optical-uni controller dwdm 0/3/0/0

Optical interface: dwdm0/3/0/0
  Overview:
    IM state: Up
    Child interface: POS0_3_0_0: IM state Up
    OLM/LMP state: Up
    Optical tunnel state: up
  Connection:
    Tunnel role: Tail
    Tunnel-id: 1001, LSP-id 23, Extended tunnel-id 10.0.0.1
    Tunnel source: 10.0.0.1, destination: 172.16.0.1
    Optical router-ids: Local: 172.16.0.1, Remote: 10.0.0.1
    Label source: UNI-N
    Upstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 51
    Downstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 51
    SRLG discovery: Disabled
    SRLG announcement: None
…..
  Optical capabilities:
    Controller type: DWDM
    Channel spacing: 50 GHz
    Default channel: 60
    89 supported channels:
      -28, -27, -26, -25, -24, -23, -22, -21
      -20, -19, -18, -17, -16, -15, -14, -13
      -12, -11, -10, -9, -8, -7, -6, -5
      -4, -3, -2, -1, 0, 1, 2, 3
      4, 5, 6, 7, 8, 9, 10, 11
      12, 13, 14, 15, 16, 17, 18, 19
```

```
      20, 21, 22, 23, 24, 25, 26, 27
      28, 29, 30, 31, 32, 33, 34, 35
      36, 37, 38, 39, 40, 41, 42, 43
      44, 45, 46, 47, 48, 49, 50, 51
      52, 53, 54, 55, 56, 57, 58, 59
      60
    Controller SRLGs
      None
```

Multiple Path Options

This example shows how to configure multiple path options.

```
mpls traffic-eng
 gmpls optical-uni
   controller dwdm0/2/0/2
    tunnel-properties
     path-option 10 explicit name explicit_path_a lockdown verbatim
     path-option 20 explicit name explicit_path_b lockdown verbatim
     path-option 30 no-ero lockdown
    !
```

The following sequence of examples show how to configure a GMPLS tunnel, add a new path option with a lower index than the path option in use, flap the tunnel and verify that the new path option (with a lower index) is used.

This example shows how to configure a GMPLS tunnel with one path option.

```
gmpls optical-uni
  controller dwdm0/3/0/0
   tunnel-properties
    tunnel-id 1001
    destination ipv4 unicast 172.16.0.1
    path-option 10 explicit name explicit_path_a lockdown verbatim
   !
```

This example shows how to verify the tunnel path and status with a show command.

```
Router# show mpls traffic-eng tunnels 1001 detail

Name: GMPLS-UNI-dwdm0_3_0_0  Destination: 172.16.0.1
  Signalled-Name: head_ot1001_172.16.0.1
GMPLS UNI tunnel controlling link dwdm0/3/0/0, tunnel-id: 1001
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10, (LOCKDOWN verbatim) type explicit explicit_path_a (Basis for Setup,
path weight 0)
    G-PID: 0x0800 (derived from egress interface properties)
    Creation Time: Fri Jul 17 08:41:21 ---- (3d06h ago)
..
```

This example shows how to add another path option with a lower index.

```
gmpls optical-uni
  controller dwdm0/3/0/0
   tunnel-properties
    tunnel-id 1001
    destination ipv4 unicast 172.16.0.1
    path-option 1 no-ero lockdown
    path-option 10 explicit name explicit_path_a lockdown verbatim
   !
```

Flag the tunnel (or trigger reoptimization) and verify that the tunnel comes up on the path with a lower index.

```
Router# show mpls traffic-eng tunnels 1001 detail

Name: GMPLS-UNI-dwdm0_3_0_0  Destination: 172.16.0.1
  Signalled-Name: head_ot1001_172.16.0.1
GMPLS UNI tunnel controlling link dwdm0/3/0/0, tunnel-id: 1001
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 1, (LOCKDOWN) type no-ero  (Basis for Setup, path weight 0)
    Last Signalled Error : Mon Jul 20 17:03:00 2015
      Info: [24] PathErr(2,2)-(Admin, reason unknown) at 50.0.0.2
    path option 10, (LOCKDOWN verbatim) type explicit explicit_all_loose_multi_hop
    Last Signalled Error : Mon Jul 20 17:03:00 ----
      Info: [25] PathErr(2,2)-(Admin, reason unknown) at 50.0.0.2
```

SRLG

SRLG Discovery

```
Router# show mpls traffic-eng tunnels 100 detail

Name: GMPLS-UNI-dwdm0_2_0_0  Destination: 192.168.1.2
  Signalled-Name: rtrA_ot100_192.168.1.2
GMPLS UNI tunnel controlling link dwdm0/2/0/0, tunnel-id: 100
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10, (LOCKDOWN) type no-ero  (Basis for Setup, path weight 0)
    G-PID: 0x0800 (derived from egress interface properties)
    Creation Time: Mon Jul 20 19:32:03 ---- (00:48:02 ago)
  Config Parameters:
    Priority:  7  7 Affinity: 0x0/0xffff
    Path Protection: Not Enabled
    BFD Fast Detection: Disabled
    Reoptimization after affinity failure: Enabled
    SRLG discovery: Enabled
….
 Soft Preemption: None
    SRLGs: mandatory collection
    Path Info:
  ….
    Resv Info:
      Record Route:
        IPv4 10.10.10.2, flags 0x0
        SRLGs: 21, 22, 23, 24
      Fspec: avg rate=10000 kbits, burst=1000 bytes, peak rate=10000 kbits
Displayed 1 (of 3) heads, 0 (of 0) midpoints, 0 (of 2) tails
Displayed 1 up, 0 down, 0 recovering, 0 recovered heads
```

This example shows how to verify SRLG discovery configuration at the headend and the tailend. The output shows the list of SRLGs.

```
Router# show srlg

  System Information::
  Interface Count          : 4 (Maximum Interfaces Supported 512)
  Group Count              : 0 (Maximum Groups Supported 50)
  Inherit Location Count   : 0 (Maximum Inherit Locations Supported 10)
  Optical Interfaces Count : 4 (Maximum Optical Interfaces Supported 500)

  Interface    : GigabitEthernet0/2/0/0, Value Count : 10, Registrations : 2
  SRLG Values  : 11, 12, 13, 14, 15
                 21, 22, 23, 24, 25                                        -> Note:
These are announced srlgs.
```

```
  Interface    : GigabitEthernet0/2/0/2, Value Count : 0, Registrations : 1
  SRLG Values  :

  Interface    : GigabitEthernet0/2/0/4, Value Count : 0, Registrations : 2
  SRLG Values  :

  Interface    : GigabitEthernet0/2/0/5, Value Count : 0, Registrations : 2
  SRLG Values  :

  Optical Interface: dwdm0/2/0/0, Value Count : 5, References: 2
  SRLG Values      : 11, 12, 13, 14, 15                                    -> Note:
These are locally configured srlgs for controller (dwdm)

  Optical Interface: dwdm0/2/0/1, Value Count : 0, References: 1
  SRLG Values      :

  Optical Interface: dwdm0/2/0/2, Value Count : 0, References: 1
  SRLG Values      :

  Optical Interface: dwdm0/2/0/3, Value Count : 0, References: 1
  SRLG Values      :
```

SRLG Announce

```
Router# show srlg

  System Information::
  Interface Count          : 2 (Maximum Interfaces Supported 512)
  Group Count              : 0 (Maximum Groups Supported 50)
  Inherit Location Count   : 0 (Maximum Inherit Locations Supported 10)
  Optical Interfaces Count : 5 (Maximum Optical Interfaces Supported 500)

  Interface    : GigabitEthernet0/2/0/4, Value Count : 0, Registrations : 2
  SRLG Values  :

  Interface    : GigabitEthernet0/2/0/5, Value Count : 0, Registrations : 2
  SRLG Values  :

  Interface: GigabitEthernet0/2/0/0, Value Count : 4, References: 1
  SRLG Values      : 21, 22, 23, 24

  Optical Interface: dwdm0/2/0/0, Value Count : 3, References: 2
  SRLG Values      : 11, 12, 13

  Optical Interface: dwdm0/2/0/1, Value Count : 0, References: 1
  SRLG Values      :

  Optical Interface: dwdm0/2/0/2, Value Count : 0, References: 1
  SRLG Values      :

  Optical Interface: dwdm0/2/0/3, Value Count : 0, References: 1
  SRLG Values      :
```

SRLG Diversity

```
Router# show mpls traffic-eng tunnels 100 detail

Name: GMPLS-UNI-dwdm0_2_0_0  Destination: 192.168.1.2
  Signalled-Name: rtrA_ot100_192.168.1.2
GMPLS UNI tunnel controlling link dwdm0/2/0/0, tunnel-id: 100
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 10, (LOCKDOWN) type no-ero  (Basis for Setup, path weight 0)
```

```
      XRO attribute-set: exclude_srlgs
        Best-effort, SRLG id 21
    Last Signalled Error : Mon Jul 20 20:55:33 ----
      Info: [5] PathErr(24,67)-(routing, route blocked by exclude route) at 10.10.10.2
    G-PID: 0x0800 (derived from egress interface properties)
    Creation Time: Mon Jul 20 19:32:03 2015 (01:25:19 ago)
  Config Parameters:
    Priority:  7  7 Affinity: 0x0/0xffff
    Path Protection: Not Enabled
    BFD Fast Detection: Disabled
    Reoptimization after affinity failure: Enabled
    SRLG discovery: Enabled
  Binding Label: 0
  History:
    Tunnel has been up for: 00:00:23 (since Mon Jul 20 20:56:59 EDT 2015)
    Current LSP:
      Uptime: 00:00:23 (since Mon Jul 20 20:56:59 EDT ----)
  Current LSP Info:
    Instance: 6
    Uptime: 00:00:23 (since Mon Jul 20 20:56:59 EDT ----)
    Upstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 16
    Downstream label:
      Optical label:
      Grid                : DWDM
      Channel spacing     : 50 GHz
      Identifier          : 0
      Channel Number      : 16
    Router-IDs: local      192.168.1.1
                downstream 192.168.1.2
    Soft Preemption: None
    SRLGs: mandatory collection
    Path Info:
      Outgoing:
        No ERO
      Route Exclusions:
        Best-effort, SRLG id 21
      Record Route: Disabled
      Tspec: avg rate=10000 kbits, burst=1000 bytes, peak rate=10000 kbits
      Session Attributes: Local Prot: Not Set, Node Prot: Not Set, BW Prot: Not Set
    Resv Info:
      Record Route:
        IPv4 10.10.10.2, flags 0x0
        SRLGs: 21, 22, 23, 24
      Fspec: avg rate=10000 kbits, burst=1000 bytes, peak rate=10000 kbits
Displayed 1 (of 3) heads, 0 (of 0) midpoints, 0 (of 2) tails
Displayed 1 up, 0 down, 0 recovering, 0 recovered heads
```

GMPLS UNI Running Configuration

Head UNI-C for a GMPLS Tunnel

```
rsvp
    controller dwdm 0/1/0/1
      signalling refresh out-of-band interval 3600
      signalling refresh out-of-band missed 24
    !
  !
  mpls traffic-eng
    gmpls optical-uni
```

```
      controller dwdm 0/1/0/1
        tunnel-properties
          tunnel-id 100
          destination 100.20.20.20
          path-option 10 no-ero
        !
      !
    !
  !
  lmp
    gmpls optical-uni
      router-id 100.11.11.11
      neighbor nbr_A
        ipcc routed
        neighbor router-id ipv4 unicast 100.12.12.12
      !
      controller dwdm 0/1/0/1
        neighbor nbr_A
        link-id ipv4 unicast 192.168.100.1
        neighbor link-id ipv4 unicast 192.168.100.2
        neighbor interface-id unnumbered 13
      !
```

Tail UNI-C for a GMPLS Tunnel

Note The controller must be specified under the GMPLS UNI submode to inform TE that incoming GMPLS path messages are to be accepted and processed.

```
rsvp
    controller dwdm 0/1/0/1
      signalling refresh out-of-band interval 3600
      signalling refresh out-of-band missed 24
    !
  !
  mpls traffic-eng
    gmpls optical-uni
      controller dwdm 0/1/0/1
      !
    !
  !
  lmp
    gmpls optical-uni
      router-id 100.20.20.20
      neighbor nbr_B
        ipcc routed
        neighbor router-id ipv4 unicast 100.19.19.19
      !
      controller dwdm 0/1/0/1
        neighbor nbr_B
        link-id ipv4 unicast 192.168.103.2
        neighbor link-id ipv4 unicast 192.168.103.1
        neighbor interface-id unnumbered 22
      !
```

LSP Diversity

This example shows the configuration for two diverse LSPs:

```
mpls traffic-eng
   attribute-set xro exclude-tun1
    exclude best-effort lsp source 88.0.0.8 destination 10.0.0.2 tunnel-id 1
extended-tunnel-id 88.0.0.8
```

```
   !
  attribute-set xro exclude-tun2
   exclude strict lsp source 88.0.0.8 destination 10.0.1.2 tunnel-id 2 extended-tunnel-id
88.0.0.8 lsp-id 2
   !
  gmpls optical-uni
   controller dwdm 0/1/0/0
    tunnel-properties
     logging events lsp-status state
     tunnel-id 1
     destination ipv4 unicast 10.0.0.2
     path-option 10 no-ero xro-attribute-set exclude-tun2
    !
   !
   controller dwdm 0/1/0/1
    tunnel-properties
     logging events lsp-status state
     tunnel-id 2
     destination ipv4 unicast 10.0.1.2
     path-option 10 no-ero xro-attribute-set exclude-tun1
    !
   !
```

Additional References

Standards

Standard	Title
OIF UNI 1.0	*User Network Interface (UNI) 1.0 Signaling Specification*

Standards

Standard	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 3471	*Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description*
RFC 3473	*Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions*
RFC 4208	*Generalized Multiprotocol Label Switching (GMPLS) User-Network Interface (UNI): Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Support for the Overlay Model*
RFC 4872	*RSVP-TE Extensions in Support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS) Recovery*
RFC 4874	*Exclude Routes - Extension to Resource ReserVation Protocol-Traffic Engineering (RSVP-TE)*
RFC 6205	*Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers*

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