



Segment Routing Configuration Guide for Cisco NCS 6000 Series Routers, IOS XR Release 6.1.x

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Preface

The *Segment Routing Configuration Guide for Cisco NCS 6000 Series Routers* preface contains these sections:

- [Changes to This Document, on page vii](#)
- [Communications, Services, and Additional Information, on page vii](#)

Changes to This Document



Note This document contains features for IOS XR Release 6.1.x and earlier.

This table lists the changes made to this document since it was first printed.

Date	Change Summary
November 2016	Initial release of this document.

Communications, Services, and Additional Information

- To receive timely, relevant information from Cisco, sign up at [Cisco Profile Manager](#).
- To get the business impact you're looking for with the technologies that matter, visit [Cisco Services](#).
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CHAPTER 1

About Segment Routing

This chapter introduces the concept of segment routing and provides a workflow for configuring segment routing.

- [Scope, on page 1](#)
- [Need, on page 2](#)
- [Benefits, on page 2](#)
- [Workflow for Deploying Segment Routing, on page 3](#)

Scope

Segment routing is a method of forwarding packets on the network based on the source routing paradigm. The source chooses a path and encodes it in the packet header as an ordered list of segments. Segments are an identifier for any type of instruction. For example, topology segments identify the next hop toward a destination. Each segment is identified by the segment ID (SID) consisting of a flat unsigned 20-bit integer.

Segments

Interior gateway protocol (IGP) distributes two types of segments: prefix segments and adjacency segments. Each router (node) and each link (adjacency) has an associated segment identifier (SID).

- A prefix SID is associated with an IP prefix. The prefix SID is manually configured from the segment routing global block (SRGB) range of labels, and is distributed by IS-IS or OSPF. The prefix segment steers the traffic along the shortest path to its destination. A node SID is a special type of prefix SID that identifies a specific node. It is configured under the loopback interface with the loopback address of the node as the prefix.

A prefix segment is a global segment, so a prefix SID is globally unique within the segment routing domain.

- An adjacency segment is identified by a label called an adjacency SID, which represents a specific adjacency, such as egress interface, to a neighboring router. The adjacency SID is distributed by IS-IS or OSPF. The adjacency segment steers the traffic to a specific adjacency.

An adjacency segment is a local segment, so the adjacency SID is locally unique relative to a specific router.

By combining prefix (node) and adjacency segment IDs in an ordered list, any path within a network can be constructed. At each hop, the top segment is used to identify the next hop. Segments are stacked in order at

the top of the packet header. When the top segment contains the identity of another node, the receiving node uses equal cost multipaths (ECMP) to move the packet to the next hop. When the identity is that of the receiving node, the node pops the top segment and performs the task required by the next segment.

Dataplane

Segment routing can be directly applied to the Multiprotocol Label Switching (MPLS) architecture with no change in the forwarding plane. A segment is encoded as an MPLS label. An ordered list of segments is encoded as a stack of labels. The segment to process is on the top of the stack. The related label is popped from the stack, after the completion of a segment.

Services

Segment Routing integrates with the rich multi-service capabilities of MPLS, including Layer 3 VPN (L3VPN), Virtual Private Wire Service (VPWS), Virtual Private LAN Service (VPLS), and Ethernet VPN (EVPN).

Segment Routing for Traffic Engineering

Segment routing for traffic engineering (SR-TE) takes place through a between a source and destination pair. Segment routing for traffic engineering uses the concept of source routing, where the source calculates the path and encodes it in the packet header as a segment. Each segment is an end-to-end path from the source to the destination, and instructs the routers in the provider core network to follow the specified path instead of the shortest path calculated by the IGP. The destination is unaware of the presence of the .

Need

With segment routing for traffic engineering (SR-TE), the network no longer needs to maintain a per-application and per-flow state. Instead, it simply obeys the forwarding instructions provided in the packet.

SR-TE utilizes network bandwidth more effectively than traditional MPLS-TE networks by using ECMP at every segment level. It uses a single intelligent source and relieves remaining routers from the task of calculating the required path through the network.

Benefits

- **Ready for SDN:** Segment routing was built for SDN and is the foundation for Application Engineered Routing (AER). SR prepares networks for business models, where applications can direct network behavior. SR provides the right balance between distributed intelligence and centralized optimization and programming.
- **Minimal configuration:** Segment routing for TE requires minimal configuration on the source router.
- **Load balancing:** Unlike in RSVP-TE, load balancing for segment routing can take place in the presence of equal cost multiple paths (ECMPs).
- **Supports Fast Reroute (FRR):** Fast reroute enables the activation of a pre-configured backup path within 50 milliseconds of path failure.
- **Plug-and-Play deployment:** Segment routing are interoperable with existing MPLS control and data planes and can be implemented in an existing deployment.

Workflow for Deploying Segment Routing

Follow this workflow to deploy segment routing.

1. Configure the Segment Routing Global Block (SRGB)
2. Enable Segment Routing and Node SID on the IGP
3. Configure Segment Routing on the BGP
4. Configure the SR-TE Policy
5. Configure TI-LFA
6. Configure the Segment Routing Mapping Server
7. Collect Traffic Statistics



CHAPTER 2

Configure Segment Routing Global Block

Local label allocation is managed by the label switching database (LSD). The Segment Routing Global Block (SRGB) is the range of label values preserved for segment routing in the LSD.

- [About the Segment Routing Global Block, on page 5](#)
- [Setup a Non-Default Segment Routing Global Block Range, on page 6](#)

About the Segment Routing Global Block

The SRGB label values are assigned as prefix segment identifiers (SIDs) to SR-enabled nodes and have global significance throughout the domain.



Note Because the values assigned from the range have domain-wide significance, we recommend that all routers within the domain be configured with the same range of values.

The default SRGB range is from 16000 to 23999.



Note On SR-capable routers, the default starting value of the dynamic label range is increased from 16000 to 24000, so that the default SRGB label values (16000 to 23999) are available when SR is enabled on a running system. If a dynamic label range has been configured with a starting value of 16000, then the default SRGB label values may already be in use when SR is enabled on a running system. Therefore, you must reload the router after enabling SR to release the currently allocated labels and allocate the SRGB.

Also, if you need to increase the SRGB range after you have enabled SR, you must reload the router to release the currently allocated labels and allocate the new SRGB.

To keep the segment routing configuration simple and to make it easier to troubleshoot segment routing issues, we recommend that you use the default SRGB range on each node in the domain. However, there are instances when you might need to define a different range. For example:

- The nodes of another vendor support a label range that is different from the default SRGB, and you want to use the same SRGB on all nodes.
- The default range is too small.
- To specify separate SRGBs for IS-IS and OSPF protocols, as long as the ranges do not overlap.

Restrictions:

- In Cisco IOS XR release 6.2.x and earlier, LSD label values 0-15999 are reserved.
- In Cisco IOS XR release 6.2.x and earlier, the maximum SRGB size is 65536.
- The SRGB upper bound cannot exceed the platform's capability.



Note Label values that are not previously reserved are available for dynamic assignment.

The SRGB can be disabled if SR is not used.

Setup a Non-Default Segment Routing Global Block Range

This task explains how to configure a non-default SRGB range.

SUMMARY STEPS

1. **configure**
2. `[router {isis instance-id | ospf process_name}]`
3. `segment-routing global-block starting_value ending_value`
4. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	<code>configure</code>	
Step 2	<code>[router {isis <i>instance-id</i> ospf <i>process_name</i>}]</code> Example: <pre>RP/0/RP0/CPU0:router(config)# router isis 1</pre>	(Optional) Enter the router isis <i>instance-id</i> or router ospf <i>process_name</i> commands if you want to configure separate SRGBs for IS-IS and OSPF protocols.
Step 3	<code>segment-routing global-block <i>starting_value ending_value</i></code> Example: <pre>RP/0/RP0/CPU0:router(config-isis)# segment-routing global-block 18000 19999</pre>	Enter the lowest value that you want the SRGB range to include as the starting value. Enter the highest value that you want the SRGB range to include as the ending value.
Step 4	<code>commit</code>	

Verify the SRGB configuration:

```
RP/0/RP0/CPU0:router# show mpls label table detail
Table Label  Owner                               State Rewrite
-----
-----
```

```
<...snip...>
0      18000  ISIS(A):1                InUse  No
      Lbl-blk SRGB, vers:0, (start_label=18000, size=2000)
0      24000  ISIS(A):1                InUse  Yes
      (SR Adj Segment IPv4, vers:0, index=1, type=0, intf=Gi0/0/0/0, nh=10.0.0.2)
```

What to do next

Configure prefix SIDs and enable segment routing.

Setup a Non-Default Segment Routing Global Block Range



CHAPTER 3

Configure Segment Routing for IS-IS Protocol

Integrated Intermediate System-to-Intermediate System (IS-IS), Internet Protocol Version 4 (IPv4), is a standards-based Interior Gateway Protocol (IGP). The Cisco IOS XR software implements the IP routing capabilities described in International Organization for Standardization (ISO)/International Engineering Consortium (IEC) 10589 and RFC 1995, and adds the standard extensions for single topology and multitopology IS-IS for IP Version 6 (IPv6).

This module provides the configuration information used to enable segment routing for IS-IS.



Note For additional information on implementing IS-IS on your Cisco NCS 6000 Series Routers, see the *Implementing IS-IS* module in the *Routing Configuration Guide for Cisco NCS 6000 Series Routers*.

- [Enabling Segment Routing for IS-IS Protocol, on page 9](#)
- [Configuring a Prefix-SID on the IS-IS Enabled Loopback Interface, on page 11](#)

Enabling Segment Routing for IS-IS Protocol

Segment routing on the IS-IS control plane supports the following:

- IPv4 and IPv6 control plane
- Level 1, level 2, and multi-level routing
- Prefix SIDs for host prefixes on loopback interfaces
- Adjacency SIDs for adjacencies
- MPLS penultimate hop popping (PHP) and explicit-null signaling

This task explains how to enable segment routing for IS-IS.

Before you begin

Your network must support the MPLS Cisco IOS XR software feature before you enable segment routing for IS-IS on your router.



Note You must enter the commands in the following task list on every IS-IS router in the traffic-engineered portion of your network.

SUMMARY STEPS

1. **configure**
2. **router isis** *instance-id*
3. **address-family** { **ipv4** | **ipv6** } [**unicast**]
4. **metric-style wide** [**level** { **1** | **2** }]
5. **mpls traffic-eng** *level*
6. **mpls traffic-eng router-id** *interface*
7. **router-id loopback** *loopback interface used for prefix-sid*
8. **segment-routing mpls**
9. **exit**
10. **mpls traffic-eng**
11. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router isis <i>instance-id</i> Example: RP/0/RP0/CPU0:router(config)# router isis <i>isp</i>	Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode. Note You can change the level of routing to be performed by a particular routing instance by using the is-type router configuration command.
Step 3	address-family { ipv4 ipv6 } [unicast] Example: RP/0/RP0/CPU0:router(config-isis)# address-family ipv4 unicast	Specifies the IPv4 or IPv6 address family, and enters router address family configuration mode.
Step 4	metric-style wide [level { 1 2 }] Example: RP/0/RP0/CPU0:router(config-isis-af)# metric-style wide level 1	Configures a router to generate and accept only wide link metrics in the Level 1 area.
Step 5	mpls traffic-eng <i>level</i> Example: RP/0/RP0/CPU0:router(config-isis-af)# mpls traffic-eng level-2-only	Enables RSVP traffic engineering functionality.

	Command or Action	Purpose
Step 6	mpls traffic-eng router-id <i>interface</i> Example: RP/0/RP0/CPU0:router(config-isis-af)# mpls traffic-eng router-id Loopback0	Sets the traffic engineering loopback interface.
Step 7	router-id loopback <i>loopback interface used for prefix-sid</i> Example: RP/0/(config-isis-af)#router-id loopback0	Configures router ID for each address-family (ipv4/ipv6).
Step 8	segment-routing mpls Example: RP/0/RP0/CPU0:router(config-isis-af)# segment-routing mpls	Segment routing is enabled by the following actions: <ul style="list-style-type: none"> • MPLS forwarding is enabled on all interfaces where IS-IS is active. • All known prefix-SIDs in the forwarding plain are programmed, with the prefix-SIDs advertised by remote routers or learned through local or remote mapping server. • The prefix-SIDs locally configured are advertised.
Step 9	exit Example: RP/0/RP0/CPU0:router(config-isis-af)# exit RP/0/RP0/CPU0:router(config-isis)# exit	
Step 10	mpls traffic-eng Example: RP/0/RP0/CPU0:router(config)# mpls traffic-eng	Enables traffic engineering functionality on the node. The node advertises the traffic engineering link attributes in IGP which populates the traffic engineering database (TED) on the head-end. The RSVP-TE head-end requires the TED to calculate and validate the path of the RSVP-TE policy.
Step 11	commit	

What to do next

Configure the prefix SID.

Configuring a Prefix-SID on the IS-IS Enabled Loopback Interface

A prefix segment identifier (SID) is associated with an IP prefix. The prefix SID is manually configured from the segment routing global block (SRGB) range of labels. A prefix SID is configured under the loopback

interface with the loopback address of the node as the prefix. The prefix segment steers the traffic along the shortest path to its destination.

A prefix SID can be a node SID or an Anycast SID. A node SID is a type of prefix SID that identifies a specific node. An Anycast SID is a type of prefix SID that identifies a set of nodes, and is configured with n-flag clear. The set of nodes (Anycast group) is configured to advertise a shared prefix address and prefix SID. Anycast routing enables the steering of traffic toward multiple advertising nodes. Packets addressed to an Anycast address are forwarded to the topologically nearest nodes.

The prefix SID is globally unique within the segment routing domain.

This task explains how to configure prefix segment identifier (SID) index or absolute value on the IS-IS enabled Loopback interface.

Before you begin

Ensure that segment routing is enabled on the corresponding address family.

SUMMARY STEPS

1. **configure**
2. **router isis** *instance-id*
3. **interface** **Loopback** *instance*
4. **address-family** { **ipv4** | **ipv6** } [**unicast**]
5. **prefix-sid** {**index** *SID-index* | **absolute** *SID-value*} [**n-flag-clear**] [**explicit-null**]
6. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router isis <i>instance-id</i> Example: RP/0/RP0/CPU0:router(config)# router isis 1	Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode. <ul style="list-style-type: none"> • You can change the level of routing to be performed by a particular routing instance by using the is-type router configuration command.
Step 3	interface Loopback <i>instance</i> Example: RP/0/RP0/CPU0:router(config-isis)# interface Loopback0	Specifies the loopback interface and instance.
Step 4	address-family { ipv4 ipv6 } [unicast] Example: The following is an example for ipv4 address family: RP/0/RP0/CPU0:router(config-isis-if)# address-family ipv4 unicast	Specifies the IPv4 or IPv6 address family, and enters router address family configuration mode.

	Command or Action	Purpose
Step 5	<p>prefix-sid {<i>index SID-index</i> <i>absolute SID-value</i>} [n-flag-clear] [explicit-null]</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-if-af)# prefix-sid index 1001</pre> <pre>RP/0/RP0/CPU0:router(config-isis-if-af)# prefix-sid absolute 17001</pre>	<p>Configures the prefix-SID index or absolute value for the interface.</p> <p>Specify index <i>SID-index</i> for each node to create a prefix SID based on the lower boundary of the SRGB + the index.</p> <p>Specify absolute <i>SID-value</i> for each node to create a specific prefix SID within the SRGB.</p> <p>By default, the n-flag is set on the prefix-SID, indicating that it is a node SID. For specific prefix-SID (for example, Anycast prefix-SID), enter the <code>n-flag-clear</code> keyword. IS-IS does not set the N flag in the prefix-SID sub Type Length Value (TLV).</p> <p>To disable penultimate-hop-popping (PHP) and add explicit-Null label, enter <code>explicit-null</code> keyword. IS-IS sets the E flag in the prefix-SID sub TLV.</p>
Step 6	commit	

Verify the prefix-SID configuration:

```
RP/0/RP0/CPU0:router# show isis database verbose

IS-IS 1 (Level-2) Link State Database
LSPID          LSP Seq Num  LSP Checksum  LSP Holdtime  ATT/P/OL
router.00-00   * 0x0000039b  0xfc27        1079          0/0/0
  Area Address: 49.0001
  NLPID:        0xcc
  NLPID:        0x8e
  MT:           Standard (IPv4 Unicast)
  MT:           IPv6 Unicast                      0/0/0
  Hostname:     router
  IP Address:   10.0.0.1
  IPv6 Address: 2001:0db8:1234::0a00:0001
  Router Cap:  10.0.0.1, D:0, S:0
  Segment Routing: I:1 V:1, SRGB Base: 16000 Range: 8000
  SR Algorithm:
    Algorithm: 0

<...>
Metric: 0          IP-Extended 10.0.0.1/32
Prefix-SID Index: 1001, Algorithm:0, R:0 N:1 P:0 E:0 V:0 L:0

<...>
```

What to do next

Configure the SR-TE policy.



CHAPTER 4

Configure Segment Routing for OSPF Protocol

Open Shortest Path First (OSPF) is an Interior Gateway Protocol (IGP) developed by the OSPF working group of the Internet Engineering Task Force (IETF). Designed expressly for IP networks, OSPF supports IP subnetting and tagging of externally derived routing information. OSPF also allows packet authentication and uses IP multicast when sending and receiving packets.

This module provides the configuration information to enable segment routing for OSPF.



Note For additional information on implementing OSPF on your Cisco NCS 6000 Series Routers, see the *Implementing OSPF* module in the *Routing Configuration Guide for Cisco NCS 6000 Series Routers*.

- [Enabling Segment Routing for OSPF Protocol, on page 15](#)
- [Configuring a Prefix-SID on the OSPF-Enabled Loopback Interface, on page 17](#)

Enabling Segment Routing for OSPF Protocol

Segment routing on the OSPF control plane supports the following:

- OSPFv2 control plane
- Multi-area
- IPv4 prefix SIDs for host prefixes on loopback interfaces
- Adjacency SIDs for adjacencies
- MPLS penultimate hop popping (PHP) and explicit-null signaling

This section describes how to enable segment routing MPLS and MPLS forwarding in OSPF. Segment routing can be configured at the instance, area, or interface level.

Before you begin

Your network must support the MPLS Cisco IOS XR software feature before you enable segment routing for OSPF on your router.



Note You must enter the commands in the following task list on every OSPF router in the traffic-engineered portion of your network.

SUMMARY STEPS

1. **configure**
2. **router ospf** *process-name*
3. **segment-routing mpls**
4. **area 0**
5. **mpls traffic-eng** *area*
6. **mpls traffic-eng router-id** *interface*
7. **segment-routing mpls**
8. **exit**
9. **mpls traffic-eng**
10. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router ospf <i>process-name</i> Example: RP/0/RP0/CPU0:router(config)# router ospf 1	Enables OSPF routing for the specified routing process and places the router in router configuration mode.
Step 3	segment-routing mpls Example: RP/0/RP0/CPU0:router(config-ospf)# segment-routing mpls	Enables segment routing using the MPLS data plane on the routing process and all areas and interfaces in the routing process. Enables segment routing forwarding on all interfaces in the routing process and installs the SIDs received by OSPF in the forwarding table.
Step 4	area 0 Example: RP/0/RP0/CPU0:router(config-ospf)# area 0	Enters area configuration mode.
Step 5	mpls traffic-eng <i>area</i> Example: RP/0/RP0/CPU0:router(config-ospf-ar)# mpls traffic-eng area 0	Enables IGP traffic engineering functionality.
Step 6	mpls traffic-eng router-id <i>interface</i> Example:	Sets the traffic engineering loopback interface.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router (config-ospf-ar) # mpls traffic-eng router-id Loopback0	
Step 7	segment-routing mpls Example: RP/0/RP0/CPU0:router (config-ospf-ar) # segment-routing mpls	(Optional) Enables segment routing using the MPLS data plane on the area and all interfaces in the area. Enables segment routing forwarding on all interfaces in the area and installs the SIDs received by OSPF in the forwarding table.
Step 8	exit Example: RP/0/RP0/CPU0:router (config-ospf-ar) # exit RP/0/RP0/CPU0:router (config-ospf) # exit	
Step 9	mpls traffic-eng Example: RP/0/RP0/CPU0:router (config) # mpls traffic-eng	Enables traffic engineering functionality on the node. The node advertises the traffic engineering link attributes in IGP which populates the traffic engineering database (TED) on the head-end. The SR-TE head-end requires the TED to calculate and validate the path of the SR-TE policy.
Step 10	commit	

What to do next

Configure the prefix SID.

Configuring a Prefix-SID on the OSPF-Enabled Loopback Interface

A prefix segment identifier (SID) is associated with an IP prefix. The prefix SID is manually configured from the segment routing global block (SRGB) range of labels. A prefix SID is configured under the loopback interface with the loopback address of the node as the prefix. The prefix segment steers the traffic along the shortest path to its destination.

A prefix SID can be a node SID or an Anycast SID. A node SID is a type of prefix SID that identifies a specific node. An Anycast SID is a type of prefix SID that identifies a set of nodes, and is configured with n-flag clear. The set of nodes (Anycast group) is configured to advertise a shared prefix address and prefix SID. Anycast routing enables the steering of traffic toward multiple advertising nodes. Packets addressed to an Anycast address are forwarded to the topologically nearest nodes.

The prefix SID is globally unique within the segment routing domain.

This task describes how to configure prefix segment identifier (SID) index or absolute value on the OSPF-enabled Loopback interface.

Before you begin

Ensure that segment routing is enabled on an instance, area, or interface.

SUMMARY STEPS

1. **configure**
2. **router ospf** *process-name*
3. **area** *value*
4. **interface Loopback** *interface-instance*
5. **prefix-sid** {*index SID-index* | *absolute SID-value* } [**n-flag-clear**] [**explicit-null**]
6. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router ospf <i>process-name</i> Example: RP/0/RP0/CPU0:router(config)# router ospf 1	Enables OSPF routing for the specified routing process, and places the router in router configuration mode.
Step 3	area <i>value</i> Example: RP/0/RP0/CPU0:router(config-ospf)# area 0	Enters area configuration mode.
Step 4	interface Loopback <i>interface-instance</i> Example: RP/0/RP0/CPU0:router(config-ospf-ar)# interface Loopback0 passive	Specifies the loopback interface and instance.
Step 5	prefix-sid { <i>index SID-index</i> <i>absolute SID-value</i> } [n-flag-clear] [explicit-null] Example: RP/0/RP0/CPU0:router(config-ospf-ar)# prefix-sid index 1001 RP/0/RP0/CPU0:router(config-ospf-ar)# prefix-sid absolute 17001	Configures the prefix-SID index or absolute value for the interface. Specify index <i>SID-index</i> for each node to create a prefix SID based on the lower boundary of the SRGB + the index. Specify absolute <i>SID-value</i> for each node to create a specific prefix SID within the SRGB. By default, the n-flag is set on the prefix-SID, indicating that it is a node SID. For specific prefix-SID (for example, Anycast prefix-SID), enter the n-flag-clear keyword. OSPF does not set the N flag in the prefix-SID sub Type Length Value (TLV). To disable penultimate-hop-popping (PHP) and add an explicit-Null label, enter the explicit-null keyword. OSPF sets the E flag in the prefix-SID sub TLV.
Step 6	commit	

Verify the prefix-SID configuration:

```
RP/0/RP0/CPU0:router# show ospf database opaque-area 7.0.0.1 self-originate
  OSPF Router with ID (10.0.0.1) (Process ID 1)
    Type-10 Opaque Link Area Link States (Area 0)
<...>
  Extended Prefix TLV: Length: 20
    Route-type: 1
    AF          : 0
    Flags       : 0x40
    Prefix      : 10.0.0.1/32

  SID sub-TLV: Length: 8
    Flags       : 0x0
    MTID        : 0
    Algo        : 0
    SID Index  : 1001
```

What to do next

[Configure SR-TE Policies](#)



CHAPTER 5

Configure Segment Routing for BGP

Border Gateway Protocol (BGP) is an Exterior Gateway Protocol (EGP) that allows you to create loop-free inter-domain routing between autonomous systems. An autonomous system is a set of routers under a single technical administration. Routers in an autonomous system can use multiple Interior Gateway Protocols (IGPs) to exchange routing information inside the autonomous system and an EGP to route packets outside the autonomous system.

This module provides the configuration information used to enable Segment Routing for BGP.



Note For additional information on implementing BGP on your Cisco NCS 6000 Series Routers, see the *Implementing BGP* module in the *Routing Configuration Guide for Cisco NCS 6000 Series Routers*.

- [Segment Routing for BGP, on page 21](#)
- [Configure BGP Prefix Segment Identifiers, on page 22](#)
- [Configure Segment Routing Egress Peer Engineering, on page 23](#)
- [Configure BGP Link-State, on page 24](#)
- [Example: Configuring SR-EPE and BGP-LS, on page 25](#)

Segment Routing for BGP

In a traditional BGP-based data center (DC) fabric, packets are forwarded hop-by-hop to each node in the autonomous system. Traffic is directed only along the external BGP (eBGP) multipath ECMP. No traffic engineering is possible.

In an MPLS-based DC fabric, the eBGP sessions between the nodes exchange BGP labeled unicast (BGP-LU) network layer reachability information (NLRI). An MPLS-based DC fabric allows any leaf (top-of-rack or border router) in the fabric to communicate with any other leaf using a single label, which results in higher packet forwarding performance and lower encapsulation overhead than traditional BGP-based DC fabric. However, since each label value might be different for each hop, an MPLS-based DC fabric is more difficult to troubleshoot and more complex to configure.

BGP has been extended to carry segment routing prefix-SID index. BGP-LU helps each node learn BGP prefix SIDs of other leaf nodes and can use ECMP between source and destination. Segment routing for BGP simplifies the configuration, operation, and troubleshooting of the fabric. With segment routing for BGP, you can enable traffic steering capabilities in the data center using a BGP prefix SID.

Configure BGP Prefix Segment Identifiers

Segments associated with a BGP prefix are known as BGP prefix SIDs. The BGP prefix SID is global within a segment routing or BGP domain. It identifies an instruction to forward the packet over the ECMP-aware best-path computed by BGP to the related prefix. The BGP prefix SID is manually configured from the segment routing global block (SRGB) range of labels.

Each BGP speaker must be configured with an SRGB using the **segment-routing global-block** command. See the [About the Segment Routing Global Block](#) section for information about the SRGB.



Note Because the values assigned from the range have domain-wide significance, we recommend that all routers within the domain be configured with the same range of values.

To assign a BGP prefix SID, first create a routing policy using the **set label-index** *index* attribute, then associate the index to the node.



Note A routing policy with the **set label-index** attribute can be attached to a network configuration or redistribute configuration. Other routing policy language (RPL) configurations are possible. For more information on routing policies, refer to the "Implementing Routing Policy" chapter in the *Routing Configuration Guide for Cisco NCS 6000 Series Routers*.

Example

The following example shows how to configure the SRGB, create a BGP route policy using a \$SID parameter and **set label-index** attribute, and then associate the prefix-SID index to the node.

```
RP/0/RSP0/CPU0:router(config)# segment-routing global-block 16000 23999

RP/0/RSP0/CPU0:router(config)# route-policy SID($SID)
RP/0/RSP0/CPU0:router(config-rpl)# set label-index $SID
RP/0/RSP0/CPU0:router(config-rpl)# end policy

RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# bgp router-id 1.1.1.1
RP/0/RSP0/CPU0:router(config-bgp)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-af)# network 1.1.1.3/32 route-policy SID(3)
RP/0/RSP0/CPU0:router(config-bgp-af)# allocate-label all
RP/0/RSP0/CPU0:router(config-bgp-af)# commit
RP/0/RSP0/CPU0:router(config-bgp-af)# end

RP/0/RSP0/CPU0:router# show bgp 1.1.1.3/32
BGP routing table entry for 1.1.1.3/32
Versions:
  Process          bRIB/RIB   SendTblVer
  Speaker          74         74
  Local Label: 16003
Last Modified: Sep 29 19:52:18.155 for 00:07:22
Paths: (1 available, best #1)
  Advertised to update-groups (with more than one peer):
    0.2
```

```

Path #1: Received by speaker 0
Advertised to update-groups (with more than one peer):
  0.2
  3
    99.3.21.3 from 99.3.21.3 (1.1.1.3)
      Received Label 3
      Origin IGP, metric 0, localpref 100, valid, external, best, group-best
      Received Path ID 0, Local Path ID 1, version 74
      Origin-AS validity: not-found
      Label Index: 3

```

Configure Segment Routing Egress Peer Engineering

Segment routing egress peer engineering (EPE) uses a controller to instruct an ingress provider edge, or a content source (node) within the segment routing domain, to use a specific egress provider edge (node) and a specific external interface to reach a destination. BGP peer SIDs are used to express source-routed inter-domain paths.

The controller learns the BGP peer SIDs and the external topology of the egress border router through BGP-LS EPE routes. The controller can program an ingress node to steer traffic to a destination through the egress node and peer node using BGP labeled unicast (BGP-LU).

EPE functionality is only required at the EPE egress border router and the EPE controller.

This task explains how to configure segment routing EPE on the EPE egress node.

SUMMARY STEPS

1. **router** *bgp as-number*
2. **neighbor** *ip-address*
3. **remote-as** *as-number*
4. **egress-engineering**

DETAILED STEPS

	Command or Action	Purpose
Step 1	router <i>bgp as-number</i> Example: RP/0/RSP0/CPU0:router(config)# router <i>bgp 1</i>	Specifies the BGP AS number and enters the BGP configuration mode, allowing you to configure the BGP routing process.
Step 2	neighbor <i>ip-address</i> Example: RP/0/RSP0/CPU0:router(config-bgp)# neighbor <i>192.168.1.3</i>	Places the router in neighbor configuration mode for BGP routing and configures the neighbor IP address as a BGP peer.
Step 3	remote-as <i>as-number</i> Example:	Creates a neighbor and assigns a remote autonomous system number to it.

	Command or Action	Purpose
	RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 3	
Step 4	egress-engineering Example: RP/0/RSP0/CPU0:router(config-bgp-nbr)# egress-engineering	Configures the egress node with EPE for the eBGP peer.

Configure BGP Link-State

BGP Link-State (LS) is an Address Family Identifier (AFI) and Sub-address Family Identifier (SAFI) defined to carry interior gateway protocol (IGP) link-state database through BGP. BGP LS delivers network topology information to topology servers and Application Layer Traffic Optimization (ALTO) servers. BGP LS allows policy-based control to aggregation, information-hiding, and abstraction. BGP LS supports IS-IS and OSPFv2.



Note IGPs do not use BGP LS data from remote peers. BGP does not download the received BGP LS data to any other component on the router.

For segment routing, the following attributes have been added to BGP LS:

- Node—Segment routing capability (including SRGB range) and algorithm
- Link—Adjacency SID and LAN adjacency SID
- Prefix—Prefix SID and segment routing mapping server (SRMS) prefix range

The following example shows how to exchange link-state information with a BGP neighbor:

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# neighbor 10.0.0.2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 1
RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family link-state link-state
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# exit
```

IGP Extensions

A given BGP node may have connections to multiple, independent routing domains; IGP link state distribution into BGP has been added for both OSPF and ISIS protocols to enable that node to pass this information, in a similar fashion, on to applications that desire to build paths spanning or including these multiple domains.

To distribute ISIS link-state data using BGP LS, use the **distribute bgp-ls** command in router configuration mode.

```
RP/0/RSP0/CPU0:router# configure
```



```
RP/0/RSP0/CPU0:router(config)# router isis isp
RP/0/RSP0/CPU0:router(config-isis)# distribute bgp-ls instance-id 32 level 2 throttle 5
```

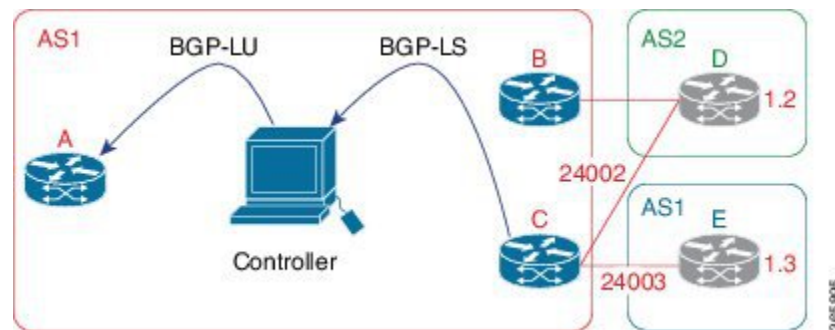
To distribute OSPFv2 and OSPFv3 link-state data using BGP LS, use the **distribute bgp-ls** command in router configuration mode.

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router ospf 100
RP/0/RSP0/CPU0:router(config-ospf)# distribute bgp-ls instance-id 32 throttle 10
```

Example: Configuring SR-EPE and BGP-LS

In the following figure, segment routing is enabled on autonomous system AS1 with ingress node A and egress nodes B and C. In this example, we configure EPE on egress node C.

Figure 1: Topology



Step 1 Configure node C with EPE for eBGP peers D and E.

Example:

```
RP/0/RSP0/CPU0:router_C(config)# router bgp 1
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 192.168.1.3
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 3
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to E
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# egress-engineering
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_in in
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_out out
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# exit
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 192.168.1.2
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 2
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to D
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# egress-engineering
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_in in
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# route-policy bgp_out out
RP/0/RSP0/CPU0:router_C(config-bgp-nbr-af)# exit
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
```

Step 2 Configure node C to advertise peer node SIDs to the controller using BGP-LS.

Example: Configuring SR-EPE and BGP-LS

Example:

```
RP/0/RSP0/CPU0:router_C(config-bgp)# neighbor 172.29.50.71
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# remote-as 1
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# description to EPE_controller
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# address-family link-state link-state
RP/0/RSP0/CPU0:router_C(config-bgp-nbr)# exit
RP/0/RSP0/CPU0:router_C(config-bgp)# exit
```

Step 3 Commit the configuration.

Example:

```
RP/0/RSP0/CPU0:router_C(config)# commit
```

Step 4 Verify the configuration.

Example:

```
RP/0/RSP0/CPU0:router_C# show bgp egress-engineering

Egress Engineering Peer Set: 192.168.1.2/32 (10b87210)
  Nexthop: 192.168.1.2
  Version: 2, rn_version: 2
  Flags: 0x00000002
  Local ASN: 1
  Remote ASN: 2
  Local RID: 1.1.1.3
  Remote RID: 1.1.1.4
  First Hop: 192.168.1.2
  NHID: 3
  Label: 24002, Refcount: 3
  rpc_set: 10b9d408

Egress Engineering Peer Set: 192.168.1.3/32 (10be61d4)
  Nexthop: 192.168.1.3
  Version: 3, rn_version: 3
  Flags: 0x00000002
  Local ASN: 1
  Remote ASN: 3
  Local RID: 1.1.1.3
  Remote RID: 1.1.1.5
  First Hop: 192.168.1.3
  NHID: 4
  Label: 24003, Refcount: 3
  rpc_set: 10be6250
```

The output shows that node C has allocated peer SIDs for each eBGP peer.

Example:

```
RP/0/RSP0/CPU0:router_C# show mpls forwarding labels 24002 24003
```

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
24002	Unlabelled	No ID	Te0/3/0/0	192.168.1.2	0
24003	Unlabelled	No ID	Te0/1/0/0	192.168.1.3	0

The output shows that node C installed peer node SIDs in the Forwarding Information Base (FIB).



CHAPTER 6

Configure SR-TE Policies

This module provides information about segment routing for traffic engineering (SR-TE) policies, how to configure SR-TE policies, and how to steer traffic into an SR-TE policy.

- [About SR-TE Policies, on page 29](#)
- [How to Configure SR-TE Policies, on page 29](#)
- [Steering Traffic into an SR-TE Policy, on page 33](#)
- [Using Binding Segments, on page 37](#)

About SR-TE Policies

Segment routing for traffic engineering (SR-TE) uses a “policy” to steer traffic through the network. An SR-TE policy path is expressed as a list of segments that specifies the path, called a segment ID (SID) list. Each segment is an end-to-end path from the source to the destination, and instructs the routers in the network to follow the specified path instead of the shortest path calculated by the IGP. If a packet is steered into an SR-TE policy, the SID list is pushed on the packet by the head-end. The rest of the network executes the instructions embedded in the SID list.

There are two types of SR-TE policies: dynamic and explicit.

Local Dynamic SR-TE Policy

When you configure local dynamic SR-TE, the head-end locally calculates the path to the destination address. Dynamic path calculation results in a list of interface IP addresses that traffic engineering (TE) maps to adj-SID labels. Routes are learned by way of forwarding adjacencies over the TE tunnel.

Explicit SR-TE Policy

An explicit path is a list of IP addresses or labels, each representing a node or link in the explicit path. This feature is enabled through the **explicit-path** command that allows you to create an explicit path and enter a configuration submode for specifying the path.

How to Configure SR-TE Policies

This section contains the following procedures:

- [Configure Local Dynamic SR-TE Policy, on page 30](#)

- [Configure Explicit SR-TE Policy, on page 31](#)

Configure Local Dynamic SR-TE Policy

This task explains how to configure a local dynamic SR-TE policy.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **destination** *ip-address*
5. **path-option** *preference-priority* **dynamic segment-routing**
6. **path-protection**
7. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	interface tunnel-te <i>tunnel-id</i> Example: RP/0/RP0/CPU0:router(config)# interface tunnel-te22	Configures the tunnel interface.
Step 3	ipv4 unnumbered <i>type interface-path-id</i> Example: RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered loopback0	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.
Step 4	destination <i>ip-address</i> Example: RP/0/RP0/CPU0:router(config-if)# destination 192.168.0.2	Assigns a destination address on the new tunnel.
Step 5	path-option <i>preference-priority</i> dynamic segment-routing Example: RP/0/RP0/CPU0:router(config-if)# path-option 1 dynamic segment-routing	Sets the path option to dynamic and assigns the path ID.

	Command or Action	Purpose
Step 6	path-protection Example: <pre>RP/0/RP0/CPU0:router(config-if)# path-protection</pre>	Enables path protection on the tunnel-te interface.
Step 7	commit	

This completes the configuration of the dynamic SR-TE policy.

Configure Explicit SR-TE Policy

This task explains how to configure an explicit SR-TE policy.

SUMMARY STEPS

1. **configure**
2. **explicit-path name** *path-name*
3. **index** *index* { **next-address** *ip-address* | **next-label** *label* }
4. **exit**
5. **interface tunnel-te** *tunnel-id*
6. **ipv4 unnumbered** *type interface-path-id*
7. **destination** *ip-address* [**verbatim**]
8. **path-option** *preference-priority* **explicit name** *path-name* **segment-routing**
9. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	explicit-path name <i>path-name</i> Example: <pre>RP/0/RP0/CPU0:router(config)# explicit-path name rlr6_exp</pre>	Enters a name for the explicit path and enters the explicit path configuration mode.
Step 3	index <i>index</i> { next-address <i>ip-address</i> next-label <i>label</i> } Example:	Specifies a label or an address in an explicit path of a tunnel.

	Command or Action	Purpose
	<pre>RP/0/RP0/CPU0:router(config-expl-path)# index 1 next-label 16001 RP/0/RP0/CPU0:router(config-expl-path)# index 2 next-label 16006</pre>	<p>Note</p> <ul style="list-style-type: none"> You can include multiple addresses, labels, or both. However, you cannot configure addresses after you have configured labels. Once you start configuring labels, you need to continue with labels. Each entry must have a unique index. If the first hop is specified as next-label, that label must be an Adj-SID of the head-end or a prefix-SID label value known by the head-end.
Step 4	exit	
Step 5	<p>interface tunnel-te <i>tunnel-id</i></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config)# interface tunnel-te22</pre>	Configures the tunnel interface.
Step 6	<p>ipv4 unnumbered <i>type interface-path-id</i></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered loopback0</pre>	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.
Step 7	<p>destination <i>ip-address</i> [verbatim]</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-if)# destination 192.168.0.2</pre>	<p>Assigns a destination address on the new tunnel.</p> <p>Typically, the tunnel destination must have a match in the routing information base (RIB). For inter-area or inter-domain policies to destinations that are otherwise not reachable, use the verbatim option to disable the RIB verification on a tunnel destination.</p>
Step 8	<p>path-option <i>preference-priority</i> explicit name <i>path-name</i> segment-routing</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-if)# path-option 1 explicit name rlr6_exp segment-routing</pre>	Specifies the explicit path name and assigns the path ID.
Step 9	commit	

This completes the configuration of the explicit SR-TE policy.

Steering Traffic into an SR-TE Policy

This section describes the following traffic steering methods:

Static Routes

Static routes can use the segment routing tunnel as a next-hop interface. Both IPv4 and IPv6 prefixes can be routed through the tunnel.

A static route to a destination with a prefix-SID removes the IGP-installed SR-forwarding entry of that prefix.

Autoroute Announce

The SR-TE policy can be advertised into an IGP as a next hop by configuring the autoroute announce statement on the source router. The IGP then installs routes in the Routing Information Base (RIB) for shortest paths that involve the tunnel destination. Autoroute announcement of IPv4 prefixes can be carried through either OSPF or IS-IS. Autoroute announcement of IPv6 prefixes can be carried only through IS-IS.

Autoroute Destination

Autoroute destination allows you to automatically route traffic through a segment routing tunnel instead of manually configuring static routes. Multiple autoroute destination addresses can be added in the routing information base (RIB) per tunnel.

Static routes are always added with zero cost metric, which can result in traffic that is mapped on multiple tunnels to always load-balance due to ECMP. This load-balancing may be undesirable when some of those tunnels have sub-optimal paths. With autoroute destination, only the tunnel whose IGP cost to its endpoint is lowest will be considered for carrying traffic.

- **Interaction Between Static Routes and Autoroute Destination**

If there is a manually configured static route to the same destination as a tunnel with autoroute destination enabled, traffic for that destination is load-shared between the static route and the tunnel with autoroute destination enabled.

- **Interaction Between Autoroute Announce and Autoroute Destination**

For intra-area tunnels, if a tunnel is configured with both autoroute announce and autoroute destination, the tunnel is announced to the RIB by both the IGP and the static process. RIBs prefer static routes, not IGP routes, so the autoroute destination features takes precedence over autoroute announce.

Configure Static Routes

This task explains how to configure a static route.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **destination** *ip-address*
5. **path-option** *preference-priority dynamic segment-routing*

6. **exit**
7. **router static**
8. **address-family ipv4 unicast**
9. *prefix mask interface-type interface-instance*
10. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	interface tunnel-te <i>tunnel-id</i> Example: RP/0/RP0/CPU0:router(config)# interface tunnel-te22	Configures the tunnel interface.
Step 3	ipv4 unnumbered <i>type interface-path-id</i> Example: RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered loopback0	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.
Step 4	destination <i>ip-address</i> Example: RP/0/RP0/CPU0:router(config-if)# destination 192.168.0.2	Assigns a destination address on the new tunnel.
Step 5	path-option <i>preference-priority</i> dynamic segment-routing Example: RP/0/RP0/CPU0:router(config-if)# path-option 1 dynamic segment-routing	Sets the path option to dynamic and assigns the path ID.
Step 6	exit	
Step 7	router static Example: RP/0/RP0/CPU0:router(config)# router static	Configures the static route and enters static configuration mode.
Step 8	address-family ipv4 unicast Example:	Enters address family mode.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router(config-static)# address-family ipv4 unicast	
Step 9	<i>prefix mask interface-type interface-instance</i> Example: RP/0/RP0/CPU0:router(config-static-af)# 192.168.0.2/32 tunnel-te22	Specifies the destination prefix is directly reachable through the tunnel interface.
Step 10	commit	

This completes the configuration of the static route.

Configure Autoroute Announce

This task explains how to configure autoroute announce to steer traffic through the SR-TE policy.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te** *tunnel-id*
3. **ipv4 unnumbered** *type interface-path-id*
4. **autoroute announce**
5. **destination** *ip-address*
6. **path-option** *preference-priority* **dynamic segment-routing**
7. **path-protection**
8. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	interface tunnel-te <i>tunnel-id</i> Example: RP/0/RP0/CPU0:router(config)# interface tunnel-te22	Configures the tunnel interface.
Step 3	ipv4 unnumbered <i>type interface-path-id</i> Example: RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered loopback0	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.

	Command or Action	Purpose
Step 4	autoroute announce Example: RP/0/RP0/CPU0:router(config-if)# autoroute announce	Enables messages that notify the neighbor nodes about the routes that are forwarding.
Step 5	destination <i>ip-address</i> Example: RP/0/RP0/CPU0:router(config-if)# destination 192.168.0.2	Assigns a destination address on the new tunnel.
Step 6	path-option <i>preference-priority</i> dynamic segment-routing Example: RP/0/RP0/CPU0:router(config-if)# path-option 1 dynamic segment-routing	Sets the path option to dynamic and assigns the path ID.
Step 7	path-protection Example: RP/0/RP0/CPU0:router(config-if)# path-protection	Enables path protection on the tunnel-te interface.
Step 8	commit	

Configure Autoroute Destination

This task explains how to configure autoroute destination to steer traffic through the SR-TE policy.

SUMMARY STEPS

1. **configure**
2. **interface tunnel-te *tunnel-id***
3. **ipv4 unnumbered *type interface-path-id***
4. **autoroute destination *destination-ip-address***
5. **destination *ip-address***
6. **path-option *preference-priority* dynamic segment-routing**
7. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	

	Command or Action	Purpose
Step 2	interface tunnel-te <i>tunnel-id</i> Example: <pre>RP/0/RP0/CPU0:router(config)# interface tunnel-te22</pre>	Configures the tunnel interface.
Step 3	ipv4 unnumbered <i>type interface-path-id</i> Example: <pre>RP/0/RP0/CPU0:router(config-if)# ipv4 unnumbered loopback0</pre>	Assigns a source address so that forwarding can be performed on the new tunnel. Loopback is commonly used as the interface type.
Step 4	autoroute destination <i>destination-ip-address</i> Example: <pre>RP/0/RP0/CPU0:router(config-if)# autoroute destination 192.168.0.1 RP/0/RP0/CPU0:router(config-if)# autoroute destination 192.168.0.2 (the default route) RP/0/RP0/CPU0:router(config-if)# autoroute destination 192.168.0.3 RP/0/RP0/CPU0:router(config-if)# autoroute destination 192.168.0.4</pre>	(Optional) Adds a route (<i>destination-ip-address</i>) in the RIB with the tunnel as outgoing interface to the tunnel destination.
Step 5	destination <i>ip-address</i> Example: <pre>RP/0/RP0/CPU0:router(config-if)# destination 192.168.0.2</pre>	Assigns a destination address on the new tunnel.
Step 6	path-option <i>preference-priority</i> dynamic segment-routing Example: <pre>RP/0/RP0/CPU0:router(config-if)# path-option 1 dynamic segment-routing</pre>	Sets the path option to dynamic and assigns the path ID.
Step 7	commit	

Using Binding Segments

The binding segment is a local segment identifying an SR-TE policy. Each SR-TE policy is associated with a binding segment ID (BSID). The BSID is a local label that is automatically allocated for each SR-TE policy when the SR-TE policy is instantiated.

BSID can be used to steer traffic into the SR-TE policy and across domain borders, creating seamless end-to-end inter-domain SR-TE policies. Each domain controls its local SR-TE policies; local SR-TE policies can be validated and rerouted if needed, independent from the remote domain's head-end. Using binding segments isolates the head-end from topology changes in the remote domain.

Packets received with a BSID as top label are steered into the SR-TE policy associated with the BSID. When the BSID label is popped, the SR-TE policy's SID list is pushed.

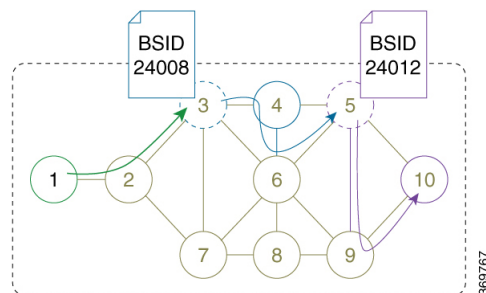
BSID can be used in the following cases:

- Multi-Domain (inter-domain, inter-autonomous system)—BSIDs can be used to steer traffic across domain borders, creating seamless end-to-end inter-domain SR-TE policies.
- Large-Scale within a single domain—The head-end can use hierarchical SR-TE policies by nesting the end-to-end (edge-to-edge) SR-TE policy within another layer of SR-TE policies (aggregation-to-aggregation). The SR-TE policies are nested within another layer of policies using the BSIDs, resulting in seamless end-to-end SR-TE policies.
- Label stack compression—If the label-stack size required for an SR-TE policy exceeds the platform capability, the SR-TE policy can be seamlessly stitched to, or nested within, other SR-TE policies using a binding segment.
- BGP SR-TE Dynamic—The head-end steers the packet into a BGP-based FIB entry whose next hop is a binding-SID.

Stitching SR-TE Polices Using Binding SID: Example

In this intra-domain example, three SR-TE policies are stitched together to form a seamless end-to-end path from node 1 to node 10.

Figure 2: Intra-Domain Topology



Step 1 Configure an SR-TE policy on node 5 to node 10 via node 9. Node 5 automatically allocates a binding-SID (24012) for the SR-TE policy.

Example:

```
RP/0/0/CPU0:xrvr-5(config)# explicit-path name PATH5-9_10
RP/0/0/CPU0:xrvr-5(config-expl-path)# index 10 next-address strict ipv4 unicast 192.168.59.9
RP/0/0/CPU0:xrvr-5(config-expl-path)# index 20 next-address strict ipv4 unicast 10.1.1.10
RP/0/0/CPU0:xrvr-5(config-expl-path)# exit

RP/0/0/CPU0:xrvr-5(config)# interface tunnel-tel
RP/0/0/CPU0:xrvr-5(config-if)# ipv4 unnumbered Loopback0
```

```

RP/0/0/CPU0:xrvr-5(config-if)# destination 10.1.1.10
RP/0/0/CPU0:xrvr-5(config-if)# path-option 1 explicit name PATH5-9_10 segment-routing
RP/0/0/CPU0:xrvr-5(config-if)# commit

RP/0/0/CPU0:xrvr-5# show mpls traffic-eng tunnels 1 detail
Name: tunnel-tel Destination: 10.1.1.10 Ifhandle:0x680
  Signalled-Name: xrvr-5_t1
  Status:
    Admin:    up Oper:    up Path:  valid Signalling: connected
    path option 1, (Segment-Routing) type dynamic (Basis for Setup, path weight 10)
<...>
  Binding SID: 24012
<...>
  Segment-Routing Path Info (IS-IS 1 level-2)
    Segment0[Link]: 192.168.59.5 - 192.168.59.9, Label: 24007
    Segment1[Node]: 10.1.1.10, Label: 16010

```

Step 2

Configure an SR-TE policy on node 3 to node 5 via node 4 and Link4-6, and push the binding-SID of the SR-TE policy at node 5 (24012) to stitch to the SR-TE policy on node 5. Node 3 automatically allocates a binding-SID (24008) for this SR-TE policy.

Example:

```

RP/0/0/CPU0:xrvr-3(config)# explicit-path name PATH4_4-6_5_BSID
RP/0/0/CPU0:xrvr-3(config-expl-path)# index 10 next-address strict ipv4 unicast 10.1.1.4
RP/0/0/CPU0:xrvr-3(config-expl-path)# index 20 next-address strict ipv4 unicast 192.168.46.6
RP/0/0/CPU0:xrvr-3(config-expl-path)# index 30 next-address strict ipv4 unicast 10.1.1.5
RP/0/0/CPU0:xrvr-3(config-expl-path)# index 40 next-label 24012
RP/0/0/CPU0:xrvr-3(config-expl-path)# exit

RP/0/0/CPU0:xrvr-3(config)# interface tunnel-tel
RP/0/0/CPU0:xrvr-3(config-if)# ipv4 unnumbered Loopback0
RP/0/0/CPU0:xrvr-3(config-if)# destination 10.1.1.10
RP/0/0/CPU0:xrvr-3(config-if)# path-option 1 explicit name PATH4_4-6_5_BSID segment-routing
RP/0/0/CPU0:xrvr-3(config-if)# commit

RP/0/0/CPU0:xrvr-3# show mpls traffic-eng tunnels 1 detail
Name: tunnel-tel Destination: 10.1.1.10 Ifhandle:0x780
  Signalled-Name: xrvr-3_t1
  Status:
    Admin:    up Oper:    up Path:  valid Signalling: connected
    path option 1, (Segment-Routing) type explicit PATH4_6_5 (Basis for Setup)
<...>
  Binding SID: 24008
<...>
  Segment-Routing Path Info (IS-IS 1 level-2)
    Segment0[Node]: 10.1.1.4, Label: 16004
    Segment1[Link]: 192.168.46.4 - 192.168.46.6, Label: 24003
    Segment2[Node]: 10.1.1.5, Label: 16005
    Segment3[ - ]: Label: 24012

```

Step 3

Configure an SR-TE policy on node 1 to node 3 and push the binding-SID of the SR-TE policy at node 3 (24008) to stitch to the SR-TE policy on node 3.

Example:

```

RP/0/0/CPU0:xrvr-1(config)# explicit-path name PATH3_BSID
RP/0/0/CPU0:xrvr-1(config-expl-path)# index 10 next-address strict ipv4 unicast 10.1.1.3
RP/0/0/CPU0:xrvr-1(config-expl-path)# index 20 next-label 24008
RP/0/0/CPU0:xrvr-1(config-expl-path)# exit

```

```

RP/0/0/CPU0:xrivr-1(config)# interface tunnel-tel
RP/0/0/CPU0:xrivr-1(config-if)# ipv4 unnumbered Loopback0
RP/0/0/CPU0:xrivr-1(config-if)# destination 10.1.1.10
RP/0/0/CPU0:xrivr-1(config-if)# path-option 1 explicit name PATH3_BSID segment-routing
RP/0/0/CPU0:xrivr-1(config-if)# commit

RP/0/0/CPU0:xrivr-1# show mpls traffic-eng tunnels 1 detail
Name: tunnel-tel Destination: 10.1.1.10 Ifhandle:0x2f80
  Signalled-Name: xrivr-1_t1
  Status:
    Admin: up Oper: up Path: valid Signalling: connected
    path option 1, (Segment-Routing) type explicit PATH3_BSID (Basis for Setup)
<...>
  Binding SID: 24002
<...>
  Segment-Routing Path Info (IS-IS 1 level-2)
    Segment0[Node]: 10.1.1.3, Label: 16003
    Segment1[ - ]: Label: 24008

```

The path is a chain of SR-TE policies stitched together using the binding-SIDs, providing a seamless end-to-end path.

```

RP/0/0/CPU0:xrivr-1# traceroute 10.1.1.10
Type escape sequence to abort.
Tracing the route to 10.1.1.10
 1 99.1.2.2 [MPLS: Labels 16003/24008 Exp 0] 29 msec 19 msec 19 msec
 2 99.2.3.3 [MPLS: Label 24008 Exp 0] 29 msec 19 msec 19 msec
 3 99.3.4.4 [MPLS: Labels 24003/16005/24012 Exp 0] 29 msec 19 msec 19 msec
 4 99.4.6.6 [MPLS: Labels 16005/24012 Exp 0] 29 msec 29 msec 19 msec
 5 99.5.6.5 [MPLS: Label 24012 Exp 0] 29 msec 29 msec 19 msec
 6 99.5.9.9 [MPLS: Label 16010 Exp 0] 19 msec 19 msec 19 msec
 7 99.9.10.10 29 msec 19 msec 19 msec

```




CHAPTER 7

Configure Topology-Independent Loop-Free Alternate (TI-LFA)

Topology-Independent Loop-Free Alternate (TI-LFA) uses segment routing to provide link protection in topologies where other fast reroute techniques cannot provide protection. The goal of TI-LFA is to reduce the packet loss that results while routers converge after a topology change due to a link failure. Rapid failure repair (< 50 msec) is achieved through the use of pre-calculated backup paths that are loop-free and safe to use until the distributed network convergence process is completed.



Note TI-LFA supports IPv4 only.

TI-LFA provides link protection. The link is excluded during the post convergence backup path calculation.

- [Configuring TI-LFA for IS-IS, on page 41](#)
- [Configuring TI-LFA for OSPF, on page 43](#)

Configuring TI-LFA for IS-IS

This task describes how to enable per-prefix Topology Independent Loop-Free Alternate (TI-LFA) computation to converge traffic flows around link failures.

Before you begin

Ensure that the following topology requirements are met:

- Router interfaces are configured as per the topology.
- Routers are configured with IS-IS.
- Segment routing for IS-IS is configured. See [Enabling Segment Routing for IS-IS Protocol, on page 9](#).
- Enter the following commands in global configuration mode:

```
Router(config)# ipv4 unnumbered mpls traffic-eng Loopback0  
Router(config)# mpls traffic-eng  
Router(config-mpls-te)# exit  
Router(config)#
```

SUMMARY STEPS

1. **configure**
2. **router isis *instance-id***
3. **interface *type interface-path-id***
4. **address-family ipv4 [unicast]**
5. **fast-reroute per-prefix**
6. **fast-reroute per-prefix ti-lfa**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router isis <i>instance-id</i> Example: RP/0/RP0/CPU0:router(config)# router isis 1	Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode. Note You can change the level of routing to be performed by a particular routing instance by using the is-type router configuration command.
Step 3	interface <i>type interface-path-id</i> Example: RP/0/RP0/CPU0:router(config-isis)# interface GigabitEthernet0/0/2/1	Enters interface configuration mode.
Step 4	address-family ipv4 [unicast] Example: RP/0/RP0/CPU0:router(config-isis-if)# address-family ipv4 unicast	Specifies the IPv4 address family, and enters router address family configuration mode.
Step 5	fast-reroute per-prefix Example: RP/0/RP0/CPU0:router(config-isis-if-af)# fast-reroute per-prefix	Enables per-prefix fast reroute .
Step 6	fast-reroute per-prefix ti-lfa Example: RP/0/RP0/CPU0:router(config-isis-if-af)# fast-reroute per-prefix ti-lfa	Enables per-prefix TI-LFA fast reroute link protection.

TI-LFA has been successfully configured for segment routing.

Configuring TI-LFA for OSPF

This task describes how to enable per-prefix Topology Independent Loop-Free Alternate (TI-LFA) computation to converge traffic flows around link failures.



Note TI-LFA can be configured on the instance, area, or interface. When configured on the instance or area, all interfaces in the instance or area inherit the configuration.

Before you begin

Ensure that the following topology requirements are met:

- Router interfaces are configured as per the topology.
- Routers are configured with OSPF.
- Segment routing for OSPF is configured. See [Enabling Segment Routing for OSPF Protocol, on page 15](#).
- Enter the following commands in global configuration mode:

```
Router(config)# ipv4 unnumbered mpls traffic-eng Loopback0
Router(config)# mpls traffic-eng
Router(config-mpls-te)# exit
Router(config)#
```

SUMMARY STEPS

1. **configure**
2. **router ospf** *process-name*
3. **area** *area-id*
4. **interface** *type interface-path-id*
5. **fast-reroute per-prefix**
6. **fast-reroute per-prefix ti-lfa**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router ospf <i>process-name</i> Example: RP/0/RP0/CPU0:router(config)# router ospf 1	Enables OSPF routing for the specified routing process, and places the router in router configuration mode.
Step 3	area <i>area-id</i> Example:	Enters area configuration mode.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router (config-ospf) # area 1	
Step 4	interface <i>type interface-path-id</i> Example: RP/0/RP0/CPU0:router (config-ospf-ar) # interface GigabitEthernet0/0/2/1	Enters interface configuration mode.
Step 5	fast-reroute per-prefix Example: RP/0/RP0/CPU0:router (config-ospf-ar-if) # fast-reroute per-prefix	Enables per-prefix fast reroute.
Step 6	fast-reroute per-prefix ti-lfa Example: RP/0/RP0/CPU0:router (config-ospf-ar-if) # fast-reroute per-prefix ti-lfa	Enables per-prefix TI-LFA fast reroute link protection.

TI-LFA has been successfully configured for segment routing.



CHAPTER 8

Configure Segment Routing Mapping Server

The mapping server is a key component of the interworking between LDP and segment routing. It enables SR-capable nodes to interwork with LDP nodes. The mapping server advertises Prefix-to-SID mappings in IGP on behalf of other non-SR-capable nodes.

- [Segment Routing Mapping Server, on page 45](#)
- [Segment Routing and LDP Interoperability, on page 46](#)
- [Configuring Mapping Server, on page 48](#)
- [Enable Mapping Advertisement, on page 50](#)
- [Enable Mapping Client, on page 52](#)

Segment Routing Mapping Server

The mapping server functionality in Cisco IOS XR segment routing centrally assigns prefix-SIDs for some or all of the known prefixes. A router must be able to act as a mapping server, a mapping client, or both.

- A router that acts as a mapping server allows the user to configure SID mapping entries to specify the prefix-SIDs for some or all prefixes. This creates the local SID-mapping policy. The local SID-mapping policy contains non-overlapping SID-mapping entries. The mapping server advertises the local SID-mapping policy to the mapping clients.
- A router that acts as a mapping client receives and parses remotely received SIDs from the mapping server to create remote SID-mapping entries.
- A router that acts as a mapping server and mapping client uses the remotely learnt and locally configured mapping entries to construct the non-overlapping consistent active mapping policy. IGP instance uses the active mapping policy to calculate the prefix-SIDs of some or all prefixes.

The mapping server automatically manages the insertions and deletions of mapping entries to always yield an active mapping policy that contains non-overlapping consistent SID-mapping entries.

- Locally configured mapping entries must not overlap each other.
- The mapping server takes the locally configured mapping policy, as well as remotely learned mapping entries from a particular IGP instance, as input, and selects a single mapping entry among overlapping mapping entries according to the preference rules for that IGP instance. The result is an active mapping policy that consists of non-overlapping consistent mapping entries.
- At steady state, all routers, at least in the same area or level, must have identical active mapping policies.

Segment Routing Mapping Server Restrictions

- The position of the mapping server in the network is not important. However, since the mapping advertisements are distributed in IGP using the regular IGP advertisement mechanism, the mapping server needs an IGP adjacency to the network.
- The role of the mapping server is crucial. For redundancy purposes, you should configure multiple mapping servers in the networks.
- The mapping server functionality does not support a scenario where SID-mapping entries learned through one IS-IS instance are used by another IS-IS instance to determine the prefix-SID of a prefix. For example, mapping entries learnt from remote routers by 'router isis 1' cannot be used to calculate prefix-SIDs for prefixes learnt, advertised, or downloaded to FIB by 'router isis 2'. A mapping server is required for each IS-IS area.
- Segment Routing Mapping Server does not support Virtual Routing and Forwarding (VRF) currently.

Segment Routing and LDP Interoperability

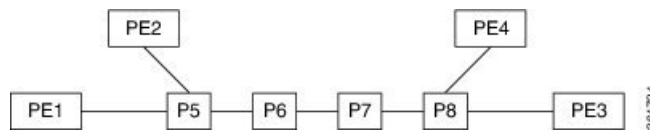
IGP provides mechanisms through which segment routing (SR) interoperate with label distribution protocol (LDP). The control plane of segment routing co-exists with LDP.

The Segment Routing Mapping Server (SRMS) functionality in SR is used to advertise SIDs for destinations, in the LDP part of the network, that do not support SR. SRMS maintains and advertises segment identifier (SID) mapping entries for such destinations. IGP propagates the SRMS mapping entries and interacts with SRMS to determine the SID value when programming the forwarding plane. IGP installs prefixes and corresponding labels, into routing information base (RIB), that are used to program the forwarding information base (FIB).

Example: Segment Routing LDP Interoperability

Consider a network with a mix of segment routing (SR) and label distribution protocol (LDP). A continuous multiprotocol label switching (MPLS) LSP (Labeled Switched Path) can be established by facilitating interoperability. One or more nodes in the SR domain act as segment routing mapping server (SRMS). SRMS advertises SID mappings on behalf of non-SR capable nodes. Each SR-capable node learns about SID assigned to non-SR capable nodes without explicitly configuring individual nodes.

Consider a network as shown in the following image. This network is a mix of both LDP and SR-capable nodes.



In this mixed network:

- Nodes P6, P7, P8, PE4 and PE3 are LDP-capable
- Nodes PE1, PE2, P5 and P6 are SR-capable
- Nodes PE1, PE2, P5 and P6 are configured with segment routing global block (SRGB) of (100, 200)
- Nodes PE1, PE2, P5 and P6 are configured with node segments of 101, 102, 105 and 106 respectively

A service flow must be established from PE1 to PE3 over a continuous MPLS tunnel. This requires SR and LDP to interoperate.

LDP to SR

The traffic flow from LDP to SR (right to left) involves:

1. PE3 learns a service route whose nhop is PE1. PE3 has an LDP label binding from the nhop P8 for the FEC PE1. PE3 forwards the packet P8.
2. P8 has an LDP label binding from its nhop P7 for the FEC PE1. P8 forwards the packet to P7.
3. P7 has an LDP label binding from its nhop P6 for the FEC PE1. P7 forwards the packet to P6.
4. P6 does not have an LDP binding from its nhop P5 for the FEC PE1. But P6 has an SR node segment to the IGP route PE1. P6 forwards the packet to P5 and swaps its local LDP label for FEC PE1 by the equivalent node segment 101. This process is called label merging.
5. P5 pops 101, assuming PE1 has advertised its node segment 101 with the penultimate-pop flag set and forwards to PE1.
6. PE1 receives the tunneled packet and processes the service label.

The end-to-end MPLS tunnel is established from an LDP LSP from PE3 to P6 and the related node segment from P6 to PE1.

SR to LDP

Suppose that the operator configures P5 as a Segment Routing Mapping Server (SRMS) and advertises the mappings (P7, 107), (P8, 108), (PE3, 103) and (PE4, 104). If PE3 was SR-capable, the operator may have configured PE3 with node segment 103. Because PE3 is non-SR capable, the operator configures that policy at the SRMS; the SRMS advertises the mapping on behalf of the non-SR capable nodes. Multiple SRMS servers can be provisioned in a network for redundancy. The mapping server advertisements are only understood by the SR-capable nodes. The SR capable routers install the related node segments in the MPLS data plane in exactly the same manner if node segments were advertised by the nodes themselves.

The traffic flow from SR to LDP (left to right) involves:

1. PE1 installs the node segment 103 with nhop P5 in exactly the same manner if PE3 had advertised node segment 103.
2. P5 swaps 103 for 103 and forwards to P6.
3. The nhop for P6 for the IGP route PE3 is non-SR capable. (P7 does not advertise the SR capability.) However, P6 has an LDP label binding from that nhop for the same FEC. (For example, LDP label 1037.) P6 swaps 103 for 1037 and forwards to P7. We refer to this process as label merging.
4. P7 swaps this label with the LDP label received from P8 and forwards to P8.
5. P8 pops the LDP label and forwards to PE3.
6. PE3 receives the packet and processes as required.

The end-to-end MPLS LSP is established from an SR node segment from PE1 to P6 and an LDP LSP from P6 to PE3.

Configuring Mapping Server

Perform these tasks to configure the mapping server and to add prefix-SID mapping entries in the active local mapping policy.

SUMMARY STEPS

1. **configure**
2. **segment-routing**
3. **mapping-server**
4. **prefix-sid-map**
5. **address-family ipv4 | ipv6**
6. *ip-address/prefix-length first-SID-value range range*
7. **commit**
8. **show segment-routing mapping-server prefix-sid-map [ipv4 | ipv6] [detail]**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	segment-routing Example: RP/0/RP0/CPU0:router(config)# segment-routing	Enables segment routing.
Step 3	mapping-server Example: RP/0/RP0/CPU0:router(config-sr)# mapping-server	Enables mapping server configuration mode.
Step 4	prefix-sid-map Example: RP/0/RP0/CPU0:router(config-sr-ms)# prefix-sid-map	Enables prefix-SID mapping configuration mode. Note Two-way prefix SID can be enabled directly under IS-IS or through a mapping server.
Step 5	address-family ipv4 ipv6 Example: This example shows the address-family for ipv4: RP/0/RP0/CPU0:router(config-sr-ms-map)# address-family ipv4 This example shows the address-family for ipv6:	Configures address-family for IS-IS.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router(config-sr-ms-map)# address-family ipv6	
Step 6	<p><i>ip-address/prefix-length first-SID-value range range</i></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-sr-ms-map-af)# 10.1.1.1/32 10 range 200 RP/0/RP0/CPU0:router(config-sr-ms-map-af)# 20.1.0.0/16 400 range 300</pre>	<p>Adds SID-mapping entries in the active local mapping policy. In the configured example:</p> <ul style="list-style-type: none"> Prefix 10.1.1.1/32 is assigned prefix-SID 10, prefix 10.1.1.2/32 is assigned prefix-SID 11,..., prefix 10.1.1.199/32 is assigned prefix-SID 200 Prefix 20.1.0.0/16 is assigned prefix-SID 400, prefix 20.2.0.0/16 is assigned prefix-SID 401,..., and so on.
Step 7	commit	
Step 8	<p>show segment-routing mapping-server prefix-sid-map [ipv4 ipv6] [detail]</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router# show segment-routing mapping-server prefix-sid-map ipv4 Prefix SID Index Range Flags 20.1.1.0/24 400 300 10.1.1.1/32 10 200 Number of mapping entries: 2 RP/0/RP0/CPU0:router# show segment-routing mapping-server prefix-sid-map ipv4 detail Prefix 20.1.1.0/24 SID Index: 400 Range: 300 Last Prefix: 20.2.44.0/24 Last SID Index: 699 Flags: 10.1.1.1/32 SID Index: 10 Range: 200 Last Prefix: 10.1.1.200/32 Last SID Index: 209 Flags: Number of mapping entries: 2</pre>	<p>Displays information about the locally configured prefix-to-SID mappings.</p> <p>Note Specify the address family for IS-IS.</p>

What to do next

Enable the advertisement of the local SID-mapping policy in the IGP.

Enable Mapping Advertisement

In addition to configuring the static mapping policy, you must enable the advertisement of the mappings in the IGP.

Perform these steps to enable the IGP to advertise the locally configured prefix-SID mapping.

Configure Mapping Advertisement for IS-IS

SUMMARY STEPS

1. `router isis instance-id`
2. `address-family { ipv4 | ipv6 } [unicast]`
3. `segment-routing prefix-sid-map advertise-local`
4. `commit`
5. `show isis database verbose`

DETAILED STEPS

	Command or Action	Purpose
Step 1	<p><code>router isis instance-id</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config)# router isis 1</pre>	<p>Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode.</p> <ul style="list-style-type: none"> • You can change the level of routing to be performed by a particular routing instance by using the is-type router configuration command.
Step 2	<p><code>address-family { ipv4 ipv6 } [unicast]</code></p> <p>Example:</p> <p>The following is an example for ipv4 address family:</p> <pre>RP/0/RP0/CPU0:router(config-isis)# address-family ipv4 unicast</pre>	<p>Specifies the IPv4 or IPv6 address family, and enters router address family configuration mode.</p>
Step 3	<p><code>segment-routing prefix-sid-map advertise-local</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-af)# segment-routing prefix-sid-map advertise-local</pre>	<p>Configures IS-IS to advertise locally configured prefix-SID mappings.</p>
Step 4	<p><code>commit</code></p>	
Step 5	<p><code>show isis database verbose</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router# show isis database verbose <...removed...></pre>	<p>Displays IS-IS prefix-SID mapping advertisement and TLV.</p>

	Command or Action	Purpose
	<pre>SID Binding: 10.1.1.1/32 F:0 M:0 S:0 D:0 A:0 Weight:0 Range:200 SID: Start:10, Algorithm:0, R:0 N:0 P:0 E:0 V:0 L:0 SID Binding: 20.1.1.0/24 F:0 M:0 S:0 D:0 A:0 Weight:0 Range:300 SID: Start:400, Algorithm:0, R:0 N:0 P:0 E:0 V:0 L:0</pre>	

Configure Mapping Advertisement for OSPF

SUMMARY STEPS

1. `router ospf process-name`
2. `segment-routing prefix-sid-map advertise-local`
3. `commit`
4. `show ospf database opaque-area`

DETAILED STEPS

	Command or Action	Purpose
Step 1	<p><code>router ospf process-name</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config)# router ospf 1</pre>	Enables OSPF routing for the specified routing instance, and places the router in router configuration mode.
Step 2	<p><code>segment-routing prefix-sid-map advertise-local</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-ospf)# segment-routing prefix-sid-map advertise-local</pre>	Configures OSPF to advertise locally configured prefix-SID mappings.
Step 3	<code>commit</code>	
Step 4	<p><code>show ospf database opaque-area</code></p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router# show ospf database opaque-area <...removed...> Extended Prefix Range TLV: Length: 24 AF : 0 Prefix : 10.1.1.1/32 Range Size: 200 Flags : 0x0 SID sub-TLV: Length: 8</pre>	Displays OSP prefix-SID mapping advertisement and TLV.

	Command or Action	Purpose
	<pre>Flags : 0x60 MTID : 0 Algo : 0 SID Index : 10</pre>	

Enable Mapping Client

By default, mapping client functionality is enabled.

You can disable the mapping client functionality by using the **segment-routing prefix-sid-map receive disable** command.

You can re-enable the mapping client functionality by using the **segment-routing prefix-sid-map receive** command.

The following example shows how to enable the mapping client for IS-IS:

```
RP/0/RP0/CPU0:router(config)# router isis 1
RP/0/RP0/CPU0:router(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:router(config-isis-af)# segment-routing prefix-sid-map receive
```

The following example shows how to enable the mapping client for OSPF:

```
RP/0/RP0/CPU0:router(config)# router ospf 1
RP/0/RP0/CPU0:router(config-ospf)# segment-routing prefix-sid-map receive
```



CHAPTER 9

Using Segment Routing Traffic Matrix

This module provides information about the Segment Routing Traffic Matrix (SR-TM) and the Traffic Collector process, and describes how to configure the TM border and the Traffic Collector and to display traffic information.

- [Segment Routing Traffic Matrix, on page 53](#)
- [Traffic Collector Process, on page 53](#)
- [Configuring Traffic Collector, on page 54](#)
- [Displaying Traffic Information, on page 55](#)

Segment Routing Traffic Matrix

A network's traffic matrix is a description, measure, or estimation of the aggregated traffic flows that enter, traverse, and leave a network.

The Segment Routing Traffic Matrix (SR-TM) is designed to help users understand traffic patterns on a router. The Traffic Matrix border divides the network into two parts: internal (interfaces that are inside the border) and external (interfaces that are outside the border). By default, all interfaces are internal. You can configure an interface as external.

Traffic Collector Process

The Traffic Collector collects packet and byte statistics from router components such as prefix counters, tunnel counters, and the TM counter, which increments when traffic that comes from an external interface to the network is destined for a segment routing prefix-SID. The Traffic Collector keeps histories of the statistics and makes them persistent across process restarts, failovers, and ISSU. Histories are retained for a configurable length of time.

Pcounters

A Pcounter is a packet and byte pair of counters. There is one Pcounter per tunnel. There are two Pcounters per prefix-SID:

- Base Pcounter – any packet that is switched on the prefix-SID forwarding information base (FIB) entry
- TM Pcounter – any packet from an external interface and switched on the prefix-SID FIB entry

The Traffic Collector periodically collects the Base Pcounters and TM Pcounters of all prefix-SIDs, and the Pcounters of all tunnel interfaces.

For each Pcounter, the Traffic Collector calculates the number of packets and bytes that have been forwarded during the last interval. The Traffic Collector keeps a history of the per-interval statistics for each of the Pcounters. Each entry in the history contains:

- The start and end time of the interval
- The number of packets forwarded during the interval
- The number of bytes forwarded during the interval

Configuring Traffic Collector

Perform these tasks to configure the traffic collector.

SUMMARY STEPS

1. **configure**
2. **traffic-collector**
3. **statistics collection-interval** *value*
4. **statistics history-size** *value*
5. **statistics history-timeout** *value*
6. **interface** *type l3-interface-address*
7. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	traffic-collector Example: RP/0/RP0/CPU0:router (config)# traffic-collector	Enables traffic collector and places the router in traffic collector configuration mode.
Step 3	statistics collection-interval <i>value</i> Example: RP/0/RP0/CPU0:router (config-tc)# statistics collection-interval 5	(Optional) Sets the frequency that the traffic collector collects and posts data, in minutes. Valid values are 1, 2, 3, 4, 5, 6, 10, 12,15, 20, 30, and 60. The default interval is 1.
Step 4	statistics history-size <i>value</i> Example:	(Optional) Specifies the number of entries kept in the history database. Valid values are from 1 to 10. The default is 5.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router(config-tc)# statistics history-size 10	Note The number of entries affects how the average packet and average byte rates are calculated. The rates are calculated over the range of the histories and are not averages based in real time.
Step 5	statistics history-timeout value Example: RP/0/RP0/CPU0:router(config-tc)# statistics history-timeout 24	(Optional) When a prefix SID or a tunnel-te interface is deleted, the history-timeout sets the length of time, in hours, that the prefix SID and tunnel statistics are retained in the history before they are removed. The minimum is one hour; the maximum is 720 hours. The default is 48. Note Enter 0 to disable the history timeout. (No history is retained.)
Step 6	interface type l3-interface-address Example: RP/0/RP0/CPU0:router(config-tc)# interface TenGigE 0/1/0/3	Identifies interfaces that handle external traffic. Only L3 interfaces are supported for external traffic.
Step 7	commit	

This completes the configuration for the traffic collector.

Displaying Traffic Information

The following show commands display information about the interfaces and tunnels:



Note For detailed information about the command syntax for the following **show** commands, see the *Segment Routing Command Reference Guide*.

- Display the configured external interfaces:

```
RP/0/RSP0/CPU0:router# show traffic-collector external-interface
Interface                Status
-----                -
Te0/1/0/3                Enabled
Te0/1/0/4                Enabled
```

- Display the counter history database for a prefix-SID:

```
RP/0/RSP0/CPU0:router# show traffic-collector ipv4 counters prefix 1.1.1.10/32 detail
Prefix: 1.1.1.10/32 Label: 16010 State: Active
Base:
Average over the last 5 collection intervals:
Packet rate: 9496937 pps, Byte rate: 9363979882 Bps
```

```

History of counters:
  23:01 - 23:02: Packets 9379529, Bytes: 9248215594
  23:00 - 23:01: Packets 9687124, Bytes: 9551504264
  22:59 - 23:00: Packets 9539200, Bytes: 9405651200
  22:58 - 22:59: Packets 9845278, Bytes: 9707444108
  22:57 - 22:58: Packets 9033554, Bytes: 8907084244
TM Counters:
Average over the last 5 collection intervals:
Packet rate: 9528754 pps, Byte rate: 9357236821 Bps

History of counters:
  23:01 - 23:02: Packets 9400815, Bytes: 9231600330
  23:00 - 23:01: Packets 9699455, Bytes: 9524864810
  22:59 - 23:00: Packets 9579889, Bytes: 9407450998
  22:58 - 22:59: Packets 9911734, Bytes: 9733322788
  22:57 - 22:58: Packets 9051879, Bytes: 8888945178

```

This output shows the average Pcounter (packets, bytes), the Pcounter history, and the collection interval of the Base and TM for the specified prefix-SID.

- Display the counter history database for a tunnel:

```

RP/0/RSP0/CPU0:router# show traffic-collector counters tunnels tunnel-te 1 detail
Tunnel: ttl State: Active
Average over the last 5 collection intervals:
Packet rate: 9694434 pps, Byte rate: 9597489858 Bps

History of counters:
  23:14 - 23:15: Packets 9870522 , Bytes: 9771816780
  23:13 - 23:14: Packets 9553048 , Bytes: 9457517520
  23:12 - 23:13: Packets 9647265 , Bytes: 9550792350
  23:11 - 23:12: Packets 9756654 , Bytes: 9659087460
  23:10 - 23:11: Packets 9694434 , Bytes: 9548235180

```

This output shows the average Pcounter (packets, bytes), the Pcounter history, and the collection interval for the tunnel.



CHAPTER 10

Using Segment Routing OAM

Segment Routing Operations, Administration, and Maintenance (OAM) helps service providers to monitor label-switched paths (LSPs) and quickly isolate forwarding problems to assist with fault detection and troubleshooting in the network. The Segment Routing OAM feature provides support for Nil-FEC (forwarding equivalence classes) LSP Ping and Traceroute functionality.

- [MPLS LSP Ping and Traceroute Nil FEC Target, on page 57](#)
- [Examples: LSP Ping and Traceroute for Nil_FEC Target , on page 58](#)

MPLS LSP Ping and Traceroute Nil FEC Target

The Nil-FEC LSP ping and traceroute operations are extensions of regular MPLS ping and traceroute.

Nil-FEC LSP Ping/Traceroute functionality supports segment routing and MPLS Static. It also acts as an additional diagnostic tool for all other LSP types. This feature allows operators to provide the ability to freely test any label stack by allowing them to specify the following:

- label stack
- outgoing interface
- nexthop address

In the case of segment routing, each segment nodal label and adjacency label along the routing path is put into the label stack of an echo request message from the initiator Label Switch Router (LSR); MPLS data plane forwards this packet to the label stack target, and the label stack target sends the echo message back.

The following table shows the syntax for the ping and traceroute commands.

Table 1: LSP Ping and Traceroute Nil FEC Commands

Command Syntax
ping mpls nil-fec labels {label[,label]} [output {interface tx-interface} [nexthop nexthop-ip-addr]]
traceroute mpls nil-fec labels {label[,label]} [output {interface tx-interface} [nexthop nexthop-ip-addr]]

Examples: LSP Ping and Traceroute for Nil_FEC Target

These examples use the following topology:

```
Node loopback IP address: 172.18.1.3   172.18.1.4   172.18.1.5   172.18.1.7
Node label:                16004           16005           16007
Nodes:                      Arizona ---- Utah ----- Wyoming ---- Texas

Interface:                  GigabitEthernet0/2/0/1   GigabitEthernet0/2/0/1
Interface IP address:       10.1.1.3                10.1.1.4
```

```
RP/0/RP0/CPU0:router-utah# show mpls forwarding
```

```
Tue Jul  5 13:44:31.999 EDT
Local  Outgoing  Prefix      Outgoing    Next Hop    Bytes
Label  Label      or ID      Interface   -----
-----
16004  Pop         No ID      Gi0/2/0/1   10.1.1.4    1392
      Pop         No ID      Gi0/2/0/2   10.1.2.2     0
16005  16005      No ID      Gi0/2/0/0   10.1.1.4     0
      16005      No ID      Gi0/2/0/1   10.1.2.2     0
16007  16007      No ID      Gi0/2/0/0   10.1.1.4    4752
      16007      No ID      Gi0/2/0/1   10.1.2.2     0
24000  Pop         SR Adj (idx 0)  Gi0/2/0/0   10.1.1.4     0
24001  Pop         SR Adj (idx 2)  Gi0/2/0/0   10.1.1.4     0
24002  Pop         SR Adj (idx 0)  Gi0/2/0/1   10.1.2.2     0
24003  Pop         SR Adj (idx 2)  Gi0/2/0/1   10.1.2.2     0
24004  Pop         No ID          tt10        point2point   0
24005  Pop         No ID          tt11        point2point   0
24006  Pop         No ID          tt12        point2point   0
24007  Pop         No ID          tt13        point2point   0
24008  Pop         No ID          tt30        point2point   0
```

Ping Nil FEC Target

```
RP/0/RP0/CPU0:router-arizona# ping mpls nil-fec labels 16005,16007 output interface
GigabitEthernet 0/2/0/1 nexthop 10.1.1.4 repeat 1
```

```
Sending 1, 72-byte MPLS Echos with Nil FEC labels 16005,16007,
  timeout is 2 seconds, send interval is 0 msec:
```

```
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
'X' - unknown return code, 'x' - return code 0
```

```
Type escape sequence to abort.
```

```
!
```

```
Success rate is 100 percent (1/1), round-trip min/avg/max = 1/1/1 ms
Total Time Elapsed 0 ms
```

Traceroute Nil FEC Target

```
RP/0/RP0/CPU0:router-arizona# traceroute mpls nil-fec labels 16005,16007 output interface
GigabitEthernet 0/2/0/1 nexthop 10.1.1.4
```

```
Tracing MPLS Label Switched Path with Nil FEC labels 16005,16007, timeout is 2 seconds
```

```
Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
'X' - unknown return code, 'x' - return code 0
```

```
Type escape sequence to abort.
```

```
0 10.1.1.3 MRU 1500 [Labels: 16005/16007/explicit-null Exp: 0/0/0]
L 1 10.1.1.4 MRU 1500 [Labels: implicit-null/16007/explicit-null Exp: 0/0/0] 1 ms
L 2 10.1.1.5 MRU 1500 [Labels: implicit-null/explicit-null Exp: 0/0] 1 ms
! 3 10.1.1.7 1 ms
```

