



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.

Procedure

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# <code>configure</code>	Enters mode.
Step 2	router isis <i>instance-id</i> Example: RP/0/RP0/CPU0:router(config)# <code>router isis isp</code>	Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode.

	Command or Action	Purpose
		<p>Note You can change the level of routing to be performed by a particular routing instance by using the is-type router configuration command.</p>
Step 3	<p>address-family { ipv4 ipv6 } [unicast]</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis)# address-family ipv4 unicast</pre>	Specifies the IPv4 or IPv6 address family, and enters router address family configuration mode.
Step 4	<p>metric-style wide [level { 1 2 }]</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-af)# metric-style wide level 1</pre>	Configures a router to generate and accept only wide link metrics in the Level 1 area.
Step 5	<p>mpls traffic-eng level</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-af)# mpls traffic-eng level-2-only</pre>	Enables RSVP traffic engineering functionality.
Step 6	<p>mpls traffic-eng router-id interface</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-af)# mpls traffic-eng router-id Loopback0</pre>	Sets the traffic engineering loopback interface.
Step 7	<p>router-id loopback loopback interface used for prefix-sid</p> <p>Example:</p> <pre>RP/0/RP0(config-isis-af)#router-id loopback0</pre>	Configures router ID for each address-family (ipv4/ipv6).
Step 8	<p>segment-routing mpls</p> <p>Example:</p> <pre>RP/0/RP0/CPU0:router(config-isis-af)# segment-routing mpls</pre>	<p>Segment routing is enabled by the following actions:</p> <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.

	Command or Action	Purpose
Step 9	exit Example: <pre>RP/0/RP0/CPU0:router(config-isis-af)# exit RP/0/RP0/CPU0:router(config-isis)# exit</pre>	
Step 10	mpls traffic-eng Example: <pre>RP/0/RP0/CPU0:router(config)# mpls traffic-eng</pre>	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	Use the commit or end command.	commit —Saves the configuration changes and remains within the configuration session. end —Prompts user to take one of these actions: <ul style="list-style-type: none"> • Yes — Saves configuration changes and exits the configuration session. • No —Exits the configuration session without committing the configuration changes. • Cancel —Remains in the configuration session, without committing the configuration changes.

What to do next

Configure the prefix SID.

- [Configuring a Prefix-SID on the IS-IS Enabled Loopback Interface, on page 3](#)
- [Configuring an Adjacency SID, on page 6](#)
- [Configuring Bandwidth-Based Local UCMP, on page 9](#)
- [IS-IS Multi-Domain Prefix SID and Domain Stitching: Example, on page 10](#)

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.

Procedure

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# configure	Enters mode.
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. • 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.
Step 5	prefix-sid {index <i>SID-index</i> absolute <i>SID-value</i>} [n-flag-clear] [explicit-null] Example: RP/0/RP0/CPU0:router(config-isis-if-af)#	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.

	Command or Action	Purpose
	<pre>prefix-sid index 1001 RP/0/RP0/CPU0:router(config-isis-if-af)# prefix-sid absolute 17001</pre>	<p>Specify absolute <i>SID-value</i> for each node to create a specific prefix SID within the SRGB.</p> <p>By default, the <code>n-flag</code> 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 <code>N</code> 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 <code>E</code> flag in the prefix-SID sub TLV.</p>
Step 6	Use the commit or end command.	<p>commit —Saves the configuration changes and remains within the configuration session.</p> <p>end —Prompts user to take one of these actions:</p> <ul style="list-style-type: none"> • Yes — Saves configuration changes and exits the configuration session. • No —Exits the configuration session without committing the configuration changes. • Cancel —Remains in the configuration session, without committing the configuration changes.

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.

Configuring an Adjacency SID

An adjacency SID (Adj-SID) is associated with an adjacency to a neighboring node. The adjacency SID steers the traffic to a specific adjacency. Adjacency SIDs have local significance and are only valid on the node that allocates them.

An adjacency SID can be allocated dynamically from the dynamic label range or configured manually from the segment routing local block (SRLB) range of labels.

Adjacency SIDs that are dynamically allocated do not require any special configuration, however there are some limitations:

- A dynamically allocated Adj-SID value is not known until it has been allocated, and a controller will not know the Adj-SID value until the information is flooded by the IGP.
- Dynamically allocated Adj-SIDs are not persistent and can be reallocated after a reload or a process restart.
- Each link is allocated a unique Adj-SID, so the same Adj-SID cannot be shared by multiple links.

Manually allocated Adj-SIDs are persistent over reloads and restarts. They can be provisioned for multiple adjacencies to the same neighbor or to different neighbors. You can specify that the Adj-SID is protected. If the Adj-SID is protected on the primary interface and a backup path is available, a backup path is installed. By default, manual Adj-SIDs are not protected.

Adjacency SIDs are advertised using the existing IS-IS Adj-SID sub-TLV. The S and P flags are defined for manually allocated Adj-SIDs.

```

 0 1 2 3 4 5 6 7
+---+---+---+---+---+---+
|F|B|V|L|S|P|   |
+---+---+---+---+---+---+

```

Table 1: Adjacency Segment Identifier (Adj-SID) Flags Sub-TLV Fields

Field	Description
S (Set)	This flag is set if the same Adj-SID value has been provisioned on multiple interfaces.
P (Persistent)	This flag is set if the Adj-SID is persistent (manually allocated).

Manually allocated Adj-SIDs are supported on point-to-point (P2P) interfaces.

This task explains how to configure an Adj-SID on an interface.

Before you begin

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

Use the **show mpls label table detail** command to verify the SRLB range.

Procedure

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# configure	Enters mode.
Step 2	router isis instance-id 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. • 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 type interface-path-id Example: RP/0/RP0/CPU0:router(config-isis)# interface GigabitEthernet0/0/0/7	Specifies the interface and enters interface configuration mode.
Step 4	point-to-point Example: RP/0/RP0/CPU0:router(config-isis-if)# point-to-point	Specifies the interface is a point-to-point interface.
Step 5	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.
Step 6	adjacency-sid {index adj-SID-index absolute adj-SID-value } [protected] Example: RP/0/RP0/CPU0:router(config-isis-if-af)# adjacency-sid index 10	Configures the Adj-SID index or absolute value for the interface. Specify index adj-SID-index for each link to create an Adj-SID based on the lower boundary of the SRLB + the index. Specify absolute adj-SID-value for each link to create a specific Adj-SID within the SRLB.

	Command or Action	Purpose
	RP/0/RP0/CPU0:router(config-isis-if-af)# adjacency-sid absolute 15010	Specify if the Adj-SID is protected . For each primary path, if the Adj-SID is protected on the primary interface and a backup path is available, a backup path is installed. By default, manual Adj-SIDs are not protected.
Step 7	Use the commit or end command.	<p>commit —Saves the configuration changes and remains within the configuration session.</p> <p>end —Prompts user to take one of these actions:</p> <ul style="list-style-type: none"> • Yes — Saves configuration changes and exits the configuration session. • No —Exits the configuration session without committing the configuration changes. • Cancel —Remains in the configuration session, without committing the configuration changes.

Verify the Adj-SID configuration:

```
RP/0/RP0/CPU0:router# show isis segment-routing label adjacency persistent
Mon Jun 12 02:44:07.085 PDT

IS-IS 1 Manual Adjacency SID Table

15010 AF IPv4
  GigabitEthernet0/0/0/3: IPv4, Protected 1/65/N, Active
  GigabitEthernet0/0/0/7: IPv4, Protected 2/66/N, Active

15100 AF IPv6
  GigabitEthernet0/0/0/3: IPv6, Not protected 255/255/N, Active
```

Verify the labels are added to the MPLS Forwarding Information Base (LFIB):

```
RP/0/RP0/CPU0:router# show mpls forwarding labels 15010
Mon Jun 12 02:50:12.172 PDT

Local  Outgoing  Prefix      Outgoing   Next Hop   Bytes
Label  Label        or ID      Interface  Interface  Switched
-----
15010  Pop          SRLB (idx 10)  Gi0/0/0/3  10.0.3.3   0
      Pop          SRLB (idx 10)  Gi0/0/0/7  10.1.0.5   0
      16004        SRLB (idx 10)  Gi0/0/0/7  10.1.0.5   0                (!)
      16004        SRLB (idx 10)  Gi0/0/0/3  10.0.3.3   0                (!)
```

What to do next

Configure the SR-TE policy.

Configuring Bandwidth-Based Local UCMP

Bandwidth-based local Unequal Cost Multipath (UCMP) allows you to enable UCMP functionality locally between Equal Cost Multipath (ECMP) paths based on the bandwidth of the local links.

Bandwidth-based local UCMP is performed for prefixes, segment routing Adjacency SIDs, and Segment Routing label cross-connects installed by IS-IS, and is supported on any physical or virtual interface that has a valid bandwidth.

For example, if the capacity of a bundle interface changes due to the link or line card up/down event, traffic continues to use the affected bundle interface regardless of the available provisioned bundle members. If some bundle members were not available due to the failure, this behavior could cause the traffic to overload the bundle interface. To address the bundle capacity changes, bandwidth-based local UCMP uses the bandwidth of the local links to load balance traffic when bundle capacity changes.

Before you begin

Procedure

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# <code>configure</code>	Enters mode.
Step 2	router isis <i>instance-id</i> Example: RP/0/RP0/CPU0:router(config)# <code>router isis 1</code>	Enables IS-IS routing for the specified routing instance, and places the router in router configuration mode. 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: The following is an example for ipv4 address family: RP/0/RP0/CPU0:router(config-isis)# <code>address-family ipv4 unicast</code>	Specifies the IPv4 or IPv6 address family, and enters IS-IS address family configuration mode.
Step 4	apply-weight ecmp-only bandwidth Example: RP/0/RP0/CPU0:router(config-isis-af)# <code>apply-weight ecmp-only bandwidth</code>	Enables UCMP functionality locally between ECMP paths based on the bandwidth of the local links.
Step 5	Use the commit or end command.	commit —Saves the configuration changes and remains within the configuration session.

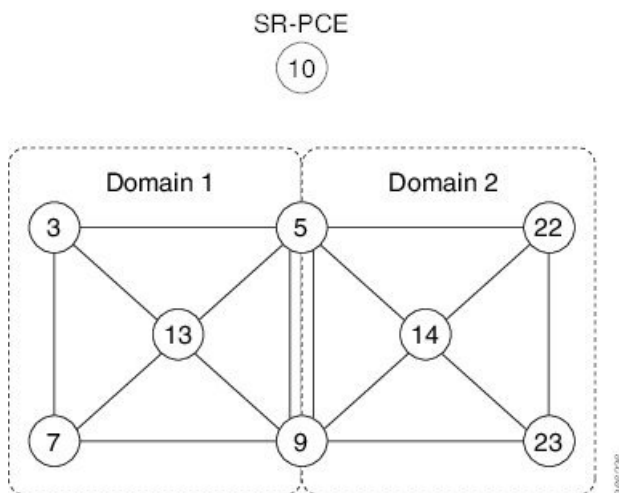
	Command or Action	Purpose
		<p>end—Prompts user to take one of these actions:</p> <ul style="list-style-type: none"> • Yes — Saves configuration changes and exits the configuration session. • No —Exits the configuration session without committing the configuration changes. • Cancel —Remains in the configuration session, without committing the configuration changes.

IS-IS Multi-Domain Prefix SID and Domain Stitching: Example

IS-IS Multi-Domain Prefix SID and Domain Stitching allows you to configure multiple IS-IS instances on the same loopback interface for domain border nodes. You specify a loopback interface and prefix SID under multiple IS-IS instances to make the prefix and prefix SID reachable in different domains.

This example uses the following topology. Node 5 and 9 are border nodes between two IS-IS domains (Domain1 and Domain2). Node 10 is configured as the Segment Routing Path Computation Element (SR-PCE).

Figure 1: Multi-Domain Topology



Configure IS-IS Multi-Domain Prefix SID

Specify a loopback interface and prefix SID under multiple IS-IS instances on each border node:

```

Example: Border Node 5
router isis Domain1
 interface Loopback0
  address-family ipv4 unicast
  prefix-sid absolute 16005

```

```
router isis Domain2
 interface Loopback0
  address-family ipv4 unicast
  prefix-sid absolute 16005
```

Example: Border Node 9

```
router isis Domain1
 interface Loopback0
  address-family ipv4 unicast
  prefix-sid absolute 16009
```

```
router isis Domain2
 interface Loopback0
  address-family ipv4 unicast
  prefix-sid absolute 16009
```

Border nodes 5 and 9 each run two IS-IS instances (Domain1 and Domain2) and advertise their Loopback0 prefix and prefix SID in both domains.

Nodes in both domains can reach the border nodes by using the same prefix and prefix SID. For example, Node 3 and Node 22 can reach Node 5 using prefix SID 16005.

Configure Common Router ID

On each border node, configure a common TE router ID under each IS-IS instance:

Example: Border Node 5

```
router isis Domain1
 address-family ipv4 unicast
  router-id loopback0
```

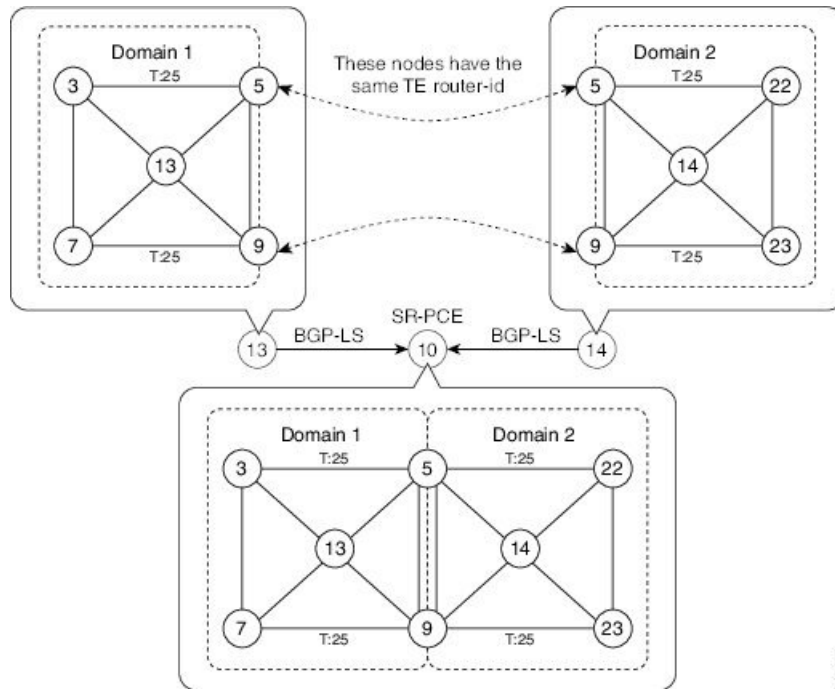
```
router isis Domain2
 address-family ipv4 unicast
  router-id loopback0
```

Example: Border Node 9

```
router isis Domain1
 address-family ipv4 unicast
  router-id loopback0
```

```
router isis Domain2
 address-family ipv4 unicast
  router-id loopback0
```

Distribute IS-IS Link-State Data



Configure BGP Link-state (BGP-LS) on Node 13 and Node 14 to report their local domain to Node 10:

Example: Node 13
 router isis Domain1
 distribute link-state instance-id *instance-id*

Example: Node 14
 router isis Domain2
 distribute link-state instance-id *instance-id*

Link-state ID starts from 32. One ID is required per IGP domain. Different domain IDs are essential to identify that the SR-TE TED belongs to a particular IGP domain.

Nodes 13 and 14 each reports its local domain in BGP-LS to Node 10.

Node 10 identifies the border nodes (Nodes 5 and 9) by their common advertised TE router ID, then combines (stitches) the domains on these border nodes for end-to-end path computations.