Configuring Segment Routing

This chapter contains information on how to configure segment routing.

About Segment Routing

Segment routing is a technique by which the path followed by a packet is encoded in the packet itself, similar to source routing. A node steers a packet through a controlled set of instructions, called segments, by prepending the packet with a segment routing header. Each segment is identified by a segment ID (SID) consisting of a flat unsigned 32-bit integer.

Border Gateway Protocol (BGP) segments, a subclass of segments, identify a BGP forwarding instruction. There are two groups of BGP segments: prefix segments and adjacency segments. Prefix segments steer packets along the shortest path to the destination, using all available equal-cost multi-path (ECMP) paths.

Adjacency segments steer packets onto a specific link to a neighbor.

The segment routing architecture is applied directly to the MPLS data plane.

Segment Routing Application Module

Segment Routing Application (SR-APP) module is used to configure the segment routing functionality. Segment Routing Application (SR-APP) is a separate internal process that handles all the CLIs related to segment routing. It is responsible for reserving the SRGB range and for notifying the clients about it. It is also responsible for maintaining the prefix to SID mappings. The SR-APP support is also available for the BGP, IS-IS, and OSPF protocols.

The SR-APP module maintains the following information:

- Segment routing operation state

- Segment routing global block label ranges

- Prefix SID mappings

For more information, see Configuring Segment Routing, on page 3.

Guidelines and Limitations for Segment Routing

Segment routing has the following guidelines and limitations:

- MPLS Segment Routing can be enabled on physical ethernet interfaces and port-channel bundles. It is not supported on ethernet sub-interfaces or Switchedx Virtual Interfaces (SVI).

- BGP allocates a SRGB label for iBGP route-reflector clients only when next-hop-self is in effect (for example, the prefix is advertised with the next hop being one of the local IP/IPv6 addresses on RR). When you have configured next-hop-self on a RR, the next hop is changed for the routes that are being affected (subject to route-map filtering).

- Static MPLS, MPLS segment routing, and MPLS stripping cannot be enabled at the same time.

- Because static MPLS, MPLS segment routing, and MPLS stripping are mutually exclusive, the only segment routing underlay for multi-hop BGP is single-hop BGP. iBGP multi-hop topologies with eBGP running as an overlay are not supported.

- MPLS pop followed by a forward to a specific interface is not supported. The penultimate hop pop (PHP) is avoided by installing the Explicit NULL label as the out-label in the label FIB (LFIB) even when the control plane installs an IPv4 Implicit NULL label.

- BGP labeled unicast and BGP segment routing are not supported for IPv6 prefixes.

- BGP labeled unicast and BGP segment routing are not supported over tunnel interfaces (including GRE and VXLAN) or with vPC access interfaces.

- MTU path discovery (RFC 2923) is not supported over MPLS label switched paths (LSPs) or segment routed paths.

- The BGP configuration commands **neighbor-down fib-accelerate** and **suppress-fib-pending** are not supported for MPLS prefixes.

- Reconfiguration of the segment routing global block (SRGB) results in an automatic restart of the BGP process to update the existing URIB and ULIB entries. Traffic loss occurs for a few seconds, so you should not reconfigure the SRGB in production.

- When the segment routing global block (SRGB) is set to a range but the route-map label-index delta value falls outside the configured range, the allocated label is dynamically generated. For example, if the SRGB is set to a range of 16000-23999 but a route-map label-index is set to 9000, the label is dynamically allocated.

- For network scalability, Cisco recommends using a hierarchical routing design with multi-hop BGP for advertising the attached prefixes from a top-of-rack (TOR) or border leaf switch.

- BGP sessions are not supported over MPLS LSPs or segment routed paths.

- The Layer 3 forwarding consistency checker is not supported for MPLS routes. However, beginning with Cisco NX-OS Release 10.3(2)F, proactive consistency checker will be supporting IPv4/IPv6,

ARP/ND adjacencies and MPLS routes for IPv4, IPv6, VPNv4, VPNv6, and PE/Deagg FEC types on Cisco Nexus 3600 platform switches (N3K-C36180YC-R and N3K-C3636C-R).

- Deleting the segment routing configuration removes all the related segment routing configurations.

- Layer3 VPN over Segment Routing is supported on Cisco Nexus 3600 platform switches with N3K-C3636C-R and N3K-C36180YC-R line cards.

- If you downgrade the Cisco Nexus device from Cisco NX-OS Release 9.3(1) to the previous NX-OS releases by setting the boot variables and reloading the switch, all earlier configurations of the segment-routing mpls will be lost.

- Before performing an ISSD from Cisco NX-OS Release 9.3(1), you must disable the segment routing configuration. Failure to do so will result in the loss of the existing segment routing configurations.

Configuring Segment Routing

Configuring Segment Routing

Before you begin

Confirm that the following conditions are met before configuring segment routing.

- The **install feature-set mpls**, **feature-set mpls** and **feature mpls segment-routing** commands should be present before configuring the **segment-routing** command.

- If the global block is configured, the specified range is used. Otherwise, the default 16000 – 23999 range is used.

- BGP now uses both **set label-index** *<value>* configuration and the new **connected-prefix-sid-map** CLI. In case of a conflict, the configuration in SR-APP is preferred.

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	
	Example:
	
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**segment-routing**
	
	Example:
	
	`switch(config)# segment-routing`
	`switch(config-sr)# mpls`
	`switch(config-sr-mpls)#`
		Enables the MPLS segment routing functionality. The **no** form of this command disables the MPLS segment routing feature.

Step 3	**connected-prefix-sid-map** **Example:**	Configures the connected prefix segment identifier mappings.

	Command or Action	Purpose
	switch(config-sr-mpls)# connected-prefix-sid-map switch(config-sr-mpls)#	
Step 4	**global-block** *<min> <max>* **Example:** switch(config-sr-mpls)# global-block <min> <max> switch(config-sr-mpls)#	Specifies the global block range for the segment routing bindings.
Step 5	**connected-prefix-sid-map** **Example:** switch(config-sr-mpls)# connected-prefix-sid-map switch(config-sr-mpls-conn-pfsid)#	Configures the connected prefix segment identifier mappings.
Step 6	**address-family ipv4** **Example:** switch(config-sr-mpls-conn-pfsid)#address-family ipv4	Configures the IPv4 address family.
Step 7	*<prefix>/<masklen>* [**index**|**absolute**] *<label>* **Example:** switch(config-sr-mpls)# 2.1.1.5/32 absolute 201101	The optional keywords **index** or **absolute** indicate whether the label value entered should be interpreted as an index into the SRGB or as an absolute value.

Example

See the following configuration examples of the show commands:

```
switch# show segment-routing mpls
Segment-Routing Global info

Service Name: segment-routing

State: Enabled

Process Id: 29123

Configured SRGB: 17000 - 24999

SRGB Allocation status: Alloc-Successful

Current SRGB: 17000 - 24999

Cleanup Interval: 60

Retry Interval: 180
```

The following CLI displays the clients that are registered with SR-APP. It lists the VRFs, for which the clients have registered interest.

```
switch# show segment-routing mpls clients
            Segment-Routing Mpls Client Info

Client: isis-1
    PIB index: 1    UUID: 0x41000118    PID: 29463    MTS SAP: 412
    TIBs registered:
        VRF: default Table: base

Client: bgp-1
    PIB index: 2    UUID: 0x11b    PID: 18546    MTS SAP: 62252
    TIBs registered:
        VRF: default Table: base

Total Clients: 2
```

In the **show segment-routing mpls ipv4 connected-prefix-sid-map** CLI command example, SRGB indicates whether the prefix SID is within the configured SRGB. The **Indx** field indicates that the configured label is an index into the global block. The **Abs** field indicates that the configured label is an absolute value.

If the SRGB field displays N, it means that the configured prefix SID is not within the SRGB range and it is not provided to the SR-APP clients. Only the prefix SIDs that fall into the SRGB range are given to the SR-APP clients.

```
switch# show segment-routing mpls ipv4 connected-prefix-sid-map
            Segment-Routing Prefix-SID Mappings
Prefix-SID mappings for VRF default Table base
Prefix              SID    Type Range SRGB
13.11.2.0/24        713    Indx 1     Y
30.7.7.7/32         730    Indx 1     Y
59.3.24.0/30        759    Indx 1     Y
150.101.1.0/24      801    Indx 1     Y
150.101.1.1/32      802    Indx 1     Y
150.101.2.0/24      803    Indx 1     Y
1.1.1.1/32          16013 Abs  1      Y
```

The following CLI displays the **show running-config segment-routing** output.

```
switch# show running-config segment-routing ?

> Redirect it to a file
>> Redirect it to a file in append mode
all Show running config with defaults
| Pipe command output to filter

switch# show running-config segment-routing
switch# show running-config segment-routing

!Command: show running-config segment-routing
!Running configuration last done at: Thu Dec 12 19:39:52 2019
!Time: Thu Dec 12 20:06:07 2019

version 9.3(3) Bios:version 05.39
segment-routing
    mpls
        connected-prefix-sid-map
            address-family ipv4
                2.1.1.1/32 absolute 100100

switch#
```

Enabling MPLS on an Interface

You can enable MPLS on an interface for use with segment routing.

Before you begin

You must install and enable the MPLS feature set using the **install feature-set mpls** and **feature-set mpls** commands.

Procedure

	Command or Action	**Purpose**

Step 1	**configure terminal**
	
	Example:
	
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**interface** *type slot/port*
	
	Example:
	
	`switch(config)# interface ethernet 2/2`
	`switch(config-if)#`
		Enters the interface configuration mode for the specified interface.

Step 3	[**no**] **mpls ip forwarding** **Example:** `switch(config-if)# mpls ip forwarding`	Enables MPLS on the specified interface. The **no** form of this command disables MPLS on the specified interface.

Step 4	(Optional) **copy running-config startup-config**
	
	Example:
	
	`switch(config-if)# copy running-config`
	`startup-config`
		Copies the running configuration to the startup configuration.

Configuring the Segment Routing Global Block

You can configure the beginning and ending MPLS labels in the segment routing global block (SRGB).

Before you begin

You must install and enable the MPLS feature set using the **install feature-set mpls** and **feature-set mpls** commands.

You must enable the MPLS segment routing feature.

Procedure

	Command or Action	**Purpose**
Step 1	**configure terminal** **Example:**	Enters global configuration mode.

	Command or Action	Purpose
	switch# configure terminal switch(config)#	
Step 2	[**no**] **segment-routing** **Example:** switch(config)# segment-routing switch(config-sr)# mpls	Enters the segment routing configuration mode and enables the default SRGB of 16000 to 23999. The **no** form of this command unallocates that block of labels. If the configured dynamic range cannot hold the default SRGB, an error message appears, and the default SRGB will not be allocated. If desired, you can configure a different SRGB in the next step.
Step 3	[**no**] **global-block** *beginning-label ending-label* **Example:** switch(config-sr-mpls)# global-block 16000 471804	Specifies the MPLS label range for the SRGB. Use this command if you want to change the default SRGB label range that is configured with the **segment-routing** command. The permissive values for the beginning MPLS label and the ending MPLS label are from 16000 to 471804. The **mpls label range** command permits 16 as the minimum label, but the SRGB can start only from 16000. **Note** The minimum value for the **global-block** command starts from 16000. If you upgrading from previous releases, you should modify the SRGB so that it falls within the supported range before triggering an upgrade.
Step 4	(Optional) **show mpls label range** **Example:** switch(config-sr-mpls)# show mpls label range	Displays the SRGB, only if the SRGB allocation is successful.
Step 5	**show segment-routing**	Displays the configured SRGB.
Step 6	**show segment-routing mpls** **Example:** switch(config-sr-mpls)# show segment-routing mpls	Displays the configured SRGB.
Step 7	(Optional) **copy running-config startup-config** **Example:** switch(config-sr-mpls)# copy running-config startup-config	Copies the running configuration to the startup configuration.

Configuration Examples for Segment Routing

The examples in this section show a common BGP prefix SID configuration between two routers.

This example shows how to advertise a BGP speaker configuration of 10.10.10.10/32 and 20.20.20.20/32 with a label index of 10 and 20, respectively. It uses the default segment routing global block (SRGB) range of 16000 to 23999.

```
hostname s1
install feature-set mpls
feature-set mpls

feature telnet
feature bash-shell
feature scp-server
feature bgp
feature mpls segment-routing

segment-routing
  mpls
  vlan 1
segment-routing
  mpls
    connected-prefix-sid-map
    address-family ipv4
    2.1.1.1/32 absolute 100100

route-map label-index-10 permit 10
  set label-index 10
route-map label-index-20 permit 10
  set label-index 20

vrf context management
  ip route 0.0.0.0/0 10.30.108.1

interface Ethernet1/1
  no switchport
  ip address 10.1.1.1/24
  no shutdown

interface mgmt0
  ip address dhcp
  vrf member management

interface loopback1
  ip address 10.10.10.10/32

interface loopback2
  ip address 20.20.20.20/32

line console
line vty

router bgp 1
  address-family ipv4 unicast
    network 10.10.10.10/32 route-map label-index-10
    network 20.20.20.20/32 route-map label-index-20
    allocate-label all
  neighbor 10.1.1.2 remote-as 2
    address-family ipv4 labeled-unicast
```

This example shows how to receive the configuration from a BGP speaker.

```
hostname s2
install feature-set mpls
feature-set mpls

feature telnet
feature bash-shell
feature scp-server
feature bgp
feature mpls segment-routing

segment-routing mpls
vlan 1

vrf context management
  ip route 0.0.0.0/0 10.30.97.1
  ip route 0.0.0.0/0 10.30.108.1

interface Ethernet1/1
  no switchport
  ip address 10.1.1.2/24
  ipv6 address 10:1:1::2/64
  no shutdown

interface mgmt0
  ip address dhcp
  vrf member management

interface loopback1
  ip address 2.2.2.2/32
line console

line vty

router bgp 2
  address-family ipv4 unicast
    allocate-label all
  neighbor 10.1.1.1 remote-as 1
    address-family ipv4 labeled-unicast
```

This example shows how to display the configuration from a BGP speaker. The **show** command in this example displays the prefix 10.10.10.10 with label index 10 mapping to label 16010 in the SRGB range of 16000 to 23999.

```
switch# show bgp ipv4 labeled-unicast 10.10.10.10/32

BGP routing table information for VRF default, address family IPv4 Label Unicast
BGP routing table entry for 10.10.10.10/32, version 7
Paths: (1 available, best #1)
Flags: (0x20c001a) on xmit-list, is in urib, is best urib route, is in HW, , has label
  label af: version 8, (0x100002) on xmit-list
  local label: 16010

  Advertised path-id 1, Label AF advertised path-id 1
  Path type: external, path is valid, is best path, no labeled nexthop, in rib
  AS-Path: 1 , path sourced external to AS
    10.1.1.1 (metric 0) from 10.1.1.1 (10.10.10.10)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 0
      Prefix-SID Attribute: Length: 10
        Label Index TLV: Length 7, Flags 0x0 Label Index 10

  Path-id 1 not advertised to any peer
  Label AF advertisement
```

```
    Path-id 1 not advertised to any peer
```

This example shows how to configure egress peer engineering on a BGP speaker.

```
hostname epe-as-1
install feature-set mpls
feature-set mpls

feature telnet
feature bash-shell
feature scp-server
feature bgp
feature mpls segment-routing

segment-routing mpls
vlan 1

vrf context management
  ip route 0.0.0.0/0 10.30.97.1
  ip route 0.0.0.0/0 10.30.108.1

interface Ethernet1/1
  no switchport
  ip address 10.1.1.1/24
  no shutdown

interface Ethernet1/2
  no switchport
  ip address 11.1.1.1/24
  no shutdown

interface Ethernet1/3
  no switchport
  ip address 12.1.1.1/24
  no shutdown

interface Ethernet1/4
  no switchport
  ip address 13.1.1.1/24
  no shutdown

interface Ethernet1/5
  no switchport
  ip address 14.1.1.1/24
  no shutdown
```

The following is an example of show ip route vrf 2 command.

```
show ip route vrf 2
IP Route Table for VRF "2"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>

41.11.2.0/24, ubest/mbest: 1/0
    *via 1.1.1.9%default, [20/0], 13:26:48, bgp-2, external, tag 11 (mpls-vpn)
42.11.2.0/24, ubest/mbest: 1/0, attached
    *via 42.11.2.1, Vlan2, [0/0], 13:40:52, direct
42.11.2.1/32, ubest/mbest: 1/0, attached
    *via 42.11.2.1, Vlan2, [0/0], 13:40:52, local
```

The following is an example of **show forwarding route vrf 2** command.

```
slot  1
=======

IPv4 routes for table 2/base

-----------------+----------------------------------+-------------------+--------------+---------------
Prefix           | Next-hop                         | Interface         | Labels
         | Partial Install
-----------------+----------------------------------+-------------------+--------------+---------------
0.0.0.0/32        Drop                                Null0
127.0.0.0/8       Drop                                Null0
255.255.255.255/32  Receive                           sup-eth1
*41.11.2.0/24     27.1.31.4                           Ethernet1/3        PUSH
  30002 492529
                  27.1.32.4                           Ethernet1/21       PUSH
  30002 492529
                  27.1.33.4                           port-channel23     PUSH
  30002 492529
                  27.11.31.4                          Ethernet1/3.11     PUSH
  30002 492529
                  27.11.33.4                          port-channel23.11  PUSH
  30002 492529
                  37.1.53.4                           Ethernet1/53/1     PUSH
  29002 492529
                  37.1.54.4                           Ethernet1/54/1     PUSH
  29002 492529
                  37.2.53.4                           Ethernet1/53/2     PUSH
  29002 492529
                  37.2.54.4                           Ethernet1/54/2     PUSH
  29002 492529
                  80.211.11.1                         Vlan801            PUSH
  30002 492529
```

The following is an example of **show bgp l2vpn evpn summary** command.

```
show bgp l2vpn evpn summary
BGP summary information for VRF default, address family L2VPN EVPN
BGP router identifier 2.2.2.3, local AS number 2
BGP table version is 17370542, L2VPN EVPN config peers 4, capable peers 1
1428 network entries and 1428 paths using 268464 bytes of memory
BGP attribute entries [476/76160], BGP AS path entries [1/6]
BGP community entries [0/0], BGP clusterlist entries [0/0]
476 received paths for inbound soft reconfiguration
476 identical, 0 modified, 0 filtered received paths using 0 bytes

Neighbor        V    AS MsgRcvd MsgSent    TblVer  InQ OutQ Up/Down  State/PfxRcd
1.1.1.1         4    11       0       0         0    0    0 23:01:53 Shut (Admin)
1.1.1.9         4    11    4637    1836 17370542    0    0 23:01:40 476
1.1.1.10        4    11       0       0         0    0    0 23:01:53 Shut (Admin)
1.1.1.11        4    11       0       0         0    0    0 23:01:52 Shut (Admin)
```

The following is an example of **show bgp l2vpn evpn** command.

```
show bgp l2vpn evpn 41.11.2.0
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 14.1.4.1:115
BGP routing table entry for [5]:[0]:[0]:[24]:[41.11.2.0]:[0.0.0.0]/224, version 17369591
Paths: (1 available, best #1)
Flags: (0x000002) on xmit-list, is not in l2rib/evpn, is not in HW

  Advertised path-id 1
  Path type: external, path is valid, received and used, is best path
            Imported to 2 destination(s)
  AS-Path: 11 , path sourced external to AS
    1.1.1.9 (metric 0) from 1.1.1.9 (14.1.4.1)
      Origin incomplete, MED 0, localpref 100, weight 0
      Received label 492529
      Extcommunity: RT:2:20

  Path-id 1 not advertised to any peer

Route Distinguisher: 2.2.2.3:113
BGP routing table entry for [5]:[0]:[0]:[24]:[41.11.2.0]:[0.0.0.0]/224, version 17369595
Paths: (1 available, best #1)
Flags: (0x000002) on xmit-list, is not in l2rib/evpn, is not in HW

  Advertised path-id 1
  Path type: external, path is valid, is best path
            Imported from 14.1.4.1:115:[5]:[0]:[0]:[24]:[41.11.2.0]:[0.0.0.0]/224
  AS-Path: 11 , path sourced external to AS
    1.1.1.9 (metric 0) from 1.1.1.9 (14.1.4.1)
```

Segment Routing with IS-IS Protocol

About IS-IS

IS-IS is an Interior Gateway Protocol (IGP) based on Standardization (ISO)/International Engineering Consortium (IEC) 10589 and RFC 1995. Cisco NX-OS supports Internet Protocol version 4 (IPv4) and IPv6. IS-IS is a dynamic link-state routing protocol that can detect changes in the network topology and calculate loop-free routes to other nodes in the network. Each router maintains a link-state database that describes the state of the network and sends packets on every configured link to discover neighbors. IS-IS floods the link-state information across the network to each neighbor. The router also sends advertisements and updates on the link-state database through all the existing neighbors

Segment routing on the IS-IS protocol supports the following:

- IPv4

- Level 1, level 2, and multi-level routing

- Prefix SIDs

- Multiple IS-IS instances on the same loopback interface for domain border nodes

- Adjacency SIDs for adjacencies

Configuring Segment Routing with IS-IS Protocol

You can configure segment routing with IS-IS protocol.

Before you begin

IS-IS segment routing is fully enabled when the following conditions are met:

- The **mpls segment-routing** feature is enabled.

- The IS-IS feature is enabled.

- Segment routing is enabled for at least one address family under IS-IS.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router isis** *instance-tag*	Creates a new IS-IS instance with the configured instance tag.
Step 3	**net** *network-entity-title*	Configures the NET for this IS-IS instance.
Step 4	**address-family** *ipv4* **unicast**	Enters address family configuration mode.
Step 5	**segment-routing mpls**	Configures segment routing with IS-IS protocol. **Note** - The IS-IS command is supported only on the IPv4 address family. It is not supported on the IPv6 address family. - Redistribution is not supported from any other protocol to ISIS for the SR prefixes. You need to enable **ip router isis** command on all the prefix SID interfaces.

Segment Routing with OSPFv2 Protocol

About OSPF

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.

Segment routing configuration on the OSPF protocol can be applied at the process or the area level. If you configure segment routing at the process level, it is enabled for all the areas. However, you can enable ore disable it per area level.

Segment routing on the OSPF protocol supports the following:

- OSPFv2 control plane

- Multi-area

- IPv4 prefix SIDs for host prefixes on loopback interfaces

- Adjacency SIDs for adjacencies

Adjacency SID Advertisement

OSPF supports the advertisement of segment routing adjacency SID. An Adjacency Segment Identifier (Adj-SID) represents a router adjacency in Segment Routing.

A segment routing-capable router may allocate an Adj-SID for each of its adjacencies and an Adj-SID sub-TLV is defined to carry this SID in the Extended Opaque Link LSA.

OSPF allocates the adjacency SID for each OSPF neighbor if the OSPF adjacency which are in two way or in FULL state. OSPF allocates the adjacency SID only if the segment routing is enabled. The label for adjacency SID is dynamically allocated by the system. This eliminates the chances of misconfiguration, as this has got only the local significance.

Connected Prefix-SID

OSPFv2 supports the advertisement of prefix SID for address associated with the loopback interfaces. In order to achieve this, OSPF uses Extended Prefix Sub TLV in its opaque Extended prefix LSA. When OSPF receives this LSA from its neighbor, SR label is added to the RIB corresponding to received prefix based upon the information present in extended prefix sub TLV.

For configuration, segment-routing has to be enabled under OSPF and corresponding to loopback interface that is configured with OSPF, prefix-sid mapping is required under the segment routing module.

Note SID will only be advertised for loopback addresses and only for intra-area and inter-area prefix types. No SID value will be advertised for external or NSSA prefixes.

Prefix Propagation Between Areas

To provide segment routing support across the area boundary, OSPF is required to propagate SID values between areas. When OSPF advertises the prefix reachability between areas, it checks if the SID has been advertised for the prefix. In a typical case, the SID value come from the router, which contributes to the best path to the prefix in the source area. In this case, OSPF uses such SID and advertises it between the areas. If the SID value is not advertised by the router which contributes to the best path inside the area, OSPF will use the SID value coming from any other router inside the source area.

Segment Routing Global Range Changes

OSPF advertises it's segment routing capability in terms of advertising the SID/Label Range TLV. In OSPFv2, SID/Label Range TLV is a carried in Router Information LSA.

The segment routing global range configuration will be under the "segment-routing mpls" configuration. When the OSPF process comes, it will get the global range values from segment-routing and subsequent changes should be propagated to it.

When OSPF segment routing is configured, OSPF must request an interaction with the segment routing module before OSPF segment routing operational state can be enabled. If the SRGB range is not created, OSPF will not be enabled. When an SRGB change event occurs, OSPF makes the corresponding changes in it's sub-block entries.

Conflict Handling of SID Entries

In an ideal situation, each prefix should have unique SID entries assigned.

When there is a conflict between the SID entries and the associated prefix entries use any of the following methods to resolve the conflict:

- Multiple SIDs for a single prefix - If the same prefix is advertised by multiple sources with different SIDs, OSPF will install the unlabeled path for the prefix. The OSPF takes into consideration only those SIDs that are from reachable routers and ignores those from unreachable routers. When multiple SIDs are advertised for a prefix, which is considered as a conflict, no SID will be advertised to the attached-areas for the prefix. Similar logic will be used when propagating the inter-area prefixes between the backbone and the non-backbone areas.

- Out of Range SID - For SIDs that do not fit in our SID range, labels are not used while updating the RIB.

MPLS Forwarding on an Interface

MPLS forwarding must be enabled before segment routing can use an interface. OSPF is responsible for enabling MPLS forwarding on an interface.

When segment routing is enabled for a OSPF topology, or OSPF segment routing operational state is enabled, it enables MPLS for any interface on which the OSPF topology is active. Similarly, when segment routing is disabled for a OSPF topology, it disables the MPLS forwarding on all interfaces for that topology.

MPLS forwarding is not supported on an interface which terminates at the IPIP/GRE tunnel.

Configuring Segment Routing with OSPFv2

Configure segment routing with OSPFv2 protocol.

Before you begin

Confirm that the following conditions are met before configuring segment routing with OSPFv2:

- The OSPFv2 feature is enabled.

- The segment-routing feature is enabled.

- Segment routing is enabled under OSPF.

Procedure

	Command or Action	**Purpose**
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	[**no**]**router ospf** *process* **Example:** switch(config)# router ospf test	Enables the OSPF mode.
Step 3	**segment-routing** **Example:** switch(config-router)# segment-routing mpls	Configures the segment routing functionality under OSPF.

Configuring Segment Routing on OSPF Network- Area Level

Before you begin

Before you configure segment routing on OSPF network, OSPF must be enabled on your network.

Procedure

	Command or Action	**Purpose**
Step 1	**router ospf process** **Example:** switch(config)# router ospf test	Enables the OSPF mode.
Step 2	**area** *<area id>* **segment-routing** [**mpls** | **disable**] **Example:** switch(config-router)# area 1 segment-routing mpls	Configures segment routing mpls mode in a specific area.
Step 3	[**no**]**area** *<area id>* **segment-routing** [**mpls** | **disable**] **Example:** switch(config-router)#area 1 segment-routing disable	Disables segment routing mpls mode for the specified area.
Step 4	**show ip ospf** *process* **segment-routing** **Example:** switch(config-router)# show ip ospf test segment-routing	Shows the output for configuring segment routing under OSPF.

Configuring Prefix-SID for OSPF

This task explains how to configure prefix segment identifier (SID) index under each interface.

Before you begin

Segment routing must be enabled on the corresponding address family.

Procedure

	Command or Action	**Purpose**
Step 1	**configure terminal** **Example:** `switch# configure terminal`	Enters global configuration mode.
Step 2	[**no**]**router ospf** *process* **Example:** `switch(config)# router ospf test`	Configures OSPF.

Step 3	**segment-routing**
	
	Example:
	
	`switch(config-router)# segment-routing`
	`switch(config-sr)#mpls`
	`switch(config-sr-mpls)#`
		Configures the segment routing functionality under OSPF.

Step 4	**interface loopback** *interface_number* **Example:** `switch(config-sr-mpls)# Interface loopback 0`	Specifies the interface where OSPF is enabled.
Step 5	**ip address 1.1.1.1/32** **Example:** `switch(config-sr-mpls)# ip address 1.1.1.1/32`	Specifies the IP address configured on the ospf interface.
Step 6	**ip router ospf 1 area 0** **Example:** `switch(config-sr-mpls)# ip router ospf 1 area 0`	Specifies the OSPF enabled on the interface in area.

Step 7	**segment-routing**
	
	Example:
	
	`switch(config-router)#segment-routing`
	`(config-sr)#mpls`
		Configures prefix-sid mapping under SR module.

Step 8	**connected-prefix-sid-map** **Example:**	Configures the prefix SID mapping under the segment routing module.

	Command or Action	Purpose
	switch(config-sr-mpls)# connected-prefix-sid-map switch(config-sr-mpls-conn-pfxsid)#	
Step 9	**address-family ipv4** **Example:** switch(config-sr-mpls-conn-pfxsid)# address-family ipv4 switch(config-sr-mpls-conn-pfxsid-af)#	Specifies the IPv4 address family configured on the OSPF interface.
Step 10	**1.1.1.1/32 index 10** **Example:** switch(config-sr-mpls-conn-af)# 1.1.1.1/32 index 10	Associates SID 10 with the address 1.1.1.1/32.
Step 11	**exit** **Example:** switch(config-sr-mpls-conn-af)# exit	Exits segment routing mode and returns to the configuration terminal mode.

Configuring Prefix Attribute N-flag-clear

OSPF advertises prefix SIDs via Extended Prefix TLV in its opaque LSAs. It carries flags for the prefix and one of them is N flag (Node) indicating that any traffic sent along to the prefix is destined to the router originating the LSA. This flag typically marks host routes of router's loopback.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	**interface loopback3** **Example:** switch(config)# interface loopback3	Specifies the interface loopback.
Step 3	**ip ospf prefix-attributes n-flag-clear** **Example:** switch#(config-if)# ip ospf prefix-attributes n-flag-clear	Clears the prefix N-flag.

Configuration Examples for Prefix SID for OSPF

This example shows the configuration for prefix SID for OSPF.

```
Router ospf 10
    Segment-routing mpls
Interface loop 0
    Ip address 1.1.1.1/32
    Ip router ospf 10 area 0
Segment-routing
  Mpls
     connected-prefix-sid-m
         address-family ipv4
             1.1.1.1/32 index 10
```

Configuring Prefix SID Using BGP

You can set the label index for routes that match the **network** command. Doing so causes the BGP prefix SID to be advertised for local prefixes that are configured with a route map that includes the **set label-index** command, provided the route map is specified in the **network** command that specifies the local prefix. (For more information on the **network** command, see the "Configuring Basic BGP" chapter in the Cisco Nexus 3600 Series NX-OS Unicast Routing Configuration Guide.)

Note   Route-map label indexes are ignored when the route map is specified in a context other than the **network** command. Also, labels are allocated for prefixes with a route-map label index independent of whether the prefix has been configured by the **allocate-label route-map** *route-map-name* command.

BGP Prefix SID

In order to support segment routing, BGP requires the ability to advertise a segment identifier (SID) for a BGP prefix. A BGP prefix SID is always global within the segment routing BGP domain and identifies an instruction to forward the packet over the ECMP-aware best path computed by BGP to the related prefix. The BGP prefix SID identifies the BGP prefix segment.

BGP Prefix SID Deployment Example

In the simple example below, all three routers are running iBGP and advertising Network Layer Reachability Information (NRLI) to one another. The routers are also advertising their loopback interface as the next hop, which provides the ECMP between routers 2.2.2.2 and 3.3.3.3.
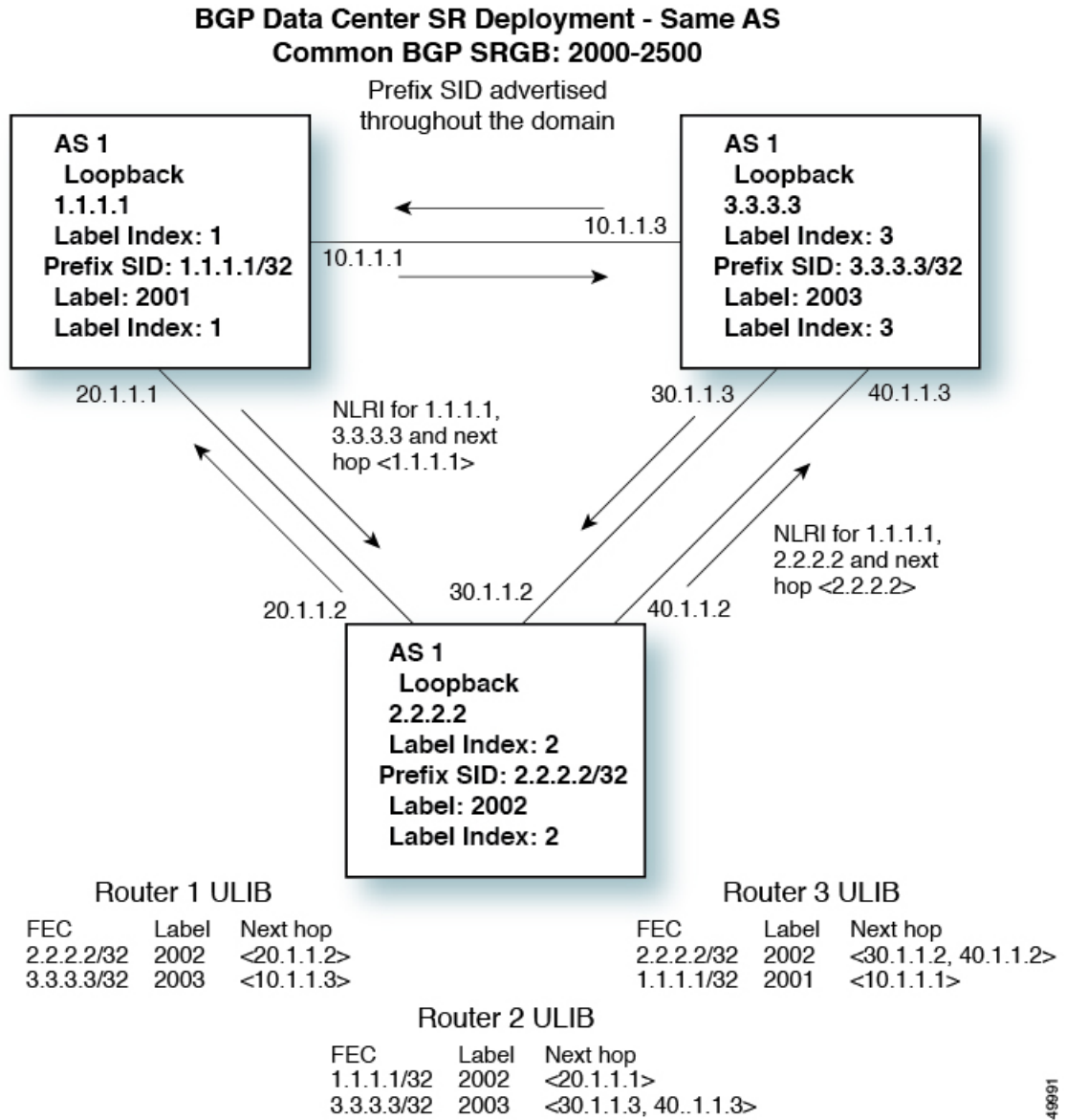
Adjacency SID

The adjacency segment Identifier (SID) is a local label that points to a specific interface and a next hop out of that interface. No specific configuration is required to enable adjacency SIDs. Once segment routing is enabled over BGP for an address family, for any interface that BGP runs over, the address family automatically allocates an adjacency SID toward every neighbor out of that interface.

High Availability for Segment Routing

In-service software upgrades (ISSUs) are minimally supported with BGP graceful restart. All states (including the segment routing state) must be relearned from the BGP router's peers. During the graceful restart period, the previously learned route and label state are retained.

Configuring the Label Index

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	
	Example:
	
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**route-map** *map-name*
	
	Example:
	
	`switch(config)# route-map SRmap`
	`switch(config-route-map)#`
		Creates a route map or enters route-map configuration mode for an existing route map.

Step 3	[**no**] **set label-index** *index*
	
	Example:
	
	`switch(config-route-map)# set label-index`
	` 10`
		Sets the label index for routes that match the **network** command. The range is from 0 to 471788. By default, a label index is not added to the route.

Step 4	**exit**
	
	Example:
	
	`switch(config-route-map)# exit`
	`switch(config)#`
		Exits route-map configuration mode.

Step 5	**router bgp** *autonomous-system-number*
	
	Example:
	
	`switch(config)# router bgp 64496`
	`switch(config-router)#`
		Enables BGP and assigns the AS number to the local BGP speaker. The AS number can be a 16-bit integer or a 32-bit integer in the form of a higher 16-bit decimal number and a lower 16-bit decimal number in xx.xx format.

Step 6	Required: **address-family ipv4 unicast**
	
	Example:
	
	`switch(config-router)# address-family`
	`ipv4 unicast`
	`switch(config-router-af)#`
		Enters global address family configuration mode for the IPv4 address family.

Step 7	**network** *ip-prefix* [**route-map** *map-name*]
	
	Example:
	
	`switch(config-router-af)# network`
	`10.10.10.10/32 route-map SRmap`
		Specifies a network as local to this autonomous system and adds it to the BGP routing table.

	Command or Action	Purpose
Step 8	(Optional) **show route-map** [*map-name*] **Example:** `switch(config-router-af)# show route-map`	Displays information about route maps, including the label index.
Step 9	(Optional) **copy running-config startup-config** **Example:** `switch(config-router-af)# copy running-config startup-config`	Copies the running configuration to the startup configuration.

Configuring the MPLS Label Allocation

You can configure MPLS label allocation for the IPv4 unicast address family.

Before you begin

You must install and enable the MPLS feature set using the **install feature-set mpls** and **feature-set mpls** commands.

You must enable the MPLS segment routing feature.

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	
	Example:
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	[**no**] **router bgp** *autonomous-system-number*
	
	Example:
	`switch(config)# router bgp 64496`
	`switch(config-router)#`
		Enables BGP and assigns the AS number to the local BGP speaker. The AS number can be a 16-bit integer or a 32-bit integer in the form of a higher 16-bit decimal number and a lower 16-bit decimal number in xx.xx format.
		
		Use the **no** option with this command to remove the BGP process and the associated configuration.

Step 3	Required: **address-family ipv4 unicast**
	
	Example:
	`switch(config-router)# address-family ipv4 unicast`
	`switch(config-router-af)#`
		Enters global address family configuration mode for the IPv4 address family.

Step 4	[**no**] **allocate-label** {**all** | **route-map** *route-map-name*} **Example:**	Configures local label allocation for routes matching the specified route map or for all routes advertised in this address family.

	Command or Action	**Purpose**
	switch(config-router-af)# allocate-label route-map map1	
Step 5	Required: **exit** **Example:** switch(config-router-af)# exit switch(config-router)#	Exits global address family configuration mode.
Step 6	**neighbor** *ipv4-address* **remote-as** *autonomous-system-number* **Example:** switch(config-router)# neighbor 10.1.1.1 remote-as 64497 switch(config-router-neighbor)#	Configures the IPv4 address and AS number for a remote BGP peer.
Step 7	**address-family ipv4 labeled-unicast** **Example:** switch(config-router-neighbor)# address-family ipv4 labeled-unicast switch(config-router-neighbor-af)#	Advertises the labeled IPv4 unicast routes as specified in RFC 3107.
Step 8	(Optional) **show bgp ipv4 labeled-unicast** *prefix* **Example:** switch(config-router-neighbor-af)# show bgp ipv4 labeled-unicast 10.10.10.10/32	Displays the advertised label index and the selected local label for the specified IPv4 prefix.
Step 9	(Optional) **copy running-config startup-config** **Example:** switch(config-router-neighbor-af)# copy running-config startup-config	Copies the running configuration to the startup configuration.

Configuration Example for BGP Prefix SID

The examples in this section show a common BGP prefix SID configuration between two routers.

This example shows how to advertise a BGP speaker configuration of 10.10.10.10/32 and 20.20.20.20/32 with a label index of 10 and 20, respectively. It uses the default segment routing global block (SRGB) range of 16000 to 23999.

```
hostname s1
install feature-set mpls
feature-set mpls

feature telnet
feature bash-shell
feature scp-server
feature bgp
feature mpls segment-routing

segment-routing mpls
vlan 1
```

```
route-map label-index-10 permit 10
  set label-index 10
route-map label-index-20 permit 10
  set label-index 20

vrf context management
  ip route 0.0.0.0/0 10.30.108.1

interface Ethernet1/1
  no switchport
  ip address 10.1.1.1/24
  no shutdown

interface mgmt0
  ip address dhcp
  vrf member management

interface loopback1
  ip address 10.10.10.10/32

interface loopback2
  ip address 20.20.20.20/32

line console
line vty

router bgp 1
  address-family ipv4 unicast
    network 10.10.10.10/32 route-map label-index-10
    network 20.20.20.20/32 route-map label-index-20
    allocate-label all
  neighbor 10.1.1.2 remote-as 2
    address-family ipv4 labeled-unicast
```

This example shows how to receive the configuration from a BGP speaker.

```
hostname s2
install feature-set mpls
feature-set mpls

feature telnet
feature bash-shell
feature scp-server
feature bgp
feature mpls segment-routing

segment-routing mpls
vlan 1

vrf context management
  ip route 0.0.0.0/0 10.30.97.1
  ip route 0.0.0.0/0 10.30.108.1

interface Ethernet1/1
  no switchport
  ip address 10.1.1.2/24
  ipv6 address 10:1:1::2/64
  no shutdown

interface mgmt0
  ip address dhcp
  vrf member management
```

```
interface loopback1
  ip address 2.2.2.2/32
line console

line vty

router bgp 2
  address-family ipv4 unicast
    allocate-label all
  neighbor 10.1.1.1 remote-as 1
    address-family ipv4 labeled-unicast
```

Configuring the BGP Link State Address Family

You can configure the BGP link state address family for a neighbor session with a controller to advertise the corresponding SIDs. You can configure this feature in global configuration mode and neighbor address family configuration mode.

Before you begin

You must enable BGP.

Procedure

	Command or Action	**Purpose**

Step 1	**configure terminal**
	
	Example:
	
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**router bgp** *<bgp autonomous number>*	Specifies the autonomous router BGP number.

Step 3	[**no**] **address-family link-state**
	
	Example:
	
	`switch(config)# router bgp 64497`
	`switch (config-router af)# address-family`
	` link-state`
		Enters address-family interface configuration mode.
		
		Note This command can also be configured in neighbor address-family configuration mode.

Step 4	**neighbor** *<IP address>*	Configures the IP address for the neighbor.

Step 5	[**no**] **address-family link-state**
	
	Example:
	
	`switch(config)#router bgp 1`
	`switch(config-router)#address-family`
	`link-state`
	`switch(config-router)#neighbor`
	`20.20.20.20`
	`switch(config-router)#address-family`
	`link-state`
		Enters address-family interface configuration mode.
		
		Note This command can also be configured in neighbor address-family configuration mode.

Verifying the Segment Routing Configuration

To display the segment routing configuration, perform one of the following tasks:

Command	Purpose
show bgp ipv4 labeled-unicast *prefix*	Displays the advertised label index and the selected local label for the specified IPv4 prefix.
show bgp paths	Displays the BGP path information, including the advertised label index.
show mpls label range	Displays the configured SRGB range of labels.
show route-map [*map-name*]	Displays information about a route map, including the label index.
show running-config | inc 'feature segment-routing'	Displays the status of the MPLS segment routing feature.
show ip ospf neighbors detail	Displays the list of OSPFv2 neighbors and the adjacency SID allocated, along with the corresponding flags.
show ip ospf database opaque-area	Displays the LSAs for the adjacency SID.
show ip ospf segment-routing adj-sid-database	Displays all locally allocated adjacency SIDs.
show running-config segment-routing	Displays the status of the segment routing feature.
show srte policy	Displays only the authorized policies.
show srte policy [**all**]	Displays the list of all policies available in the SR-TE.
show srte policy [**detail**]	Displays the detailed view of all the requested policies.
show srte policy *<name>*	Filters the SR-TE policy with the name and displays the list of all policies available with that name in the SR-TE. **Note** This command has the autocomplete feature for the policy-name. To use this feature, add a question mark or press TAB.
show srte policy color *<color>* **endpoint** *<endpoint>*	Displays the SR-TE policy for the color and endpoint. **Note** This command has the autocomplete feature for color and endpoint. To use this feature, add a question mark or press TAB.

Command	Purpose
show srte policy fh	Displays the set of first hops.
show segment-routing mpls clients	Displays the clients registered with the SR-APP.
show segment-routing mpls details	Displays detailed information.
show segment-routing ipv4	Displays the information for the IPv4 address family.
show segment-routing mpls	Displays segment routing mpls information
show segment-routing ipv4 connected-prefix-sid	Displays the MPLS label range for the SRGB. **Note** This command is only available in Cisco NX-OS Release 9.3(1) .
show ip ospf *process*	Displays the OSPF mode.
show ip ospf *process* **segment-routing sid-database**	Displays the segment routing database details.
show ip ospf *process* **segment-routing global block**	Displays the segment routing global block information.

Additional References

Related Documents

Related Topic	Document Title
BGP	*Cisco Nexus 3600 Series Unicast Routing Configuration Guide*