



Configuring Segment Routing

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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 6](#).

NetFlow for MPLS

NetFlow identifies packet flows for ingress IP packets and provides statistics that are based on these packet flows. NetFlow does not require any change to either the packets themselves or to any networking device. You can export the data that NetFlow gathers for your flow by using a flow exporter and export this data to a remote NetFlow Collector, such as Cisco Stealthwatch. Cisco NX-OS exports flow as part of a NetFlow export User Datagram Protocol (UDP) datagram. You can export the data that NetFlow gathers for your flow by using a flow exporter and export this data to a remote NetFlow Collector, such as Cisco Stealthwatch. Cisco NX-OS exports a flow as part of a NetFlow export User Datagram Protocol (UDP) datagram.

Beginning with Cisco NX-OS Release 9.3(1), NetFlow Collector over segment routing is supported on Cisco Nexus 9300-EX, 9300-FX, 9300-FX2, 9500-EX, and 9500-FX platform switches.

Beginning with Cisco NX-OS Release 9.3(5), NetFlow Collector over segment routing is supported on Cisco Nexus 9300-FX3 platform switches.

NetFlow is not supported on Cisco Nexus 9300-GX platform switches..

NetFlow Collector supports both, single and double MPLS labels. Both, default and the non-default VRF in the exporter destination configurations is supported. NetFlow does not support an MPLS data path.

Since segment routing does not support a single label, you must configure the **address-family ipv4 labeled-unicast** command under BGP neighbor and the **allocate-label** command under the bgp configuration.

sFlow Collector

Sampled flow (sFlow) allows you to monitor real-time traffic in data networks that contain switches and routers. It uses the sampling mechanism in the sFlow agent software on switches and routers to monitor traffic and to forward the sample data to the central data collector.

Beginning with Cisco NX-OS Release 9.3(1), sFlow collector over segment routing is supported on Cisco Nexus 9300-EX, 9300-FX, 9300-FX2, 9500-EX, and 9500-FX platform switches.

Beginning Cisco NX-OS Release 9.3(5), sFlow collector over segment routing is supported on Cisco Nexus 9300-FX3 platform switches.

sFlow is not supported on Cisco Nexus 9364C-GX, Cisco Nexus 9316D-GX, and Cisco Nexus 93600CD-GX switches.

For information on configuring sFlow, see the *Configuring sFlow* section in the *Cisco Nexus 9000 Series NX-OS System Management Configuration Guide, Release 9.3(x)*.

Guidelines and Limitations for Segment Routing

Segment routing has the following guidelines and limitations:

- MPLS segment routing is not supported for FEX modules.
- Beginning with Cisco NX-OS Release 9.3(1), the **segment-routing mpls** command has changed to **segment-routing**.
- When you enable MPLS segment routing on Cisco Nexus 9504 and 9508 platform switches with a -R series line card, there can be instances of the BFD sessions going down and coming back. BGP peerings, if configured with BFD, also go down and come back up. When a BGP session goes down, it withdraws routes from the hardware. This results in packet loss until the BGP session is re-established and routes are re-installed. However, once the BFD comes up, no additional flaps occurs.
- You can run segment routing under IGP(like OSPF) or by AF labeled unicast in BGP.
- Segment Routing is supported on Cisco Nexus 9300-FX platform switches and the Cisco Nexus N9K-X9736C-FX line cards.
- Segment routing and SR-EVPN are supported on Cisco Nexus C31108PC-V, C31108TC-V, and C3132Q-V switches.
- Beginning with Cisco NX-OS Release 9.3(3), you can configure Layer 3 VPNs on Cisco Nexus 9300-GX platform switches.
- Beginning with Cisco NX-OS Release 9.3(3), segment routing and SR-EVPN is supported on Cisco Nexus 9364C-GX, Cisco Nexus 9316D-GX, and Cisco Nexus 93600CD-GX platform switches.
- Beginning with Cisco NX-OS Release 9.3(3), adjacency SIDs on OSPF are supported on Cisco Nexus 9364C-GX, Cisco Nexus 9316D-GX, and Cisco Nexus 93600CD-GX platform switches.
- Beginning with Cisco NX-OS Release 9.3(3), segment routing with OSPF, IS-IS underlay, and BGP labeled unicast is supported on Cisco Nexus 9364C-GX, Cisco Nexus 9316D-GX, and Cisco Nexus 93600CD-GX platform switches.
- BGP allocates the 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 an RR, the next hop is changed for the routes that are being affected (subject to route-map filtering).
- A nondisruptive ISSU is not supported with MPLS features for Cisco Nexus 9300-EX and 9300-FX platform switches.
- Static MPLS, MPLS segment routing, and MPLS stripping cannot be enabled at the same time.
- Beginning with Cisco NX-OS Release 9.3(5), MPLS stripping is supported on Cisco Nexus 9300-GX platform switches and the following guidelines are applicable:
 - For the MPLS strip feature to work, both the **mpls strip** and the **hardware acl tap-agg** commands should be configured after the switches are reloaded.

- When the MPLS strip is enabled on the Cisco Nexus 9300-GX platform switches, the ACL log process is not displayed.
- MPLS strip with dot1q VLAN is not supported.
- For all double VLAN tags, the second VLAN range should be between 2-510.
- MPLS strip with dot1q is not supported.
- For PACL redirect support, you must use the **mode tap-aggregation** command on the ingress TAP interface.
- 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 outlabel 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.
- For the Cisco Nexus 9200 Series switches, adjacency statistics are not maintained for Layer 3 or MPLS adjacencies.
- For the Cisco Nexus 9500 Series switches, MPLS LSPs and segment routed paths are not supported on subinterfaces (either port channels or normal Layer 3 ports).
- For the Cisco Nexus 9500 platform switches, segment routing is supported only in the nonhierarchical routing mode.
- The BGP configuration commands **neighbor-down fib-accelerate** and **suppress-fib-pending** are not supported for MPLS prefixes.
- The uniform model as defined in RFC 2973 and RFC 3270 is not supported. Therefore, the IP DSCP bits are not copied into the imposed MPLS header.
- 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.
- If the segment routing global block (SRGB) is set to a range but the route-map label-index delta value is outside of the configured range, the allocated label is dynamically generated. For example, if the SRGB is set to range of 16000-23999 when 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.

- You can configure segment routing traffic engineering with on-demand next hop on Cisco Nexus 9000 Series switches.
- Layer 3 VPN and Layer 3 EVPN stitching for segment routing is supported on Cisco Nexus 9000 Series switches.
- Beginning with Cisco NX-OS Release 9.3(3), Layer 3 VPN and Layer 3 EVPN stitching for segment routing is supported on 9300-GX platform switches.
- You can configure OSPFv2 as an IGP control plane for segment routing on Cisco Nexus 9000 Series switches.
- Layer 3 VPN and Layer 3 EVPN Stitching for segment routing is not supported on Cisco Nexus 9364C, 9200, 9300-EX, and 9500 platform switches with the -EX line cards.
- The OSPF segment routing command and segment-routing traffic engineering with on-demand next hop is not supported on Cisco Nexus 9364C switches.
- Segment Routing is supported on Cisco Nexus 9300-FX2 and 9300-FX3 platform switches.
- Layer 3 VPN and Layer 3 EVPN Stitching for Segment Routing, the OSPF segment routing command, and the segment-routing traffic engineering with on-demand next hop is supported on Cisco Nexus 9364C switches.
- Layer 3 VPN over Segment Routing is supported on Cisco Nexus 3100, 3200, 9200, 9300, 9300-EX/FX/FX2/FX3 platform switches and Cisco Nexus 9500 platform switches with -EX/FX and -R line cards.
- Deleting the segment routing configuration removes all the related segment routing configurations including the MPLS and the traffic engineering configurations.
- 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 are 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.
- Segment routing MPLS adjacency statistics are collected based on the out label stack and the next hop on the intermediate nodes. However, in the PHP mode, the statistics are shown on all adjacencies because the same stack is shared on all the FECs.
- If segment routing is enabled on a switch, Q-in-Q tagging on a dot1Q tagged MPLS packet is not supported, packets egress with only the outer tag.

For example: Consider an ingress port in access dot1q tunnel mode, with VLAN 100. Incoming MPLS traffic has a dot1Q tag of 200. Typically, the traffic should egress with an outer tag of 100, and inner tag of 200 (same as the tag of the incoming packet). However, the packet egresses with an outer tag and loses the inner tag.
- When an incoming MPLS packet is untagged and the ingress port is in access VLAN mode, packets egress without any tag, if segment routing is enabled.
- We recommend that you do not configure segment routing using BGP, OSPF, and IS-IS underlay simultaneously.

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: switch(config-sr-mpls)# connected-prefix-sid-map switch(config-sr-mpls)#	Configures the connected prefix segment identifier mappings.
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.

	Command or Action	Purpose
Step 6	address-family ipv4 Example: switch(config-sr-mps-conn-pfsid)#address-family ipv4	Configures the IPv4 address family.
Step 7	<prefix>/<masklen> [index absolute] <label> Example: switch(config-sr-mps)# 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 <i>type slot/port</i> 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: switch# configure terminal switch(config)#	Enters global configuration mode.
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

	Command or Action	Purpose
		desired, you can configure a different SRGB in the next step.
Step 3	<p>[no] global-block <i>beginning-label ending-label</i></p> <p>Example:</p> <pre>switch(config-sr-mpls)# global-block 16000 471804</pre>	<p>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.</p> <p>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.</p> <p>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.</p>
Step 4	<p>(Optional) show mpls label range</p> <p>Example:</p> <pre>switch(config-sr-mpls)# show mpls label range</pre>	Displays the SRGB, only if the SRGB allocation is successful.
Step 5	show segment-routing	Displays the configured SRGB.
Step 6	<p>show segment-routing mpls</p> <p>Example:</p> <pre>switch(config-sr-mpls)# show segment-routing mpls</pre>	Displays the configured SRGB.
Step 7	<p>(Optional) copy running-config startup-config</p> <p>Example:</p> <pre>switch(config-sr-mpls)# copy running-config startup-config</pre>	Copies the running configuration to the startup configuration.

Configuring the Label Index

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 9000 Series NX-OS Unicast Routing Configuration Guide](#).)



Note Segment Routing Application (SR-APP) module is used to configure the segment routing functionality. BGP now uses both **set label-index <value>** configuration under route-map and the new **connected-prefix-sid-map** CLI for prefix SID configuration. In case of a conflict, the configuration in SR-APP is preferred.



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.

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.

	Command or Action	Purpose
Step 7	network <i>ip-prefix</i> [route-map <i>map-name</i>] 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.
Step 8	(Optional) show route-map [<i>map-name</i>] 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.

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)
```

Configuring 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 <i>instance-tag</i>	Creates a new IS-IS instance with the configured instance tag.
Step 3	net <i>network-entity-title</i>	Configures the NET for this IS-IS instance.
Step 4	address-family <i>ipv4 unicast</i>	Enters address family configuration mode.
Step 5	segment-routing mpls	Configures segment routing with IS-IS protocol.

	Command or Action	Purpose
		<p>Note</p> <ul style="list-style-type: none"> • 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.

Configuring 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 or 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: <pre>switch# configure terminal switch(config)#</pre>	Enters global configuration mode.
Step 2	[no]router ospf process Example: <pre>switch(config)# router ospf test</pre>	Enables the OSPF mode.
Step 3	segment-routing Example: <pre>switch(config-router)# segment-routing mpls</pre>	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:	Configures the segment routing functionality under OSPF.

	Command or Action	Purpose
	<pre>switch(config-router)# segment-routing switch(config-sr)#mpls switch(config-sr-mpls)#</pre>	
Step 4	interface loopback <i>interface_number</i> Example: <pre>switch(config-sr-mpls)# Interface loopback 0</pre>	Specifies the interface where OSPF is enabled.
Step 5	ip address 1.1.1.1/32 Example: <pre>switch(config-sr-mpls)# ip address 1.1.1.1/32</pre>	Specifies the IP address configured on the ospf interface.
Step 6	ip router ospf 1 area 0 Example: <pre>switch(config-sr-mpls)# ip router ospf 1 area 0</pre>	Specifies the OSPF enabled on the interface in area.
Step 7	segment-routing Example: <pre>switch(config-router)#segment-routing (config-sr)#mpls</pre>	Configures prefix-sid mapping under SR module.
Step 8	connected-prefix-sid-map Example: <pre>switch(config-sr-mpls)# connected-prefix-sid-map switch(config-sr-mpls-conn-pfxsid)#</pre>	Configures the prefix SID mapping under the segment routing module.
Step 9	address-family ipv4 Example: <pre>switch(config-sr-mpls-conn-pfxsid)# address-family ipv4 switch(config-sr-mpls-conn-pfxsid-af)#</pre>	Specifies the IPv4 address family configured on the OSPF interface.
Step 10	1.1.1.1/32 index 10 Example: <pre>switch(config-sr-mpls-conn-af)# 1.1.1.1/32 index 10</pre>	Associates SID 10 with the address 1.1.1.1/32.
Step 11	exit Example: <pre>switch(config-sr-mpls-conn-af)# exit</pre>	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 Segment Routing for Traffic Engineering

About Segment Routing for Traffic Engineering

Segment routing for traffic engineering (SR-TE) takes place through a tunnel 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. A Traffic Engineered (TE) tunnel is a container of TE LSPs instantiated between the tunnel ingress and the tunnel destination. A TE tunnel can instantiate one or more SR-TE LSPs that are associated with the same tunnel.

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.

SR-TE Policies

Segment routing for traffic engineering (SR-TE) uses a “policy” to steer traffic through the network. A SR-TE policy is a container that includes sets of segments or labels. This list of segments can be provisioned by an operator, a stateful PCE. The head-end imposes the corresponding MPLS label stack on a traffic flow to be carried over the SR-TE policy. Each transit node along the SR-TE policy path uses the incoming top label to select the next-hop, pop or swap the label, and forward the packet to the next node with the remainder of the label stack, until the packet reaches the ultimate destination.

A SR-TE policy is uniquely identified by a tuple (color, end-point). A color is represented as a 32-bit number and an end-point is an IPv4. Every SR-TE policy has a color value. Every policy between the same node pairs requires a unique color value. Multiple SR-TE policies can be created between the same two endpoints by choosing different colors for the policies.

Cisco Nexus 9000 Series switches support the following two types of SR-TE policies:

- **Dynamic SR-TE Policy** - When you configure dynamic path preference under the SR-TE policy configuration or an on-demand color configuration, the path computation engine (PCE) calculates the path to the destination address. Dynamic path calculation at PCE results in a list of segments/labels that gets applied to the head-end SR-TE policy, hence the traffic gets routed through the network by hitting the segments that the SR-TE policy holds.
- **Explicit SR-TE Policy** - An explicit path is a list of 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 submenu for specifying the path.

SR-TE Policy Paths

A SR-TE policy path is a list of segments that specifies the path, called a segment ID (SID) list. Every SR-TE policy consists of one or more candidate paths, which can be either a dynamic or an explicit path. The SR-TE policy instantiates a single path and the selected path is the preferred valid candidate path.

You can also add on-demand color with dynamic path option and explicit policy configuration with an explicit path option for the same color and endpoint. In this case, a single policy is created on the head-end and the path with the highest preference number configured is used for forwarding traffic.

The following two methods are used to compute the SR-TE policy path:

- **Dynamic Path** - When you specify the dynamic PCEP option while configuring the path preference under an on-demand color configuration or a policy configuration, the path computation is delegated to a path computation engine(PCE).
- **Explicit Path** - This path is an explicitly specified SID-list or a set of SID-lists.

Affinity and Disjoint Constraints

Affinity Constraints - You can assign attributes to a link which gets advertised to path computation engine (PCE). SRTE process hosts the affinity-map and interface level configurations. Routing protocol(IGP) will

register for interface updates and SRTE will notify IGP with interface updates. IGP tlvs will be passed to BGP to advertise it to external peers. There are three types of affinity constraints:

- **exclude-any:** specifies that links that have any of the specified affinity colors must not be traversed by the path.
- **include-any:** specifies that only links that have any of the specified affinity colors must be traversed by the path. Thus, links that do not have any of the specified affinity colors must not be used.
- **include-all:** specifies that only links that have all of the specified affinity colors must be traversed by the path. Thus, links that do not have all of the specified affinity colors must not be used.

Disjoint Constraints - You can assign disjoint constraints to the SR-TE policies which gets advertised to the PCE. The PCE then provides the disjoint path for the policies that share the same association group ID and the disjoint disjointness type.

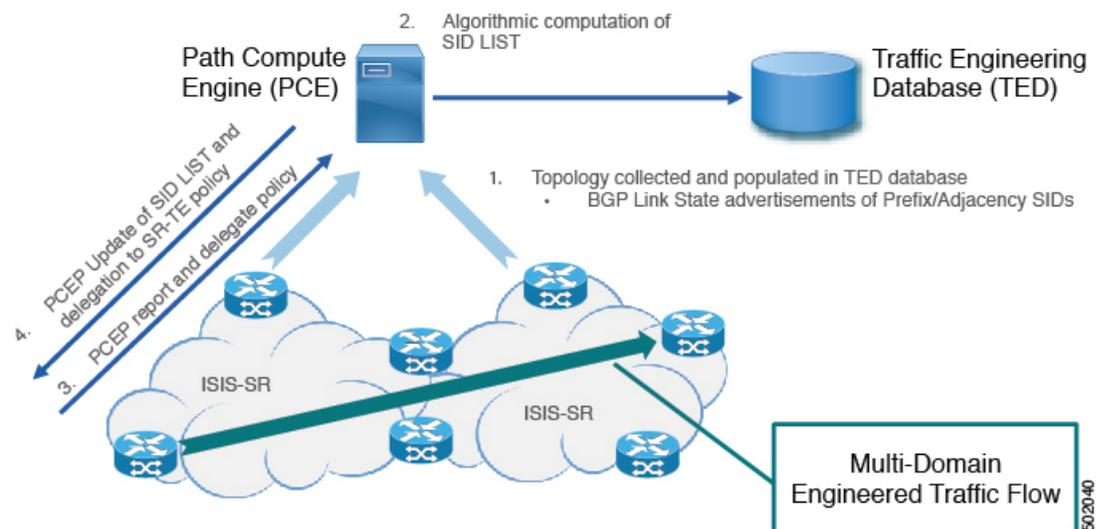
Cisco NX-OS Release 9.3(1) supports the following disjoint path levels :

- **Link** – The paths transit different links (but may transit same nodes).
- **Node disjointness** – The paths transit different links but may transit same node.

Segment Routing On Demand Next Hop

On-Demand Next hop (ODN) leverages upon BGP Dynamic SR-TE capabilities and adds the path computation (PCE) ability to find and download the end to end path based on the requirements. ODN triggers an SR-TE auto-tunnel based on the defined BGP policy. As shown in the following figure, an end-to-end path between ToR1 and AC1 can be established from both ends based on IGP Metric. The work-flow for ODN is summarized as follows:

Figure 1: ODN Operation



Guidelines and Limitations for SR-TE

SR-TE has the following guidelines and limitations:

- SR-TE ODN for both, IPv4 and IPv6 overlay is supported.
- SR-TE ODN is supported only with IS-IS underlay.
- Forwarding does not support routes with recursive next hops, where the recursive next hop resolves to a route with a binding SID.
- Forwarding does not support mixing paths with binding labels and paths without binding labels for the same route.
- The affinity and disjoint constraints are applicable only to those SR-TE policies that have a dynamic PCEP option.
- XTC supports only two policies with disjointness in the same group.
- When configuring the SR-TE affinity interfaces, the interface range is not supported.
- A preference cannot have both, the dynamic PCEP and the explicit segment lists configured together for the same preference.
- Only one preference can have a dynamic PCEP option per policy.
- For explicit policy, when configuring ECMP paths under same preference, if the first hop (NHLFE) is same for both the ECMP paths, ULIB will only install one path in switching. This occurs because both the ECMP paths create the same SRTE FEC as the NHLFE is same for both.
- In Cisco NX-OS Release 9.3(1), unprotected mode with affinity configuration is not supported by PCE (XTC).
- Beginning with Cisco NX-OS Release 9.3(3), SR-TE ODN, policies, policy paths, and the affinity and disjoint constraints are supported on Cisco Nexus 9364C-GX, Cisco Nexus 9316D-GX, and Cisco Nexus 93600CD-GX switches.

Configuring SR-TE

You can configure segment routing for traffic engineering.

Before you begin

You must ensure that the mpls segment routing feature is enabled.

Procedure

	Command or Action	Purpose
Step 1	configure terminal	Enters global configuration mode.
Step 2	segment-routing	Enters the segment-routing mode
Step 3	traffic-engineering	Enters the traffic engineering mode.
Step 4	encapsulation mpls source ipv4 <i>tunnel_ip_address</i>	Configures the source address for the SR-TE Tunnel.
Step 5	pcc	Enters the PCC mode.

	Command or Action	Purpose
Step 6	<code>source-address ipv4 pcc_source_address</code>	Configure source address for the PCC
Step 7	<code>pce-address ipv4 pce_source_address precedence num</code>	Configure IP address of the PCE. The lowest numbered PCE will take precedence, and the other(s) be used as a backup.
Step 8	<code>on-demand color color_num</code>	Enters the on-demand mode to configure the color.
Step 9	<code>candidate-paths</code>	Specifies the candidate paths of the policy.
Step 10	<code>preference preference_number</code>	Specifies the preference of the candidate path.
Step 11	<code>dynamic</code>	Specifies the path option.
Step 12	<code>pcep</code>	Specifies the path computation that needs to be done from the PCE.

Configuring Affinity Constraints

You can configure the affinity constraints to the SR-TE policy.

Before you begin

You must ensure that the mpls segment routing feature is enabled.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: <code>switch# configure terminal switch(config)#</code>	Enters global configuration mode.
Step 2	segment-routing Example: <code>switch(config)# segment-routing switch(config-sr)#</code>	Enables the MPLS segment routing functionality.
Step 3	traffic-engineering Example: <code>switch(config-sr)# traffic-engineering switch(config-sr-te)#</code>	Enters the traffic engineering mode.
Step 4	pcc	Enters the PCC mode.
Step 5	<code>source-address ipv4 pcc_source_address</code>	Configure source address for the PCC

	Command or Action	Purpose
Step 6	pce-address ipv4 pce_source_address precedence num	Configure IP address of the PCE. The lowest numbered PCE takes precedence and the other(s) are used as a backup.
Step 7	affinity-map Example: switch(config-sr-te)#affinity-map switch(config-sr-te-affmap)#	Configures the affinity-map configuration mode.
Step 8	color name bit-position position Example: switch(config-sr-te-affmap)# color red bit-position 2 switch(config-sr-te-affmap)#	Configures a mapping of the user-defined name to a specific bit position in the affinity bit-map.
Step 9	interface interface-name Example: Enter SRTE interface config mode switch(config-sr-te-if)#interface eth1/1 switch(config-sr-te-if)#	Specifies the name of the interface. This is the affinity mapping name which refers to the specific bit in the affinity bitmap.
Step 10	affinity Example: switch(config-sr-te-if)# affinity switch(config-sr-te-if-aff)# switch(config-sr-te-if-aff)# color red switch(config-sr-te-if-aff)#	Adds the affinity color to the interface.
Step 11	policy name on-demand color color_num Example: switch(config-sr-te)# on-demand color 211 or switch(config-sr-te-color)# policy test_policy	Configures the policy.
Step 12	color color end-point address Example: switch(config-sr-te-pol)#color 200 endpoint 2.2.2.2	Configures the color and the end point of the policy. This is required when you are configuring the policy using the “policy name” config mode.
Step 13	candidate-path Example: switch(config-sr-te-color)# candidate-paths switch(cfg-cndpath)#	Specifies the candidate paths for the policy.

	Command or Action	Purpose
Step 14	preference <i>preference_number</i> Example: <pre>switch(cfg-cndpath)# preference 100 switch(cfg-pref)#</pre>	Specifies the preference of the candidate path.
Step 15	dynamic Example: <pre>switch(cfg-pref)# dynamic switch(cfg-dyn)#</pre>	Specifies the path option.
Step 16	pcep Example: <pre>switch(cfg-dyn)# pcep switch(cfg-dyn)#</pre>	Specifies that the headend uses PCEP to request the PCE to compute a path from itself to the segment routing's policy's end point.
Step 17	constraints Example: <pre>switch(cfg-dyn)# constraints switch(cfg-constraints)#</pre>	Enters the candidate path preference constraint mode.
Step 18	affinity Example: <pre>switch(cfg-constraints)# affinity switch(cfg-const-aff)#</pre>	Specifies the affinity constraints of the policy.
Step 19	exclude-any include-all include-any Example: <pre>switch(cfg-const-aff)# include-any switch(cfg-aff-inclany)#</pre>	Specifies the affinity constraint type. The following affinity types are available: <ul style="list-style-type: none"> • exclude-any - specifies that links that have any of the specified affinity colors must not be traversed by the path. • include-any - specifies that only links that have any of the specified affinity colors must be traversed by the path. • include-all - specifies that only links that have all of the specified affinity colors must be traversed by the path.
Step 20	color <i>color_name</i> Example: <pre>switch(cfg-aff-inclany)# color blue switch(cfg-aff-inclany)#</pre>	Specifies the affinity color definition.

Configuring Disjoint Paths

You can configure disjoint path constraints to the SR-TE policy.

Before you begin

You must ensure that the mpls segment routing feature is enabled.

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)#	Enables the MPLS segment routing functionality.
Step 3	traffic-engineering Example: switch(config-sr)# traffic-engineering switch(config-sr-te)#	Enters the traffic engineering mode.
Step 4	pcc	Enters the PCC mode.
Step 5	source-address ipv4 pcc_source_address	Configure source address for the PCC
Step 6	pce-address ipv4 pce_source_address precedence num	Configure IP address of the PCE. The lowest numbered PCE takes precedence and the other(s) are used as a backup.
Step 7	policy name on-demand color color_num Example: switch(config-sr-te)# on-demand color 211 or switch(config-sr-te-color)# policy test_policy	Configures the policy.
Step 8	color color end-point address Example: switch2(config-sr-te-pol)# color 200 endpoint 2.2.2.2	Configures the color and the end point of the policy. This is required when you are configuring the policy using the “policy name” config mode.
Step 9	candidate-path Example: switch(config-sr-te-color)# candidate-paths switch(cfg-cndpath)#	Specifies the candidate-paths for the policy

	Command or Action	Purpose
Step 10	preference <i>preference_number</i> Example: switch(cfg-cndpath)# preference 100 switch(cfg-pref)#	Specifies the preference of the candidate path.
Step 11	dynamic Example: switch(cfg-pref)# dynamic switch(cfg-dyn)#	Specifies the path option.
Step 12	pcep Example: switch(cfg-dyn)# pcep switch(cfg-dyn)#	Specifies that the headend uses PCEP to request the PCE to compute a path from itself to the segment routing's policy's end point.
Step 13	constraints Example: switch(cfg-dyn)# constraints switch(cfg-constraints)#	Enters the candidate path preference constraint mode.
Step 14	association-group Example: switch(cfg-constraints)# association-group switch(cfg-assoc)#	Specifies the association group type.
Step 15	disjoint Example: switch(cfg-assoc)# disjoint switch(cfg-disj)#	Specifies the path that belongs to the disjointness association group.
Step 16	type link node Example: switch(config-if)#type link	Specifies the disjointness group type.
Step 17	id <i>number</i> Example: switch(config-if)#id 1	Specifies the identifier of the association-group.

Configuration Examples for SR-TE

The examples in this section show affinity and disjoint configurations.

This example shows the mappings of a user defined name to an administrative group.

```
segment-routing
 traffic-eng
  affinity-map
```

```

color green bit-position 0
color blue bit-position 2
color red bit-position 3

```

This example shows the affinity link colors red and green for the adjacency on eth1/1 and affinity link color green for the adjacency on eth1/2.

```

segment-routing
traffic-eng
interface eth1/1
affinity
color red
color green
!
interface eth1/2
affinity
color green

```

This examples shows the affinity constraints for the policy.

```

segment-routing
traffic-engineering
affinity-map
color blue bit-position 0
color red bit-position 1
on-demand color 10
candidate-paths
preference 100
dynamic
pcep
constraints
affinity
[include-any|include-all|exclude-any]
color <col_name>
color <col_name>
policy new_policy
color 201 endpoint 2.2.2.0
candidate-paths
preference 200
dynamic
pcep
constraints
affinity
include-all
color red

```

This examples shows the disjoint constraints for the policy.

```

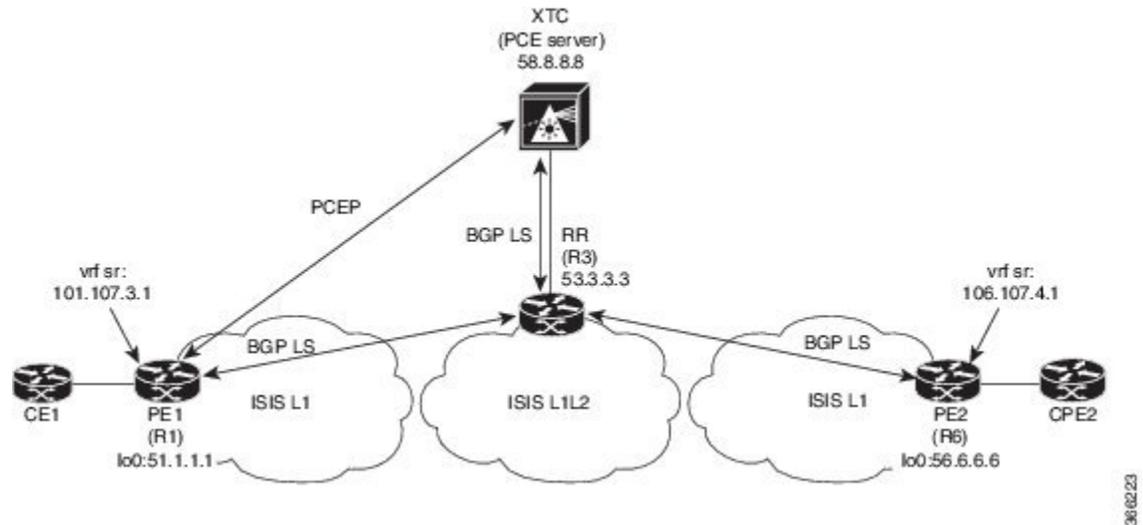
segment-routing
traffic-eng
on-demand color 99
candidate-paths
preference 100
dynamic
pcep
constraints
association-group
disjoint
type link
id 1

```

Configuration Example for an SR-TE ODN - Use Case

Perform the following steps to configure ODN for SR-TE. The following figure is used as a reference to explain the configuration steps.

Figure 2: Reference Topology



1. Configure all links with IS-IS point-to-point session from PE1 to PE2. Also, configure the domains as per the above topology.
2. Enable “distribute link-state” for IS-IS session on R1, R3, and R6.

```
router isis 1
 net 31.0000.0000.0000.712a.00
 log-adjacency-changes
 distribute link-state
 address-family ipv4 unicast
 bfd
 segment-routing mpls
 maximum-paths 32
 advertise interface loopback0
```

3. Configure the router R1 (headend) and R6 (tailend) with a VRF interface.

VRF configuration on R1:

```
interface Ethernet1/49.101
 encapsulation dot1q 201
 vrf member sr
 ip address 101.10.1.1/24
 no shutdown

vrf context sr
 rd auto
 address-family ipv4 unicast
 route-target import 101:101
 route-target import 101:101 evpn
 route-target export 101:101
 route-target export 101:101 evpn
router bgp 6500
 vrf sr
 bestpath as-path multipath-relax
```

```

address-family ipv4 unicast
advertise l2vpn evpn

```

4. Tags VRF prefix with BGP community on R6 (tailend).

```

route-map color1001 permit 10
set extcommunity color 1001

```

5. Enable BGP on R6 (tailend) and R1 (headend) to advertise and receive VRF SR prefix and match on community set on R6 (tailend).

```
R6 < EVPN > R3 < EVPN > R1
```

BGP Configuration R6:

```

router bgp 6500
address-family ipv4 unicast
allocate-label all
neighbor 53.3.3.3
remote-as 6500
log-neighbor-changes
update-source loopback0
address-family l2vpn evpn
send-community extended
route-map Color1001 out
encapsulation mpls

```

BGP Configuration R1:

```

router bgp 6500
address-family ipv4 unicast
allocate-label all
neighbor 53.3.3.3
remote-as 6500
log-neighbor-changes
update-source loopback0
address-family l2vpn evpn
send-community extended
encapsulation mpls

```

6. Enable BGP configuration on R3 and BGP LS with XTC on R1, R3.abd

BGP Configuration R3:

```

router bgp 6500
router-id 2.20.1.2
address-family ipv4 unicast
allocate-label all
address-family l2vpn evpn
retain route-target all
neighbor 56.6.6.6
remote-as 6500
log-neighbor-changes
update-source loopback0
address-family l2vpn evpn
send-community extended
route-reflector-client
route-map NH_UNCHANGED out
encapsulation mpls
neighbor 51.1.1.1
remote-as 6500
log-neighbor-changes
update-source loopback0
address-family l2vpn evpn
send-community extended

```

```

route-reflector-client
route-map NH_UNCHANGED out
encapsulation mpls
neighbor 58.8.8.8
  remote-as 6500
  log-neighbor-changes
  update-source loopback0
  address-family link-state

route-map NH_UNCHANGED permit 10
  set ip next-hop unchanged

```

BGP Configuration R1:

```

router bgp 6500
neighbor 58.8.8.8
  remote-as 6500
  log-neighbor-changes
  update-source loopback0
  address-family link-state

```

BGP Configuration R6:

```

outer bgp 6500
neighbor 58.8.8.8
  remote-as 6500
  log-neighbor-changes
  update-source loopback0
  address-family link-state

```

7. Enable PCE and SR-TE tunnel configurations on R1.

```

segment-routing
traffic-engineering
  pcc
  source-address ipv4 51.1.1.1
  pce-address ipv4 58.8.8.8
  on-demand color 1001
  metric-type igp

```

Configuring Egress Peer Engineering with Segment Routing

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.

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.

Overview of BGP Egress Peer Engineering With Segment Routing

Cisco Nexus 9000 Series switches are often deployed in massive scale data centers (MSDCs). In such environments, there is a requirement to support BGP Egress Peer Engineering (EPE) with Segment Routing (SR).

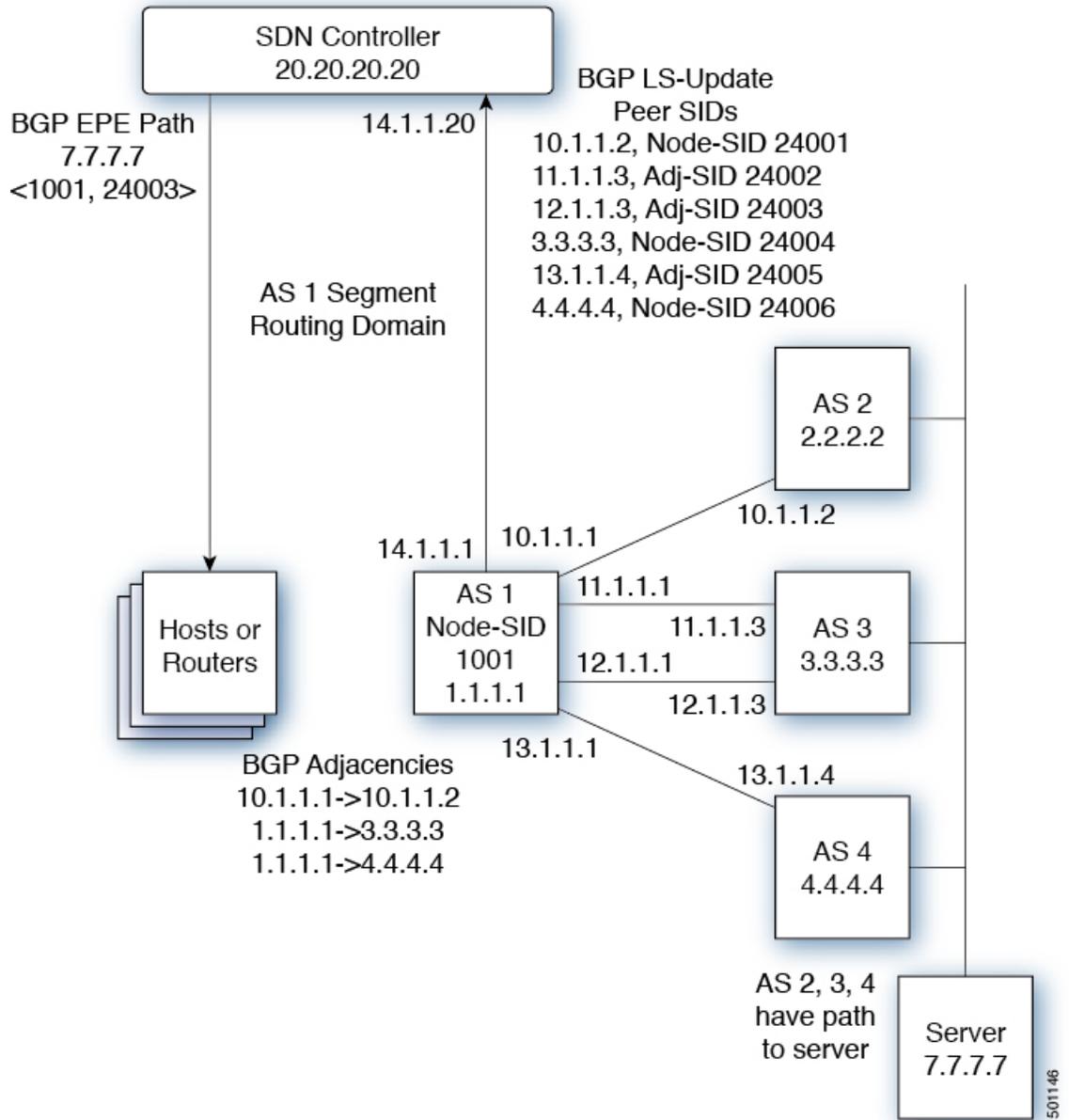
Segment Routing (SR) leverages source routing. A node steers a packet through a controlled set of instructions, known as segments, by prepending the packet with an SR header. A segment can represent any topological or service-based instruction. SR allows steering a flow through any topological path or any service chain while maintaining per-flow state only at the ingress node of the SR domain. For this feature, the Segment Routing architecture is applied directly to the MPLS data plane.

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

The SR-based Egress Peer Engineering (EPE) solution allows a centralized (SDN) controller to program any egress peer policy at ingress border routers or at hosts within the domain.

In the following example, all three routers run iBGP and they advertise NRLI to one another. The routers also advertise their loopback as the next-hop and it is recursively resolved. This provides an ECMP between the routers as displayed in the illustration.

Figure 3: Example of Egress Peer Engineering



The SDN controller receives the Segment IDs from the egress router 1.1.1.1 for each of its peers and adjacencies. It can then intelligently advertise the exit points to the other routers and the hosts within the controller’s routing domain. As displayed in the illustration, the BGP Network Layer Reachability Information (NLRI) contains both the Node-SID to Router 1.1.1.1 and the Peer-Adjacency-SID 24003 indicating that the traffic to 7.7.7.7 should egress over the link 12.1.1.1->12.1.1.3.

Guidelines and Limitations for BGP Egress Peer Engineering

BGP Egress Peer Engineering has the following guidelines and limitations:

- BGP Egress Peer Engineering is only supported for IPv4 BGP peers. IPv6 BGP peers are not supported.
- BGP Egress Peer Engineering is only supported in the default VPN Routing and Forwarding (VRF) instance.
- Any number of Egress Peer Engineering (EPE) peers may be added to an EPE peer set. However, the installed resilient per-CE FEC is limited to 32 peers.
- A given BGP neighbor can only be a member of a single peer-set. Peer-sets are configured. Multiple peer-sets are not supported. An optional **peer-set** name may be specified to add neighbor to a peer-set. The corresponding RPC FEC load-balances the traffic across all the peers in the peer-set. The peer-set name is a string that is a maximum length of 63 characters (64 NULL terminated). This length is consistent with the NX-OS policy name lengths. A peer can only be a member of a single peer-set.
- Adjacencies for a given peer are not separately assignable to different peer-sets.
- Beginning with Cisco NX-OS Release 9.3(3), BGP Egress Peer Engineering is supported on Cisco Nexus 9300-GX platform switches.

Configuring Neighbor Egress Peer Engineering Using BGP

With the introduction of RFC 7752 and draft-ietf-idr-bgpls-segment-routing-epe, you can configure Egress Engineering. The feature is valid only for external BGP neighbors and it is not configured by default. Egress Engineering uses RFC 7752 encoding.

Before you begin

- You must enable BGP.
- After an upgrade from Release 7.0(3)I3(1) or Release 7.0(3)I4(1), configure the TCAM region before configuring Egress Peer Engineering (EPE) on Cisco Nexus 9000 Series switches using the following commands:
 1. switch# **hardware access-list tcam region vpc-convergence 0**
 2. switch# **hardware access-list tcam region racl 0**
 3. switch# **hardware access-list tcam region mpls 256 double-wide**
- Save the configuration and reload the switch.

For more information, see the Using Templates to Configure ACL TCAM Region Sizes and Configuring ACL TCAM Region Sizes sections in the *Cisco Nexus 9000 Series NX-OS Security Configuration Guide*.

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	router bgp <bgp autonomous number>	Specifies the autonomous router BGP number.
Step 3	neighbor <IP address>	Configures the IP address for the neighbor.
Step 4	<p>[no default] egress-engineering [peer-set peer-set-name]</p> <p>Example:</p> <pre>switch(config)# router bgp 1 switch(config-router)# neighbor 4.4.4.4 switch(config-router)# egress-engineering peer-set NewPeer</pre>	<p>Specifies whether a Peer-Node-SID is allocated for the neighbor and it is advertised in an instance of a BGP Link-State (BGP-LS) address family Link NLRI. If the neighbor is a multi-hop neighbor, a BGP-LS Link NLRI instance is also advertised for each Equal-Cost-MultiPath (ECMP) path to the neighbor and it includes a unique Peer-Adj-SID.</p> <p>Optionally, you can add the neighbor to a peer-set. The Peer-Set-SID is also advertised in the BGP-LS Link NLRI in the same instance as the Peer-Node-SID. BGP Link-State NLRI is advertised to all neighbors with the link-state address family configured.</p> <p>See RFC 7752 and draft-ietf-idr-bgpls-segment-routing-epe-05 for more information on EPE.</p>

Configuration Example for Egress Peer Engineering

See the Egress Peer Engineering sample configuration for the BGP speaker 1.1.1.1. Note that the neighbor 20.20.20.20 is the SDN controller.

```
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

interface mgmt0
ip address dhcp
vrf member management

interface loopback1
ip address 1.1.1.1/32
line console

line vty
ip route 2.2.2.2/32 10.1.1.2
ip route 3.3.3.3/32 11.1.1.3
ip route 3.3.3.3/32 12.1.1.3
ip route 4.4.4.4/32 13.1.1.4
ip route 20.20.20.20/32 14.1.1.20

router bgp 1
address-family ipv4 unicast
address-family link-state
neighbor 10.1.1.2
remote-as 2
address-family ipv4
egress-engineering
neighbor 3.3.3.3
remote-as 3
address-family ipv4
update-source loopback1
ebgp-multihop 2
egress-engineering
neighbor 4.4.4.4
remote-as 4
address-family ipv4
update-source loopback1
ebgp-multihop 2
egress-engineering
neighbor 20.20.20.20
remote-as 1
address-family link-state
update-source loopback1
ebgp-multihop 2
neighbor 124.11.50.5
bfd
remote-as 6
update-source port-channel50.11
egress-engineering peer-set pset2 <<<<<<<
address-family ipv4 unicast

```

```
neighbor 124.11.101.2
  bfd
  remote-as 6
  update-source Vlan2401
  egress-engineering
  address-family ipv4 unicast
```

This example shows sample output for the **show bgp internal epe** command.

```
switch# show bgp internal epe
BGP Egress Peer Engineering (EPE) Information:
Link-State Server: Inactive
Link-State Client: Active
Configured EPE Peers: 26
Active EPE Peers: 3
EPE SID State:
RPC SID Peer or Set Assigned
ID Type Set Name ID Label Adj-Info, iod
1 Node 124.1.50.5 1 1600
2 Set pset1 2 1601
3 Node 6.6.6.6 3 1602
4 Node 124.11.50.5 4 1603
5 Set pset2 5 1604
6 Adj 6.6.6.6 6 1605 124.11.50.4->124.11.50.5/0x1600b031, 80
7 Adj 6.6.6.6 7 1606 124.1.50.4->124.1.50.5/0x16000031, 78
EPE Peer-Sets:
IPv4 Peer-Set: pset1, RPC-Set 2, Count 7, SID 1601
Peers: 124.11.116.2 124.11.111.2 124.11.106.2 124.11.101.2
124.11.49.5 124.1.50.5 124.1.49.5
IPv4 Peer-Set: pset2, RPC-Set 5, Count 5, SID 1604
Peers: 124.11.117.2 124.11.112.2 124.11.107.2 124.11.102.2
124.11.50.5
IPv4 Peer-Set: pset3, RPC-Set 0, Count 4, SID unspecified
Peers: 124.11.118.2 124.11.113.2 124.11.108.2 124.11.103.2
IPv4 Peer-Set: pset4, RPC-Set 0, Count 4, SID unspecified
Peers: 124.11.119.2 124.11.114.2 124.11.109.2 124.11.104.2
IPv4 Peer-Set: pset5, RPC-Set 0, Count 4, SID unspecified
Peers: 124.11.120.2 124.11.115.2 124.11.110.2 124.11.105.2
switch#
```

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

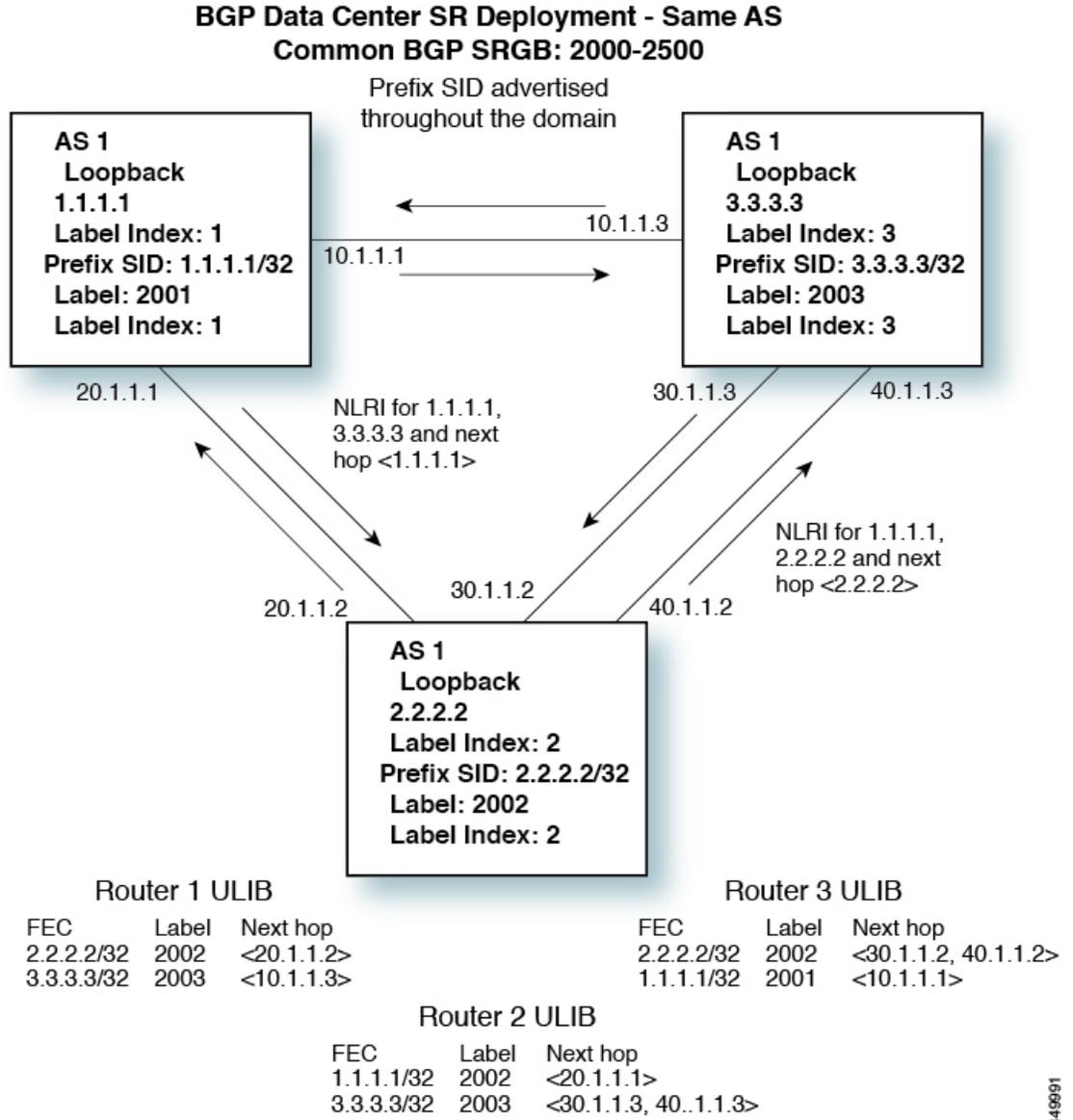
	Command or Action	Purpose
Step 1	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.

	Command or Action	Purpose
Step 2	router bgp <bgp autonomous number>	Specifies the autonomous router BGP number.
Step 3	<p>[no] address-family link-state</p> <p>Example:</p> <pre>switch(config)# router bgp 64497 switch (config-router af)# address-family link-state</pre>	<p>Enters address-family interface configuration mode.</p> <p>Note This command can also be configured in neighbor address-family configuration mode.</p>
Step 4	neighbor <IP address>	Configures the IP address for the neighbor.
Step 5	<p>[no] address-family link-state</p> <p>Example:</p> <pre>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</pre>	<p>Enters address-family interface configuration mode.</p> <p>Note This command can also be configured in neighbor address-family configuration mode.</p>

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.

Figure 4: BGP Prefix SID Simple Example



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Configuring Layer2 EVPN over Segment Routing MPLS

About Layer 2 EVPN

Ethernet VPN (EVPN) is a next generation solution that provides ethernet multipoint services over MPLS networks. EVPN operates in contrast to the existing Virtual Private LAN Service (VPLS) by enabling control-plane based MAC learning in the core. In EVPN, PEs participating in the EVPN instances learn customer MAC routes in control-plane using MP-BGP protocol. Control-plane MAC learning brings several

benefits that allow EVPN to address the VPLS shortcomings, including support for multihoming with per-flow load balancing.

In a data center network, the EVPN control plane provides:

- Flexible workload placement that is not restricted with the physical topology of the data center network. Therefore, you can place virtual machines (VM) anywhere within the data center fabric.
- Optimal East-West traffic between servers within and across data centers. East-West traffic between servers, or virtual machines, is achieved by most specific routing at the first hop router. First hop routing is done at the access layer. Host routes must be exchanged to ensure most specific routing to and from servers or hosts. VM mobility is supported by detecting new endpoint attachment when a new MAC address or the IP address is directly connected to the local switch. When the local switch sees the new MAC or the IP address, it signals the new location to rest of the network.
- Segmentation of Layer 2 and Layer 3 traffic, where traffic segmentation is achieved using MPLS encapsulation and the labels (per-BD label and per-VRF labels) act as the segment identifier.

Guidelines and Limitations for Layer 2 EVPN over Segment Routing MPLS

Layer 2 EVPN over segment routing MPLS has the following guidelines and limitations:

- Segment routing Layer 2 EVPN flooding is based on the ingress replication mechanism. MPLS core does not support multicast.
- ARP suppression is not supported.
- Consistency checking on vPC is not supported.
- The same Layer 2 EVI and Layer 3 EVI cannot be configured together.
- Beginning with Cisco NX-OS Release 9.3(1), Layer 2 EVPN is supported on Cisco Nexus 9300-FX2 platform switches.
- Beginning with Cisco NX-OS Release 9.3(5), Layer 2 EVPN over segment routing MPLS is supported on Cisco Nexus 9300-GX and Cisco Nexus 9300-FX3 platform switches.

Configuring Layer 2 EVPN over Segment Routing MPLS

Before you begin

Do the following:

- 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.
- You must enable the nv overlay feature using the **nv overlay** command.
- You must enable EVPN control plane using the **nv overlay evpn** command.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	feature bgp Example: switch(config)#feature bgp	Enables BGP feature and configurations.
Step 3	install feature-set mpls Example: switch(config)#install feature-set mpls	Enables MPLS configuration commands.
Step 4	feature-set mpls Example: switch(config)#install feature-set mpls	Enables MPLS configuration commands.
Step 5	feature mpls segment-routing Example: switch(config)#feature mpls segment-routing	Enables segment routing configuration commands.
Step 6	feature mpls evpn Example: switch(config)#feature mpls evpn	Enables EVPN over MPLS configuration commands. This command is mutually exclusive with the feature-nv CLI command.
Step 7	feature nv overlay Example: switch(config)#feature nv overlay	Enables the NVE feature that is used for the segment routing Layer 2 EVPN.
Step 8	nv overlay evpn Example: switch(config)#nv overlay evpn	Enables EVPN.
Step 9	interface loopback <i>Interface_Number</i> Example: switch(config)#interface loopback 1	Configures the loopback interface for NVE.
Step 10	ip address <i>address</i> Example: switch(config-if)#ip address 192.168.15.1	Configures the IP address.

	Command or Action	Purpose
Step 11	exit Example: switch(config-if)#exit	Exits global address family configuration mode.
Step 12	evpn Example: switch(config)#evpn	Enters the EVPN configuration mode.
Step 13	evi number Example: switch(config-evpn)#evi 1000 switch(config-evpn-sr)#	Configures Layer 2 EVI. If required, you can manually configure the RT based on the EVI that is generated automatically.
Step 14	encapsulation mpls Example: switch(config-evpn)#encapsulation mpls	Enables MPLS encapsulation and ingress-replication.
Step 15	source-interface loopback <i>Interface_Number</i> Example: switch(config-evpn-nve-encap)#source-interface loopback 1	Specifies the NVE source interface.
Step 16	exit Example: switch(config-evpn-nve-encap)#exit	Exits the configuration.
Step 17	vrf context <i>VRF_NAME</i> Example: switch(config)#vrf context Tenant-A	Configures the VRF.
Step 18	evi <i>EVI_ID</i> Example: switch(config-vrf)#evi 30001	Configures L3 EVI.
Step 19	exit Example: switch(config-vrf)#exit	Exits the configuration.
Step 20	VLAN <i>VLAN_ID</i> Example: switch(config)#vlan 1001	Configures VLAN.
Step 21	evi auto Example:	Configures L2 EVI.

	Command or Action	Purpose
	<code>switch(config-vlan)#evi auto</code>	
Step 22	exit Example: <code>switch(config-vlan)#exit</code>	
Step 23	router bgp <i>autonomous-system-number</i> Example: <code>switch(config)#router bgp 1</code>	Enters the BGP configuration mode.
Step 24	address-family l2vpn evpn Example: <code>switch(config-router)#address-family l2vpn evpn</code>	Enables EVPN address family globally.
Step 25	neighbor address <i>remote-as autonomous-system-number</i> Example: <code>switch(config-router)#neighbor 192.169.13.1 remote as 2</code>	Configures BGP neighbor.
Step 26	address-family l2vpn evpn Example: <code>switch(config-router-neighbor)#address-family l2vpn evpn</code>	Enables EVPN address family for neighbor.
Step 27	encapsulation mpls Example: <code>switch(config-router-neighbor)#encapsulation mpls</code>	Enables MPLS encapsulation.
Step 28	send-community extended Example: <code>switch(config-router-neighbor)#send-community extended</code>	Configures BGP to advertise extended community lists.
Step 29	vrf <i>VRF_NAME</i> Example: <code>switch(config-router)#vrf Tenant-A</code>	Configures BGP VRF.
Step 30	exit Example: <code>switch(config-router)#exit</code>	Exits the configuration.

Configuring VLAN for EVI

Procedure

	Command or Action	Purpose
Step 1	<code>vlan <i>number</i></code>	Specifies the VLAN.
Step 2	<code>evi <i>auto</i></code>	Creates a BD label for the VLAN. This label is used as an identifier for the VLAN across the segment routing Layer 2 EVPN.

Configuring the NVE Interface

Procedure

	Command or Action	Purpose
Step 1	<code>configure terminal</code> Example: <code>switch# configure terminal</code> <code>switch(config)#</code>	Enters global configuration mode.
Step 2	<code>interface loopback <i>loopback_number</i></code> Example: <code>switch(config)# interface loopback 1</code>	Associates the IP address with this loopback interface and uses this IP address for the segment routing configuration.
Step 3	<code>ip address</code> Example: <code>switch(config-if)# ip address</code> <code>192.169.15.1/32</code>	Specifies the IPv4 address family and enters router address family configuration mode.
Step 4	<code>evpn</code> Example: <code>switch(config)# evpn</code>	Enters EVPN configuration mode.
Step 5	<code>encapsulation mpls</code> Example: <code>switch(config-evpn)# encapsulation mpls</code>	Enables MPLS encapsulation and ingress-replication.
Step 6	<code>source-interface <i>loopback_number</i></code> Example: <code>switch(config-evpn-nve-encap)# source-interface</code> <code>loopback 1</code>	Specifies the NVE source interface.
Step 7	<code>exit</code> Example:	Exits segment routing mode and returns to the configuration terminal mode.

	Command or Action	Purpose
	<code>switch(config)# exit</code>	

Configuring EVI Under VRF

Procedure

	Command or Action	Purpose
Step 1	<code>vrf context <i>tenant</i></code>	Create a VRF Tenant.
Step 2	<code>evi <i>number</i></code>	Configure Layer 3 EVI under VRF.

Configuring Anycast Gateway

The fabric forwarding configuration is necessary only if the SVIs are configured in the anycast mode.

Procedure

	Command or Action	Purpose
Step 1	<code>fabric forwarding anycast-gateway-mac 0000.aabb.ccdd</code>	Configures the distributed gateway virtual MAC address.
Step 2	<code>fabric forwarding mode anycast-gateway</code>	Associates SVI with the Anycast Gateway under the interface configuration mode.

Advertising Labelled Path for the Loopback Interface

The loopback interface, advertised as Layer 2 EVPN endpoint should be mapped to a label index. Thereby BGP advertises MPLS labelled path for the same.

Procedure

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

	Command or Action	Purpose
	<code>switch(config-router)# segment-routing mpls</code>	
Step 4	connected-prefix-sid-map Example: <code>switch(config-sr-mpls)# connected-prefix-sid-map</code>	Enters a sub-mode where you can configure address-family specific mappings for local prefixes and SIDs.
Step 5	address-family ipv4 Example: <code>switch(config-sr-mpls-conn)# address-family ipv4</code>	Specifies IPv4 address prefixes.
Step 6	1.1.1.1/32 index 100 Example: <code>switch(config-sr-mpls-conn-af)# 1.1.1.1/32 100</code>	Associates SID 100 with the address 1.1.1.1/32.
Step 7	exit-address-family Example: <code>switch(config-sr-mpls-conn-af)# exit-address-family</code>	Exits the address family.

About SRv6 Static Per-Prefix TE

The SRv6 Static Per-Prefix TE feature allows you to map and advertise prefixes that are mapped to non-default VRFs. This feature allows you to advertise multiple prefixes in a single instance using the matching VRF route target and prevents the manual entry of each prefix.

In Cisco NX-OS Release 9.3(5), only one VNF can service a VM.

Configuring a SRv6 Static Per-Prefix TE

Before you begin

Do the following:

- 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	vrf context <i>VRF_Name</i> Example: switch(config)# vrf context vrf_2_7_8	Defines VRF and enters the VRF configuration mode.
Step 3	rd <i>rd_format</i> Example: switch(config-vrf)# rd 2.2.2.0:2	Assign the RD to VRF.
Step 4	address-family { <i>ipv4</i> <i>ipv6</i> } Example: switch(config-vrf)# address-family ipv4 unicast	Specifies either the IPv4 or the IPv6 address family for the VRF instance and enters the address family configuration mode.
Step 5	route-target import <i>route-target-id</i> Example: switch(config-vrf)# route-target import 1:2	Configures the importing of routes to the VRF.
Step 6	route-target import <i>route-target-id evpn</i> Example: switch(config-vrf)# route-target import 1:2 evpn	Configures importing of routes that have a matching route target value from the Layer 3 EVPN to the VRF.
Step 7	route-target export <i>route-target-id</i> Example: switch(config-vrf)# route-target export 1:2	Configures the exporting of routes from the VRF.
Step 8	route-target export <i>route-target-id evpn</i> Example: switch(config-vrf)# route-target export 1:2 evpn	Configures exporting of routes that have a matching route target value from the VRF to the Layer 3 EVPN.
Step 9	router bgp <i>autonomous-system-number</i> Example: switch(config)# router bgp 65000	Enables BGP and assigns the AS number to the local BGP speaker.
Step 10	router-id <i>id</i> Example: switch(config-router)# router-id 2.2.2.0	Configures the router ID.
Step 11	address-family l2vpn evpn Example:	Enters global address family configuration mode for the Layer 2 VPN EVPN.

	Command or Action	Purpose
	<code>switch(config-router-af)# address-family l2vpn evpn</code>	
Step 12	neighbor <i>ipv4-address</i> remote-as Example: <code>switch(config-router)# neighbor 7.7.7.0 remote-as 65000 switch(config-router-neighbor)#</code>	Configures the IPv4 address and AS number for a remote BGP peer.
Step 13	update-source loopback <i>number</i> Example: <code>switch(config-router-neighbor)# update-source loopback0</code>	Specifies the loopback number.
Step 14	address-family l2vpn evpn Example: <code>switch(config-router-neighbor)#address-family l2vpn evpn</code>	Enables EVPN address family for a neighbor.
Step 15	send-community extended Example: <code>switch(config-router-neighbor)#send-community extended</code>	Configures BGP to advertise extended community lists.
Step 16	encapsulation mpls Example: <code>switch(config-router-neighbor)#encapsulation mpls</code>	Enables MPLS encapsulation.
Step 17	exit Example: <code>switch(config-router-neighbor)#exit</code>	Exits the configuration.

Example

The following example shows how to configure RPM configuration in order to define the VRF VT.

```
rf context vrf_2_7_8
  rd 2.2.2.0:2
  address-family ipv4 unicast
    route-target import 0.0.1.1:2
    route-target import 0.0.1.1:2 evpn
    route-target export 0.0.1.1:2
    route-target export 0.0.1.1:2 evpn
ip extcommunity-list standard vrf_2_7_8-test permit rt 0.0.1.1:2
  route-map Node-2 permit 4
  match extcommunity vrf_2_7_8-test
  set extcommunity color 204
```

About RD Auto

The auto-derived Route Distinguisher (rd auto) is based on the Type 1 encoding format as described in IETF RFC 4364 section 4.2 (<https://tools.ietf.org/html/rfc4364#section-4.2>). The Type 1 encoding allows a 4-byte administrative field and a 2-byte numbering field. Within Cisco NX-OS, the auto derived RD is constructed with the IP address of the BGP Router ID as the 4-byte administrative field (RID) and the internal VRF identifier for the 2-byte numbering field (VRF ID).

The 2-byte numbering field is always derived from the VRF, but results in a different numbering scheme depending on its use for the IP-VRF or the MAC-VRF:

- The 2-byte numbering field for the IP-VRF uses the internal VRF ID starting at 1 and increments. VRF IDs 1 and 2 are reserved for the default VRF and the management VRF respectively. The first custom defined IP VRF uses VRF ID 3.
- The 2-byte numbering field for the MAC-VRF uses the VLAN ID + 32767, which results in 32768 for VLAN ID 1 and incrementing.

Example auto-derived Route Distinguisher (RD)

- IP-VRF with BGP Router ID 192.0.2.1 and VRF ID 6 - RD 192.0.2.1:6
- MAC-VRF with BGP Router ID 192.0.2.1 and VLAN 20 - RD 192.0.2.1:32787

About Route-Target Auto

The auto-derived Route-Target (route-target import/export/both auto) is based on the Type 0 encoding format as described in IETF RFC 4364 section 4.2 (<https://tools.ietf.org/html/rfc4364#section-4.2>). IETF RFC 4364 section 4.2 describes the Route Distinguisher format and IETF RFC 4364 section 4.3.1 refers that it is desirable to use a similar format for the Route-Targets. The Type 0 encoding allows a 2-byte administrative field and a 4-byte numbering field. Within Cisco NX-OS, the auto derived Route-Target is constructed with the Autonomous System Number (ASN) as the 2-byte administrative field and the Service Identifier (EVI) for the 4-byte numbering field.

2-byte ASN

The Type 0 encoding allows a 2-byte administrative field and a 4-byte numbering field. Within Cisco NX-OS, the auto-derived Route-Target is constructed with the Autonomous System Number (ASN) as the 2-byte administrative field and the Service Identifier (EVI) for the 4-byte numbering field.

Examples of an auto derived Route-Target (RT):

- IP-VRF within ASN 65001 and L3EVI 50001 - Route-Target 65001:50001
- MAC-VRF within ASN 65001 and L2EVI 30001 - Route-Target 65001:30001

For Multi-AS environments, the Route-Targets must either be statically defined or rewritten to match the ASN portion of the Route-Targets.



Note Auto derived Route-Targets for a 4-byte ASN are not supported.

4-byte ASN

The Type 0 encoding allows a 2-byte administrative field and a 4-byte numbering field. Within Cisco NX-OS, the auto-derived Route-Target is constructed with the Autonomous System Number (ASN) as the 2-byte administrative field and the Service Identifier (EVI) for the 4-byte numbering field. With the ASN demand of 4-byte length and the EVI requiring 24-bit (3-bytes), the Sub-Field length within the Extended Community is exhausted (2-byte Type and 6-byte Sub-Field). As a result of the length and format constraint and the importance of the Service Identifiers (EVI) uniqueness, the 4-byte ASN is represented in a 2-byte ASN named AS_TRANS, as described in IETF RFC 6793 section 9 (<https://tools.ietf.org/html/rfc6793#section-9>). The 2-byte ASN 23456 is registered by the IANA (<https://www.iana.org/assignments/iana-as-numbers-special-registry/iana-as-numbers-special-registry.xhtml>) as AS_TRANS, a special purpose AS number that aliases 4-byte ASNs.

Example auto derived Route-Target (RT) with 4-byte ASN (AS_TRANS):

- IP-VRF within ASN 65656 and L3EVI 50001 - Route-Target 23456:50001
- MAC-VRF within ASN 65656 and L2EVI 30001 - Route-Target 23456:30001

Configuring RD and Route Targets for BD

The Bridge Domain (BD) RD and Route Targets are automatically generated when you configure **evi auto** under the VLAN. To configure the BD RD and Route Targets manually, perform these steps:

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: <pre>switch# configure terminal switch(config)#</pre>	Enters global configuration mode.
Step 2	evpn Example: <pre>switch(config)# evpn</pre>	Enters EVPN configuration mode.
Step 3	evi VLAN_ID Example: <pre>switch(config-evpn)# evi 1001</pre>	Specifies L2 EVI to configure RD/Route Target.
Step 4	rd rd_format Example: <pre>switch(config-evpn-evi-sr)# rd 192.1.1.1:33768</pre>	Configures RD.
Step 5	route-target both rt_format Example: <pre>switch(config-evpn-evi-sr)# route-target both 1:20001</pre>	Configures Route Target.

Configuring RD and Route Targets for VRF

The VRF RD and Route Targets are automatically generated when you configure the `evi evi_ID` under the VRF. To configure the VRF RD and Route Targets manually, perform these steps:

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	vrf context <i>VRF_NAME</i> Example: switch(config)# vrf context A	Configures the VRF.
Step 3	rd auto or rd_format Example: switch(config-vrf)# rd auto	Configures RD.
Step 4	address-family ipv4 unicast Example: switch(config-vrf)# address-family ipv4 unicast	Enables IPv4 address family.
Step 5	route-target both <i>rt_format</i> evpn Example: switch(config-vrf-af-ipv4)# route-target both 1:30001 evpn	Configures Route Target.

Configuration Examples for Layer 2 EVPN over Segment Routing MPLS

The following examples show the configuration for Layer 2 EVPN over Segment Routing MPLS:

```
install feature-set mpls
feature-set mpls
nv overlay evpn
feature bgp
feature mpls segment-routing
feature mpls evpn
feature interface-vlan
feature nv overlay

fabric forwarding anycast-gateway-mac 0000.1111.2222

vlan 1001
  evi auto

vrf context Tenant-A
  evi 30001
```

```

interface loopback 1
  ip address 192.168.15.1/32

interface vlan 1001
  no shutdown
  vrf member Tenant-A
  ip address 111.1.0.1/16
  fabric forwarding mode anycast-gateway

router bgp 1
  address-family l2vpn evpn
  neighbor 192.169.13.1
  remote-as 2
  address-family l2vpn evpn
  send-community extended
  encapsulation mpls
  vrf Tenant-A

evpn
  encapsulation mpls
  source-interface loopback 1

```

Configuring Proportional Multipath for VNF for Segment Routing

About Proportional Multipath for VNF for Segment Routing

In Network Function Virtualization Infrastructures (NFVi), service networks (Portable IPs) are routed by Virtual Network Functions (VNFs). The VNFs, also referred to as portable IP-Gateway (PIP-GW) routes the data packets to and from the VMs in the VNF. The Proportional Multipath for VNF for Segment Routing feature enables advertising the VNF of a service network (PIP) in the EVPN address-family. The IP address of the VNF is encoded in the “Gateway-IP Address” field of the EVPN IP Prefix Route NLRI advertisement of a service network.

By advertising the IP address of the VNFs, ingress nodes in the EVPN fabric recursively resolve the VNF IP address to the leaf attached to the VNF, which could be the same node that advertises the service network (PIP).

Route-injectors are BGP protocols that inject routes in the IPv4 or IPv6 AF. In this case, the route-injector injects routes to the VMs whose next hop is set as VNFs.

Unlike a route-injector, VNFs can participate in a routing protocol to advertise the VM reachability. The supported protocols are eBGP, IS-IS, and OSPF.

Enabling Proportional Multipath for VNF for Segment Routing

You can enable the Proportional Multipath for VNF for Segment Routing feature to redistribute routes for IGP or static routes by preserving the next-hop paths. You can then export and advertise the gateway-IP for the reoriginated EVPN type-5 routes.

In Cisco NX-OS Release 9.3(5), only one VNF can service a VM.

Before you begin

Do the following:

- Install and enable the MPLS feature set using the **install feature-set mpls** and **feature-set mpls** commands.
- Enable the MPLS segment routing feature.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: <pre>switch# configure terminal switch(config)#</pre>	Enter global configuration mode.
Step 2	route-map export-l2evpn-rtmap permit 10 Example: <pre>switch(config)# route-map export-l2evpn-rtmap permit 10</pre>	<<need description>>
Step 3	match ip address prefix-list pip-pfx-list Example: <pre>switch(config-route-map)# match ip prefix-list vm-pfx-list</pre>	Defines the prefixes that must be advertised with PIP-GW as the gateway.
Step 4	set evpn gateway-ip use-nexthop Example: <pre>switch(config-route-map)# set evpn gateway-ip use-nexthop</pre>	Defines specific routes to advertise the gateway-ip.
Step 5	vrf context VRF_Name Example: <pre>switch(config-route-map)# vrf context vrf switch(config-route-map)# address-family ipv4 unicast switch(config-route-map)# export map export-l2evpn-rtmap</pre>	Applies the route map to the vrf context.
Step 6	address-family ipv4 unicast Example: <pre>switch(config-route-map)# address-family ipv4 unicast switch(config-route-map)# export map export-l2evpn-rtmap</pre>	Applies the route map to the vrf context.
Step 7	export map export-l2evpn-rtmap Example: <pre>switch(config-route-map)# export map export-l2evpn-rtmap</pre>	Applies the route map to the vrf context.

	Command or Action	Purpose
Step 8	router bgp number Example: switch(config)# router bgp 100	Configure BGP.
Step 9	vrf VRF_Name Example: switch(config-route-map)# vrf vrf3	Applies the route map to the vrf context.
Step 10	address-family ipv4 unicast Example: switch(config-router)# address-family ipv4 unicast	Configure address family for IPv4.
Step 11	export-gateway-ip Example: switch(config-route-map)# export-gateway-ip	Exports and advertises the gateway-ip to reconnect the EVPN type-5 routes. Note The export gateway-ip and set the EVPN gateway configurations can be performed simultaneously. If you configure them simultaneously, all prefixes are exported with the gateway-ip.

vPC Multihoming

About Multihoming

Cisco Nexus platform switches support vPC-based multihoming, where a pair of switches act as a single device for redundancy and both switches function in active mode. With Cisco Nexus platform switches in an EVPN environment, there are two solutions that support Layer 2 multihoming; these solutions are based on the traditional vPC (emulated or virtual IP address), where the MCT link is required and the BGP EVPN techniques.

While using the BGP EVPN control plane, each vPC pair uses a common virtual IP (VIP) to provide active/active redundancy. BGP EVPN based multihoming further provides fast convergence during certain failure scenarios, that otherwise cannot be achieved without a control protocol (data plane flood and learn).

Per-BD label on vPC Peers

To ensure that the vPC peers have the same per-BD label, you must specify the per-BD label to have the following value:

```
Label value = Label_base + VLAN_ID
```

The label base is configured on the same vPC peers. Currently, the VLAN configuration is identical on both the vPC peers, which ensures that both vPC peers have the same label.

In Cisco NX-OS Release 9.3(1), configuring the per-BD label is not supported. This release supports only evi auto.

Per-VRF label on vPC Peers

To ensure that the vPC peers have the same per-VRF label, you must specify the per-VRF label to have the following value:

```
Label value = Label_base + vrf_allocate_index
```

To configure the allocate-index for the vPC peers, do the following:

```
Router bgp 1
  vrf Tenant_A
    allocate-index 11
```

Configuring Backup Link

The backup link needs to be configured between the vPC peers. This link can be any Layer 3 link which is parallel to MCT.

Example

```
interface vlan 100
  ip add 10.1.1.1/24
  mpls ip forwarding

< enable underlay protocol >
```

Guidelines and Limitations for vPC Multihoming

vPC multihoming has the following guidelines and limitations:

- ESI-based multihoming is not supported.
- The physical and virtual secondary IP addresses should be both advertised via the MPLS labeled path.
- vPC consistency checking is not supported for the per-BD label configuration.

Configuration Examples for vPC Multihoming

This example shows the configuration for vPC multihoming:

- vPC Primary

```
interface loopback1
  ip address 192.169.15.1/32
  ip address 192.169.15.15/32 secondary

evpn
  encapsulation mpls
  source-interface loopback1

vlan 101
  evi auto

vrf context A
  evi 301
```

```

router bgp 1
  vrf A
    allocate-index 1001

• vPC Secondary

interface loopback1
  ip address 192.169.15.2/32
  ip address 192.169.15.15/32 secondary

evpn
  encapsulation mpls
  source-interface loopback1

vlan 101
  evi auto

vrf context A
  evi 301

router bgp 1
  vrf A
    allocate-index 1001

```

Configuring Layer 3 EVPN and Layer 3 VPN over Segment Routing MPLS

This section describes tasks to configure the Layer 3 EVPN and stitching of L3 EVPN and L3VPN router. Perform the following tasks to complete the configuration:

Configuring the Features to Enable Layer3 EVPN and Layer3 VPN

Before you begin

Install the VPN Fabric license.

Make sure that the **feature interface-vlan** command is enabled.

Procedure

	Command or Action	Purpose
Step 1	feature bgp	Enables BGP feature and configurations.
Step 2	install feature-set mpls	Enables MPLS configuration commands.
Step 3	feature-set mpls	Enables MPLS configuration commands.
Step 4	feature mpls segment-routing	Enables segment routing configuration commands.
Step 5	feature mpls evpn	Enables EVPN over MPLS configuration commands. This command is mutually exclusive with the feature-nv CLI command.

	Command or Action	Purpose
Step 6	<code>feature mpls l3vpn</code>	Enables EVPN over MPLS configuration commands. This command is mutually exclusive with the <code>feature-nv</code> CLI command.

Configuring VRF and Route Targets for Import and Export Rules

Procedure

	Command or Action	Purpose
Step 1	<code>configure terminal</code>	Enters global configuration mode.
Step 2	<code>vrf <i>vrf-name</i></code>	Defines a VPN routing and forwarding (VRF) instance and enters the VRF configuration mode.
Step 3	<code>rd auto</code>	Automatically assigns a unique route distinguisher (RD) to VRF.
Step 4	<code>address-family { ipv4 ipv6 } unicast</code>	Specifies either the IPv4 or IPv6 address family for the VRF instance and enters address family configuration submenu.
Step 5	<code>route-target import <i>route-target-id</i></code>	Configures importing of routes to the VRF from the L3VPN BGP NLRI that have the matching route-target value.
Step 6	<code>route-target export <i>route-target-id</i></code>	Configures exporting of routes from the VRF to the L3VPN BGP NLRI and assigns the specified route-target identifiers to the L3VPN BGP NLRI.
Step 7	<code>route-target import <i>route-target-id</i> evpn</code>	Configures importing of routes from the L3 EVPN BGP NLRI that have the matching route-target value.
Step 8	<code>route-target export <i>route-target-id</i> evpn</code>	Configures exporting of routes from the VRF to the L3 EVPN BGP NLRI and assigns the specified route-target identifiers to the BGP EVPN NLRI.

Configuring BGP EVPN and Label Allocation Mode

You can use MPLS tunnel encapsulation using the `encapsulation mpls` command. You can configure the label allocation mode for the EVPN address family. The default tunnel encapsulation in EVPN for IP Route type in NX-OS is VXLAN.

Advertisement of (IP or Label) bindings from a Cisco Nexus 9000 Series switch via BGP EVPN enables a remote switch to send the routed traffic to that IP using the label for that IP to the switch that advertised the IP over MPLS.

The IP prefix route (Type-5) is:

- Type-5 route with MPLS encapsulation

```
RT-5 Route - IP Prefix

RD: L3 RD
IP Length: prefix length
IP address: IP (4 bytes)
Label1: BGP MPLS Label
Route Target
RT for IP-VRF
```

The default label allocation mode is per-VRF for Layer 3 EVPN over MPLS.

Complete the following steps to configure BGP EVPN and label allocation mode:

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	Enters global configuration mode.
Step 2	<p>[no] router bgp <i>autonomous-system-number</i></p> <p>Example:</p> <pre>switch(config)# router bgp 64496 switch(config-router)#</pre>	<p>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.</p> <p>Use the no option with this command to remove the BGP process and the associated configuration.</p>
Step 3	<p>Required: address-family l2vpn evpn</p> <p>Example:</p> <pre>switch(config-router)# address-family l2vpn evpn switch(config-router-af)#</pre>	Enters global address family configuration mode for the Layer 2 VPN EVPN.
Step 4	<p>Required: exit</p> <p>Example:</p> <pre>switch(config-router-af)# exit switch(config-router)#</pre>	Exits global address family configuration mode.

	Command or Action	Purpose
Step 5	<p>neighbor <i>ipv4-address</i> remote-as <i>autonomous-system-number</i></p> <p>Example:</p> <pre>switch(config-router)# neighbor 10.1.1.1 remote-as 64497 switch(config-router-neighbor)#</pre>	Configures the IPv4 address and AS number for a remote BGP peer.
Step 6	<p>address-family l2vpn evpn</p> <p>Example:</p> <pre>switch(config-router-neighbor)# address-family l2vpn evpn switch(config-router-neighbor-af)#</pre>	Advertises the labeled Layer 2 VPN EVPN.
Step 7	<p>encapsulation mpls</p> <p>Example:</p> <pre>router bgp 100 address-family l2vpn evpn neighbor NVE2 remote-as 100 address-family l2vpn evpn send-community extended encapsulation mpls vrf foo address-family ipv4 unicast advertise l2vpn evpn</pre> <p>BGP segment routing configuration:</p> <pre>router bgp 100 address-family ipv4 unicast network 200.0.0.1/32 route-map label_index_pol_100 network 192.168.5.1/32 route-map label_index_pol_101 network 101.0.0.0/24 route-map label_index_pol_103 allocate-label all neighbor 192.168.5.6 remote-as 20 address-family ipv4 labeled-unicast send-community extended</pre>	<p>Enables BGP EVPN address family and sends EVPN type-5 route update to the neighbors.</p> <p>Note The default tunnel encapsulation in EVPN for the IP route type in NX-OS is VXLAN. To override that, a new CLI is introduced to indicate MPLS tunnel encapsulation.</p>
Step 8	vrf <i><customer_name></i>	Configures the VRF.
Step 9	address-family ipv4 unicast	Enters global address family configuration mode for the IPv4 address family.
Step 10	advertise l2vpn evpn	Advertises Layer 2 VPN EVPN.
Step 11	redistribute direct route-map DIRECT_TO_BGP	Redistributes the directly connected routes into BGP-EVPN.
Step 12	label-allocation-mode per-vrf	Sets the label allocation mode to per-VRF. If you want to configure the per-prefix label

	Command or Action	Purpose
		<p>mode, use the no label-allocation-mode per-vrf CLI command.</p> <p>For the EVPN address family, the default label allocation is per-vrf, compared to per-prefix mode for the other address-families where the label allocation CLI is supported. No form of CLI is displayed in the running configuration.</p>

Example

See the following example for configuring per-prefix label allocation:

```
router bgp 65000
  [address-family l2vpn evpn]
  neighbor 10.1.1.1
    remote-as 100
    address-family l2vpn evpn
    send-community extended
  neighbor 20.1.1.1
    remote-as 65000
    address-family l2vpn evpn
    encapsulation mpls
    send-community extended
  vrf customer1
    address-family ipv4 unicast
      advertise l2vpn evpn
      redistribute direct route-map DIRECT_TO_BGP
      no label-allocation-mode per-vrf
```

Configuring BGP Layer 3 EVPN and Layer 3 VPN Stitching

In order to configure the stitching on the same router, configure the layer 3 VPN neighbor relationship and router advertisement.

Procedure

	Command or Action	Purpose
Step 1	<p>configure terminal</p> <p>Example:</p> <pre>switch# configure terminal switch(config)#</pre>	Enters global configuration mode.
Step 2	<p>[no] router bgp <i>autonomous-system-number</i></p> <p>Example:</p> <pre>switch# configure terminal switch(config)# router bgp 64496 switch(config-router)#</pre>	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.

	Command or Action	Purpose
		Use the no option with this command to remove the BGP process and the associated configuration.
Step 3	address-family {vpnv4 vpnv6} unicast Example: <pre>switch(config-router)# address-family vpnv4 unicast switch(config-router-af)# address-family vpnv6 unicast switch(config-router-af)#</pre>	Enters global address family configuration mode for the Layer 3 VPNv4 or VPNv6.
Step 4	exit Example: <pre>switch(config-router-af)# exit switch(config-router)#</pre>	Exits global address family configuration mode.
Step 5	neighbor ipv4-address remote-as autonomous-system-number Example: <pre>switch(config-router)# neighbor 20.1.1.1 remote-as 64498</pre>	Configures the IPv4 address and AS number for a remote BGP L3VPN peer.
Step 6	address-family {vpnv4 vpnv6} unicast Example: <pre>switch(config-router)# address-family vpnv4 unicast switch(config-router-af)# address-family vpnv6 unicast switch(config-router-af)#</pre>	Configure the neighbor address-family for VPNv4 or VPNv6.
Step 7	send-community extended	Enables BGP VPN address family
Step 8	import l2vpn evpn reoriginate	Configures import of routing information from the Layer 3 VPN BGP NLRIs that has route target identifier matching the normal route target identifier and exports this routing information after re-origination that assigns it with stitching route target identifier, to the BGP EVPN neighbor.
Step 9	neighbor ipv4-address remote-as autonomous-system-number Example: <pre>switch(config-router)# neighbor 10.1.1.1 remote-as 64497 switch(config-router-neighbor)#</pre>	Configures the IPv4 address and AS number for a remote Layer 3 EVPN BGP peer.
Step 10	address-family {l2vpn evpn} Example:	Configure the neighbor address-family for Layer 3 EVPN.

	Command or Action	Purpose
	switch(config-router-neighbor) # address-family l2vpn evpn switch(config-router-neighbor-af) #	
Step 11	import vpn unicast reoriginate	Enables import of routing information from BGP EVPN NLRIs that has route target identifier matching the stitching route target identifier and exports this routing information after re-origination to the Layer 3 VPN BGP neighbor.
Step 12	vrf <customer_name>	Configures the VRF.
Step 13	address-family ipv4 unicast	Enters global address family configuration mode for the IPv4 address family.
Step 14	advertise l2vpn evpn	Advertises Layer 2 VPN EVPN.

Example

```
vrf context Customer1
  rd auto
  address-family ipv4 unicast
    route-target import 100:100
    route-target export 100:100
    route-target import 100:100 evpn
    route-target export 100:100 evpn

segment-routing
  mpls
    global-block 11000 20000
    connected-prefix-sid
    address-family ipv4 unicast
    200.0.0.1 index 101
!
int lo1
  ip address 200.0.0.1/32
!
interface e1/13
  description "MPLS interface towards Core"
  ip address 192.168.5.1/24
  mpls ip forwarding
  no shut

router bgp 100
  address-family ipv4 unicast
  allocate-label all
  address-family ipv6 unicast
  address-family l2vpn evpn
  address-family vpnv4 unicast
  address-family vpnv6 unicast
  neighbor 10.0.0.1 remote-as 200
  update-source loopback1
  address-family vpnv4 unicast
  send-community extended
  import l2vpn evpn reoriginate
  address-family vpnv6 unicast
  import l2vpn evpn reoriginate
```

```

    send-community extended
neighbor 20.0.0.1 remote-as 300
  address-family l2vpn evpn
    send-community extended
    import vpn unicast reoriginate
    encapsulation mpls
neighbor 192.168.5.6 remote-as 300
  address-family ipv4 labeled-unicast
vrf Customer1
  address-family ipv4 unicast
  advertise l2vpn evpn
  address-family ipv6 unicast
  advertise l2vpn evpn

```

Configuring BGP L3 VPN over 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.

You must enable the MPLS segment routing feature.

You must enable the MPLS L3 VPN feature using the **feature mpls l3vpn** command.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	[no] router bgp <i>autonomous-system-number</i> 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	address-family {vpnv4 vpnv6} unicast Example: switch(config-router)# address-family vpnv4 unicast switch(config-router-af)# address-family vpnv6 unicast switch(config-router-af)#	Enters global address family configuration mode for the Layer 3 VPNv4 or VPNv6.
Step 4	[no] allocate-label option-b	Disables the inter-AS option-b

	Command or Action	Purpose
Step 5	Required: exit Example: <pre>switch(config-router-af) # exit switch(config-router) #</pre>	Exits global address family configuration mode.
Step 6	neighbor ipv4-address remote-as autonomous-system-number Example: <pre>switch(config-router) # neighbor 20.1.1.1 remote-as 64498 switch(config-router-neighbor) #</pre>	Configures the IPv4 address and AS number for a remote BGP L3VPN peer.
Step 7	address-family {vpn4 vpn6 } unicast Example: <pre>switch(config-router-neighbor) # address-family vpn4 unicast switch(config-router-neighbor-af) #</pre>	Configure the neighbor address-family for VPNv4 or VPNv6.
Step 8	send-community extended	Enables BGP VPN address family.
Step 9	vrf <customer_name>	Configures the VRF.
Step 10	allocate-index x	Configure the allocate-index.
Step 11	address-family ipv4 unicast	Enters global address family configuration mode for the IPv4 address family.
Step 12	redistribute direct route-map DIRECT_TO_BGP	Redistributes the directly connected routes into BGP-L3VPN.

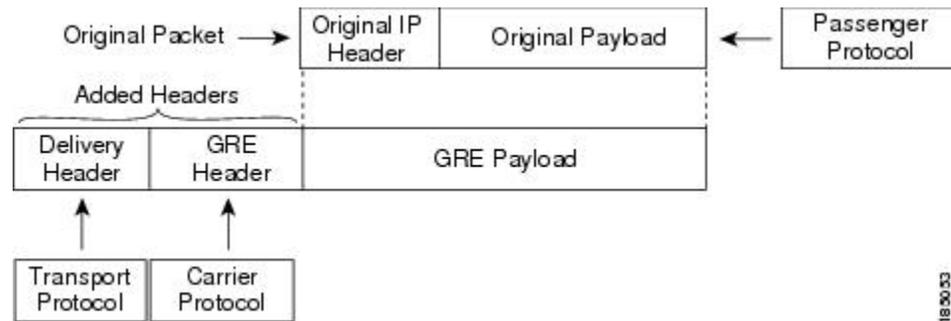
Configuring Segment Routing MPLS and GRE Tunnels

GRE Tunnels

You can use generic routing encapsulation (GRE) as the carrier protocol for a variety of passenger protocols.

The following figure shows the IP tunnel components for a GRE tunnel. The original passenger protocol packet becomes the GRE payload and the device adds a GRE header to the packet. The device then adds the transport protocol header to the packet and transmits it.

Figure 5: GRE PDU



Segment Routing MPLS and GRE

Beginning Cisco NX-OS Release 9.3(1), you can configure both, segment routing MPLS and generic routing encapsulation (GRE) on a Cisco Nexus device. Both these technologies operate seamlessly. All MPLS traffic can be forwarded to the GRE tunnel after the MPLS tunnel termination. Similarly, you can forward all traffic from the GRE tunnel to the MPLS cloud after the GRE termination.

All PE routers can initiate, forward, or terminate the GRE traffic from or to another GRE cloud. Similarly, all tunnel transit or tunnel end nodes can configure MPLS tunnel encapsulation.

When both, the tunnel and segment routing is enabled on the Cisco Nexus 9000 switches, the following is the TTL behavior is for the respective flows:

- Incoming IP traffic, egresses with GRE header, the TTL value in the GRE header is one less than the TTL value of the incoming IP packet.
- Incoming IP traffic, egresses with MPLS header, the TTL value in the MPLS header is one less than the TTL value of the incoming IP packet.
- Incoming GRE traffic, egresses with MPLS header, the TTL value in the MPLS header is default (255).
- Incoming MPLS traffic, egresses with GRE header, the TTL value in the GRE header is default (255).

Guidelines and Limitations for Segment Routing MPLS and GRE

Segment routing MPLS and GRE have the following guidelines and limitations:

- Ingress stats are not supported for tunnel packets.
- Only template-mpls-heavy template is supported.
- MPLS segment routing is not supported on the tunnel interfaces.
- Due to a hardware limitation on the modular switches, the tunnel Tx traffic is not supported if the egress interface for the tunnel destination IP address is over the Cisco Nexus 9300-FX/FX2 platform switches.
- Maximum four GRE tunnels are supported.
- Beginning with Cisco NX-OS Release 9.3(3), you can configure both, segment routing MPLS and GRE on Cisco Nexus 9300-GX platform switches.
- Tunnel Rx packet counters do not work when both segment routing MPLS and GRE coexist.

Configuring Segment Routing MPLS and GRE

You can enable MPLS segment routing as long as mutually-exclusive MPLS features such as static MPLS are not enabled.

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 tunneling feature using the **feature tunnel** command.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.
Step 2	[no] feature segment-routing Example: switch(config)# feature segment-routing	Enables the MPLS segment routing feature. The no form of this command disables the MPLS segment routing feature.
Step 3	(Optional) show running-config inc 'feature segment-routing' Example: switch(config)# show running-config inc 'feature segment-routing'	Displays the status of the MPLS segment routing feature.
Step 4	(Optional) copy running-config startup-config Example: switch(config)# copy running-config startup-config	Copies the running configuration to the startup configuration.
Step 5	configure terminal Example: switch# configure terminal switch(config)#	Enters global configuration mode.
Step 6	feature tunnel Example: switch(config)# feature tunnel switch(config-if)#	Allows the creation of a new tunnel interface. To disable the tunnel interface feature, use the no form of this command.
Step 7	switch(config)# interface tunnel <i>number</i>	Enters a tunnel interface configuration mode.
Step 8	switch(config-if)# tunnel mode {gre ip }	Sets this tunnel mode to GRE.

	Command or Action	Purpose
		The gre and ip keywords specify that GRE encapsulation over IP will be used.
Step 9	tunnel source <i>{ip-address interface-name}</i> Example: switch(config-if)# tunnel source ethernet 1/2	Configures the source address for this IP tunnel. The source can be specified by IP address or logical interface name.
Step 10	tunnel destination <i>{ip-address host-name}</i> Example: switch(config-if)# tunnel destination 192.0.2.1	Configures the destination address for this IP tunnel. The destination can be specified by IP address or logical host name.
Step 11	tunnel use-vrf <i>vrf-name</i> Example: switch(config-if)# tunnel use-vrf blue	
Step 12	ipv6 address <i>IPv6 address</i>	switch(config-if)# 10.1.1.1 Configures the IPv6 address. Note The tunnel source and the destination addresses are still the same (IPv4 address.)
Step 13	(Optional) switch(config-if)# show interface tunnel number	Displays the tunnel interface statistics.
Step 14	switch(config-if)# mtu value	Sets the maximum transmission unit (MTU) of IP packets sent on an interface.
Step 15	(Optional) switch(config-if)# copy running-config startup-config	Saves the change persistently through reboots and restarts by copying the running configuration to the startup configuration.

Verifying the Segment Routing MPLS and GRE Configuration

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

Command	Purpose
show segment-routing mpls	Displays segment routing mpls information

Verifying SR-TE for Layer 3 EVPN

The ODN verifications are based on L3VPN VRF prefixes.

1. Verify that the PCEP session between R1 (headend and PCE server) is established.

```
R1# show srte pce ipv4 peer

PCC's peer database:
-----
Remote PCEP conn IPv4 addr: 58.8.8.8
Local PCEP conn IPv4 addr: 51.1.1.1
Precedence: 0
State: up
```

2. Verify BGP LS and BGP EVPN session on R1, R3, and R6 using the following commands:

- Show bgp l2vpn evpn summary
- Show bgp link-state summary

3. Verify that the R1 (headend) has no visibility to the R6 loopback address.

```
R1# show ip route 56.6.6.6
IP Route Table for VRF "default"
'*' denotes best ucast next-hop
'***' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>

56.6.6.6/32, ubest/mbest: 1/0
    *via Null0, [1/0], 1d02h, static
```

4. Verify that the VRF prefix is injected via MP-BGP in a R1 VRF SR routing table.

```
R1# show ip route vrf sr
106.107.4.1/32, ubest/mbest: 1/0
    *via binding label 100534%default, [20/0], 1d01h, bgp-6503, external, tag 6500
    (mpls-vpn)
```

5. Verify the SR-TE Tunnel.

```
R1# show srte policy
Policy name: 51.1.1.1|1001
Source: 51.1.1.1
End-point: 56.6.6.6
Created by: bgp
State: UP
Color: 1001
Insert: FALSE
Re-opt timer: 0
Binding-sid Label: 100534
Policy-Id: 2
Flags:
Path type = MPLS           Path options count: 1
Path-option Preference:100 ECMP path count: 1
  1.      PCE           Weighted: No
        Delegated PCE: 58.8.8.8
                Index: 1           Label: 101104
                Index: 2           Label: 201102
                Index: 3           Label: 201103
```

Verifying the Segment Routing Configuration

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

Command	Purpose
show bgp ipv4 labeled-unicast <i>prefix</i>	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 [<i>map-name</i>]	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 the list of policies available in the SR-TE.
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.
show nve evi	Displays the status of the EVIs.
show nve peer mpls	Displays the status of the segment routing peers.
show nve adjacency mpls	Displays the status of the peer adjacencies.

Additional References

Related Documents

Related Topic	Document Title
BGP	<i>Cisco Nexus 9000 Series Unicast Routing Configuration Guide</i>