



Configure SR-TE Policies

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

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SR-TE Policy Overview

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

An SR-TE policy is identified as an ordered list (head-end, color, end-point):

- Head-end – Where the SR-TE policy is instantiated
- Color – A numerical value that distinguishes between two or more policies to the same node pairs (Head-end – End point)
- End-point – The destination of the SR-TE policy

Every SR-TE policy has a color value. Every policy between the same node pairs requires a unique color value.

An SR-TE policy uses one or more candidate paths. A candidate path is a single segment list (SID-list) or a set of weighted SID-lists (for weighted equal cost multi-path [WECCMP]). A candidate path is either dynamic or explicit. See *SR-TE Policy Path Types* section for more information.

Usage Guidelines and Limitations

Observe the following guidelines and limitations for the platform.

- GRE tunnel as primary interface for an SR policy is not supported.
- GRE tunnel as backup interface for an SR policy with TI-LFA protection is not supported.
- Head-end computed inter-domain SR policy with Flex Algo constraint and IGP redistribution is not supported.

Instantiation of an SR Policy

An SR policy is instantiated, or implemented, at the head-end router.

The following sections provide details on the SR policy instantiation methods:

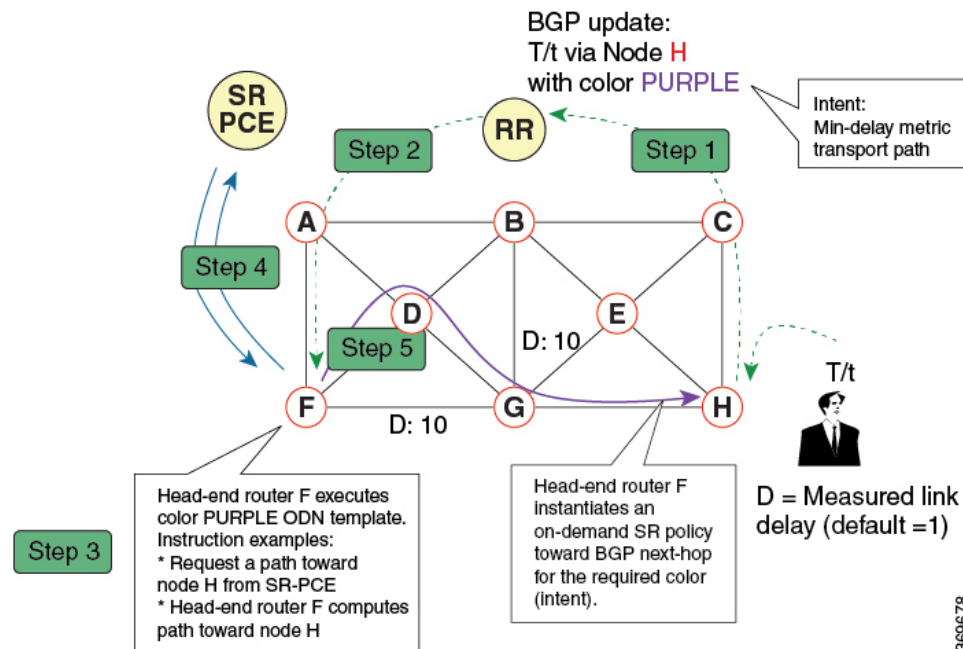
- [On-Demand SR Policy – SR On-Demand Next-Hop](#), on page 2
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On-Demand SR Policy – SR On-Demand Next-Hop

Segment Routing On-Demand Next Hop (SR-ODN) allows a service head-end router to automatically instantiate an SR policy to a BGP next-hop when required (on-demand). Its key benefits include:

- **SLA-aware BGP service** – Provides per-destination steering behaviors where a prefix, a set of prefixes, or all prefixes from a service can be associated with a desired underlay SLA. The functionality applies equally to single-domain and multi-domain networks.
- **Simplicity** – No prior SR Policy configuration needs to be configured and maintained. Instead, operator simply configures a small set of common intent-based optimization templates throughout the network.
- **Scalability** – Device resources at the head-end router are used only when required, based on service or SLA connectivity needs.

The following example shows how SR-ODN works:



1. An egress PE (node H) advertises a BGP route for prefix T/t. This advertisement includes an SLA intent encoded with a BGP color extended community. In this example, the operator assigns color purple (example value = 100) to prefixes that should traverse the network over the delay-optimized path.
2. The route reflector receives the advertised route and advertises it to other PE nodes.
3. Ingress PEs in the network (such as node F) are pre-configured with an ODN template for color purple that provides the node with the steps to follow in case a route with the intended color appears, for example:
 - Contact SR-PCE and request computation for a path toward node H that does not share any nodes with another LSP in the same disjointness group.
 - At the head-end router, compute a path towards node H that minimizes cumulative delay.
4. In this example, the head-end router contacts the SR-PCE and requests computation for a path toward node H that minimizes cumulative delay.
5. After SR-PCE provides the compute path, an intent-driven SR policy is instantiated at the head-end router. Other prefixes with the same intent (color) and destined to the same egress PE can share the same on-demand SR policy. When the last prefix associated with a given [intent, egress PE] pair is withdrawn, the on-demand SR policy is deleted, and resources are freed from the head-end router.

An on-demand SR policy is created dynamically for BGP global or VPN (service) routes. The following services are supported with SR-ODN:

- IPv4 BGP global routes
- IPv6 BGP global routes (6PE)
- VPNv4
- VPNv6 (6vPE)
- EVPN-VPWS (single-homing)

SR-ODN Configuration Steps

To configure SR-ODN, complete the following configurations:

1. Define the SR-ODN template on the SR-TE head-end router.
(Optional) If using Segment Routing Path Computation Element (SR-PCE) for path computation:
 - a. Configure SR-PCE. For detailed SR-PCE configuration information, see [Configure SR-PCE](#).
 - b. Configure the head-end router as Path Computation Element Protocol (PCEP) Path Computation Client (PCC). For detailed PCEP PCC configuration information, see [Configure the Head-End Router as PCEP PCC](#).
2. Define BGP color extended communities. Refer to the "Implementing BGP" chapter in the [Routing Configuration Guide for Cisco NCS 6000 Series Routers](#).
3. Define routing policies (using routing policy language [RPL]) to set BGP color extended communities. Refer to the "Implementing Routing Policy" chapter in the [Routing Configuration Guide for Cisco NCS 6000 Series Routers](#).

The following RPL attach-points for setting/matching BGP color extended communities are supported:



Note The following table shows the supported RPL match operations; however, routing policies are required primarily to set BGP color extended community. Matching based on BGP color extended communities is performed automatically by ODN's on-demand color template.

Attach Point	Set	Match
VRF export	X	X
VRF import	–	X
Neighbor-in	X	X
Neighbor-out	X	X
Inter-AFI export	–	X
Inter-AFI import	–	X
Default-originate	X	–

4. Apply routing policies to a service. Refer to the "Implementing Routing Policy" chapter in the [Routing Configuration Guide for Cisco NCS 6000 Series Routers](#).

Configure On-Demand Color Template

- Use the **on-demand color** *color* command to create an ODN template for the specified color value. The head-end router automatically follows the actions defined in the template upon arrival of BGP global or VPN routes with a BGP color extended community that matches the color value specified in the template.

The *color* range is from 1 to 4294967295.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# on-demand color 10
```



Note Matching based on BGP color extended communities is performed automatically via ODN's on-demand color template. RPL routing policies are not required.

- Use the **on-demand color color dynamic** command to associate the template with on-demand SR policies with a locally computed dynamic path (by SR-TE head-end router utilizing its TE topology database) or centrally (by SR-PCE). The head-end router will first attempt to install the locally computed path; otherwise, it will use the path computed by the SR-PCE.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# on-demand color 10 dynamic
```

- Use the **on-demand color color dynamic pcep** command to indicate that only the path computed by SR-PCE should be associated with the on-demand SR policy. With this configuration, local path computation is not attempted; instead the head-end router will only instantiate the path computed by the SR-PCE.

```
Router(config-sr-te)# on-demand color 10 dynamic pcep
```

Configure Dynamic Path Optimization Objectives

- Use the **metric type {igp | te | latency}** command to configure the metric for use in path computation.

```
Router(config-sr-te-color-dyn)# metric type te
```

- Use the **metric margin {absolute value| relative percent}** command to configure the On-Demand dynamic path metric margin. The range for *value* and *percent* is from 0 to 2147483647.

```
Router(config-sr-te-color-dyn)# metric margin absolute 5
```

Configure Dynamic Path Constraints

- Use the **disjoint-path group-id group-id type {link | node | srlg | srlg-node} [sub-id sub-id]** command to configure the disjoint-path constraints. The *group-id* and *sub-id* range is from 1 to 65535.

```
Router(config-sr-te-color-dyn)# disjoint-path group-id 775 type link
```

- Use the **affinity {include-any | include-all | exclude-any} {name WORD}** command to configure the affinity constraints.

```
Router(config-sr-te-color-dyn)# affinity exclude-any name CROSS
```

- Use the **maximum-sid-depth value** command to customize the maximum SID depth (MSD) constraints advertised by the router.

The default MSD *value* is equal to the maximum MSD supported by the platform ().

```
Router(config-sr-te-color)# maximum-sid-depth 5
```

See [Customize MSD Value at PCC, on page 43](#) for information about SR-TE label imposition capabilities.

- Use the **sid-algorithm** *algorithm-number* command to configure the SR Flexible Algorithm constraints. The *algorithm-number* range is from 128 to 255.

```
Router(config-sr-te-color-dyn)# sid-algorithm 128
```

Configuring SR-ODN: Examples

Configuring SR-ODN: Layer-3 Services Examples

The following examples show end-to-end configurations used in implementing SR-ODN on the head-end router.

Configuring ODN Color Templates: Example

Configure ODN color templates on routers acting as SR-TE head-end nodes. The following example shows various ODN color templates:

- color 10: minimization objective = te-metric
- color 20: minimization objective = igp-metric
- color 21: minimization objective = igp-metric; constraints = affinity
- color 22: minimization objective = te-metric; path computation at SR-PCE; constraints = affinity

```
segment-routing
traffic-eng
on-demand color 10
dynamic
metric
type te
!
!
on-demand color 20
dynamic
metric
type igp
!
!
on-demand color 21
dynamic
metric
type igp
!
affinity exclude-any
name CROSS
!
!
on-demand color 22
dynamic
pcep
!
metric
type te
!
```

```

    affinity exclude-any
      name CROSS
    !
  !
  !
  !
end

```

Configuring BGP Color Extended Community Set: Example

The following example shows how to configure BGP color extended communities that are later applied to BGP service routes via route-policies.



Note In most common scenarios, egress PE routers that advertise BGP service routes apply (set) BGP color extended communities. However, color can also be set at the ingress PE router.

```

extcommunity-set opaque color10-te
  10
end-set
!
extcommunity-set opaque color20-igp
  20
end-set
!
extcommunity-set opaque color21-igp-excl-cross
  21
end-set
!

```

Configuring RPL to Set BGP Color (Layer-3 Services): Examples

The following example shows various representative RPL definitions that set BGP color community.

The examples include the set color action only. The last RPL example performs the set color action for selected destinations based on a prefix-set.

```

route-policy SET_COLOR_LOW_LATENCY_TE
  set extcommunity color color10-te
  pass
end-policy
!
route-policy SET_COLOR_HI_BW
  set extcommunity color color20-igp
  pass
end-policy
!

prefix-set sample-set
  88.1.0.0/24
end-set
!
route-policy SET_COLOR_GLOBAL
  if destination in sample-set then
    set extcommunity color color10-te
  else
    pass
  endif
end-policy

```

Applying RPL to BGP Services (Layer-3 Services): Example

The following example shows various RPLs that set BGP color community being applied to BGP Layer-3 VPN services (VPNv4/VPNv6) and BGP global.

- The L3VPN examples show the RPL applied at the VRF export attach-point.
- The BGP global example shows the RPL applied at the BGP neighbor-out attach-point.

```
vrf vrf_cust1
  address-family ipv4 unicast
    export route-policy SET_COLOR_LOW_LATENCY_TE
  !
  address-family ipv6 unicast
    export route-policy SET_COLOR_LOW_LATENCY_TE
  !
!
vrf vrf_cust2
  address-family ipv4 unicast
    export route-policy SET_COLOR_HI_BW
  !
  address-family ipv6 unicast
    export route-policy SET_COLOR_HI_BW
  !
!

router bgp 100
  neighbor-group BR-TO-RR
  address-family ipv4 unicast
    route-policy SET_COLOR_GLOBAL out
  !
!
end
```

Verifying BGP VRF Information

Use the **show bgp vrf** command to display BGP prefix information for VRF instances. The following output shows the BGP VRF table including a prefix (88.1.1.0/24) with color 10 advertised by router 1.1.1.8.

```
RP/0/RP0/CPU0:R4# show bgp vrf vrf_cust1

BGP VRF vrf_cust1, state: Active
BGP Route Distinguisher: 1.1.1.4:101
VRF ID: 0x60000007
BGP router identifier 1.1.1.4, local AS number 100
Non-stop routing is enabled
BGP table state: Active
Table ID: 0xe0000007 RD version: 282
BGP main routing table version 287
BGP NSR Initial initsync version 31 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0

Status codes: s suppressed, d damped, h history, * valid, > best
                i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop          Metric LocPrf Weight Path
Route Distinguisher: 1.1.1.4:101 (default for vrf vrf_cust1)
*> 44.1.1.0/24      40.4.101.11          0 400 {1} i
*>i55.1.1.0/24      1.1.1.5              100   0 500 {1} i
*>i88.1.1.0/24     1.1.1.8 C:10         100   0 800 {1} i
*>i99.1.1.0/24      1.1.1.9              100   0 800 {1} i
```


Processed 4 prefixes, 4 paths

The following output displays the details for prefix 88.1.1.0/24. Note the presence of BGP extended color community 10, and that the prefix is associated with an SR policy with color 10 and BSID value of 24036.

```
RP/0/RP0/CPU0:R4# show bgp vrf vrf_cust1 88.1.1.0/24
```

BGP routing table entry for 88.1.1.0/24, Route Distinguisher: 1.1.1.4:101

Versions:

```
Process          bRIB/RIB  SendTblVer
Speaker          282      282
```

Last Modified: May 20 09:23:34.112 for 00:06:03

Paths: (1 available, best #1)

Advertised to CE peers (in unique update groups):

```
40.4.101.11
```

Path #1: Received by speaker 0

Advertised to CE peers (in unique update groups):

```
40.4.101.11
```

```
800 {1}
```

```
1.1.1.8 C:10 (bsid:24036) (metric 20) from 1.1.1.55 (1.1.1.8)
```

```
Received Label 24012
```

```
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
```

```
Received Path ID 0, Local Path ID 1, version 273
```

```
Extended community: Color:10 RT:100:1
```

```
Originator: 1.1.1.8, Cluster list: 1.1.1.55
```

```
SR policy color 10, up, registered, bsid 24036, if-handle 0x08000024
```

```
Source AFI: VPNv4 Unicast, Source VRF: default, Source Route Distinguisher: 1.1.1.8:101
```

Verifying Forwarding (CEF) Table

Use the **show cef vrf** command to display the contents of the CEF table for the VRF instance. Note that prefix 88.1.1.0/24 points to the BSID label corresponding to an SR policy. Other non-colored prefixes, such as 55.1.1.0/24, point to BGP next-hop.

```
RP/0/RP0/CPU0:R4# show cef vrf vrf_cust1
```

Prefix	Next Hop	Interface
0.0.0.0/0	drop	default handler
0.0.0.0/32	broadcast	
40.4.101.0/24	attached	TenGigE0/0/0/0.101
40.4.101.0/32	broadcast	TenGigE0/0/0/0.101
40.4.101.4/32	receive	TenGigE0/0/0/0.101
40.4.101.11/32	40.4.101.11/32	TenGigE0/0/0/0.101
40.4.101.255/32	broadcast	TenGigE0/0/0/0.101
44.1.1.0/24	40.4.101.11/32	<recursive>
55.1.1.0/24	1.1.1.5/32	<recursive>
88.1.1.0/24	24036 (via-label)	<recursive>
99.1.1.0/24	1.1.1.9/32	<recursive>
224.0.0.0/4	0.0.0.0/32	
224.0.0.0/24	receive	
255.255.255.255/32	broadcast	

The following output displays CEF details for prefix 88.1.1.0/24. Note that the prefix is associated with an SR policy with BSID value of 24036.

```
RP/0/RP0/CPU0:R4# show cef vrf vrf_cust1 88.1.1.0/24
```

```
88.1.1.0/24, version 51, internal 0x5000001 0x0 (ptr 0x98c60ddc) [1], 0x0 (0x0), 0x208
```

```
(0x98425268)
Updated May 20 09:23:34.216
Prefix Len 24, traffic index 0, precedence n/a, priority 3
via local-label 24036, 5 dependencies, recursive [flags 0x6000]
  path-idx 0 NHID 0x0 [0x97091ec0 0x0]
  recursion-via-label
  next hop VRF - 'default', table - 0xe0000000
  next hop via 24036/0/21
  next hop srte_c_10_ep labels imposed {ImplNull 24012}
```

Verifying SR Policy

Use the **show segment-routing traffic-eng policy** command to display SR policy information.

The following outputs show the details of an on-demand SR policy that was triggered by prefixes with color 10 advertised by node 1.1.1.8.

```
RP/0/RP0/CPU0:R4# show segment-routing traffic-eng policy color 10 tabular
```

Color	Endpoint	Admin State	Oper State	Binding SID
10	1.1.1.8	up	up	24036

The following outputs show the details of the on-demand SR policy for BSID 24036.



Note

There are 2 candidate paths associated with this SR policy: the path that is computed by the head-end router (with preference 200), and the path that is computed by the SR-PCE (with preference 100). The candidate path with the highest preference is the active candidate path (highlighted below) and is installed in forwarding.

```
RP/0/RP0/CPU0:R4# show segment-routing traffic-eng policy binding-sid 24036
```

```
SR-TE policy database
-----
```

```
Color: 10, End-point: 1.1.1.8
Name: srte_c_10_ep_1.1.1.8
Status:
  Admin: up Operational: up for 4d14h (since Jul  3 20:28:57.840)
Candidate-paths:
  Preference: 200 (BGP ODN) (active)
    Requested BSID: dynamic
    PCC info:
      Symbolic name: bgp_c_10_ep_1.1.1.8_discr_200
      PLSP-ID: 12
    Dynamic (valid)
      Metric Type: TE, Path Accumulated Metric: 30
      16009 [Prefix-SID, 1.1.1.9]
      16008 [Prefix-SID, 1.1.1.8]
  Preference: 100 (BGP ODN)
    Requested BSID: dynamic
    PCC info:
      Symbolic name: bgp_c_10_ep_1.1.1.8_discr_100
      PLSP-ID: 11
    Dynamic (pce 1.1.1.57) (valid)
      Metric Type: TE, Path Accumulated Metric: 30
      16009 [Prefix-SID, 1.1.1.9]
      16008 [Prefix-SID, 1.1.1.8]
```

Attributes:

```

Binding SID: 24036
Forward Class: 0
Steering BGP disabled: no
IPv6 caps enable: yes

```

Verifying SR Policy Forwarding

Use the `show segment-routing traffic-eng forwarding policy` command to display the SR policy forwarding information.

The following outputs show the forwarding details for an on-demand SR policy that was triggered by prefixes with color 10 advertised by node 1.1.1.8.

```
RP/0/RP0/CPU0:R4# show segment-routing traffic-eng forwarding policy binding-sid 24036
tabular
```

Color	Endpoint	Segment List	Outgoing Label	Outgoing Interface	Next Hop	Bytes Switched	Pure Backup
10	1.1.1.8	dynamic	16009	Gi0/0/0/4	10.4.5.5	0	
			16001	Gi0/0/0/5	11.4.8.8	0	Yes

```
RP/0/RP0/CPU0:R4# show segment-routing traffic-eng forwarding policy binding-sid 24036
detail
```

```
Mon Jul 8 11:56:46.887 PST
```

```
SR-TE Policy Forwarding database
-----
```

```
Color: 10, End-point: 1.1.1.8
```

```
Name: srte_c_10_ep_1.1.1.8
```

```
Binding SID: 24036
```

```
Segment Lists:
```

```
SL[0]:
```

```
Name: dynamic
```

```
Paths:
```

```
Path[0]:
```

```
Outgoing Label: 16009
```

```
Outgoing Interface: GigabitEthernet0/0/0/4
```

```
Next Hop: 10.4.5.5
```

```
Switched Packets/Bytes: 0/0
```

```
FRR Pure Backup: No
```

```
Label Stack (Top -> Bottom): { 16009, 16008 }
```

```
Path-id: 1 (Protected), Backup-path-id: 2, Weight: 64
```

```
Path[1]:
```

```
Outgoing Label: 16001
```

```
Outgoing Interface: GigabitEthernet0/0/0/5
```

```
Next Hop: 11.4.8.8
```

```
Switched Packets/Bytes: 0/0
```

```
FRR Pure Backup: Yes
```

```
Label Stack (Top -> Bottom): { 16001, 16009, 16008 }
```

```
Path-id: 2 (Pure-Backup), Weight: 64
```

```
Policy Packets/Bytes Switched: 0/0
```

```
Local label: 80013
```

Configuring SR-ODN for EVPN-VPWS: Use Case

This use case shows how to set up a pair of ELINE services using EVPN-VPWS between two sites. Services are carried over SR policies that must not share any common links along their paths (link-disjoint). The SR policies are triggered on-demand based on ODN principles. An SR-PCE computes the disjoint paths.

This use case uses the following topology with 2 sites: Site 1 with nodes A and B, and Site 2 with nodes C and D.

Figure 1: Topology for Use Case: SR-ODN for EVPN-VPWS

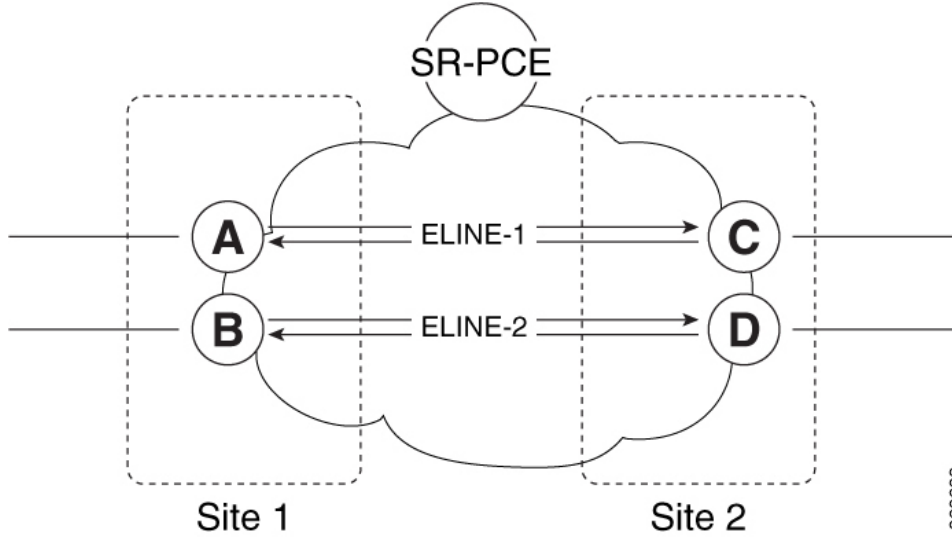


Table 1: Use Case Parameters

IP Addresses of Loopback0 (Lo0) Interfaces	SR-PCE Lo0: 1.1.1.207	
	Site 1: <ul style="list-style-type: none"> Node A Lo0: 1.1.1.5 Node B Lo0: 1.1.1.6 	Site 2: <ul style="list-style-type: none"> Node C Lo0: 1.1.1.2 Node D Lo0: 1.1.1.4
EVPN-VPWS Service Parameters	ELINE-1: <ul style="list-style-type: none"> EVPN-VPWS EVI 100 Node A: AC-ID = 11 Node C: AC-ID = 21 	ELINE-2: <ul style="list-style-type: none"> EVPN-VPWS EVI 101 Node B: AC-ID = 12 Node D: AC-ID = 22
ODN BGP Color Extended Communities	Site 1 routers (Nodes A and B): <ul style="list-style-type: none"> set color 10000 match color 11000 	Site 2 routers (Nodes C and D): <ul style="list-style-type: none"> set color 11000 match color 10000
Note	These colors are associated with the EVPN route-type 1 routes of the EVPN-VPWS services.	
PCEP LSP Disjoint-Path Association Group ID	Site 1 to Site 2 LSPs (from Node A to Node C/from Node B to Node D): <ul style="list-style-type: none"> group-id = 775 	Site 2 to Site 1 LSPs (from Node C to Node A/from Node D to Node B): <ul style="list-style-type: none"> group-id = 776

The use case provides configuration and verification outputs for all devices.

Configuration	Verification
Configuration: SR-PCE, on page 13	Verification: SR-PCE, on page 17
Configuration: Site 1 Node A, on page 13	Verification: Site 1 Node A, on page 21
Configuration: Site 1 Node B, on page 14	Verification: Site 1 Node B, on page 24
Configuration: Site 2 Node C, on page 15	Verification: Site 2 Node C, on page 27
Configuration: Site 2 Node D, on page 16	Verification: Site 2 Node D, on page 29

Configuration: SR-PCE

For cases when PCC nodes support, or signal, PCEP association-group object to indicate the pair of LSPs in a disjoint set, there is no extra configuration required at the SR-PCE to trigger disjoint-path computation.



Note SR-PCE also supports disjoint-path computation for cases when PCC nodes do not support PCEP association-group object. See [Configure the Disjoint Policy \(Optional\)](#) for more information.

Configuration: Site 1 Node A

This section depicts relevant configuration of Node A at Site 1. It includes service configuration, BGP color extended community, and RPL. It also includes the corresponding ODN template required to achieve the disjointness SLA.

Nodes in Site 1 are configured to set color 10000 on originating EVPN routes, while matching color 11000 on incoming EVPN routes from routers located at Site 2.

Since both nodes in Site 1 request path computation from SR-PCE using the same disjoint-path group-id (775), the PCE will attempt to compute disjointness for the pair of LSPs originating from Site 1 toward Site 2.

```
/* EVPN-VPWS configuration */

interface GigabitEthernet0/0/0/3.2500 l2transport
 encapsulation dot1q 2500
 rewrite ingress tag pop 1 symmetric
!
l2vpn
 xconnect group evpn_vpws_group
  p2p evpn_vpws_100
   interface GigabitEthernet0/0/0/3.2500
    neighbor evpn evi 100 target 21 source 11
   !
  !
 !
!

/* BGP color community and RPL configuration */

extcommunity-set opaque color-10000
 10000
end-set
```

```

!
route-policy SET_COLOR_EVPN_VPWS
  if evpn-route-type is 1 and rd in (ios-regex '.*...*...:(100)') then
    set extcommunity color color-10000
  endif
  pass
end-policy
!
router bgp 65000
  neighbor 1.1.1.253
  address-family l2vpn evpn
    route-policy SET_COLOR_EVPN_VPWS out
  !
!
!

/* ODN template configuration */

segment-routing
traffic-eng
  on-demand color 11000
  dynamic
  pcep
  !
  metric
  type igp
  !
  disjoint-path group-id 775 type link
  !
!
!
!

```

Configuration: Site 1 Node B

This section depicts relevant configuration of Node B at Site 1.

```

/* EVPN-VPWS configuration */

interface TenGigE0/3/0/0/8.2500 l2transport
  encapsulation dot1q 2500
  rewrite ingress tag pop 1 symmetric
!
l2vpn
xconnect group evpn_vpws_group
p2p evpn_vpws_101
  interface TenGigE0/3/0/0/8.2500
    neighbor evpn evi 101 target 22 source 12
  !
!
!
!

/* BGP color community and RPL configuration */

extcommunity-set opaque color-10000
  10000
end-set
!
route-policy SET_COLOR_EVPN_VPWS
  if evpn-route-type is 1 and rd in (ios-regex '.*...*...:(101)') then
    set extcommunity color color-10000
  endif
  pass

```

```

end-policy
!
router bgp 65000
 neighbor 1.1.1.253
   address-family l2vpn evpn
     route-policy SET_COLOR_EVPN_VPWS out
   !
!
!

/* ODN template configuration */

segment-routing
traffic-eng
  on-demand color 11000
  dynamic
    pcep
    !
    metric
      type igp
    !
  disjoint-path group-id 775 type link
!
!
!
!
!
!

```

Configuration: Site 2 Node C

This section depicts relevant configuration of Node C at Site 2. It includes service configuration, BGP color extended community, and RPL. It also includes the corresponding ODN template required to achieve the disjointness SLA.

Nodes in Site 2 are configured to set color 11000 on originating EVPN routes, while matching color 10000 on incoming EVPN routes from routers located at Site 1.

Since both nodes on Site 2 request path computation from SR-PCE using the same disjoint-path group-id (776), the PCE will attempt to compute disjointness for the pair of LSPs originating from Site 2 toward Site 1.

```

/* EVPN-VPWS configuration */

interface GigabitEthernet0/0/0/3.2500 l2transport
 encapsulation dot1q 2500
 rewrite ingress tag pop 1 symmetric
!
l2vpn
 xconnect group evpn_vpws_group
 p2p evpn_vpws_100
   interface GigabitEthernet0/0/0/3.2500
     neighbor evpn evi 100 target 11 source 21
   !
!
!
!

/* BGP color community and RPL configuration */

extcommunity-set opaque color-11000
  11000
end-set
!
route-policy SET_COLOR_EVPN_VPWS

```

```

    if evpn-route-type is 1 and rd in (ios-regex '.*.*.*.*.*:(100)') then
      set extcommunity color color-11000
    endif
  pass
end-policy
!
router bgp 65000
neighbor 1.1.1.253
address-family l2vpn evpn
  route-policy SET_COLOR_EVPN_VPWS out
!
!
!
/* ODN template configuration */

segment-routing
traffic-eng
  on-demand color 10000
  dynamic
    pcep
    !
    metric
      type igp
    !
    disjoint-path group-id 776 type link
  !
!
!
!
```

Configuration: Site 2 Node D

This section depicts relevant configuration of Node D at Site 2.

```

/* EVPN-VPWS configuration */

interface GigabitEthernet0/0/0/1.2500 l2transport
encapsulation dot1q 2500
rewrite ingress tag pop 1 symmetric
!
l2vpn
xconnect group evpn_vpws_group
p2p evpn vpws_101
interface GigabitEthernet0/0/0/1.2500
  neighbor evpn evi 101 target 12 source 22
!
!
!

/* BGP color community and RPL configuration */

extcommunity-set opaque color-11000
  11000
end-set
!
route-policy SET_COLOR_EVPN_VPWS
  if evpn-route-type is 1 and rd in (ios-regex '.*.*.*.*.*:(101)') then
    set extcommunity color color-11000
  endif
  pass
end-policy
!
```



```

router bgp 65000
 neighbor 1.1.1.253
   address-family l2vpn evpn
     route-policy SET_COLOR_EVPN_VPWS out
   !
 !
 !

/* ODN template configuration */

segment-routing
 traffic-eng
   on-demand color 10000
   dynamic
     pcep
     !
     metric
       type igp
     !
     disjoint-path group-id 776 type link
   !
 !
 !
 !

```

Verification: SR-PCE

Use the **show pce ipv4 peer** command to display the SR-PCE's PCEP peers and session status. SR-PCE performs path computation for the 4 nodes depicted in the use-case.

```

RP/0/0/CPU0:SR-PCE# show pce ipv4 peer
Mon Jul 15 19:41:43.622 UTC

```

PCE's peer database:

Peer address: 1.1.1.2

State: Up

Capabilities: Stateful, Segment-Routing, Update, Instantiation

Peer address: 1.1.1.4

State: Up

Capabilities: Stateful, Segment-Routing, Update, Instantiation

Peer address: 1.1.1.5

State: Up

Capabilities: Stateful, Segment-Routing, Update, Instantiation

Peer address: 1.1.1.6

State: Up

Capabilities: Stateful, Segment-Routing, Update, Instantiation

Use the **show pce association group-id** command to display information for the pair of LSPs assigned to a given association group-id value.

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. In particular, disjoint LSPs from site 1 to site 2 are identified by association group-id 775. The output includes high-level information for LSPs associated to this group-id:

- At Node A (1.1.1.5): LSP symbolic name = bgp_c_11000_ep_1.1.1.2_discr_100
- At Node B (1.1.1.6): LSP symbolic name = bgp_c_11000_ep_1.1.1.4_discr_100

In this case, the SR-PCE was able to achieve the desired disjointness level; therefore the Status is shown as "Satisfied".

```
RP/0/0/CPU0:SR-PCE# show pce association group-id 775
Thu Jul 11 03:52:20.770 UTC
```

PCE's association database:

```
-----
Association: Type Link-Disjoint, Group 775, Not Strict
```

Associated LSPs:

LSP[0]:

```
PCC 1.1.1.6, tunnel name bgp_c_11000_ep_1.1.1.4_discr_100, PLSP ID 18, tunnel ID 17,
LSP ID 3, Configured on PCC
```

LSP[1]:

```
PCC 1.1.1.5, tunnel name bgp_c_11000_ep_1.1.1.2_discr_100, PLSP ID 18, tunnel ID 18,
LSP ID 3, Configured on PCC
```

```
Status: Satisfied
```

Use the **show pce lsp** command to display detailed information of an LSP present in the PCE's LSP database. This output shows details for the LSP at Node A (1.1.1.5) that is used to carry traffic of EVPN VPWS EVI 100 towards node C (1.1.1.2).

```
RP/0/0/CPU0:SR-PCE# show pce lsp pcc ipv4 1.1.1.5 name bgp_c_11000_ep_1.1.1.2_discr_100
Thu Jul 11 03:58:45.903 UTC
```

PCE's tunnel database:

```
-----
PCC 1.1.1.5:
```

Tunnel Name: bgp_c_11000_ep_1.1.1.2_discr_100

```
Color: 11000
```

```
Interface Name: srte_c_11000_ep_1.1.1.2
```

LSPs:

LSP[0]:

```
source 1.1.1.5, destination 1.1.1.2, tunnel ID 18, LSP ID 3
```

```
State: Admin up, Operation up
```

```
Setup type: Segment Routing
```

```
Binding SID: 80037
```

```
Maximum SID Depth: 10
```

```
Absolute Metric Margin: 0
```

```
Relative Metric Margin: 0%
```

```
Preference: 100
```

```
Bandwidth: signaled 0 kbps, applied 0 kbps
```

```
PCEP information:
```

```
PLSP-ID 0x12, flags: D:1 S:0 R:0 A:1 O:1 C:0
```

```
LSP Role: Exclude LSP
```

```
State-sync PCE: None
```

```
PCC: 1.1.1.5
```

```
LSP is subdelegated to: None
```

```
Reported path:
```

```
Metric type: IGP, Accumulated Metric 40
```

```
SID[0]: Adj, Label 80003, Address: local 11.5.8.5 remote 11.5.8.8
```

```
SID[1]: Node, Label 16007, Address 1.1.1.7
```

```
SID[2]: Node, Label 16002, Address 1.1.1.2
```

```
Computed path: (Local PCE)
```

```
Computed Time: Thu Jul 11 03:49:48 UTC 2019 (00:08:58 ago)
```

```
Metric type: IGP, Accumulated Metric 40
```

```
SID[0]: Adj, Label 80003, Address: local 11.5.8.5 remote 11.5.8.8
```

```
SID[1]: Node, Label 16007, Address 1.1.1.7
```

```
SID[2]: Node, Label 16002, Address 1.1.1.2
```

```
Recorded path:
```

```
None
```

```
Disjoint Group Information:
```

```
Type Link-Disjoint, Group 775
```

This output shows details for the LSP at Node B (1.1.1.6) that is used to carry traffic of EVPN VPWS EVI 101 towards node D (1.1.1.4).

```
RP/0/0/CPU0:SR-PCE# show pce lsp pcc ipv4 1.1.1.6 name bgp_c_11000_ep_1.1.1.4_discr_100
Thu Jul 11 03:58:56.812 UTC
```

```
PCE's tunnel database:
```

```
-----
PCC 1.1.1.6:
```

```
Tunnel Name: bgp_c_11000_ep_1.1.1.4_discr_100
```

```
Color: 11000
```

```
Interface Name: srte_c_11000_ep_1.1.1.4
```

```
LSPs:
```

```
LSP[0]:
```

```
source 1.1.1.6, destination 1.1.1.4, tunnel ID 17, LSP ID 3
```

```
State: Admin up, Operation up
```

```
Setup type: Segment Routing
```

```
Binding SID: 80061
```

```
Maximum SID Depth: 10
```

```
Absolute Metric Margin: 0
```

```
Relative Metric Margin: 0%
```

```
Preference: 100
```

```
Bandwidth: signaled 0 kbps, applied 0 kbps
```

```
PCEP information:
```

```
PLSP-ID 0x12, flags: D:1 S:0 R:0 A:1 O:1 C:0
```

```
LSP Role: Disjoint LSP
```

```
State-sync PCE: None
```

```
PCC: 1.1.1.6
```

```
LSP is subdelegated to: None
```

```
Reported path:
```

```
Metric type: IGP, Accumulated Metric 40
```

```
SID[0]: Node, Label 16001, Address 1.1.1.1
```

```
SID[1]: Node, Label 16004, Address 1.1.1.4
```

```
Computed path: (Local PCE)
```

```
Computed Time: Thu Jul 11 03:49:48 UTC 2019 (00:09:08 ago)
```

```
Metric type: IGP, Accumulated Metric 40
```

```
SID[0]: Node, Label 16001, Address 1.1.1.1
```

```
SID[1]: Node, Label 16004, Address 1.1.1.4
```

```
Recorded path:
```

```
None
```

```
Disjoint Group Information:
```

```
Type Link-Disjoint, Group 775
```

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. In particular, disjoint LSPs from site 2 to site 1 are identified by association group-id 776. The output includes high-level information for LSPs associated to this group-id:

- At Node C (1.1.1.2): LSP symbolic name = bgp_c_10000_ep_1.1.1.5_discr_100
- At Node D (1.1.1.4): LSP symbolic name = bgp_c_10000_ep_1.1.1.6_discr_100

In this case, the SR-PCE was able to achieve the desired disjointness level; therefore, the Status is shown as "Satisfied".

```
RP/0/0/CPU0:SR-PCE# show pce association group-id 776
Thu Jul 11 03:52:24.370 UTC
```

```
PCE's association database:
```

```
-----
Association: Type Link-Disjoint, Group 776, Not Strict
```

```
Associated LSPs:
```

```
LSP[0]:
```

```

PCC 1.1.1.4, tunnel name bgp_c_10000_ep_1.1.1.6_discr_100, PLSP ID 16, tunnel ID 14,
LSP ID 1, Configured on PCC
LSP[1]:
PCC 1.1.1.2, tunnel name bgp_c_10000_ep_1.1.1.5_discr_100, PLSP ID 6, tunnel ID 21, LSP
ID 3, Configured on PCC
Status: Satisfied

```

Use the **show pce lsp** command to display detailed information of an LSP present in the PCE's LSP database. This output shows details for the LSP at Node C (1.1.1.2) that is used to carry traffic of EVPN VPWS EVI 100 towards node A (1.1.1.5).

```

RP/0/0/CPU0:SR-PCE# show pce lsp pcc ipv4 1.1.1.2 name bgp_c_10000_ep_1.1.1.5_discr_100
Thu Jul 11 03:55:21.706 UTC

```

```

PCE's tunnel database:
-----

```

```

PCC 1.1.1.2:

```

```

Tunnel Name: bgp_c_10000_ep_1.1.1.5_discr_100

```

```

Color: 10000

```

```

Interface Name: srte_c_10000_ep_1.1.1.5

```

```

LSPs:

```

```

LSP[0]:

```

```

source 1.1.1.2, destination 1.1.1.5, tunnel ID 21, LSP ID 3
State: Admin up, Operation up
Setup type: Segment Routing
Binding SID: 80052
Maximum SID Depth: 10
Absolute Metric Margin: 0
Relative Metric Margin: 0%
Preference: 100
Bandwidth: signaled 0 kbps, applied 0 kbps
PCEP information:
  PLSP-ID 0x6, flags: D:1 S:0 R:0 A:1 O:1 C:0
LSP Role: Exclude LSP
State-sync PCE: None
PCC: 1.1.1.2
LSP is subdelegated to: None
Reported path:
  Metric type: IGP, Accumulated Metric 40
  SID[0]: Node, Label 16007, Address 1.1.1.7
  SID[1]: Node, Label 16008, Address 1.1.1.8
  SID[2]: Adj, Label 80005, Address: local 11.5.8.8 remote 11.5.8.5
Computed path: (Local PCE)
  Computed Time: Thu Jul 11 03:50:03 UTC 2019 (00:05:18 ago)
  Metric type: IGP, Accumulated Metric 40
  SID[0]: Node, Label 16007, Address 1.1.1.7
  SID[1]: Node, Label 16008, Address 1.1.1.8
  SID[2]: Adj, Label 80005, Address: local 11.5.8.8 remote 11.5.8.5
Recorded path:
  None

```

```

Disjoint Group Information:

```

```

Type Link-Disjoint, Group 776

```

This output shows details for the LSP at Node D (1.1.1.4) used to carry traffic of EVPN VPWS EVI 101 towards node B (1.1.1.6).

```

RP/0/0/CPU0:SR-PCE# show pce lsp pcc ipv4 1.1.1.4 name bgp_c_10000_ep_1.1.1.6_discr_100
Thu Jul 11 03:55:23.296 UTC

```

```

PCE's tunnel database:
-----

```

```

PCC 1.1.1.4:

```

```

Tunnel Name: bgp_c_10000_ep_1.1.1.6_discr_100
Color: 10000
Interface Name: srte_c_10000_ep_1.1.1.6
LSPs:
LSP[0]:
  source 1.1.1.4, destination 1.1.1.6, tunnel ID 14, LSP ID 1
  State: Admin up, Operation up
  Setup type: Segment Routing
  Binding SID: 80047
  Maximum SID Depth: 10
  Absolute Metric Margin: 0
  Relative Metric Margin: 0%
  Preference: 100
  Bandwidth: signaled 0 kbps, applied 0 kbps
  PCEP information:
    PLSP-ID 0x10, flags: D:1 S:0 R:0 A:1 O:1 C:0
  LSP Role: Disjoint LSP
  State-sync PCE: None
  PCC: 1.1.1.4
  LSP is subdelegated to: None
  Reported path:
    Metric type: IGP, Accumulated Metric 40
    SID[0]: Node, Label 16001, Address 1.1.1.1
    SID[1]: Node, Label 16006, Address 1.1.1.6
  Computed path: (Local PCE)
    Computed Time: Thu Jul 11 03:50:03 UTC 2019 (00:05:20 ago)
    Metric type: IGP, Accumulated Metric 40
    SID[0]: Node, Label 16001, Address 1.1.1.1
    SID[1]: Node, Label 16006, Address 1.1.1.6
  Recorded path:
    None
Disjoint Group Information:
Type Link-Disjoint, Group 776

```

Verification: Site 1 Node A

This section depicts verification steps at Node A.

Use the **show bgp l2vpn evpn** command to display BGP prefix information for EVPN-VPWS EVI 100 (rd 1.1.1.5:100). The output includes an EVPN route-type 1 route with color 11000 originated at Node C (1.1.1.2).

```

RP/0/RSP0/CPU0:Node-A# show bgp l2vpn evpn rd 1.1.1.5:100
Wed Jul 10 18:57:57.704 PST
BGP router identifier 1.1.1.5, local AS number 65000
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0 RD version: 0
BGP main routing table version 360
BGP NSR Initial initsync version 1 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
               i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop          Metric LocPrf Weight Path
Route Distinguisher: 1.1.1.5:100 (default for vrf VPWS:100)
*> [1][0000.0000.0000.0000.0000][11]/120
                                0.0.0.0                                0 i
*>i [1][0000.0000.0000.0000.0000][21]/120
                                1.1.1.2 C:11000                            100    0 i

```

The following output displays the details for the incoming EVPN RT1. Note the presence of BGP extended color community 11000, and that the prefix is associated with an SR policy with color 11000 and BSID value of 80044.

```
RP/0/RSP0/CPU0:Node-A# show bgp l2vpn evpn rd 1.1.1.5:100
[1][0000.0000.0000.0000.0000][21]/120
Wed Jul 10 18:57:58.107 PST
BGP routing table entry for [1][0000.0000.0000.0000.0000][21]/120, Route Distinguisher:
1.1.1.5:100
Versions:
  Process          bRIB/RIB  SendTblVer
  Speaker          360      360
Last Modified: Jul 10 18:36:18.369 for 00:21:40
Paths: (1 available, best #1)
  Not advertised to any peer
  Path #1: Received by speaker 0
  Not advertised to any peer
  Local
  1.1.1.2 C:11000 (bsid:80044) (metric 40) from 1.1.1.253 (1.1.1.2)
    Received Label 80056
    Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate,
imported, rib-install
    Received Path ID 0, Local Path ID 1, version 358
    Extended community: Color:11000 RT:65000:100
    Originator: 1.1.1.2, Cluster list: 1.1.1.253
    SR policy color 11000, up, registered, bsid 80044, if-handle 0x00001b20

    Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 1.1.1.2:100
```

Use the **show l2vpn xconnect** command to display the state associated with EVPN-VPWS EVI 100 service.

```
RP/0/RSP0/CPU0:Node-A# show l2vpn xconnect group evpn_vpws_group
Wed Jul 10 18:58:02.333 PST
Legend: ST = State, UP = Up, DN = Down, AD = Admin Down, UR = Unresolved,
        SB = Standby, SR = Standby Ready, (PP) = Partially Programmed

XConnect          Segment 1          Segment 2
Group  Name      ST  Description      ST  Description      ST
-----
evpn_vpws_group
      evpn_vpws_100
      UP Gi0/0/0/3.2500 UP EVPN 100,21,1.1.1.2 UP
```

The following output shows the details for the service. Note that the service is associated with the on-demand SR policy with color 11000 and end-point 1.1.1.2 (node C).

```
RP/0/RSP0/CPU0:Node-A# show l2vpn xconnect group evpn_vpws_group xc-name evpn_vpws_100
detail
Wed Jul 10 18:58:02.755 PST

Group evpn_vpws_group, XC evpn_vpws_100, state is up; Interworking none
AC: GigabitEthernet0/0/0/3.2500, state is up
Type VLAN; Num Ranges: 1
Rewrite Tags: []
VLAN ranges: [2500, 2500]
MTU 1500; XC ID 0x120000c; interworking none
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0
  drops: illegal VLAN 0, illegal length 0
EVPN: neighbor 1.1.1.2, PW ID: evi 100, ac-id 21, state is up ( established )
```

```

XC ID 0xa0000007
Encapsulation MPLS
Source address 1.1.1.5
Encap type Ethernet, control word enabled
Sequencing not set
Preferred path Active : SR TE srte_c_11000_ep_1.1.1.2, On-Demand, fallback enabled
Tunnel : Up
Load Balance Hashing: src-dst-mac

      EVPN          Local          Remote
-----
Label          80040          80056
MTU             1500          1500
Control word    enabled        enabled
AC ID           11            21
EVPN type       Ethernet       Ethernet

-----
Create time: 10/07/2019 18:31:30 (1d17h ago)
Last time status changed: 10/07/2019 19:42:00 (1d16h ago)
Last time PW went down: 10/07/2019 19:40:55 (1d16h ago)
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0

```

Use the **show segment-routing traffic-eng policy** command with **tabular** option to display SR policy summary information.

The following output shows the on-demand SR policy with BSID 80044 that was triggered by EVPN RT1 prefix with color 11000 advertised by node C (1.1.1.2).

```

RP/0/RSP0/CPU0:Node-A# show segment-routing traffic-eng policy color 11000 tabular
Wed Jul 10 18:58:00.732 PST

```

Color	Endpoint	Admin State	Oper State	Binding SID
11000	1.1.1.2	up	up	80044

The following output shows the details for the on-demand SR policy. Note that the SR policy's active candidate path (preference 100) is computed by SR-PCE (1.1.1.207).

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. Specifically, from site 1 to site 2, LSP at Node A (srte_c_11000_ep_1.1.1.2) is link-disjoint from LSP at Node B (srte_c_11000_ep_1.1.1.4).

```

RP/0/RSP0/CPU0:Node-A# show segment-routing traffic-eng policy color 11000
Wed Jul 10 19:15:47.217 PST

```

```

SR-TE policy database
-----

```

```

Color: 11000, End-point: 1.1.1.2
Name: srte_c_11000_ep_1.1.1.2
Status:
  Admin: up Operational: up for 00:39:31 (since Jul 10 18:36:00.471)
Candidate-paths:
  Preference: 200 (BGP ODN) (shutdown)
  Requested BSID: dynamic
  PCC info:
    Symbolic name: bgp_c_11000_ep_1.1.1.2_discr_200
    PLSP-ID: 19

```

```

Dynamic (invalid)
Preference: 100 (BGP ODN) (active)
Requested BSID: dynamic
PCC info:
Symbolic name: bgp_c_11000_ep_1.1.1.2_discr_100
PLSP-ID: 18
Dynamic (pce 1.1.1.207) (valid)
Metric Type: IGP, Path Accumulated Metric: 40
80003 [Adjacency-SID, 11.5.8.5 - 11.5.8.8]
16007 [Prefix-SID, 1.1.1.7]
16002 [Prefix-SID, 1.1.1.2]
Attributes:
Binding SID: 80044
Forward Class: 0
Steering BGP disabled: no
IPv6 caps enable: yes

```

Verification: Site 1 Node B

This section depicts verification steps at Node B.

Use the **show bgp l2vpn evpn** command to display BGP prefix information for EVPN-VPWS EVI 101 (rd 1.1.1.6:101). The output includes an EVPN route-type 1 route with color 11000 originated at Node D (1.1.1.4).

```

RP/0/RSP0/CPU0:Node-B# show bgp l2vpn evpn rd 1.1.1.6:101
Wed Jul 10 19:08:54.964 PST
BGP router identifier 1.1.1.6, local AS number 65000
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0 RD version: 0
BGP main routing table version 322
BGP NSR Initial initsync version 7 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
               i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop          Metric LocPrf Weight Path
Route Distinguisher: 1.1.1.6:101 (default for vrf VPWS:101)
*> [1][0000.0000.0000.0000.0000][12]/120
      0.0.0.0                                0 i
*>i[1][0000.0000.0000.0000.0000][22]/120
      1.1.1.4 C:11000                        100 0 i

Processed 2 prefixes, 2 paths

```

The following output displays the details for the incoming EVPN RT1. Note the presence of BGP extended color community 11000, and that the prefix is associated with an SR policy with color 11000 and BSID value of 80061.

```

RP/0/RSP0/CPU0:Node-B# show bgp l2vpn evpn rd 1.1.1.6:101
[1][0000.0000.0000.0000.0000][22]/120
Wed Jul 10 19:08:55.039 PST
BGP routing table entry for [1][0000.0000.0000.0000.0000][22]/120, Route Distinguisher:
1.1.1.6:101
Versions:
  Process          bRIB/RIB  SendTblVer
  Speaker          322      322
Last Modified: Jul 10 18:42:10.408 for 00:26:44
Paths: (1 available, best #1)

```



```

Not advertised to any peer
Path #1: Received by speaker 0
Not advertised to any peer
Local
1.1.1.4 C:11000 (bsid:80061) (metric 40) from 1.1.1.253 (1.1.1.4)
  Received Label 80045
  Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate,
imported, rib-install
  Received Path ID 0, Local Path ID 1, version 319
Extended community: Color:11000 RT:65000:101
  Originator: 1.1.1.4, Cluster list: 1.1.1.253
SR policy color 11000, up, registered, bsid 80061, if-handle 0x00000560

  Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 1.1.1.4:101
    
```

Use the **show l2vpn xconnect** command to display the state associated with EVPN-VPWS EVI 101 service.

```

RP/0/RSP0/CPU0:Node-B# show l2vpn xconnect group evpn_vpws_group
Wed Jul 10 19:08:56.388 PST
Legend: ST = State, UP = Up, DN = Down, AD = Admin Down, UR = Unresolved,
       SB = Standby, SR = Standby Ready, (PP) = Partially Programmed

XConnect
Group      Name      ST      Segment 1
          Description      ST      Segment 2
          Description      ST
-----
evpn_vpws_group
          evpn_vpws_101
          UP      Te0/3/0/0/8.2500      UP      EVPN 101,22,1.1.1.4      UP
-----
    
```

The following output shows the details for the service. Note that the service is associated with the on-demand SR policy with color 11000 and end-point 1.1.1.4 (node D).

```

RP/0/RSP0/CPU0:Node-B# show l2vpn xconnect group evpn_vpws_group xc-name evpn_vpws_101
Wed Jul 10 19:08:56.511 PST

Group evpn_vpws_group, XC evpn_vpws_101, state is up; Interworking none
AC: TenGigE0/3/0/0/8.2500, state is up
Type VLAN; Num Ranges: 1
Rewrite Tags: []
VLAN ranges: [2500, 2500]
MTU 1500; XC ID 0x2a0000e; interworking none
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0
  drops: illegal VLAN 0, illegal length 0
EVPN: neighbor 1.1.1.4, PW ID: evi 101, ac-id 22, state is up ( established )
XC ID 0xa0000009
Encapsulation MPLS
Source address 1.1.1.6
Encap type Ethernet, control word enabled
Sequencing not set
Preferred path Active : SR TE srte_c_11000_ep_1.1.1.4, On-Demand, fallback enabled
Tunnel : Up
Load Balance Hashing: src-dst-mac
    
```

EVPN	Local	Remote
Label	80060	80045
MTU	1500	1500
Control word	enabled	enabled
AC ID	12	22
EVPN type	Ethernet	Ethernet

```

-----
Create time: 10/07/2019 18:32:49 (00:36:06 ago)
Last time status changed: 10/07/2019 18:42:07 (00:26:49 ago)
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0

```

Use the **show segment-routing traffic-eng policy** command with **tabular** option to display SR policy summary information.

The following output shows the on-demand SR policy with BSID 80061 that was triggered by EVPN RT1 prefix with color 11000 advertised by node D (1.1.1.4).

```
RP/0/RSP0/CPU0:Node-B# show segment-routing traffic-eng policy color 11000 tabular
Wed Jul 10 19:08:56.146 PST
```

Color	Endpoint	Admin State	Oper State	Binding SID
11000	1.1.1.4	up	up	80061

The following output shows the details for the on-demand SR policy. Note that the SR policy's active candidate path (preference 100) is computed by SR-PCE (1.1.1.207).

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. Specifically, from site 1 to site 2, LSP at Node B (srte_c_11000_ep_1.1.1.4) is link-disjoint from LSP at Node A (srte_c_11000_ep_1.1.1.2).

```
RP/0/RSP0/CPU0:Node-B# show segment-routing traffic-eng policy color 11000
Wed Jul 10 19:08:56.207 PST
```

```
SR-TE policy database
-----
```

```

Color: 11000, End-point: 1.1.1.4
Name: srte_c_11000_ep_1.1.1.4
Status:
  Admin: up Operational: up for 00:26:47 (since Jul 10 18:40:05.868)
Candidate-paths:
  Preference: 200 (BGP ODN) (shutdown)
  Requested BSID: dynamic
  PCC info:
    Symbolic name: bgp_c_11000_ep_1.1.1.4_discr_200
    PLSP-ID: 19
    Dynamic (invalid)
  Preference: 100 (BGP ODN) (active)
  Requested BSID: dynamic
  PCC info:
    Symbolic name: bgp_c_11000_ep_1.1.1.4_discr_100
    PLSP-ID: 18
  Dynamic (pce 1.1.1.207) (valid)
  Metric Type: IGP, Path Accumulated Metric: 40
    16001 [Prefix-SID, 1.1.1.1]
    16004 [Prefix-SID, 1.1.1.4]
Attributes:
  Binding SID: 80061
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes

```

Verification: Site 2 Node C

This section depicts verification steps at Node C.

Use the **show bgp l2vpn evpn** command to display BGP prefix information for EVPN-VPWS EVI 100 (rd 1.1.1.2:100). The output includes an EVPN route-type 1 route with color 10000 originated at Node A (1.1.1.5).

```
RP/0/RSP0/CPU0:Node-C# show bgp l2vpn evpn rd 1.1.1.2:100
BGP router identifier 1.1.1.2, local AS number 65000
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0 RD version: 0
BGP main routing table version 21
BGP NSR Initial initsync version 1 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
               i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network                Next Hop                Metric LocPrf Weight Path
Route Distinguisher: 1.1.1.2:100 (default for vrf VPWS:100)
*>i [1] [0000.0000.0000.0000.0000] [11]/120
                               1.1.1.5 C:10000                100      0 i
*> [1] [0000.0000.0000.0000.0000] [21]/120
                               0.0.0.0                                0 i
```

The following output displays the details for the incoming EVPN RT1. Note the presence of BGP extended color community 10000, and that the prefix is associated with an SR policy with color 10000 and BSID value of 80058.

```
RP/0/RSP0/CPU0:Node-C# show bgp l2vpn evpn rd 1.1.1.2:100
[1] [0000.0000.0000.0000.0000] [11]/120
BGP routing table entry for [1] [0000.0000.0000.0000.0000] [11]/120, Route Distinguisher:
1.1.1.2:100
Versions:
  Process                bRIB/RIB  SendTblVer
  Speaker                 20        20
Last Modified: Jul 10 18:36:20.503 for 00:45:21
Paths: (1 available, best #1)
  Not advertised to any peer
  Path #1: Received by speaker 0
  Not advertised to any peer
  Local
    1.1.1.5 C:10000 (bsid:80058) (metric 40) from 1.1.1.253 (1.1.1.5)
    Received Label 80040
    Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate,
imported, rib-install
    Received Path ID 0, Local Path ID 1, version 18
    Extended community: Color:10000 RT:65000:100
    Originator: 1.1.1.5, Cluster list: 1.1.1.253
    SR policy color 10000, up, registered, bsid 80058, if-handle 0x000006a0

Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 1.1.1.5:100
```

Use the **show l2vpn xconnect** command to display the state associated with EVPN-VPWS EVI 100 service.

```
RP/0/RSP0/CPU0:Node-C# show l2vpn xconnect group evpn_vpws_group
Legend: ST = State, UP = Up, DN = Down, AD = Admin Down, UR = Unresolved,
       SB = Standby, SR = Standby Ready, (PP) = Partially Programmed

XConnect                Segment 1                Segment 2
```

Group	Name	ST	Description	ST	Description	ST
evpn_vpws_group	evpn_vpws_100	UP	Gi0/0/0/3.2500	UP	EVPN 100,11,1.1.1.5	UP

The following output shows the details for the service. Note that the service is associated with the on-demand SR policy with color 10000 and end-point 1.1.1.5 (node A).

```
RP/0/RSP0/CPU0:Node-C# show l2vpn xconnect group evpn_vpws_group xc-name evpn_vpws_100
```

```
Group evpn_vpws_group, XC evpn_vpws_100, state is up; Interworking none
AC: GigabitEthernet0/0/0/3.2500, state is up
  Type VLAN; Num Ranges: 1
  Rewrite Tags: []
  VLAN ranges: [2500, 2500]
  MTU 1500; XC ID 0x1200008; interworking none
  Statistics:
    packets: received 0, sent 0
    bytes: received 0, sent 0
    drops: illegal VLAN 0, illegal length 0
  EVPN: neighbor 1.1.1.5, PW ID: evi 100, ac-id 11, state is up ( established )
  XC ID 0xa0000003
  Encapsulation MPLS
  Source address 1.1.1.2
  Encap type Ethernet, control word enabled
  Sequencing not set
Preferred path Active : SR TE srte_c_10000_ep_1.1.1.5, On-Demand, fallback enabled
  Tunnel : Up
  Load Balance Hashing: src-dst-mac

      EVPN          Local                               Remote
      -----
      Label         80056                               80040
      MTU           1500                               1500
      Control word  enabled                             enabled
      AC ID         21                                  11
      EVPN type     Ethernet                             Ethernet

      -----
      Create time: 10/07/2019 18:36:16 (1d19h ago)
      Last time status changed: 10/07/2019 19:41:59 (1d18h ago)
      Last time PW went down: 10/07/2019 19:40:54 (1d18h ago)
      Statistics:
        packets: received 0, sent 0
        bytes: received 0, sent 0
```

Use the **show segment-routing traffic-eng policy** command with **tabular** option to display SR policy summary information.

The following output shows the on-demand SR policy with BSID 80058 that was triggered by EVPN RT1 prefix with color 10000 advertised by node A (1.1.1.5).

```
RP/0/RSP0/CPU0:Node-C# show segment-routing traffic-eng policy color 10000 tabular
```

Color	Endpoint	Admin State	Oper State	Binding SID
10000	1.1.1.5	up	up	80058

The following output shows the details for the on-demand SR policy. Note that the SR policy's active candidate path (preference 100) is computed by SR-PCE (1.1.1.207).

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. Specifically, from site 2 to site 1, LSP at Node C (srte_c_10000_ep_1.1.1.5) is link-disjoint from LSP at Node D (srte_c_10000_ep_1.1.1.6).

```
RP/0/RSP0/CPU0:Node-C# show segment-routing traffic-eng policy color 10000
```

```
SR-TE policy database
```

```
-----
Color: 10000, End-point: 1.1.1.5
Name: srte_c_10000_ep_1.1.1.5
Status:
  Admin: up Operational: up for 00:12:35 (since Jul 10 19:49:21.890)
Candidate-paths:
  Preference: 200 (BGP ODN) (shutdown)
    Requested BSID: dynamic
    PCC info:
      Symbolic name: bgp_c_10000_ep_1.1.1.5_discr_200
      PLSP-ID: 7
    Dynamic (invalid)
  Preference: 100 (BGP ODN) (active)
    Requested BSID: dynamic
    PCC info:
      Symbolic name: bgp_c_10000_ep_1.1.1.5_discr_100
      PLSP-ID: 6
  Dynamic (pce 1.1.1.207) (valid)
    Metric Type: IGP, Path Accumulated Metric: 40
    16007 [Prefix-SID, 1.1.1.7]
    16008 [Prefix-SID, 1.1.1.8]
    80005 [Adjacency-SID, 11.5.8.8 - 11.5.8.5]
Attributes:
  Binding SID: 80058
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes
```

Verification: Site 2 Node D

This section depicts verification steps at Node D.

Use the **show bgp l2vpn evpn** command to display BGP prefix information for EVPN-VPWS EVI 101 (rd 1.1.1.4:101). The output includes an EVPN route-type 1 route with color 10000 originated at Node B (1.1.1.6).

```
RP/0/RSP0/CPU0:Node-D# show bgp l2vpn evpn rd 1.1.1.4:101
```

```
BGP router identifier 1.1.1.4, local AS number 65000
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0 RD version: 0
BGP main routing table version 570
BGP NSR Initial initsync version 1 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs
```

```
Status codes: s suppressed, d damped, h history, * valid, > best
               i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network      Next Hop          Metric LocPrf Weight Path
Route Distinguisher: 1.1.1.4:101 (default for vrf VPWS:101)
*>i [1] [0000.0000.0000.0000.0000] [12]/120
```

```

1.1.1.6 C:10000          100      0 i
*> [1][0000.0000.0000.0000.0000][22]/120
0.0.0.0                  0 i

```

Processed 2 prefixes, 2 paths

The following output displays the details for the incoming EVPN RT1. Note the presence of BGP extended color community 10000, and that the prefix is associated with an SR policy with color 10000 and BSID value of 80047.

```

RP/0/RSP0/CPU0:Node-D# show bgp l2vpn evpn rd 1.1.1.4:101
[1][0000.0000.0000.0000.0000][12]/120
BGP routing table entry for [1][0000.0000.0000.0000.0000][12]/120, Route Distinguisher:
1.1.1.4:101
Versions:
  Process          bRIB/RIB  SendTblVer
  Speaker          569      569
Last Modified: Jul 10 18:42:12.455 for 00:45:38
Paths: (1 available, best #1)
  Not advertised to any peer
  Path #1: Received by speaker 0
  Not advertised to any peer
  Local
    1.1.1.6 C:10000 (bsid:80047) (metric 40) from 1.1.1.253 (1.1.1.6)
      Received Label 80060
      Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate,
imported, rib-install
      Received Path ID 0, Local Path ID 1, version 568
      Extended community: Color:10000 RT:65000:101
      Originator: 1.1.1.6, Cluster list: 1.1.1.253
      SR policy color 10000, up, registered, bsid 80047, if-handle 0x00001720

  Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 1.1.1.6:101

```

Use the **show l2vpn xconnect** command to display the state associated with EVPN-VPWS EVI 101 service.

```

RP/0/RSP0/CPU0:Node-D# show l2vpn xconnect group evpn_vpws_group
Legend: ST = State, UP = Up, DN = Down, AD = Admin Down, UR = Unresolved,
      SB = Standby, SR = Standby Ready, (PP) = Partially Programmed

```

XConnect Group	Name	ST	Segment 1 Description	ST	Segment 2 Description	ST
evpn_vpws_group	evpn_vpws_101	UP	Gi0/0/0/1.2500	UP	EVPN 101,12,1.1.1.6	UP

The following output shows the details for the service. Note that the service is associated with the on-demand SR policy with color 10000 and end-point 1.1.1.6 (node B).

```

RP/0/RSP0/CPU0:Node-D# show l2vpn xconnect group evpn_vpws_group xc-name evpn_vpws_101

```

```

Group evpn_vpws_group, XC evpn_vpws_101, state is up; Interworking none
AC: GigabitEthernet0/0/0/1.2500, state is up
Type VLAN; Num Ranges: 1
Rewrite Tags: []
VLAN ranges: [2500, 2500]
MTU 1500; XC ID 0x120000c; interworking none
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0

```

```

    drops: illegal VLAN 0, illegal length 0
EVPN: neighbor 1.1.1.6, PW ID: evi 101, ac-id 12, state is up ( established )
XC ID 0xa000000d
Encapsulation MPLS
Source address 1.1.1.4
Encap type Ethernet, control word enabled
Sequencing not set
Preferred path Active : SR TE srte_c_10000_ep_1.1.1.6, On-Demand, fallback enabled
Tunnel : Up
Load Balance Hashing: src-dst-mac

      EVPN          Local          Remote
-----
Label            80045          80060
MTU              1500          1500
Control word enabled          enabled
AC ID            22           12
EVPN type       Ethernet       Ethernet
-----
Create time: 10/07/2019 18:42:07 (00:45:49 ago)
Last time status changed: 10/07/2019 18:42:09 (00:45:47 ago)
Statistics:
  packets: received 0, sent 0
  bytes: received 0, sent 0

```

Use the **show segment-routing traffic-eng policy** command with **tabular** option to display SR policy summary information.

The following output shows the on-demand SR policy with BSID 80047 that was triggered by EVPN RT1 prefix with color 10000 advertised by node B (1.1.1.6).

```
RP/0/RSP0/CPU0:Node-D# show segment-routing traffic-eng policy color 10000 tabular
```

Color	Endpoint	Admin State	Oper State	Binding SID
10000	1.1.1.6	up	up	80047

The following output shows the details for the on-demand SR policy. Note that the SR policy's active candidate path (preference 100) is computed by SR-PCE (1.1.1.207).

Based on the goals of this use case, SR-PCE computes link-disjoint paths for the SR policies associated with a pair of ELINE services between site 1 and site 2. Specifically, from site 2 to site 1, LSP at Node D (srte_c_10000_ep_1.1.1.6) is link-disjoint from LSP at Node C (srte_c_10000_ep_1.1.1.5).

```
RP/0/RSP0/CPU0:Node-D# show segment-routing traffic-eng policy color 10000
```

```
SR-TE policy database
-----
```

```

Color: 10000, End-point: 1.1.1.6
Name: srte_c_10000_ep_1.1.1.6
Status:
  Admin: up Operational: up for 01:23:04 (since Jul 10 18:42:07.350)
Candidate-paths:
  Preference: 200 (BGP ODN) (shutdown)
  Requested BSID: dynamic
  PCC info:
    Symbolic name: bgp_c_10000_ep_1.1.1.6_discr_200
    PLSP-ID: 17
  Dynamic (invalid)

```

```

Preference: 100 (BGP ODN) (active)
Requested BSID: dynamic
PCC info:
  Symbolic name: bgp_c_10000_ep_1.1.1.6_discr_100
  PLSP-ID: 16
Dynamic (pce 1.1.1.207) (valid)
  Metric Type: IGP, Path Accumulated Metric: 40
  16001 [Prefix-SID, 1.1.1.1]
  16006 [Prefix-SID, 1.1.1.6]
Attributes:
  Binding SID: 80047
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes

```

Manually Provisioned SR Policy

Manually provisioned SR policies are configured on the head-end router. These policies can use dynamic paths or explicit paths. See the [SR-TE Policy Path Types, on page 32](#) section for information on manually provisioning an SR policy using dynamic or explicit paths.

PCE-Initiated SR Policy

An SR-TE policy can be configured on the path computation element (PCE) to reduce link congestion or to minimize the number of network touch points.

The PCE collects network information, such as traffic demand and link utilization. When the PCE determines that a link is congested, it identifies one or more flows that are causing the congestion. The PCE finds a suitable path and deploys an SR-TE policy to divert those flows, without moving the congestion to another part of the network. When there is no more link congestion, the policy is removed.

To minimize the number of network touch points, an application, such as a Network Services Orchestrator (NSO), can request the PCE to create an SR-TE policy. PCE deploys the SR-TE policy using PCC-PCE communication protocol (PCEP).

For more information, see the [PCE-Initiated SR Policies](#) section.

SR-TE Policy Path Types

A **dynamic** path is based on an optimization objective and a set of constraints. The head-end computes a solution, resulting in a SID-list or a set of SID-lists. When the topology changes, a new path is computed. If the head-end does not have enough information about the topology, the head-end might delegate the computation to a Segment Routing Path Computation Element (SR-PCE). For information on configuring SR-PCE, see *Configure Segment Routing Path Computation Element* chapter.

An **explicit** path is a specified SID-list or set of SID-lists.

An SR-TE policy initiates a single (selected) path in RIB/FIB. This is the preferred valid candidate path.

A candidate path has the following characteristics:

- It has a preference – If two policies have same {color, endpoint} but different preferences, the policy with the highest preference is selected.

- It is associated with a single binding SID (BSID) – A BSID conflict occurs when there are different SR policies with the same BSID. In this case, the policy that is installed first gets the BSID and is selected.
- It is valid if it is usable.

A path is selected when the path is valid and its preference is the best among all candidate paths for that policy.



Note The protocol of the source is not relevant in the path selection logic.

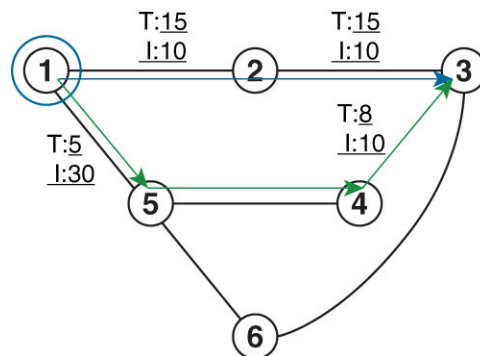
Dynamic Paths

Optimization Objectives

Optimization objectives allow the head-end router to compute a SID-list that expresses the shortest dynamic path according to the selected metric type:

- IGP metric — Refer to the "Implementing IS-IS" and "Implementing OSPF" chapters in the *Routing Configuration Guide for Series Routers*.
- TE metric — See the [Configure Interface TE Metrics, on page 33](#) section for information about configuring TE metrics.

This example shows a dynamic path from head-end router 1 to end-point router 3 that minimizes IGP or TE metric:



Default IGP link metric: I:10
Default TE link metric T:10

520018

- The blue path uses the minimum IGP metric: Min-Metric (1 → 3, IGP) = SID-list <16003>; cumulative IGP metric: 20
- The green path uses the minimum TE metric: Min-Metric (1 → 3, TE) = SID-list <16005, 16004, 16003>; cumulative TE metric: 23

Configure Interface TE Metrics

Use the **metric value** command in SR-TE interface submode to configure the TE metric for interfaces. The **value** range is from 0 to 2147483647.

```

Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# interface type interface-path-id
Router(config-sr-te-if)# metric value

```

Configuring TE Metric: Example

The following configuration example shows how to set the TE metric for various interfaces:

```

segment-routing
traffic-eng
interface TenGigE0/0/0/0
metric 100
!
interface TenGigE0/0/0/1
metric 1000
!
interface TenGigE0/0/2/0
metric 50
!
!
end

```

Constraints

Constraints allow the head-end router to compute a dynamic path according to the selected metric type:

- **Affinity** — You can apply a color or name to links or interfaces by assigning affinity bit-maps to them. You can then specify an affinity (or relationship) between an SR policy path and link colors. SR-TE computes a path that includes or excludes links that have specific colors, or combinations of colors. See the [Named Interface Link Admin Groups and SR-TE Affinity Maps, on page 34](#) section for information on named interface link admin groups and SR-TE Affinity Maps.
- **Disjoint** — SR-TE computes a path that is disjoint from another path in the same disjoint-group. Disjoint paths do not share network resources. Path disjointness may be required for paths between the same pair of nodes, between different pairs of nodes, or a combination (only same head-end or only same end-point).
- **Flexible Algorithm** — Flexible Algorithm allows for user-defined algorithms where the IGP computes paths based on a user-defined combination of metric type and constraint.

Named Interface Link Admin Groups and SR-TE Affinity Maps

Named Interface Link Admin Groups and SR-TE Affinity Maps provide a simplified and more flexible means of configuring link attributes and path affinities to compute paths for SR-TE policies.

In the traditional TE scheme, links are configured with attribute-flags that are flooded with TE link-state parameters using Interior Gateway Protocols (IGPs), such as Open Shortest Path First (OSPF).

Named Interface Link Admin Groups and SR-TE Affinity Maps let you assign, or map, up to color names for affinity and attribute-flag attributes instead of 32-bit hexadecimal numbers. After mappings are defined, the attributes can be referred to by the corresponding color name in the CLI. Furthermore, you can define constraints using *include-any*, *include-all*, and *exclude-any* arguments, where each statement can contain up to 10 colors.



Note You can configure affinity constraints using attribute flags or the Flexible Name Based Policy Constraints scheme; however, when configurations for both schemes exist, only the configuration pertaining to the new scheme is applied.

Configure Named Interface Link Admin Groups and SR-TE Affinity Maps

Use the **affinity name** *NAME* command in SR-TE interface submode to assign affinity to interfaces. Configure this on routers with interfaces that have an associated admin group attribute.

```
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# interface TenGigE0/0/1/2
Router(config-sr-if)# affinity
Router(config-sr-if-affinity)# name RED
```

Use the **affinity-map name** *NAME* **bit-position** *bit-position* command in SR-TE sub-mode to define affinity maps. The *bit-position* range is from 0 to 255.

Configure affinity maps on the following routers:

- Routers with interfaces that have an associated admin group attribute.
- Routers that act as SR-TE head-ends for SR policies that include affinity constraints.

```
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# affinity-map
Router(config-sr-te-affinity-map)# name RED bit-position 23
```

Configuring Link Admin Group: Example

The following example shows how to assign affinity to interfaces and to define affinity maps. This configuration is applicable to any router (SR-TE head-end or transit node) with colored interfaces.

```
segment-routing
traffic-eng
interface TenGigE0/0/1/1
affinity
name CROSS
name RED
!
!
interface TenGigE0/0/1/2
affinity
name RED
!
!
interface TenGigE0/0/2/0
affinity
name BLUE
!
!
affinity-map
name RED bit-position 23
name BLUE bit-position 24
name CROSS bit-position 25
```

```

!
end

```

Configure SR Policy with Dynamic Path

To configure a SR-TE policy with a dynamic path, optimization objectives, and affinity constraints, complete the following configurations:

1. Define the optimization objectives. See the [Optimization Objectives, on page 33](#) section.
2. Define the constraints. See the [Constraints, on page 34](#) section.
3. Create the policy.

Behaviors and Limitations

Examples

The following example shows a configuration of an SR policy at an SR-TE head-end router. The policy has a dynamic path with optimization objectives and affinity constraints computed by the head-end router.

```

segment-routing
traffic-eng
policy foo
color 100 end-point ipv4 1.1.1.2
candidate-paths
preference 100
dynamic
metric
type te
!
!
constraints
affinity
exclude-any
name RED
!
!
!
!
!
!
!
!

```

The following example shows a configuration of an SR policy at an SR-TE head-end router. The policy has a dynamic path with optimization objectives and affinity constraints computed by the SR-PCE.

```

segment-routing
traffic-eng
policy baa
color 101 end-point ipv4 1.1.1.2
candidate-paths
preference 100
dynamic
pcep
!
metric
type te
!
!
constraints

```

```

affinity
  exclude-any
  name BLUE
!
!
!
!
!
!

```

Explicit Paths

Configure SR-TE Policy with Explicit Path

To configure an SR-TE policy with an explicit path, complete the following configurations:

1. Create the segment lists.
2. Create the SR-TE policy.

Behaviors and Limitations

A segment list can use IP addresses or MPLS labels, or a combination of both.

- The IP address can be link or a Loopback address.
- Once you enter an MPLS label, you cannot enter an IP address.

When configuring an explicit path using IP addresses of links along the path, the SR-TE process selects either the protected or the unprotected Adj-SID of the link, depending on the order in which the Adj-SIDs were received.

Configure Local SR-TE Policy Using Explicit Paths

Create a segment list with IP addresses:

```

Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# segment-list name SIDLIST1
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.2
Router(config-sr-te-sl)# index 20 address ipv4 1.1.1.3
Router(config-sr-te-sl)# index 30 address ipv4 1.1.1.4
Router(config-sr-te-sl)# exit

```

Create a segment list with MPLS labels:

```

Router(config-sr-te)# segment-list name SIDLIST2
Router(config-sr-te-sl)# index 10 mpls label 16002
Router(config-sr-te-sl)# index 20 mpls label 16003
Router(config-sr-te-sl)# index 30 mpls label 16004
Router(config-sr-te-sl)# exit

```

Create a segment list with invalid MPLS label:

```

Router(config-sr-te)# segment-list name SIDLIST4
Router(config-sr-te-sl)# index 10 mpls label 16009
Router(config-sr-te-sl)# index 20 mpls label 16003

```

```
Router(config-sr-te-sl)# index 30 mpls label 16004
Router(config-sr-te-sl)# exit
```

Create a segment list with IP addresses and MPLS labels:

```
Router(config-sr-te)# segment-list name SIDLIST3
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.2
Router(config-sr-te-sl)# index 20 mpls label 16003
Router(config-sr-te-sl)# index 30 mpls label 16004
Router(config-sr-te-sl)# exit
```

Create the SR-TE policy:

```
Router(config-sr-te)# policy POLICY2
Router(config-sr-te-policy)# color 20 end-point ipv4 1.1.1.4
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST2
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# exit
Router(config-sr-te-policy-path)# preference 200
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST1
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST4
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# exit
```

Running Configuration

```
Router# show running-configuration
segment-routing
traffic-eng
segment-list SIDLIST1
index 10 address ipv4 1.1.1.2
index 20 address ipv4 1.1.1.3
index 30 address ipv4 1.1.1.4
!
segment-list SIDLIST2
index 10 mpls label 16002
index 20 mpls label 16003
index 30 mpls label 16004
!
segment-list SIDLIST3
index 10 address ipv4 1.1.1.2
index 20 mpls label 16003
index 30 mpls label 16004
!
segment-list SIDLIST4
index 10 mpls label 16009
index 20 mpls label 16003
index 30 mpls label 16004
!
policy POLICY1
color 10 end-point ipv4 1.1.1.4
candidate-paths
preference 100
explicit segment-list SIDLIST1
!
!
!
policy POLICY2
color 20 end-point ipv4 1.1.1.4
```

```

candidate-paths
  preference 100
    explicit segment-list SIDLIST1
    !
  !
  preference 200
    explicit segment-list SIDLIST2
    !
    explicit segment-list SIDLIST4
    !
  !
  !
  !
policy POLICY3
  color 30 end-point ipv4 1.1.1.4
  candidate-paths
    preference 100
      explicit segment-list SIDLIST3
    !
  !
  !
  !
  !
  !

```

Verification

Verify the SR-TE policy configuration using:

```
Router# show segment-routing traffic-eng policy name srte_c_20_ep_1.1.1.4
```

```

SR-TE policy database
-----
Color: 20, End-point: 1.1.1.4
Name: srte_c_20_ep_1.1.1.4
Status:
  Admin: up Operational: up for 00:00:15 (since Jul 14 00:53:10.615)
Candidate-paths:
  Preference: 200 (configuration) (active)
    Name: POLICY2
    Requested BSID: dynamic
    Protection Type: protected-preferred
    Maximum SID Depth: 8
    Explicit: segment-list SIDLIST2 (active)
    Weight: 1, Metric Type: TE
      16002
      16003
      16004
  Attributes:
    Binding SID: 51301
  Forward Class: Not Configured
  Steering labeled-services disabled: no
  Steering BGP disabled: no
  IPv6 caps enable: yes
  Invalidation drop enabled: no

```

Configuring Explicit Path with Affinity Constraint Validation

To fully configure SR-TE flexible name-based policy constraints, you must complete these high-level tasks in order:

1. Assign Color Names to Numeric Values
2. Associate Affinity-Names with SR-TE Links
3. Associate Affinity Constraints for SR-TE Policies

```

/* Enter the global configuration mode and assign color names to numeric values
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# affinity-map
Router(config-sr-te-affinity-map)# blue bit-position 0
Router(config-sr-te-affinity-map)# green bit-position 1
Router(config-sr-te-affinity-map)# red bit-position 2
Router(config-sr-te-affinity-map)# exit

/* Associate affinity-names with SR-TE links
Router(config-sr-te)# interface Gi0/0/0/0
Router(config-sr-te-if)# affinity
Router(config-sr-te-if-affinity)# blue
Router(config-sr-te-if-affinity)# exit
Router(config-sr-te-if)# exit
Router(config-sr-te)# interface Gi0/0/0/1
Router(config-sr-te-if)# affinity
Router(config-sr-te-if-affinity)# blue
Router(config-sr-te-if-affinity)# green
Router(config-sr-te-if-affinity)# exit
Router(config-sr-te-if)# exit
Router(config-sr-te)#

/* Associate affinity constraints for SR-TE policies
Router(config-sr-te)# segment-list name SIDLIST1
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.2
Router(config-sr-te-sl)# index 20 address ipv4 2.2.2.23
Router(config-sr-te-sl)# index 30 address ipv4 1.1.1.4
Router(config-sr-te-sl)# exit
Router(config-sr-te)# segment-list name SIDLIST2
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.2
Router(config-sr-te-sl)# index 30 address ipv4 1.1.1.4
Router(config-sr-te-sl)# exit
Router(config-sr-te)# segment-list name SIDLIST3
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.5
Router(config-sr-te-sl)# index 30 address ipv4 1.1.1.4
Router(config-sr-te-sl)# exit

Router(config-sr-te)# policy POLICY1
Router(config-sr-te-policy)# color 20 end-point ipv4 1.1.1.4
Router(config-sr-te-policy)# binding-sid mpls 1000
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 200
Router(config-sr-te-policy-path-pref)# constraints affinity exclude-any red
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST1
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST2
Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# exit
Router(config-sr-te-policy-path)# preference 100

```



```
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST3
```

Running Configuration

```
Router# show running-configuration
segment-routing
traffic-eng

interface GigabitEthernet0/0/0/0
  affinity
    blue
  !
!
interface GigabitEthernet0/0/0/1
  affinity
    blue
    green
  !
!

segment-list name SIDLIST1
  index 10 address ipv4 1.1.1.2
  index 20 address ipv4 2.2.2.23
  index 30 address ipv4 1.1.1.4
!
segment-list name SIDLIST2
  index 10 address ipv4 1.1.1.2
  index 30 address ipv4 1.1.1.4
!
segment-list name SIDLIST3
  index 10 address ipv4 1.1.1.5
  index 30 address ipv4 1.1.1.4
!
policy POLICY1
  binding-sid mpls 1000
  color 20 end-point ipv4 1.1.1.4
  candidate-paths
  preference 100
    explicit segment-list SIDLIST3
  !
!
  preference 200
    explicit segment-list SIDLIST1
  !
    explicit segment-list SIDLIST2
  !
  constraints
  affinity
    exclude-any
    red
  !
  !
  !
!
!
affinity-map
  blue bit-position 0
  green bit-position 1
  red bit-position 2
!
!
```

!

Protocols

Path Computation Element Protocol

The path computation element protocol (PCEP) describes a set of procedures by which a path computation client (PCC) can report and delegate control of head-end label switched paths (LSPs) sourced from the PCC to a PCE peer. The PCE can request the PCC to update and modify parameters of LSPs it controls. The stateful model also enables a PCC to allow the PCE to initiate computations allowing the PCE to perform network-wide orchestration.

Configure the Head-End Router as PCEP PCC

Configure the head-end router as PCEP Path Computation Client (PCC) to establish a connection to the PCE. The PCC and PCE addresses must be routable so that TCP connection (to exchange PCEP messages) can be established between PCC and PCE.

Configure the PCC to Establish a Connection to the PCE

Use the **segment-routing traffic-eng pcc** command to configure the PCC source address, the SR-PCE address, and SR-PCE options.

A PCE can be given an optional precedence. If a PCC is connected to multiple PCEs, the PCC selects a PCE with the lowest precedence value. If there is a tie, a PCE with the highest IP address is chosen for computing path. The precedence *value* range is from 0 to 255.

```
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# pcc
Router(config-sr-te-pcc)# source-address ipv4 local-source-address
Router(config-sr-te-pcc)# pce address ipv4 PCE-address[precedence value]
Router(config-sr-te-pcc)# pce address ipv4 PCE-address[keychain WORD]
```

Configure PCEP-Related Timers

Use the **timers keepalive** command to specify how often keepalive messages are sent from PCC to its peers. The range is from 0 to 255 seconds; the default value is 30.

```
Router(config-sr-te-pcc)# timers keepalive seconds
```

Use the **timers deadtimer** command to specify how long the remote peers wait before bringing down the PCEP session if no PCEP messages are received from this PCC. The range is from 1 to 255 seconds; the default value is 120.

```
Router(config-sr-te-pcc)# timers deadtimer seconds
```

Use the **timers delegation-timeout** command to specify how long a delegated SR policy can remain up without an active connection to a PCE. The range is from 0 to 3600 seconds; the default value is 60.

```
Router(config-sr-te-pcc)# timers delegation-timeout seconds
```

PCE-Initiated SR Policy Timers

Use the **timers initiated orphans** command to specify the amount of time that a PCE-initiated SR policy will remain delegated to a PCE peer that is no longer reachable by the PCC. The range is from 10 to 180 seconds; the default value is 180.

```
Router(config-sr-te-pcc)# timers initiated orphans seconds
```

Use the **timers initiated state** command to specify the amount of time that a PCE-initiated SR policy will remain programmed while not being delegated to any PCE. The range is from 15 to 14440 seconds (24 hours); the default value is 600.

```
Router(config-sr-te-pcc)# timers initiated state seconds
```

To better understand how the PCE-initiated SR policy timers operate, consider the following example:

- PCE A instantiates SR policy P at head-end N.
- Head-end N delegates SR policy P to PCE A and programs it in forwarding.
- If head-end N detects that PCE A is no longer reachable, then head-end N starts the PCE-initiated **orphan** and **state** timers for SR policy P.
- If PCE A reconnects before the **orphan** timer expires, then SR policy P is automatically delegated back to its original PCE (PCE A).
- After the **orphan** timer expires, SR policy P will be eligible for delegation to any other surviving PCE(s).
- If SR policy P is not delegated to another PCE before the **state** timer expires, then head-end N will remove SR policy P from its forwarding.

Enable SR-TE SYSLOG Alarms

Use the **logging policy status** command to enable SR-TE related SYSLOG alarms.

```
Router(config-sr-te)# logging policy status
```

Enable PCEP Reports to SR-PCE

Use the **report-all** command to enable the PCC to report all SR policies in its database to the PCE.

```
Router(config-sr-te-pcc)# report-all
```

Customize MSD Value at PCC

Use the **maximum-sid-depth** *value* command to customize the Maximum SID Depth (MSD) signaled by PCC during PCEP session establishment.

The default MSD *value* is equal to the maximum MSD supported by the platform ().

```
Router(config-sr-te)# maximum-sid-depth value
```

For cases with path computation at PCE, a PCC can signal its MSD to the PCE in the following ways:

- During PCEP session establishment – The signaled MSD is treated as a node-wide property.
 - MSD is configured under **segment-routing traffic-eng maximum-sid-depth** *value* command

- During PCEP LSP path request – The signaled MSD is treated as an LSP property.
 - On-demand (ODN) SR Policy: MSD is configured using the **segment-routing traffic-eng on-demand color color maximum-sid-depth value** command
 - Local SR Policy: MSD is configured using the **segment-routing traffic-eng policy WORD candidate-paths preference preference dynamic metric sid-limit value** command.



Note If the configured MSD values are different, the per-LSP MSD takes precedence over the per-node MSD.

After path computation, the resulting label stack size is verified against the MSD requirement.

- If the label stack size is larger than the MSD and path computation is performed by PCE, then the PCE returns a "no path" response to the PCC.
- If the label stack size is larger than the MSD and path computation is performed by PCC, then the PCC will not install the path.



Note A sub-optimal path (if one exists) that satisfies the MSD constraint could be computed in the following cases:

- For a dynamic path with TE metric, when the PCE is configured with the **pce segment-routing te-latency** command or the PCC is configured with the **segment-routing traffic-eng te-latency** command.
- For a dynamic path with LATENCY metric
- For a dynamic path with affinity constraints

For example, if the PCC MSD is 4 and the optimal path (with an accumulated metric of 100) requires 5 labels, but a sub-optimal path exists (with accumulated metric of 110) requiring 4 labels, then the sub-optimal path is installed.

Customize the SR-TE Path Calculation

Use the **te-latency** command to enable ECMP-aware path computation for TE metric.

```
Router(config-sr-te)# te-latency
```



Note ECMP-aware path computation is enabled by default for IGP and LATENCY metrics.

Configure PCEP Redundancy Type

Use the **redundancy pcc-centric** command to enable PCC-centric high-availability model. The PCC-centric model changes the default PCC delegation behavior to the following:

- After LSP creation, LSP is automatically delegated to the PCE that computed it.

- If this PCE is disconnected, then the LSP is redelegated to another PCE.
- If the original PCE is reconnected, then the delegation fallback timer is started. When the timer expires, the LSP is redelegated back to the original PCE, even if it has worse preference than the current PCE.

```
Router(config-sr-te-pcc)# redundancy pcc-centric
```

Configuring Head-End Router as PCEP PCC and Customizing SR-TE Related Options: Example

The following example shows how to configure an SR-TE head-end router with the following functionality:

- Enable the SR-TE head-end router as a PCEP client (PCC) with 3 PCEP servers (PCE) with different precedence values. The PCE with IP address 1.1.1.57 is selected as BEST.
- Enable SR-TE related syslogs.
- Set the Maximum SID Depth (MSD) signaled during PCEP session establishment to 5.
- Enable PCEP reporting for all policies in the node.

```
segment-routing
traffic-eng
pcc
source-address ipv4 1.1.1.2
pce address ipv4 1.1.1.57
precedence 150
password clear <password>
!
pce address ipv4 1.1.1.58
precedence 200
password clear <password>
!
pce address ipv4 1.1.1.59
precedence 250
password clear <password>
!
!
logging
policy status
!
maximum-sid-depth 5
pcc
report-all
!
!
end
```

Verification

```
RP/0/RSP0/CPU0:Router# show segment-routing traffic-eng pcc ipv4 peer
```

```
PCC's peer database:
```

```
-----
```

```
Peer address: 1.1.1.57, Precedence: 150, (best PCE)
```

```
State up
```

```
Capabilities: Stateful, Update, Segment-Routing, Instantiation
```

```
Peer address: 1.1.1.58, Precedence: 200
```

State up

Capabilities: Stateful, Update, Segment-Routing, Instantiation

Peer address: 1.1.1.59, Precedence: 250**State up**

Capabilities: Stateful, Update, Segment-Routing, Instantiation

BGP SR-TE

BGP may be used to distribute SR Policy candidate paths to an SR-TE head-end. Dedicated BGP SAFI and NLRI have been defined to advertise a candidate path of an SR Policy. The advertisement of Segment Routing policies in BGP is documented in the IETF draft <https://datatracker.ietf.org/doc/draft-ietf-idr-segment-routing-te-policy/>

SR policies with IPv4 and IPv6 end-points can be advertised over BGPv4 or BGPv6 sessions between the SR-TE controller and the SR-TE headend.

The Cisco IOS-XR implementation supports the following combinations:

- IPv4 SR policy advertised over BGPv4 session
- IPv6 SR policy advertised over BGPv4 session
- IPv6 SR policy advertised over BGPv6 session

Configure BGP SR Policy Address Family at SR-TE Head-End

Perform this task to configure BGP SR policy address family at SR-TE head-end:

SUMMARY STEPS

1. **configure**
2. **router bgp** *as-number*
3. **bgp router-id** *ip-address*
4. **address-family** {**ipv4** | **ipv6**} **sr-policy**
5. **exit**
6. **neighbor** *ip-address*
7. **remote-as** *as-number*
8. **address-family** {**ipv4** | **ipv6**} **sr-policy**
9. **route-policy** *route-policy-name* {**in** | **out**}

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure	
Step 2	router bgp <i>as-number</i> Example: RP/0/RSP0/CPU0:router(config)# router bgp 65000	Specifies the BGP AS number and enters the BGP configuration mode, allowing you to configure the BGP routing process.

	Command or Action	Purpose
Step 3	bgp router-id <i>ip-address</i> Example: <pre>RP/0/RSP0/CPU0:router(config-bgp)# bgp router-id 1.1.1.1</pre>	Configures the local router with a specified router ID.
Step 4	address-family {<i>ipv4</i> <i>ipv6</i>} sr-policy Example: <pre>RP/0/RSP0/CPU0:router(config-bgp)# address-family ipv4 sr-policy</pre>	Specifies either the IPv4 or IPv6 address family and enters address family configuration submenu.
Step 5	exit	
Step 6	neighbor <i>ip-address</i> Example: <pre>RP/0/RSP0/CPU0:router(config-bgp)# neighbor 10.10.0.1</pre>	Places the router in neighbor configuration mode for BGP routing and configures the neighbor IP address as a BGP peer.
Step 7	remote-as <i>as-number</i> Example: <pre>RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 1</pre>	Creates a neighbor and assigns a remote autonomous system number to it.
Step 8	address-family {<i>ipv4</i> <i>ipv6</i>} sr-policy Example: <pre>RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family ipv4 sr-policy</pre>	Specifies either the IPv4 or IPv6 address family and enters address family configuration submenu.
Step 9	route-policy <i>route-policy-name</i> {<i>in</i> <i>out</i>} Example: <pre>RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# route-policy pass out</pre>	Applies the specified policy to IPv4 or IPv6 unicast routes.

Example: BGP SR-TE with BGPv4 Neighbor to BGP SR-TE Controller

The following configuration shows the an SR-TE head-end with a BGPv4 session towards a BGP SR-TE controller. This BGP session is used to signal both IPv4 and IPv6 SR policies.

```
router bgp 65000
bgp router-id 1.1.1.1
!
```

```

address-family ipv4 sr-policy
!
address-family ipv6 sr-policy
!
neighbor 10.1.3.1
  remote-as 10
  description *** eBGP session to BGP SRTE controller ***
  address-family ipv4 sr-policy
    route-policy pass in
    route-policy pass out
  !
  address-family ipv6 sr-policy
    route-policy pass in
    route-policy pass out
  !
!
!
!

```

Example: BGP SR-TE with BGPv6 Neighbor to BGP SR-TE Controller

The following configuration shows an SR-TE head-end with a BGPv6 session towards a BGP SR-TE controller. This BGP session is used to signal IPv6 SR policies.

```

router bgp 65000
  bgp router-id 1.1.1.1
  address-family ipv6 sr-policy
  !
  neighbor 3001::10:1:3:1
    remote-as 10
    description *** eBGP session to BGP SRTE controller ***
    address-family ipv6 sr-policy
      route-policy pass in
      route-policy pass out
    !
  !
!
!
!

```

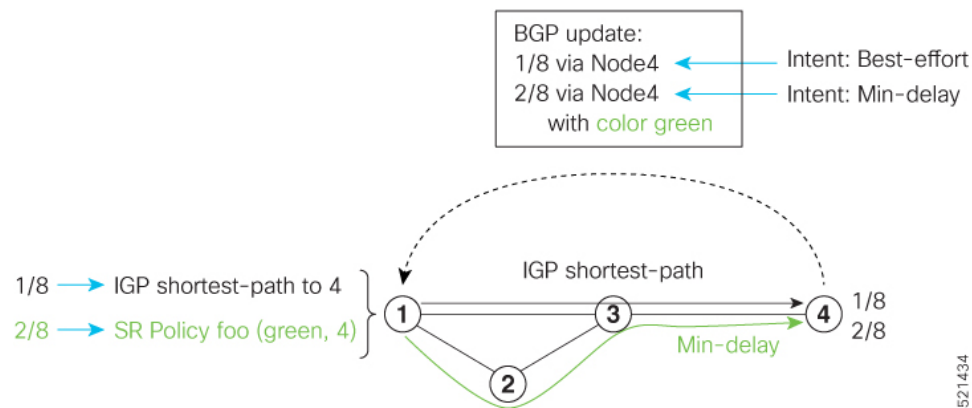
Traffic Steering

Automated Steering

Automated steering (AS) allows service traffic to be automatically steered onto the required transport SLA path programmed by an SR policy.

With AS, BGP automatically steers traffic onto an SR Policy based on the next-hop and color of a BGP service route. The color of a BGP service route is specified by a color extended community attribute. This color is used as a transport SLA indicator, such as min-delay or min-cost.

When the next-hop and color of a BGP service route matches the end-point and color of an SR Policy, BGP automatically installs the route resolving onto the BSID of the matching SR Policy. Recall that an SR Policy on a head-end is uniquely identified by an end-point and color.



When a BGP route has multiple extended-color communities, each with a valid SR Policy, the BGP process installs the route on the SR Policy giving preference to the color with the highest numerical value.

The granularity of AS behaviors can be applied at multiple levels, for example:

- At a service level—When traffic destined to all prefixes in a given service is associated to the same transport path type. All prefixes share the same color.
- At a destination/prefix level—When traffic destined to a prefix in a given service is associated to a specific transport path type. Each prefix could be assigned a different color.
- At a flow level—When flows destined to the same prefix are associated with different transport path types

AS behaviors apply regardless of the instantiation method of the SR policy, including:

- On-demand SR policy
- Manually provisioned SR policy
- PCE-initiated SR policy

Per-Flow Automated Steering

The steering of traffic through a Segment Routing (SR) policy is based on the candidate paths of that policy. For a given policy, a candidate path specifies the path to be used to steer traffic to the policy's destination. The policy determines which candidate path to use based on the candidate path's preference and state. The candidate path that is valid and has the highest preference is used to steer all traffic using the given policy. This type of policy is called a Per-Destination Policy (PDP).

Per-Flow Automated Traffic Steering using SR-TE Policies introduces a way to steer traffic on an SR policy based on the attributes of the incoming packets, called a Per-Flow Policy (PFP).

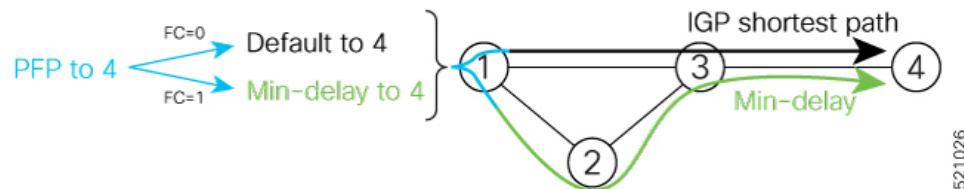
A PFP provides up to 8 "ways" or options to the endpoint. With a PFP, packets are classified by a classification policy and marked using internal tags called forward classes (FCs). The FC setting of the packet selects the "way". For example, this "way" can be a traffic-engineered SR path, using a low-delay path to the endpoint. The FC is represented as a numeral with a value of 0 to 7.

A PFP defines an array of FC-to-PDP mappings. A PFP can then be used to steer traffic into a given PDP based on the FC assigned to a packet.

As with PDPs, PFPs are identified by a {headend, color, endpoint} tuple. The color associated with a given FC corresponds to a valid PDP policy of that color and same endpoint as the parent PFP. So PFP policies contain mappings of different FCs to valid PDP policies of different colors. Every PFP has an FC designated as its default FC. The default FC is associated to packets with a FC undefined under the PFP or for packets with a FC with no valid PDP policy.

The following example shows a per-flow policy from Node1 to Node4:

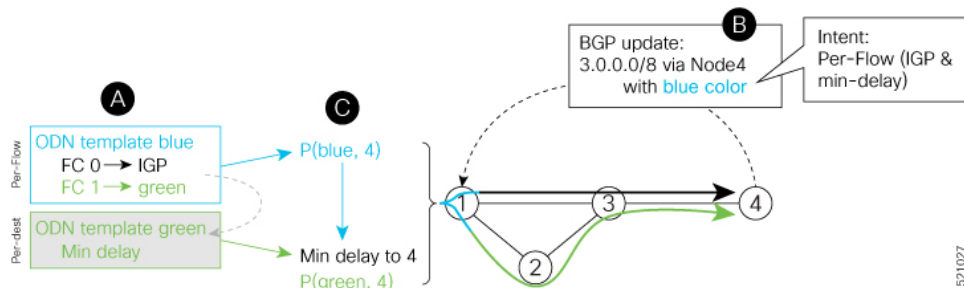
Figure 2: PFP Example



- FC=0 -> shortest path to Node4
 - IGP shortest path = 16004
- FC=1 -> Min-delay path to Node4
 - SID list = {16002,16004}

The same on-demand instantiation behaviors of PDPs apply to PFPs. For example, an edge node automatically (on demand) instantiates Per-Flow SR Policy paths to an endpoint by service route signaling. Automated Steering steers the service route in the matching SR Policy.

Figure 3: PFP with ODN Example



Like PDPs, PFPs have a binding SID (BSID). Existing SR-TE automated steering (AS) mechanisms for labeled traffic (via BSID) and unlabeled traffic (via BGP) onto a PFP is similar to that of a PDP. For example, a packet having the BSID of a PFP as the top label is steered onto that PFP. The classification policy on the ingress interface marks the packet with an FC based on the configured class-map. The packet is then steered to the PDP that corresponds to that FC.

Usage Guidelines and Limitations

The following guidelines and limitations apply to the platform when acting as a head-end of a PFP policy:

- BGP IPv4 unicast over PFP (steered via ODN/AS) is supported
- BGP IPv6 unicast (with IPv4 next-hop [6PE]) over PFP (steered via ODN/AS) is supported
- BGP IPv6 unicast (with IPv6 next-hop) over PFP (steered via ODN/AS) is supported

- BGP EVPN over PFP is not supported
- Pseudowire and VPLS over PFP are not supported
- BGP PIC is not supported
- When not explicitly configured, FC 0 is the default FC.
- A PFP is considered valid as long as its default FC has a valid PDP.
- The following counters are supported:
 - PFP's BSID counter (packet, bytes)
 - Per-FC counters (packet, byte)
 - Collected from the PDP's segment-list-per-path egress counters
 - If an SR policy is used for more than one purpose (as a regular policy as well as a PDP under one or more PFPs), then the collected counters will represent the aggregate of all contributions. To preserve independent counters, it is recommended that an SR policy be used only for one purpose.
- Inbound packet classification, based on the following fields, is supported:
 - IP precedence
 - IP DSCP
 - L3 ACL-based (L3 source/destination IP; L4 source/destination port)
- A color associated with a PFP SR policy cannot be used by a non-PFP SR policy. For example, if a per-flow ODN template for color 100 is configured, then the system will reject the configuration of any non-PFP SR policy using the same color. You must assign different color value ranges for PFP and non-PFP SR policies.

Configuring ODN Template for PFP Policies: Example

The following example depicts an ODN template for PFP policies that includes three FCs.

The example also includes the corresponding ODN templates for PDPs as follows:

- FC0 (default FC) mapped to color 10 = Min IGP path
- FC1 mapped to color 20 = Flex Algo 128 path
- FC2 mapped to color 30 = Flex Algo 129 path

```
segment-routing
traffic-eng
on-demand color 10
dynamic
metric
type igp
!
!
!
on-demand color 20
dynamic
```

```

    sid-algorithm 128
  !
  !
  on-demand color 30
  dynamic
    sid-algorithm 129
  !
  !
  on-demand color 1000
  per-flow
    forward-class 0 color 10
    forward-class 1 color 20
    forward-class 2 color 30

```

Manually Configuring a PFP and PDPs: Example

The following example depicts a manually defined PFP that includes three FCs and corresponding manually defined PDPs.

The example also includes the corresponding PDPs as follows:

- FC0 (default FC) mapped to color 10 = Min IGP path
- FC1 mapped to color 20 = Min TE path
- FC2 mapped to color 30 = Min delay path

```

segment-routing
traffic-eng
policy MyPerFlow
  color 1000 end-point ipv4 1.1.1.4
  candidate-paths
  preference 100
  per-flow
    forward-class 0 color 10
    forward-class 1 color 20
    forward-class 2 color 30
  !
policy MyLowIGP
  color 10 end-point ipv4 1.1.1.4
  candidate-paths
  preference 100
  dynamic
  metric type igp
  !
policy MyLowTE
  color 20 end-point ipv4 1.1.1.4
  candidate-paths
  preference 100
  dynamic
  metric type te
  !
policy MyLowDelay
  color 30 end-point ipv4 1.1.1.4
  candidate-paths
  preference 100
  dynamic
  metric type delay

```

Determining Per-Flow Policy State

A PFP is brought down for the following reasons:

- The PDP associated with the default FC is in a down state.
- All FCs are associated with PDPs in a down state.
- The FC assigned as the default FC is missing in the forward class mapping.

Scenario 1—FC 0 (default FC) is not configured in the FC mappings below:

```
policy foo
  color 1 end-point ipv4 1.1.1.1
  per-flow
    forward-class 1 color 10
    forward-class 2 color 20
```

Scenario 2—FC 1 is configured as the default FC, however it is not present in the FC mappings:

```
policy foo
  color 1 end-point ipv4 1.1.1.1
  per-flow
    forward-class 0 color 10
    forward-class 2 color 20
    forward-class default 1
```

Using Binding Segments

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

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

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

BSID can be used in the following cases:

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

Explicit Binding SID

Use the **binding-sid mpls label** command in SR-TE policy configuration mode to specify the explicit BSID. Explicit BSIDs are allocated from the segment routing local block (SRLB) or the dynamic range of labels. A best-effort is made to request and obtain the BSID for the SR-TE policy. If requested BSID is not available (if it does not fall within the available SRLB or is already used by another application or SR-TE policy), the policy stays down.

Use the **binding-sid explicit {fallback-dynamic | enforce-srlb}** command to specify how the BSID allocation behaves if the BSID value is not available.

- Fallback to dynamic allocation – If the BSID is not available, the BSID is allocated dynamically and the policy comes up:

```
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# binding-sid explicit fallback-dynamic
```

- Strict SRLB enforcement – If the BSID is not within the SRLB, the policy stays down:

```
Router# configure
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# binding-sid explicit enforce-srlb
```

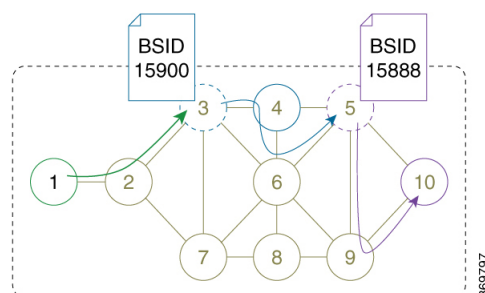
This example shows how to configure an SR policy to use an explicit BSID of 1000. If the BSID is not available, the BSID is allocated dynamically and the policy comes up.

```
segment-routing
traffic-eng
binding-sid explicit fallback-dynamic
policy goo
binding-sid mpls 1000
!
!
!
```

Stitching SR-TE Policies Using Binding SID: Example

In this example, three SR-TE policies are stitched together to form a seamless end-to-end path from node 1 to node 10. The path is a chain of SR-TE policies stitched together using the binding-SIDs of intermediate policies, providing a seamless end-to-end path.

Figure 4: Stitching SR-TE Policies Using Binding SID



Step 1

On node 5, do the following:

- a) Define an SR-TE policy with an explicit path configured using the loopback interface IP addresses of node 9 and node 10.
- b) Define an explicit binding-SID (**mpls label 15888**) allocated from SRLB for the SR-TE policy.

Example:**Node 5**

```
segment-routing
traffic-eng
segment-list PATH-9_10
index 10 address ipv4 1.1.1.9
index 20 address ipv4 1.1.1.10
!
policy foo
binding-sid mpls 15888
color 777 end-point ipv4 1.1.1.10
candidate-paths
preference 100
explicit segment-list PATH5-9_10
!
!
!
!
!
```

```
RP/0/RSP0/CPU0:Node-5# show segment-routing traffic-eng policy color 777
```

```
SR-TE policy database
-----
```

```
Color: 777, End-point: 1.1.1.10
Name: srte_c_777_ep_1.1.1.10
Status:
  Admin: up Operational: up for 00:00:52 (since Aug 19 07:40:12.662)
Candidate-paths:
  Preference: 100 (configuration) (active)
  Name: foo
  Requested BSID: 15888
  PCC info:
    Symbolic name: cfg_foo_discr_100
    PLSP-ID: 70
  Explicit: segment-list PATH-9_10 (valid)
    Weight: 1, Metric Type: TE
      16009 [Prefix-SID, 1.1.1.9]
      16010 [Prefix-SID, 1.1.1.10]
Attributes:
  Binding SID: 15888 (SRLB)
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes
```

Step 2

On node 3, do the following:

- a) Define an SR-TE policy with an explicit path configured using the following:
 - Loopback interface IP address of node 4
 - Interface IP address of link between node 4 and node 6

- Loopback interface IP address of node 5
- Binding-SID of the SR-TE policy defined in Step 1 (**mpls label 15888**)

Note This last segment allows the stitching of these policies.

- b) Define an explicit binding-SID (**mpls label 15900**) allocated from SRLB for the SR-TE policy.

Example:

Node 3

```
segment-routing
traffic-eng
segment-list PATH-4_4-6_5_BSID
index 10 address ipv4 1.1.1.4
index 20 address ipv4 10.4.6.6
index 30 address ipv4 1.1.1.5
index 40 mpls label 15888
!
policy baa
binding-sid mpls 15900
color 777 end-point ipv4 1.1.1.5
candidate-paths
preference 100
explicit segment-list PATH-4_4-6_5_BSID
!
!
!
!
!
```

```
RP/0/RSP0/CPU0:Node-3# show segment-routing traffic-eng policy color 777
```

```
SR-TE policy database
```

```
-----
Color: 777, End-point: 1.1.1.5
Name: srte_c_777_ep_1.1.1.5
Status:
  Admin: up Operational: up for 00:00:32 (since Aug 19 07:40:32.662)
Candidate-paths:
  Preference: 100 (configuration) (active)
  Name: baa
  Requested BSID: 15900
  PCC info:
    Symbolic name: cfg_baa_discr_100
    PLSP-ID: 70
  Explicit: segment-list PATH-4_4-6_5_BSID (valid)
  Weight: 1, Metric Type: TE
    16004 [Prefix-SID, 1.1.1.4]
    80005 [Adjacency-SID, 10.4.6.4 - 10.4.6.6]
    16005 [Prefix-SID, 1.1.1.5]
    15888
Attributes:
  Binding SID: 15900 (SRLB)
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes
```


Step 3 On node 1, define an SR-TE policy with an explicit path configured using the loopback interface IP address of node 3 and the binding-SID of the SR-TE policy defined in step 2 (**mpls label 15900**). This last segment allows the stitching of these policies.

Example:

Node 1

```
segment-routing
traffic-eng
  segment-list PATH-3_BSID
  index 10 address ipv4 1.1.1.3
  index 20 mpls label 15900
  !
  policy bar
  color 777 end-point ipv4 1.1.1.3
  candidate-paths
  preference 100
  explicit segment-list PATH-3_BSID
  !
  !
  !
  !
  !
  !
```

```
RP/0/RSP0/CPU0:Node-1# show segment-routing traffic-eng policy color 777
```

```
SR-TE policy database
```

```
-----
Color: 777, End-point: 1.1.1.3
Name: srte_c_777_ep_1.1.1.3
Status:
  Admin: up Operational: up for 00:00:12 (since Aug 19 07:40:52.662)
Candidate-paths:
  Preference: 100 (configuration) (active)
  Name: bar
  Requested BSID: dynamic
  PCC info:
    Symbolic name: cfg_bar_discr_100
    PLSP-ID: 70
  Explicit: segment-list PATH-3_BSID (valid)
    Weight: 1, Metric Type: TE
    16003 [Prefix-SID, 1.1.1.3]
    15900
Attributes:
  Binding SID: 80021
  Forward Class: 0
  Steering BGP disabled: no
  IPv6 caps enable: yes
```

L2VPN Preferred Path

EVPN VPWS Preferred Path over SR-TE Policy feature allows you to set the preferred path between the two end-points for EVPN VPWS pseudowire (PW) using SR-TE policy.

L2VPN VPLS or VPWS Preferred Path over SR-TE Policy feature allows you to set the preferred path between the two end-points for L2VPN Virtual Private LAN Service (VPLS) or Virtual Private Wire Service (VPWS) using SR-TE policy.

Refer to the [EVPN VPWS Preferred Path over SR-TE Policy](#) and [L2VPN VPLS or VPWS Preferred Path over SR-TE Policy](#) sections in the "L2VPN Services over Segment Routing for Traffic Engineering Policy" chapter of the *L2VPN and Ethernet Services Configuration Guide*.

Policy-Based Tunnel Selection for SR-TE Policy

Policy-Based Tunnel Selection (PBTS) is a mechanism that lets you direct traffic into specific SR-TE policies based on different classification criteria. PBTS benefits Internet service providers (ISPs) that carry voice and data traffic through their networks, who want to route this traffic to provide optimized voice service.

PBTS works by selecting SR-TE policies based on the classification criteria of the incoming packets, which are based on the IP precedence, experimental (EXP), differentiated services code point (DSCP), or type of service (ToS) field in the packet. Default-class configured for paths is always zero (0). If there is no TE for a given forward-class, then the default-class (0) will be tried. If there is no default-class, then the packet is dropped. PBTS supports up to seven (exp 1 - 7) EXP values associated with a single SR-TE policy.

For more information about PBTS, refer to the "Policy-Based Tunnel Selection" section in the *MPLS Configuration Guide for Cisco NCS 6000 Series Routers*.

Configure Policy-Based Tunnel Selection for SR-TE Policies

The following section lists the steps to configure PBTS for an SR-TE policy.



Note Steps 1 through 4 are detailed in the "Implementing MPLS Traffic Engineering" chapter of the *MPLS Configuration Guide for Cisco NCS 6000 Series Routers*.

1. Define a class-map based on a classification criteria.
2. Define a policy-map by creating rules for the classified traffic.
3. Associate a forward-class to each type of ingress traffic.
4. Enable PBTS on the ingress interface, by applying this service-policy.
5. Create one or more egress SR-TE policies (to carry packets based on priority) to the destination and associate the egress SR-TE policy to a forward-class.

Configuration Example

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy POLICY-PBTS
Router(config-sr-te-policy)# color 1001 end-point ipv4 1.1.1.20
Router(config-sr-te-policy)# autoroute
Router(config-sr-te-policy-autoroute)# include all
Router(config-sr-te-policy-autoroute)# forward-class 1
Router(config-sr-te-policy-autoroute)# exit
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 1
Router(config-sr-te-policy-path-pref)# explicit segment-list SIDLIST1
Router(config-sr-te-policy-path-pref)# exit
```

```

Router(config-sr-te-pp-info)# exit
Router(config-sr-te-policy-path-pref)# exit
Router(config-sr-te-policy-path)# preference 2
Router(config-sr-te-policy-path-pref)# dynamic
Router(config-sr-te-pp-info)# metric
Router(config-sr-te-path-metric)# type te
Router(config-sr-te-path-metric)# commit

```

Running Configuration

```

segment-routing
traffic-eng
policy POLICY-PBTS
color 1001 end-point ipv4 1.1.1.20
autoroute
include all
forward-class 1
!
candidate-paths
preference 1
explicit segment-list SIDLIST1
!
!
preference 2
dynamic
metric
type te

```

Miscellaneous

LDP over Segment Routing Policy

The LDP over Segment Routing Policy feature enables an LDP-targeted adjacency over a Segment Routing (SR) policy between two routers. This feature extends the existing MPLS LDP address family neighbor configuration to specify an SR policy as the targeted end-point.

LDP over SR policy is supported for locally configured SR policies with IPv4 end-points.

For more information about MPLS LDP, see the "Implementing MPLS Label Distribution Protocol" chapter in the *MPLS Configuration Guide*.

For more information about Autoroute, see the *Autoroute Announce for SR-TE* section.



Note Before you configure an LDP targeted adjacency over SR policy name, you need to create the SR policy under Segment Routing configuration. The SR policy interface names are created internally based on the color and endpoint of the policy. LDP is non-operational if SR policy name is unknown.

The following functionality applies:

1. Configure the SR policy – LDP receives the associated end-point address from the interface manager (IM) and stores it in the LDP interface database (IDB) for the configured SR policy.

- Configure the SR policy name under LDP – LDP retrieves the stored end-point address from the IDB and uses it. Use the auto-generated SR policy name assigned by the router when creating an LDP targeted adjacency over an SR policy. Auto-generated SR policy names use the following naming convention: **srte_c_color_val_ep_endpoint-address**. For example, **srte_c_1000_ep_1.1.1.2**

Configuration Example

```

/* Enter the SR-TE configuration mode and create the SR policy. This example corresponds
to a local SR policy with an explicit path. */
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# segment-list sample-sid-list
Router(config-sr-te-sl)# index 10 address ipv4 1.1.1.7
Router(config-sr-te-sl)# index 20 address ipv4 1.1.1.2
Router(config-sr-te-sl)# exit
Router(config-sr-te)# policy sample_policy
Router(config-sr-te-policy)# color 1000 end-point ipv4 1.1.1.2
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list sample-sid-list
Router(config-sr-te-pp-info)# end

/* Configure LDP over an SR policy */
Router(config)# mpls ldp
Router(config-ldp)# address-family ipv4
Router(config-ldp-af)# neighbor sr-policy srte_c_1000_ep_1.1.1.2 targeted
Router(config-ldp-af)#

```



Note Do one of the following to configure LDP discovery for targeted hellos:

- Active targeted hellos (SR policy head end):

```

mpls ldp
  interface GigabitEthernet0/0/0/0
  !
  !

```

- Passive targeted hellos (SR policy end-point):

```

mpls ldp
  address-family ipv4
  discovery targeted-hello accept
  !
  !

```

Running Configuration

```

segment-routing
traffic-eng
  segment-list sample-sid-list
    index 10 address ipv4 1.1.1.7
    index 20 address ipv4 1.1.1.2
  !
  policy sample_policy
    color 1000 end-point ipv4 1.1.1.2
    candidate-paths
    preference 100

```

```

        explicit segment-list sample-sid-list
        !
    !
    !
    !
    !
mpls ldp
  address-family ipv4
    neighbor sr-policy srte_c_1000_ep_1.1.1.2 targeted
    discovery targeted-hello accept
  !
  !

```

Verification

Router# **show mpls ldp interface brief**

Interface	VRF Name	Config	Enabled	IGP-Auto-Cfg	TE-Mesh-Grp	cfg
Te0/3/0/0/3	default	Y	Y	0	N/A	
Te0/3/0/0/6	default	Y	Y	0	N/A	
Te0/3/0/0/7	default	Y	Y	0	N/A	
Te0/3/0/0/8	default	N	N	0	N/A	
Te0/3/0/0/9	default	N	N	0	N/A	
srte_c_1000	default	Y	Y	0	N/A	

Router# **show mpls ldp interface**

```

Interface TenGigE0/3/0/0/3 (0xa000340)
  VRF: 'default' (0x60000000)
  Enabled via config: LDP interface
Interface TenGigE0/3/0/0/6 (0xa000400)
  VRF: 'default' (0x60000000)
  Enabled via config: LDP interface
Interface TenGigE0/3/0/0/7 (0xa000440)
  VRF: 'default' (0x60000000)
  Enabled via config: LDP interface
Interface TenGigE0/3/0/0/8 (0xa000480)
  VRF: 'default' (0x60000000)
  Disabled:
Interface TenGigE0/3/0/0/9 (0xa0004c0)
  VRF: 'default' (0x60000000)
  Disabled:
Interface srte_c_1000_ep_1.1.1.2 (0x520)
VRF: 'default' (0x60000000)
Enabled via config: LDP interface

```

Router# **show segment-routing traffic-eng policy color 1000**

SR-TE policy database

```

-----
Color: 1000, End-point: 1.1.1.2
Name: srte_c_1000_ep_1.1.1.2
Status:
  Admin: up Operational: up for 00:02:00 (since Jul  2 22:39:06.663)
Candidate-paths:
  Preference: 100 (configuration) (active)
  Name: sample_policy
  Requested BSID: dynamic
  PCC info:
    Symbolic name: cfg_sample_policy_discr_100

```

```

    PLSP-ID: 17
    Explicit: segment-list sample-sid-list (valid)
    Weight: 1, Metric Type: TE
    16007 [Prefix-SID, 1.1.1.7]
    16002 [Prefix-SID, 1.1.1.2]
Attributes:
    Binding SID: 80011
    Forward Class: 0
    Steering BGP disabled: no
    IPv6 caps enable: yes

```

```
Router# show mpls ldp neighbor 1.1.1.2 detail
```

```

Peer LDP Identifier: 1.1.1.2:0
TCP connection: 1.1.1.2:646 - 1.1.1.6:57473
Graceful Restart: No
Session Holdtime: 180 sec
State: Oper; Msgs sent/rcvd: 421/423; Downstream-Unsolicited
Up time: 05:22:02
LDP Discovery Sources:
  IPv4: (1)
Targeted Hello (1.1.1.6 -> 1.1.1.2, active/passive)
  IPv6: (0)
Addresses bound to this peer:
  IPv4: (9)
    1.1.1.2      2.2.2.99      10.1.2.2      10.2.3.2
    10.2.4.2    10.2.22.2     10.2.222.2    10.30.110.132
    11.2.9.2
  IPv6: (0)
Peer holdtime: 180 sec; KA interval: 60 sec; Peer state: Estab
NSR: Disabled
Clients: LDP over SR Policy
Capabilities:
  Sent:
    0x508 (MP: Point-to-Multipoint (P2MP))
    0x509 (MP: Multipoint-to-Multipoint (MP2MP))
    0x50a (MP: Make-Before-Break (MBB))
    0x50b (Typed Wildcard FEC)
  Received:
    0x508 (MP: Point-to-Multipoint (P2MP))
    0x509 (MP: Multipoint-to-Multipoint (MP2MP))
    0x50a (MP: Make-Before-Break (MBB))
    0x50b (Typed Wildcard FEC)

```

Configure Seamless Bidirectional Forwarding Detection

Bidirectional forwarding detection (BFD) provides low-overhead, short-duration detection of failures in the path between adjacent forwarding engines. BFD allows a single mechanism to be used for failure detection over any media and at any protocol layer, with a wide range of detection times and overhead. The fast detection of failures provides immediate reaction to failure in the event of a failed link or neighbor.

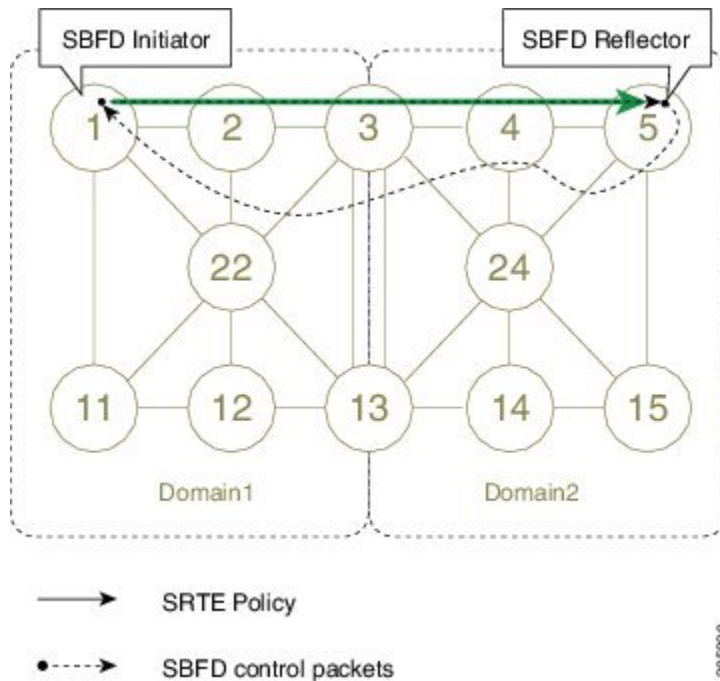
In BFD, each end of the connection maintains a BFD state and transmits packets periodically over a forwarding path. Seamless BFD (SBFD) is unidirectional, resulting in faster session activation than BFD. The BFD state and client context is maintained on the head-end (initiator) only. The tail-end (reflector) validates the BFD packet and responds, so there is no need to maintain the BFD state on the tail-end.

Initiators and Reflectors

SBFD runs in an asymmetric behavior, using initiators and reflectors.

The following figure represents the roles of the SBFDR initiator and reflector.

Figure 5: SBFDR Initiator and Reflector



The initiator is an SBFDR session on a network node that performs a continuity test to a remote entity by sending SBFDR packets. The initiator injects the SBFDR packets into the segment-routing traffic-engineering (SRTE) policy. The initiator triggers the SBFDR session and maintains the BFD state and client context.

The reflector is an SBFDR session on a network node that listens for incoming SBFDR control packets to local entities and generates response SBFDR control packets. The reflector is stateless and only reflects the SBFDR packets back to the initiator.

A node can be both an initiator and a reflector, if you want to configure different SBFDR sessions.

For SR-TE, SBFDR control packets are label switched in forward and reverse direction. For SBFDR, the tail-end node is the reflector node; other nodes cannot be a reflector. When using SBFDR with SR-TE, if the forward and return directions are label-switched paths, SBFDR need not be configured on the reflector node.

Discriminators

The BFD control packet carries 32-bit discriminators (local and remote) to demultiplex BFD sessions. SBFDR requires globally unique SBFDR discriminators that are known by the initiator.

The SBFDR control packets contain the discriminator of the initiator, which is created dynamically, and the discriminator of the reflector, which is configured as a local discriminator on the reflector.

Configure the SBFDR Reflector

To ensure the SBFDR packet arrives on the intended reflector, each reflector has at least one globally unique discriminator. Globally unique discriminators of the reflector are known by the initiator before the session starts. An SBFDR reflector only accepts BFD control packets where "Your Discriminator" is the reflector discriminator.

This task explains how to configure local discriminators on the reflector.

Before you begin

Enable mpls oam on the reflector to install a routing information base (RIB) entry for 127.0.0.0/8.

```
Router_5# configure
Router_5(config)# mpls oam
Router_5(config-oam)#
```

SUMMARY STEPS

1. **configure**
2. **sbfd**
3. **local-discriminator** { *ipv4-address* | *32-bit-value* | **dynamic** | **interface** *interface* }
4. **commit**

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# configure	Enters XR Config mode.
Step 2	sbfd Example: Router_5(config)# sbfd	Enters SBFDD configuration mode.
Step 3	local-discriminator { <i>ipv4-address</i> <i>32-bit-value</i> dynamic interface <i>interface</i> } Example: Router_5(config-sbfd)# local-discriminator 1.1.1.5 Router_5(config-sbfd)# local-discriminator 987654321 Router_5(config-sbfd)# local-discriminator dynamic Router_5(config-sbfd)# local-discriminator interface Loopback0	Configures the local discriminator. You can configure multiple local discriminators.
Step 4	commit	

Verify the local discriminator configuration.

Example

```
Router_5# show bfd target-identifier local

Local Target Identifier Table
-----
Discr          Discr Src   VRF          Status  Flags
                Name
-----
16843013       Local      default      enable  ----ia-
987654321     Local      default      enable  ----v---
2147483649     Local      default      enable  -----d

Legend: TID - Target Identifier
       a - IP Address mode
       d - Dynamic mode
       i - Interface mode
       v - Explicit Value mode
```

What to do next

Configure the SBFDD initiator.

Configure the SBFDD Initiator

Perform the following configurations on the SBFDD initiator.

Enable Line Cards to Host BFD Sessions

The SBFDD initiator sessions are hosted by the line card CPU.

This task explains how to enable line cards to host BFD sessions.

SUMMARY STEPS

1. **configure**
2. **bfd**
3. **multipath include location *node-id***

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure Example: RP/0/RP0/CPU0:router# configure	Enters XR Config mode.
Step 2	bfd Example: Router_1(config)# bfd	Enters BFD configuration mode.

Map a Destination Address to a Remote Discriminator

	Command or Action	Purpose
Step 3	multipath include location <i>node-id</i> Example: <pre>Router_1(config-bfd)# multipath include location 0/1/CPU0 Router_1(config-bfd)# multipath include location 0/2/CPU0 Router_1(config-bfd)# multipath include location 0/3/CPU0</pre>	Configures BFD multiple path on specific line card. Any of the configured line cards can be instructed to host a BFD session.

What to do next

Map a destination address to a remote discriminator.

Map a Destination Address to a Remote Discriminator

The Sbfd initiator uses a Remote Target Identifier (RTI) table to map a destination address (Target ID) to a remote discriminator.

This task explains how to map a destination address to a remote discriminator.

SUMMARY STEPS

1. **configure**
2. **sbfd**
3. **remote-target ipv4** *ipv4-address*
4. **remote-discriminator** *remote-discriminator*

DETAILED STEPS

	Command or Action	Purpose
Step 1	configure Example: <pre>RP/0/RP0/CPU0:router# configure</pre>	Enters XR Config mode.
Step 2	sbfd Example: <pre>Router_1(config)# sbfd</pre>	Enters Sbfd configuration mode.
Step 3	remote-target ipv4 <i>ipv4-address</i> Example: <pre>Router_1(config-sbfd)# remote-target ipv4 1.1.1.5</pre>	Configures the remote target.

	Command or Action	Purpose
Step 4	remote-discriminator <i>remote-discriminator</i> Example: <pre>Router_1 (config-sbfd-nnnn) # remote-discriminator 16843013</pre>	Maps the destination address (Target ID) to a remote discriminator.

Verify the remote discriminator configuration.

Example

```
Router_1# show bfd target-identifier remote

Remote Target Identifier Table
-----
Discr      Discr Src  VRF      TID Type  Status
-----
-----
16843013   Remote    default  ipv4      enable
           1.1.1.5

Legend: TID - Target Identifier
```

What to do next

Enable SBFDF on an SR-TE policy.

Enable Seamless BFD Under an SR-TE Policy or SR-ODN Color Template

This example shows how to enable SBFDF on an SR-TE policy or an SR on-demand (SR-ODN) color template.



Note Do not use BFD with disjoint paths. The reverse path might not be disjoint, causing a single link failure to bring down BFD sessions on both the disjoint paths.

Enable BFD

- Use the **bfd** command in SR-TE policy configuration mode to enable BFD and enters BFD configuration mode.

```
Router (config) # segment-routing traffic-eng
Router (config-sr-te) # policy POLICY1
Router (config-sr-te-policy) # bfd
Router (config-sr-te-policy-bfd) #
```

Use the **bfd** command in SR-ODN configuration mode to enable BFD and enters BFD configuration mode.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# on-demand color 10
Router(config-sr-te-color)# bfd
Router(config-sr-te-color-bfd)#
```

Configure BFD Options

- Use the **minimum-interval** *milliseconds* command to set the interval between sending BFD hello packets to the neighbor. The range is from 15 to 200. The default is 15.

```
Router(config-sr-te-policy-bfd)# minimum-interval 50
```

- Use the **multiplier** *multiplier* command to set the number of times a packet is missed before BFD declares the neighbor down. The range is from 2 to 10. The default is 3.

```
Router(config-sr-te-policy-bfd)# multiplier 2
```

- Use the **invalidation-action** {*down* | *none*} command to set the action to be taken when BFD session is invalidated.

- **down**: LSP can only be operationally up if the BFD session is up
- **none**: BFD session state does not affect LSP state, use for diagnostic purposes

```
Router(config-sr-te-policy-bfd)# invalidation-action down
```

- **(SR-TE policy only)** Use the **reverse-path binding-label** *label* command to specify BFD packets return to head-end by using a binding label.

By default, the S-BFD return path (from tail-end to head-end) is via IPv4. You can use a reverse binding label so that the packet arrives at the tail-end with the reverse binding label as the top label. This label is meant to point to a policy that will take the BFD packets back to the head-end. The reverse binding label is configured per-policy.

Note that when MPLS return path is used, BFD uses echo mode packets, which means the tail-end's BFD reflector does not process BFD packets at all.

The MPLS label value at the tail-end and the head-end must be synchronized by the operator or controller. Because the tail-end binding label should remain constant, configure it as an explicit BSID, rather than dynamically allocated.

```
Router(config-sr-te-policy-bfd)# reverse-path binding-label 24036
```

- Use the **logging session-state-change** command to log when the state of the session changes

```
Router(config-sr-te-policy-bfd)# logging session-state-change
```

Examples

This example shows how to enable SBFD on an SR-TE policy.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy POLICY1
Router(config-sr-te-policy)# bfd
Router(config-sr-te-policy-bfd)# invalidation-action down
```

```

Router(config-sr-te-policy-bfd) # minimum-interval 50
Router(config-sr-te-policy-bfd) # multiplier 2
Router(config-sr-te-policy-bfd) # reverse-path binding-label 24036
Router(config-sr-te-policy-bfd) # logging session-state-change

segment-routing
 traffic-eng
  policy POLICY1
  bfd
    minimum-interval 50
    multiplier 2
    invalidation-action down
    reverse-path
      binding-label 24036
    !
    logging
      session-state-change
    !
  !
!
!
!
!

```

This example shows how to enable Sbfd on an SR-ODN color.

```

Router(config) # segment-routing traffic-eng
Router(config-sr-te) # on-demand color 10
Router(config-sr-te-color) # bfd
Router(config-sr-te-color-bfd) # minimum-interval 50
Router(config-sr-te-color-bfd) # multiplier 2
Router(config-sr-te-color-bfd) # logging session-state-change
Router(config-sr-te-color-bfd) # invalidation-action down

segment-routing
 traffic-eng
  on-demand color 10
  bfd
    minimum-interval 50
    multiplier 2
    invalidation-action down
    logging
      session-state-change
    !
  !
!
!
!
!

```

SR-TE Reoptimization Timers

SR-TE path re-optimization occurs when the head-end determines that there is a more optimal path available than the one currently used. For example, in case of a failure along the SR-TE LSP path, the head-end could detect and revert to a more optimal path by triggering re-optimization.

Re-optimization can occur due to the following events:

- The explicit path hops used by the primary SR-TE LSP explicit path are modified
- The head-end determines the currently used path-option are invalid due to either a topology path disconnect, or a missing SID in the SID database that is specified in the explicit-path

- A more favorable path-option (lower index) becomes available

For event-based re-optimization, you can specify various delay timers for path re-optimization. For example, you can specify how long to wait before switching to a reoptimized path

Additionally, you can configure a timer to specify how often to perform reoptimization of policies. You can also trigger an immediate reoptimization for a specific policy or for all policies.

SR-TE Reoptimization

To trigger an immediate SR-TE reoptimization, use the **segment-routing traffic-eng reoptimization** command in Exec mode:

```
Router# segment-routing traffic-eng reoptimization {all | name policy}
```

Use the **all** option to trigger an immediate reoptimization for all policies. Use the **name policy** option to trigger an immediate reoptimization for a specific policy.

Configuring SR-TE Reoptimization Timers

Use these commands in SR-TE configuration mode to configure SR-TE reoptimization timers:

- **timers candidate-path cleanup-delay seconds**—Specifies the delay before cleaning up candidate paths, in seconds. The range is from 0 (immediate clean-up) to 86400; the default value is 120
- **timers cleanup-delay seconds**—Specifies the delay before cleaning up previous path, in seconds. The range is from 0 (immediate clean-up) to 300; the default value is 10.
- **timers init-verify-restart seconds**—Specifies the delay for topology convergence after the topology starts populating due to a restart, in seconds. The range is from 10 to 10000; the default is 40.
- **timers init-verify-startup seconds**—Specifies the delay for topology convergence after topology starts populating for due to startup, in seconds. The range is from 10 to 10000; the default is 300
- **timers init-verify-switchover seconds**—Specifies the delay for topology convergence after topology starts populating due to a switchover, in seconds. The range is from 10 to 10000; the default is 60.
- **timers install-delay seconds**—Specifies the delay before switching to a reoptimized path, in seconds. The range is from 0 (immediate installation of new path) to 300; the default is 10.
- **timers periodic-reoptimization seconds**—Specifies how often to perform periodic reoptimization of policies, in seconds. The range is from 0 to 86400; the default is 600.

Example Configuration

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# timers
Router(config-sr-te-timers)# candidate-path cleanup-delay 600
Router(config-sr-te-timers)# cleanup-delay 60
Router(config-sr-te-timers)# init-verify-restart 120
Router(config-sr-te-timers)# init-verify-startup 600
Router(config-sr-te-timers)# init-verify-switchover 30
Router(config-sr-te-timers)# install-delay 60
Router(config-sr-te-timers)# periodic-reoptimization 3000
```

Running Config

```
segment-routing
traffic-eng
timers
install-delay 60
periodic-reoptimization 3000
cleanup-delay 60
candidate-path cleanup-delay 600
init-verify-restart 120
init-verify-startup 600
init-verify-switchover 30
!
!
!
```

