



Segment Routing On Demand Next Hop for L3/L3VPN

When redistributing routing information across domains, provisioning of multi-domain services (L2VPN & L3VPN) has its own complexity and scalability issues. On Demand Next Hop (ODN) triggers delegation of computation of an end-to-end LSP to a PCE controller including constraints and policies without doing any redistribution. It then installs the replied multi-domain LSP for the duration of the service into the local forwarding information base (FIB).

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Restrictions for Segment Routing On Demand SR PFP ODN AUTO STEERING (PCE DELEGATED) for L3/L3VPN

- On Demand Next Hop (ODN) anycast SID is not supported.
- ODN for IPv6 is not supported.
- SR ODN tunnel is not supported with BGP Nonstop Routing (NSR). It is only supported with BGP Nonstop Forwarding (NSF).

To enable BGP NSF, use the following command:

```

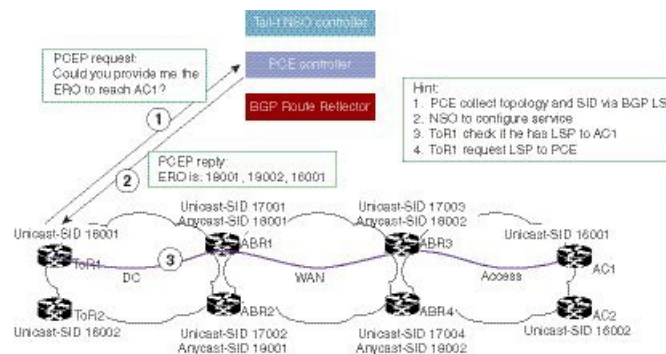
bgp grace-full restart
neighbor 10.0.0.2 ha-mode graceful-restart

```

Information About Segment Routing On Demand SR PFP ODN AUTO STEERING (PCE DELEGATED) for L3/L3VPN

On Demand SR PFP ODN AUTO STEERING (PCE DELEGATED) leverages upon BGP Dynamic SR-TE capabilities and adds the path computation (PCE) ability to find and download the end to end path based on the requirements. ODN triggers an SR-TE auto-tunnel based on the defined BGP policy. As shown in the below figure, an end to end path between ToR1 and AC1 can be established from both ends based on low latency or other criteria for VRF (L3VPN) or IPv4 services. The work-flow for ODN is summarized as follows:

Figure 1: ODN Operation



1. PCE controller collects topology and SIDs information via BGP Link State (BGP-LS). For more information on BGP-LS, refer [BGP Link-State](#).
2. If NSO controller is enable, it configures L3VPN VRF or IPv4 prefixes and requests are sent to ToR1 and AC1.
3. ToR1 and AC1 checks if a LSP towards each other exists. If not, a request is sent to the PCE controller to compute that SR-TE path that matches SR-TE policy that is carried via BGP.
4. PCE controller computes the path and replies with a label stack (18001, 18002, 16001, example in ToR1).
5. ToR1 and AC1 create a SR-TE auto-tunnel and reply back to the NSO controller indicating that the LSP for VRF or IPv4 is up and operational.

SR-TE Policy, Color Extended Community, Affinity Constraint, and Disjointness Constraint

Effective Cisco IOS XE Gibraltar 16.12.1, the router supports:

- MPLS TE new SR-TE policy command—**segment-routing traffic-eng**
- Color-extended community

- Affinity constraints
- Disjointness constraints

SR-TE Policy Command

Effective Cisco IOS XE Gibraltar 16.12.1, a new command (**segment-routing traffic-eng**) is added to configure the SR policy under segment routing. For information on using this command, see the *Configuring Color-Extended Community* section.

Color Extended Community

In earlier releases, the router created segment routed Traffic Engineering (SR-TE) tunnels based on a tunnel-profile or attribute set. As part of this functionality, an inbound route-map with a “match community” and “set attribute-set” was added on the ingress node and the route-map matched against communities received in the BGP updates. A BGP update with a matching community would initiate an SR-TE tunnel for the nexthop TE-profile.

However, effective Cisco IOS XE Gibraltar 16.12.1, ‘color extended’ community is now added as follows:

- An SR-TE policy is created on the ingress router for the Color-Endpoint pair.
- The egress router adds the ‘color extended’ community to the BGP updates that require a Traffic-Engineered path.

Affinity Constraint

Affinity is a 32-bit constraint used by the PCE and PCALC for calculating paths that take the “affinity constraint” into account.

Affinity constraints let you assign, or map, color names for path affinities. After mappings are defined, the attributes can be referred to by the corresponding color name in the command.

Affinity maps are used to map operator-defined color names to a bit position in the affinity bitmap.

Supported Affinity constraints are:

- include-all—indicates that constrained shortest path first (CSPF) includes a link when calculating a path, only if each link administrative group bit has the same name as each affinity bit.
- include-any—indicates that CSPF includes a link when calculating a path, if at least one link administrative group bit has the same name as an affinity bit.
- exclude-any—indicates that CSPF excludes a link when calculating a path, if any link administrative group bit has the same name as an affinity bit.

Disjointness Constraint

Disjointness is used to describe two or more services that must be completely disjoint of each other. Disjointness is useful for providing traffic flow redundancy in the network.

Disjointness is controlled by the PCE. The PCE learns of the network topology through an IGP (OSPF or IS-IS) through the BGP-LS protocol and is capable of computing paths based on the IGP or TE metric.

The PCE uses the disjoint policy to compute two lists of segments that steer traffic from the source node towards the destination node along disjoint paths. Disjoint paths can originate from either the same or different head-ends.

A "disjoint level" refers to the type of resources that should not be shared by the two computed paths. The PCE supports the following disjoint path computations:

- Link
- Node
- Shared risk link group (SRLG)

When the first request is received from Path Computation client (PCC) or an ingress node, with a given disjoint-group ID, a list of segments is computed based on the metric requested, encoding the shortest path from source to destination.

When the second request is received with the same disjoint-group ID, based on the information received in both requests, the PCE computes two disjoint paths from the source to the destination.

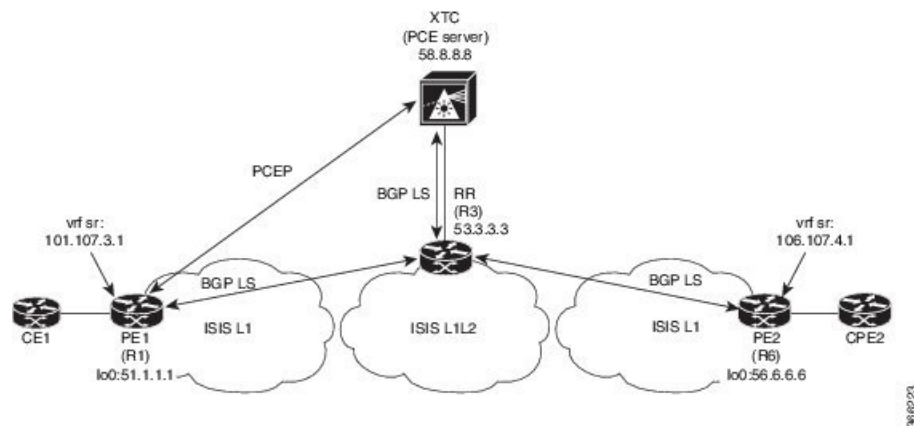
Both paths are computed at the same time. The shortest list of segments is calculated to steer traffic on the computed paths.

How to Configure Segment Routing On Demand Next Hop for L3/L3VPN

Configuring Segment Routing On Demand Next Hop for L3/L3VPN

Perform the following steps to configure on-demand next hop for SR-TE. The below figure is used as a reference to explain the configuration steps.

Figure 2: ODN Auto-Tunnel Setup



1. Configure the router (R6 tail end) with VRF interface.

```
interface GigabitEthernet0/2/2
vrf forwarding sr
ip address 10.0.0.1 255.0.0.0
negotiation auto

interface Loopback0
ip address 192.168.0.1 255.255.0.0
ip router isis 1
```

2. Tags VRF prefix with BGP community on R6 (tail end).

```
route-map BGP_TE_MAP permit 9
match ip address traffic
set community 3276850

ip access-list extended traffic
permit ip 10.0.0.1 255.255.0.0 any
```

3. Enable BGP on R6 (tail end) and R1 (head end) to advertise and receive VRF SR prefix and match on community set on R6 (tail end).

```
router bgp 100
bgp router-id 172.16.0.1
bgp log-neighbor-changes
bgp graceful-restart
no bgp default ipv4-unicast
neighbor 10.0.0.2 remote-as 100
neighbor 10.0.0.2 update-source Loopback0

address-family ipv4
neighbor 10.0.0.2 activate
neighbor 10.0.0.2 send-community both
neighbor 10.0.0.2 next-hop-self
exit-address-family

address-family vpv4
neighbor 10.0.0.2 activate
neighbor 10.0.0.2 send-community both
neighbor 10.0.0.2 route-map BGP_TE_MAP out
exit-address-family

address-family link-state link-state
neighbor 10.0.0.2 activate
exit-address-family

address-family ipv4 vrf sr
redistribute connected
exit-address-family

route-map BGP_TE_MAP permit 9
match ip address traffic
set community 3276850

ip access-list extended traffic
permit ip 10.0.0.1 255.255.0.0 any

router bgp 100
bgp router-id 192.168.0.2
bgp log-neighbor-changes
bgp graceful-restart
no bgp default ipv4-unicast
neighbor 10.0.0.2 remote-as 100
```

```

neighbor 10.0.0.2 update-source Loopback0

address-family ipv4
  neighbor 10.0.0.2 activate
  neighbor 10.0.0.2 send-community both
  neighbor 10.0.0.2 next-hop-self
exit-address-family

address-family vpnv4
  neighbor 10.0.0.2 activate
  neighbor 10.0.0.2 send-community both
  neighbor 10.0.0.2 route-map BGP_TE_MAP in
exit-address-family

address-family link-state link-state
  neighbor 10.0.0.2 activate
exit-address-family

address-family ipv4 vrf sr
  redistribute connected
exit-address-family

route-map BGP_TE_MAP permit 9
  match community 1
  set attribute-set BGP_TE5555

ip community-list 1 permit 3276850

mpls traffic-eng lsp attributes BGP_TE5555
  path-selection metric igp
  pce

```

4. Enable PCE and auto-tunnel configurations on R1.

```

mpls traffic-eng tunnels
mpls traffic-eng pcc peer 10.0.0.3 source 10.0.0.4 precedence 255
mpls traffic-eng auto-tunnel p2p tunnel-num min 2000 max 5000

```

5. Enable all core links with SR-TE configurations and ensure that they are enabled as point to point interfaces.

```

mpls traffic-eng tunnels

interface GigabitEthernet0/2/0
  ip address 101.102.6.1 255.255.255.0
  ip router isis 1
  mpls traffic-eng tunnels
  isis network point-to-point

interface GigabitEthernet0/3/1
  vrf forwarding sr
  ip address 101.107.3.1 255.255.255.0
  negotiation auto

end

```

6. Enable R3 (RR) to advertise TED to the PCE server via BGP-LS.

```

router isis 1
  net 49.0002.0000.0000.0003.00
  ispf level-1-2
  metric-style wide
  nsf cisco

```

```

nsf interval 0
distribute link-state
segment-routing mpls
segment-routing prefix-sid-map advertise-local
redistribute static ip level-1-2
mpls traffic-eng router-id Loopback0
mpls traffic-eng level-1
mpls traffic-eng level-2

router bgp 100
  bgp router-id 10.0.0.2
  bgp log-neighbor-changes
  bgp graceful-restart
  no bgp default ipv4-unicast
  neighbor 10.0.0.3 remote-as 100
  neighbor 10.0.0.3 update-source Loopback0

  address-family ipv4
  neighbor 10.0.0.3 activate
  exit-address-family

```

7. Enable PCE server configuration and verify BGP-LS session is properly established with RR.

```

Device# sh bgp li li summary
BGP router identifier 10.0.0.3, local AS number 100
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0   RD version: 1436
BGP main routing table version 1436
BGP NSR Initial initsync version 1 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs
BGP is operating in STANDALONE mode.
Process          RcvTblVer   bRIB/RIB   LabelVer   ImportVer   SendTblVer   StandbyVer
Speaker          1436        1436        1436        1436        1436        1436
0

Neighbor         Spk   AS MsgRcvd  MsgSent   TblVer   InQ   OutQ   Up/Down   St/PfxRcd
10.0.0.2          0     100  19923     17437    1436    0     0
1w2d             103

Device# sh pce ipv4 topo | b Node 3
Node 3
  TE router ID: 10.0.0.2
  Host name: R3
  ISIS system ID: 0000.0000.0003 level-1

  ISIS system ID: 0000.0000.0003 level-2
  Prefix SID:
    Prefix 10.0.0.2, label 20011 (regular)

```

Verifying Segment Routing On Demand Next Hop for L3/L3VPN

The ODN verifications are based on L3VPN VRF prefixes.

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

```

Device# sh pce client peer
PCC's peer database:
-----
Peer address: 10.0.0.3 (best PCE)

```

```
State up
Capabilities: Stateful, Update, Segment-Routing
```

- Verify that PCEP session is established between all the peers (PCCs).

```
Device# sh pce ipv4 peer
PCE's peer database:
-----
Peer address: 10.0.0.4
State: Up
Capabilities: Stateful, Segment-Routing, Update
Peer address: 172.16.0.5
State: Up
Capabilities: Stateful, Segment-Routing, Update
```

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

```
Device# sh ip route 192.168.0.1
% Network not in table
```

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

```
Device# sh ip route vrf sr
Routing Table: sr
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
a - application route
+ - replicated route, % - next hop override, p - overrides from PfR
Gateway of last resort is not set
 10.0.0.6/8 is variably subnetted, 2 subnets, 2 masks
C    10.0.0.7/24 is directly connected, GigabitEthernet0/3/1
L    10.0.0.7/32 is directly connected, GigabitEthernet0/3/1
    10.0.0.8/24 is subnetted, 1 subnets
B    10.0.0.9 [200/0] via binding label: 865, 4d21h
```

- Verify that BGP is associating properly the policy and binding SID with the VRF prefix.

```
Device# sh ip bgp vpnv4 vrf sr 106.107.4.0
BGP routing table entry for 100:100:106.107.4.0/24, version 3011
Paths: (1 available, best #1, table sr)
Not advertised to any peer
Refresh Epoch 4
Local
 192.168.0.1 (metric 10) (via default) from 10.0.0.2 (10.0.0.2)
Origin incomplete, metric 0, localpref 100, valid, internal, best
Community: 3276850
Extended Community: RT:100:100
Originator: 192.168.0.1, Cluster list: 10.0.0.2
mpls labels in/out nolabel/1085
binding SID: 865 (BGP_TE5555)
rx pathid: 0, tx pathid: 0x0
```

- Verify binding label association with VRF prefix.

```
Device# sh ip route vrf sr 106.107.4.0
Routing Table: sr
Routing entry for 106.107.4.0/24
Known via "bgp 100", distance 200, metric 0, type internal
Routing Descriptor Blocks:
* Binding Label: 865, from 10.0.0.2, 4d22h ago
Route metric is 0, traffic share count is 1
```



```

AS Hops 0
MPLS label: 1085
MPLS Flags: NSF

```

7. Verify that VRF prefix is forwarded via ODN auto-tunnel.

```

Device# sh ip cef label-table
Label      Next Hop      Interface
0          no route
865       attached      Tunnel2000

```

```

Device# sh ip cef vrf sr 106.107.4.0 detail
10.0.0.8/24, epoch 15, flags [rib defined all labels]
recursive via 865 label 1085
attached to Tunnel2000

```

8. Verify ODN auto-tunnel status.

```

Device# sh mpls traffic-eng tunnels
P2P TUNNELS/LSPs:
Name: R1_t2000 (Tunnel2000) Destination: 192.168.0.1 Ifhandle: 0x6F5
(auto-tunnel for BGP TE)
Status:
Admin: up Oper: up Path: valid Signalling: connected---□
auto-tunnel 2000
path option 1, (SEGMENT-ROUTING) (PCE) type dynamic (Basis for Setup, path weight
10)
Config Parameters:
Bandwidth: 0 kbps (Global) Priority: 7 7 Affinity: 0x0/0xFFFF
Metric Type: IGP (interface)
Path Selection:
Protection: any (default)
Path-selection Tiebreaker:
Global: not set Tunnel Specific: not set Effective: min-fill (default)
Hop Limit: disabled
Cost Limit: disabled
Path-invalidation timeout: 10000 msec (default), Action: Tear
AutoRoute: disabled LockDown: disabled Loadshare: 0 [0] bw-based
auto-bw: disabled
Attribute-set: BGP_TE5555---□ attribute-set
Fault-OAM: disabled, Wrap-Protection: disabled, Wrap-Capable: No
Active Path Option Parameters:
State: dynamic path option 1 is active
BandwidthOverride: disabled LockDown: disabled Verbatim: disabled
PCEP Info:
Delegation state: Working: yes Protect: no
Working Path Info:
Request status: processed
Created via PCRep message from PCE server: 10.0.0.3---□ via PCE server
PCE metric: 30, type: IGP
Reported paths:
Tunnel Name: Tunnel2000_w
LSPs:
LSP[0]:
source 10.0.0.4, destination 192.168.0.1, tunnel ID 2000, LSP ID 1
State: Admin up, Operation active
Binding SID: 865
Setup type: SR
Bandwidth: requested 0, used 0
LSP object:
PLSP-ID 0x807D0, flags: D:0 S:0 R:0 A:1 O:2
Metric type: IGP, Accumulated Metric 0
ERO:
SID[0]: Adj, Label 2377, NAI: local 101.102.6.1 remote 10.0.0.10
SID[1]: Unspecified, Label 17, NAI: n/a

```

```

        SID[2]: Unspecified, Label 20, NAI: n/a
History:
Tunnel:
    Time since created: 4 days, 22 hours, 21 minutes
    Time since path change: 4 days, 22 hours, 21 minutes
    Number of LSP IDs (Tun_Instances) used: 1
    Current LSP: [ID: 1]
    Uptime: 4 days, 22 hours, 21 minutes
Tun_Instance: 1
Segment-Routing Path Info (isis level-1)
    Segment0[Link]: 101.102.6.1 - 10.0.0.10, Label: 2377
    Segment1[ - ]: Label: 17
    Segment2[ - ]: Label: 20

```

9. Verify ODN auto-tunnel LSP status on R1 (headend).

```

Device# sh pce client lsp brief
PCC's tunnel database:
-----
Tunnel Name: Tunnel2000_w
    LSP ID 1
Tunnel Name: Tunnel2000_p

R1# sh pce client lsp detail
PCC's tunnel database:
-----
Tunnel Name: Tunnel2000_w
LSPs:
LSP[0]:
    source 10.0.0.4, destination 192.168.0.1, tunnel ID 2000, LSP ID 1
    State: Admin up, Operation active
    Binding SID: 865
    Setup type: SR
    Bandwidth: requested 0, used 0
    LSP object:
        PLSP-ID 0x807D0, flags: D:0 S:0 R:0 A:1 O:2
    Metric type: IGP, Accumulated Metric 0
    ERO:
        SID[0]: Adj, Label 2377, NAI: local 101.102.6.1 remote 10.0.0.10
        SID[1]: Unspecified, Label 17, NAI: n/a
        SID[2]: Unspecified, Label 20, NAI: n/a

```

10. Verify ODN LSP status on the PCE server.

```

Device# sh pce lsp summ

PCE's LSP database summary:
-----
All peers:
Number of LSPs:          1
Operational: Up:         1 Down:          0
Admin state: Up:        1 Down:          0
Setup type: RSVP:       0 Segment routing: 1

Peer 10.0.0.4:
Number of LSPs:          1
Operational: Up:         1 Down:          0
Admin state: Up:        1 Down:          0
Setup type: RSVP:       0 Segment routing: 1

```

11. Verify detailed LSP information on the PCE server.

```

Device# sh pce lsp det
PCE's tunnel database:

```

```

-----
PCC 10.0.0.4:
Tunnel Name: Tunnel2000_w
LSPs:
LSP[0]:
  source 10.0.0.4, destination 192.168.0.1, tunnel ID 2000, LSP ID 48
  State: Admin up, Operation active
  Binding SID: 872
  PCEP information:
    plsp-id 526288, flags: D:1 S:0 R:0 A:1 O:2
  Reported path:
    Metric type: IGP, Accumulated Metric 0
    SID[0]: Adj, Label 885, Address: local 10.0.0.9 remote 10.0.0.10
    SID[1]: Unknown, Label 17,
    SID[2]: Unknown, Label 20,
  Computed path:
    Computed Time: Tue Dec 20 13:12:57 2016 (00:11:53 ago)
    Metric type: IGP, Accumulated Metric 30
    SID[0]: Adj, Label 885, Address: local 10.0.0.9 remote 10.0.0.10
    SID[1]: Adj, Label 17, Address: local 10.0.0.12 remote 10.0.0.13
    SID[2]: Adj, Label 20, Address: local 10.0.0.14 remote 10.0.0.14
  Recorded path:
    None

```

12. Shutdown the interface that is connected to VRF SR so that the prefix is no longer advertised by MP-BGP.

```

Device# int gig0/2/2
Device(config-if)#shut

```

13. Verify that VRF prefix is no longer advertised to R1 (headend) via R6 (tailend).

```

Device# sh ip route vrf sr
Routing Table: sr
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default, U - per-user static route
        o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
        a - application route
        + - replicated route, % - next hop override, p - overrides from PfR
Gateway of last resort is not set
  10.0.0.6/8 is variably subnetted, 2 subnets, 2 masks
C       10.0.0.7/24 is directly connected, GigabitEthernet0/3/1
L       10.0.0.8/32 is directly connected, GigabitEthernet0/3/1

```

14. Verify that no ODN auto-tunnel exists.

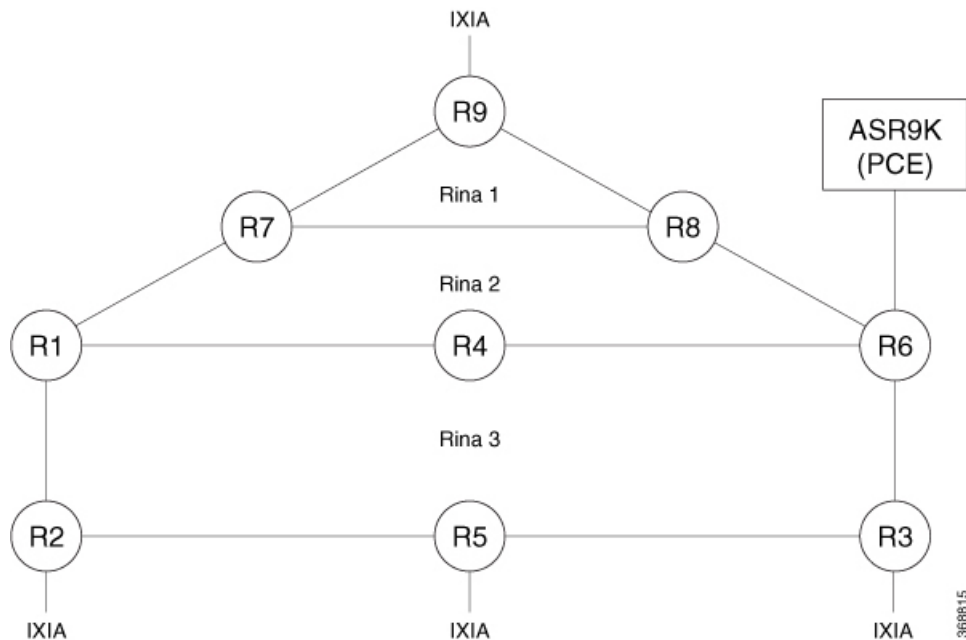
```

Device# sh mpls traffic-eng tunnels
P2P TUNNELS/LSPs:
P2MP TUNNELS:
P2MP SUB-LSPS:

```

Configuring Color Extended Community, Affinity Constraint, and Disjointness Constraint

Consider the following topology:



Configuring Color Extended Community

SR-TE Policy Headend Configuration on Node R3

```
segment-routing traffic-eng
on-demand color 100
  authorize restrict
  ipv4 prefix-list R9350_BGP_INTER_DOMAIN
  candidate-paths
  preference 1
  constraints
  segments
  dataplane mpls
  !
!
dynamic
  pcep
  !
!
!
!
pcc
  pce address <pce loopback ip>source-address <pcc loopback ip>
  !
```

SR-TE Policy Tailend Configuration on Node R9

```
route-map R9_R3_R5_R2_BGP_INTER_DOMAIN permit 10
  match ip address prefix-list R9350_BGP_INTER_DOMAIN
  set extcommunity color 100 ----- Extended Color community configuration
route-map R9_R3_R5_R2_BGP_INTER_DOMAIN permit 20
ip prefix-list R9350_BGP_INTER_DOMAIN seq 35 permit 50.0.0.0/11 le 32
router bgp 1
  address-family vpnv4
  neighbor 201.201.201.201 activate
  neighbor 201.201.201.201 send-community both
  neighbor 201.201.201.201 route-map R9_R3_R5_R2_BGP_INTER_DOMAIN out
```



```

identifier 1
disjointness type node -----□ Disjointness Type configuration
  source 1.0.0.0
  !
  !
  dynamic
  pcep
  !
  !
  !
  !
  !
  pcc
  pce address <pce loopback ip> source-address <pcc loopback ip>
  !
  affinity-map
  name 1 bit-position 1

```

Verifying SR-TE ODN Color Extended Community, Affinity Constraint, and Disjointness Constraint

SR-TE Policy Name: 209.209.209.209|100

```

Router# show segment-routing traffic-eng policy name 209.209.209.209|100
Name: 209.209.209.209|100 (Color: 100 End-point: 209.209.209.209)
Status:
  Admin: up, Operational: up for 51:34:38 (since 01-07 06:19:08.040)-□ Policy state is
UP
Candidate-paths:
  Preference 1:
  Constraints:
  Affinity:
    include-any: -----□ Affinity Type
    1 -----□ Affinity Name
  Disjointness information:
    Group ID: 1, Source: 1.0.0.0
    Type: Node Disjointness -----□ Disjointness Type
    Dynamic (pce 12.12.12.12) (active) -----□ PCE Computed Candidate-path
    Weight: 0, Metric Type: TE -----□ Metric Type
    Metric Type: TE, Path Accumulated Metric: 53 -□ Total IGP Metric from Source to
Destination
    18010 [Prefix-SID, 202.202.202.202] -----|
    18007 [Prefix-SID, 211.211.211.211] -----|
    18002 [Prefix-SID, 207.207.207.207] -----□ This Segment List should
follow Affinity path
    21 [Adjacency-SID, 10.10.20.2 - 10.10.20.1] -----|

Attributes:
  Binding SID: 87 -----□ Binding SID Allocated
  Allocation mode: dynamic
  State: Programmed
  Auto-policy info:
  Creator: BGP SR Policy Client
  IPv6 caps enable: yes

```

To view detailed information about SR-TE Policy 209.209.209.209|100

```

Router# show segment-routing traffic-eng policy name 209.209.209.209|100 detail
Name: 209.209.209.209|100 (Color: 100 End-point: 209.209.209.209)
Status:
  Admin: up, Operational: up for 00:04:19 (since 01-10 06:20:57.810)

```

```

Candidate-paths:
  Preference 1:
    Constraints:
      Affinity:
        include-any:
          1

Disjointness information:
  Group ID: 1, Source: 1.0.0.0
  Type: Node Disjointness
  Dynamic (pce 12.12.12.12) (active)
  Weight: 0, Metric Type: TE
  Metric Type: TE, Path Accumulated Metric: 53
  18010 [Prefix-SID, 202.202.202.202]
  18007 [Prefix-SID, 211.211.211.211]
  18002 [Prefix-SID, 207.207.207.207]
  21 [Adjacency-SID, 10.10.20.2 - 10.10.20.1]

Attributes:
  Binding SID: 87
  Allocation mode: dynamic
  State: Programmed
  Auto-policy info:
  Creator: BGP SR Policy Client
  IPv6 caps enable: yes
  Forwarding-ID: 65711 (0x44) ----- This FWD-ID is used for forwarding traffic
  Stats:
  Packets: 8893      Bytes: 852848 ----- This counter indicates traffic flowing
  through this SRTE policy
  
```

Event history: --- This indicates event happened with this SRTE Policy

Timestamp Value	Client	Event type	Context:
01-06 05:59:26.096	BGP SR Policy Cl	Policy created	Name:
209.209.209.209 100			
01-06 05:59:26.096	BGP SR Policy Cl	Set colour	Colour: 100
01-06 05:59:26.096	BGP SR Policy Cl	Set end point	End-point:
209.209.209.209			
01-06 05:59:26.096	BGP SR Policy Cl	Set dynamic pce	Path option:
dynamic pce			
01-06 05:59:26.480	FH Resolution	Policy state UP	Status:
PATH RESOLVED			
01-06 05:59:40.424	FH Resolution	REOPT triggered	Status:
REOPTIMIZED			
01-06 05:59:49.249	FH Resolution	REOPT triggered	Status:
REOPTIMIZED			
01-06 05:59:56.469	FH Resolution	REOPT triggered	Status:
REOPTIMIZED			
01-07 05:15:19.918	FH Resolution	Policy state DOWN	Status:
PATH NOT RESOLVED			
01-07 06:15:55.739	FH Resolution	Policy state UP	Status:
PATH RESOLVED			
01-07 06:16:08.552	FH Resolution	REOPT triggered	Status:
REOPTIMIZED			
01-07 06:19:08.040	FH Resolution	Policy state DOWN	Status:
PATH NOT RESOLVED			
01-10 06:20:57.810	FH Resolution	Policy state UP	Status:
PATH RESOLVED			
01-10 06:21:05.211	FH Resolution	REOPT triggered	Status:
REOPTIMIZED			
01-10 06:21:08.036	FH Resolution	REOPT triggered	Status:

```

REOPTIMIZED
  01-10 06:21:10.073          FH Resolution          REOPT triggered          Status:
REOPTIMIZED

```

To check if the Affinity constraint is working, shut down any of the interfaces falling under the Affinity-defined path. If the constraint works, the SR-TE policy goes down instead of taking the another path (if available) to reach to the destination.

To check if the disjointness constraint is working, check the SR-TE policy information given by the PCE, which consists of Segment IDs used for the computed path from source to destination.

Disjointness constraint works, if the Segment IDs of both the SR-TE policies are different. For example:

```

SRTE Policy 1:          SRTE Policy 2:

      SID[0]: Node, Label 16002, NAI: 207.207.207.207          SID[0]: Node, Label
16003, NAI: 208.208.208.208
      SID[1]: Node, Label 16004, NAI: 201.201.201.201          SID[1]: Node, Label 16006,
NAI: 206.206.206.206
      SID[2]: Node, Label 16011, NAI: 205.205.205.205          SID[2]: Node, Label 16011,
NAI: 205.205.205.205

```



Note SID[2] of policies 1 and 2 is the same since destination of both the SR-TE policies is the same.

To view the SR-TE policy and Affinity constraint in the PCE:

```

RP/0/RSP0/CPU0:ASR9K# show pce lsp pcc ipv4 213.213.213.213 private

Thu Jan 10 00:11:52.983 UTC

PCE's tunnel database:
-----
PCC 213.213.213.213:
Tunnel Name: 209.209.209.209|100
LSPs:
  LSP[0]:
    source 203.203.203.203, destination 209.209.209.209, tunnel ID 177, LSP ID 0
    State: Admin up, Operation ---- SRTE Policy is up
    Setup type: Segment Routing
    Binding SID: 87
    Maximum SID Depth: 4
    Absolute Metric Margin: 0
    Relative Metric Margin: 0%
    Affinity: exclude-any 0x0 include-any 0x2 include-all 0x0 ---- This indicates Affinity
    taken into account by PCE

PCEP information:
  PLSP-ID 0x800b1, flags: D:1 S:0 R:0 A:1 O:2 C:0
  LSP Role: Disjoint LSP
  State-sync PCE: None
  PCC: 213.213.213.213
  LSP is subdelegated to: None
  Reported path:
    Metric type: TE, Accumulated Metric 53
    SID[0]: Node, Label 18010, Address 202.202.202.202
    SID[1]: Node, Label 18007, Address 211.211.211.211
    SID[2]: Node, Label 18002, Address 207.207.207.207
    SID[3]: Adj, Label 21, Address: local 10.10.20.2 remote 10.10.20.1
  Computed path: (Local PCE)
    Computed Time: Thu Jan 10 00:09:36 UTC 2019 (00:02:17 ago)

```



```

Metric type: TE, Accumulated Metric 53
SID[0]: Node, Label 18010, Address 202.202.202.202
SID[1]: Node, Label 18007, Address 211.211.211.211
SID[2]: Node, Label 18002, Address 207.207.207.207
SID[3]: Adj, Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Recorded path:
None
Disjoint Group Information:
Type Node-Disjoint, Group 1, Sub-Group 1.0.0.0

```

Event history (latest first):

```

Time                               Event
Thu Jan 10 00:09:37 UTC 2019      Report from 213.213.213.213 (LSP owner)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0,
                                   Source: 203.203.203.203 Destination: 209.209.209.209,
                                   D:1, R:0, A:1 O:2, Sig.BW: 0, Act.BW: 0
                                   Reported Path: (Metric 53)
                                   Label 18010, Address 202.202.202.202
                                   Label 18007, Address 211.211.211.211
                                   Label 18002, Address 207.207.207.207
                                   Label 21, Address: local 10.10.20.2 remote 10.10.20.1
                                   Chng:0, AssoChng:0
Thu Jan 10 00:09:36 UTC 2019      Update to 213.213.213.213 (PCC)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
                                   Path: (Metric 53)
                                   Label 18010, Address 202.202.202.202
                                   Label 18007, Address 211.211.211.211
                                   Label 18002, Address 207.207.207.207
                                   Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Thu Jan 10 00:09:36 UTC 2019      Path Computation (Disjoint LSP)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
                                   Source: 203.203.203.203 Destination: 209.209.209.209
                                   Status: Disjoint Path Success
Wed Jan 09 23:54:42 UTC 2019      Update to 213.213.213.213 (PCC)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
                                   Path: (Metric 53)
                                   Label 18007, Address 211.211.211.211
                                   Label 18002, Address 207.207.207.207
                                   Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Wed Jan 09 23:54:42 UTC 2019      Path Computation (Disjoint LSP)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
                                   Source: 203.203.203.203 Destination: 209.209.209.209
                                   Status: Fallback Node to Shortest Path
                                   Computed Path: (Metric 53)
                                   Label 18007, Address 211.211.211.211
                                   Label 18002, Address 207.207.207.207
                                   Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Wed Jan 09 23:54:21 UTC 2019      Path Computation (Disjoint LSP)
                                   Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
                                   Source: 203.203.203.203 Destination: 209.209.209.209
                                   Status: Disjoint Path Success
Computed Path: (Metric 53)
                                   Label 18010, Address 202.202.202.202
                                   Label 18007, Address 211.211.211.211
                                   Label 18002, Address 207.207.207.207
                                   Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Computed Path: (Metric 53)
                                   Label 18010, Address 202.202.202.202

```

```

Label 18007, Address 211.211.211.211
Label 18002, Address 207.207.207.207
Thu Jan 10 00:09:05 UTC 2019 Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Path Computation (Disjoint LSP)
Symbolic-name: 209.209.209.209|100, LSP-ID: 0, D:1
Source: 203.203.203.203 Destination: 209.209.209.209
Status: Fallback Node to Shortest Path
Computed Path: (Metric 53)
Label 18007, Address 211.211.211.211
Label 18002, Address 207.207.207.207
Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Wed Jan 09 23:54:42 UTC 2019 Report from 213.213.213.213 (LSP owner)
Symbolic-name: 209.209.209.209|100, LSP-ID: 0,
Source: 203.203.203.203 Destination: 209.209.209.209,
D:1, R:0, A:1 O:2, Sig.BW: 0, Act.BW: 0
Reported Path: (Metric 53)
Label 18007, Address 211.211.211.211
Label 18002, Address 207.207.207.207
Label 21, Address: local 10.10.20.2 remote 10.10.20.1
Chng:0, AssoChng:0

RP/0/RSP0/CPU0:ASR9K#

```

To view disjointness between policies 1 and 2:

```
RP/0/RSP0/CPU0:ASR9K# show pce association type link group-id 3
```

```
Wed Aug 29 05:56:52.228 UTC
PCE's association database:
-----
```

```
Association: Type Link-Disjoint, Group 3, Sub-Group 1.0.0.0, Not Strict
```

```
Associated LSPs:
```

```
LSP[0]:
```

```
PCC 213.213.213.213, tunnel name 209.209.209.209|104, PLSP ID 524460, tunnel ID 172,
LSP ID 0, Configured on PCC
```

```
LSP[1]:
```

```
PCC 213.213.213.213, tunnel name 209.209.209.209|105, PLSP ID 524461, tunnel ID 173,
LSP ID 0, Configured on PCC
```

```
Status: Satisfied ----- This indicates that Disjointness between SRTE Policies
is working
```

```
RP/0/RSP0/CPU0:ASR9K#
```

Troubleshooting the SR-TE ODN Color Extended Community, Affinity Constraint, and Disjointness Constraint

If SR-TE policy is down, check the status of the SR-TE Policy under the SR-TE policy information

```

Router# show segment-routing traffic-eng policy name 209.209.209.209|100
Name: 209.209.209.209|106 (Color: 106 End-point: 209.209.209.209)
Status:
  Admin: up, Operational: down for 00:00:18 (since 01-10 13:06:42.142)
Candidate-paths:
  Preference 1:
  Constraints:
    Affinity:
      include-any:
        1
    Dynamic (pce) (inactive)
    Weight: 0, Metric Type: IGP
Attributes:
  Binding SID: 269
  Allocation mode: dynamic

```

```

State: Programmed
Auto-policy info:
  Creator: BGP SR Policy Client
  IPv6 caps enable: yes
Router#

```



Note The possible reasons for the policy being down are:

- Connection to PCE is down.
- Max SID depth is exceeded.
- An interface falling under Affinity-defined path from source to destination has been shut down.

To check the SR-TE policy status on the PCE:

```

RP/0/RSP0/CPU0:ASR9K#show pce lsp pcc ipv4 213.213.213.213 private
Thu Jan 10 00:11:52.983 UTC
PCE's tunnel database:
-----
PCC 213.213.213.213:
Tunnel Name: 209.209.209.209|100
LSPs:
LSP[0]:
  source 203.203.203.203, destination 209.209.209.209, tunnel ID 177, LSP ID 0
  State: Admin up, Operation active   ----- SRTE Policy is up
  Setup type: Segment Routing
  Binding SID: 87

```

```

Maximum SID Depth: 4
Absolute Metric Margin: 0
Relative Metric Margin: 0%

```

```

Affinity: exclude-any 0x0 include-any 0x2 include-all 0x0   --- This indicates Affinity
is taken into account by the PCE

```

PCE is aware of the network topology. This information is used for path computation using the following command. This information is also used to determine if nodes and links are present and have the expected attributes (IGP/TE admin weights, SIDs and so on).

```

RP/0/RSP0/CPU0:ASR9K# show pce ipv4 topology
Tue Jan 15 01:36:20.298 UTC
PCE's topology database - detail:
-----
Node 1
  TE router ID: 207.207.207.207
  Host name: 920-R7
  ISIS system ID: 0000.0000.0207 level-1 ASN: 1
  ISIS system ID: 0000.0000.0207 level-2 ASN: 1
  Prefix SID:
  ISIS system ID: 0000.0000.0207 level-1 ASN: 1 domain ID: 0
    Prefix 207.207.207.207, label 16002 (regular), flags: N
  ISIS system ID: 0000.0000.0207 level-1 ASN: 1 domain ID: 0
    Prefix 207.207.207.207, label 18002 (strict), flags: N
  ISIS system ID: 0000.0000.0207 level-2 ASN: 1 domain ID: 0
    Prefix 207.207.207.207, label 16002 (regular), flags: N
  ISIS system ID: 0000.0000.0207 level-2 ASN: 1 domain ID: 0
    Prefix 207.207.207.207, label 18002 (strict), flags: N

```

```

SRGB INFO:
  ISIS system ID: 0000.0000.0207 level-1 ASN: 1
  SRGB Start: 16000 Size: 8000
  ISIS system ID: 0000.0000.0207 level-2 ASN: 1
  SRGB Start: 16000 Size: 8000
Link[0]: local address 10.10.21.1, remote address 10.10.21.2
  Local node:
    ISIS system ID: 0000.0000.0207 level-1 ASN: 1
  Remote node:
    TE router ID: 208.208.208.208
    Host name: 920-R8
    ISIS system ID: 0000.0000.0208 level-1 ASN: 1
    Metric: IGP 10, TE 10, Latency 10
    Bandwidth: Total 1250000000 Bps, Reservable 0 Bps
    Admin-groups: 0x00000000
    Adj SID: 16 (unprotected) 17 (protected)
Link[1]: local address 10.10.21.1, remote address 10.10.21.2
  Local node:
    ISIS system ID: 0000.0000.0207 level-2 ASN: 1
  Remote node:
    TE router ID: 208.208.208.208
    Host name: 920-R8
    ISIS system ID: 0000.0000.0208 level-2 ASN: 1
    Metric: IGP 10, TE 10, Latency 10
    Bandwidth: Total 1250000000 Bps, Reservable 0 Bps
    Admin-groups: 0x00000000
    Adj SID: 18 (unprotected) 19 (protected)
Link[2]: local address 10.10.20.2, remote address 10.10.20.1
  Local node:
    ISIS system ID: 0000.0000.0207 level-2 ASN: 1
  Remote node:
    TE router ID: 209.209.209.209
    Host name: 920-R9
    ISIS system ID: 0000.0000.0209 level-2 ASN: 1
    Metric: IGP 40, TE 40, Latency 40
    Bandwidth: Total 1250000000 Bps, Reservable 0 Bps
    Admin-groups: 0x00000052
    Adj SID: 20 (unprotected) 22 (protected)
    SRLG Values: 25
Node 2
  TE router ID: 209.209.209.209
  Host name: 920-R9
  ISIS system ID: 0000.0000.0209 level-1 ASN: 1
  ISIS system ID: 0000.0000.0209 level-2 ASN: 1
  Prefix SID:
    ISIS system ID: 0000.0000.0209 level-1 ASN: 1 domain ID: 0
    Prefix 209.209.209.209, label 16001 (regular), flags: N
    ISIS system ID: 0000.0000.0209 level-1 ASN: 1 domain ID: 0
    Prefix 209.209.209.209, label 18001 (strict), flags: N
    ISIS system ID: 0000.0000.0209 level-2 ASN: 1 domain ID: 0
    Prefix 209.209.209.209, label 16001 (regular), flags: N
    ISIS system ID: 0000.0000.0209 level-2 ASN: 1 domain ID: 0
    Prefix 209.209.209.209, label 18001 (strict), flags: N
  SRGB INFO:
    ISIS system ID: 0000.0000.0209 level-1 ASN: 1
    SRGB Start: 16000 Size: 8000
    ISIS system ID: 0000.0000.0209 level-2 ASN: 1
    SRGB Start: 16000 Size: 8000
Link[0]: local address 10.10.20.1, remote address 10.10.20.2
  Local node:
    ISIS system ID: 0000.0000.0209 level-2 ASN: 1
  Remote node:
    TE router ID: 207.207.207.207
    Host name: 920-R7

```

```

    ISIS system ID: 0000.0000.0207 level-2 ASN: 1
    Metric: IGP 40, TE 40, Latency 40
    Bandwidth: Total 1250000000 Bps, Reservable 0 Bps
    Admin-groups: 0x00000052
    Adj SID: 1980 (unprotected) 1981 (protected)
    Link[1]: local address 10.10.22.1, remote address 10.10.22.2
    Local node:
      ISIS system ID: 0000.0000.0209 level-2 ASN: 1
    Remote node:
      TE router ID: 208.208.208.208
      Host name: 920-R8
      ISIS system ID: 0000.0000.0208 level-2 ASN: 1
    Metric: IGP 10, TE 50, Latency 50
    Bandwidth: Total 1250000000 Bps, Reservable 0 Bps
    Admin-groups: 0x0000002C
    Adj SID: 1971 (unprotected) 1972 (protected)

```

RP/0/RSP0/CPU0:ASR9K#

Further troubleshooting tips:

- Enable the following debug commands on the PCCs:
 - debug segment-routing traffic-eng path
 - debug segment-routing traffic-eng pcalc
 - debug segment-routing traffic-eng policy
 - debug segment-routing traffic-eng topology
 - debug segment-routing traffic-eng ha
- Enable the following debug commands on the PCE:
 - debug pce pcep
 - debug pce cspf
 - debug pce cspf-internal
 - debug pce error
 - debug pce path

Additional References for Segment Routing On Demand Segment Routing ODN PFP AUTO STEERING (PCE DELEGATED) for L3/L3VPN

Related Documents

Related Topic	Document Title
Cisco IOS Commands	Cisco IOS Master Command List, All Releases

Feature Information for Segment Routing On Demand Next Hop for L3/L3VPN

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Table 1: Feature Information for Segment Routing On Demand Next Hop for L3/L3VPN

Feature Name	Releases	Feature Information
Segment Routing On Demand Next Hop for L3/L3VPN	Cisco IOS XE Everest 16.5.1b	On-Demand Next Hop (ODN) triggers delegation of computation of an end-to-end LSP to a PCE controller including constraints and policies without doing any redistribution. The following commands were introduced or modified: route-map BGP_TE_MAP permit, mpls traffic-eng tunnels, sh bgp li li summary, sh pce client peer, sh pce ipv4 peer, sh ip route vrf sr, sh ip bgp vpnv4 vrf sr, sh ip cef label-table, sh mpls traffic-eng tunnels, sh pce client lsp brief, sh pce lsp summ, sh pce lsp det, routing-default-optimize
SR-TE Policy, Color Extended Community, Affinity Constraint, and Disjointness Constraint	Cisco IOS XE Gibraltar 16.12.1	A new command segment-routing traffic-eng is added to configure the SR policy under segment routing. Also, the configuration of affinity and disjointness constraints is supported. Support for ODN with color extended community is introduced.