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How to migrate a MPLS network from RSVP-TE to SR-TE

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BRKMPL-2130

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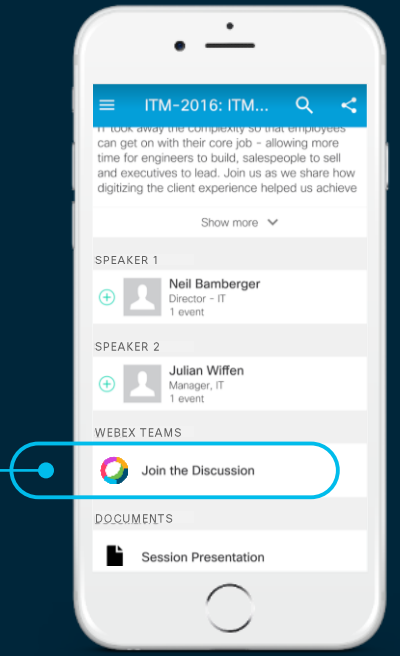

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Agenda

- Welcome and Introduction
- RSVP-TE Network Challenges
- Solution Overview of Network Migration
- SR-TE Policies and Traffic Steering
- RSVP-TE Bandwidth Accounting
- Key Takeaways

Objective

- Introduce a solution that facilitates migration by allowing the coexistence of non-zero bandwidth RSVP-TE tunnel and Segment Routing in same network domain
  - SR-TE Policy Setup and Traffic Steering Techniques
  - SR Traffic Accounting and RSVP-TE resvBW Refresh

Reason of Network Migration

RSVP-TE Network Challenges and SR Benefits

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Today Business Drivers

Scalability

- Distribute massive traffic volumes
- High-scale system

Optimization

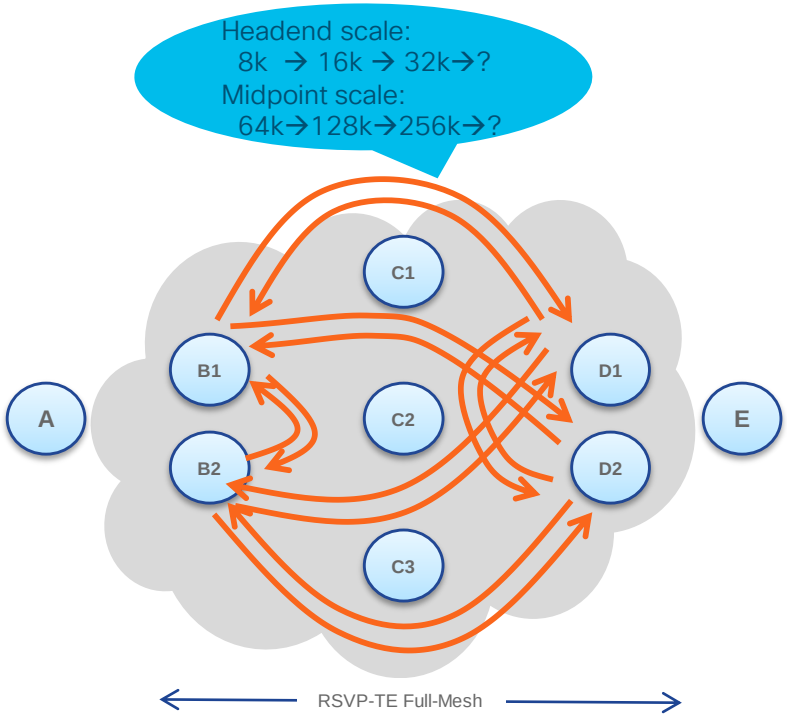
- Feature richness to optimize traffic steering
- API programmability

Automation

- Telemetry and visibility
- Model driven and machine learning

RSVP-TE Network Challenges

- Complicated MPLS WAN network
- Full-mesh of RSVP-TE Tunnels
  - ❖ RSVP state maintained at every hop
  - ❖ Large headend and midpoint scale
  - ❖ Core state n^2 problem
    - ❖ Compounded by emerging new service SLAs
- Doesn't scale well as network continues to growth

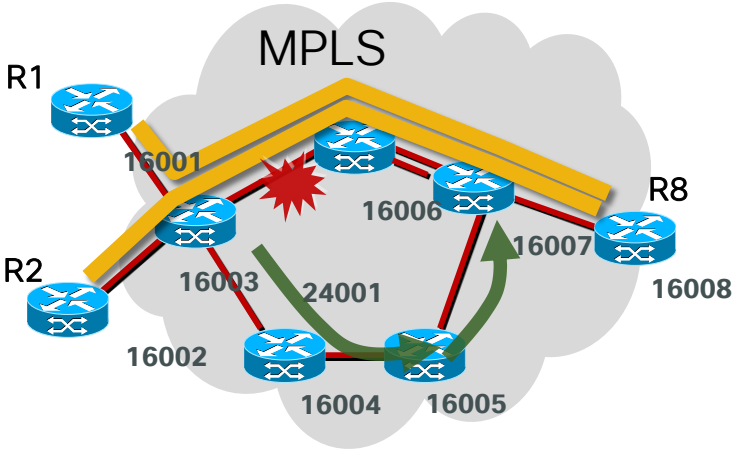


Why Segment Routing?

- Simple
  - Reduced control plane state
  - Utilize existing MPLS data plane
  - Path Control with SR source routing label stack
- Agile and Scalable
  - Eliminate LDP, RSVP protocols
- Programmable
  - Centralized path computation option
  - Ability for application integration

SR Path Control and Ti-LFA

Segment Routing Traffic Engineering (SR-TE)



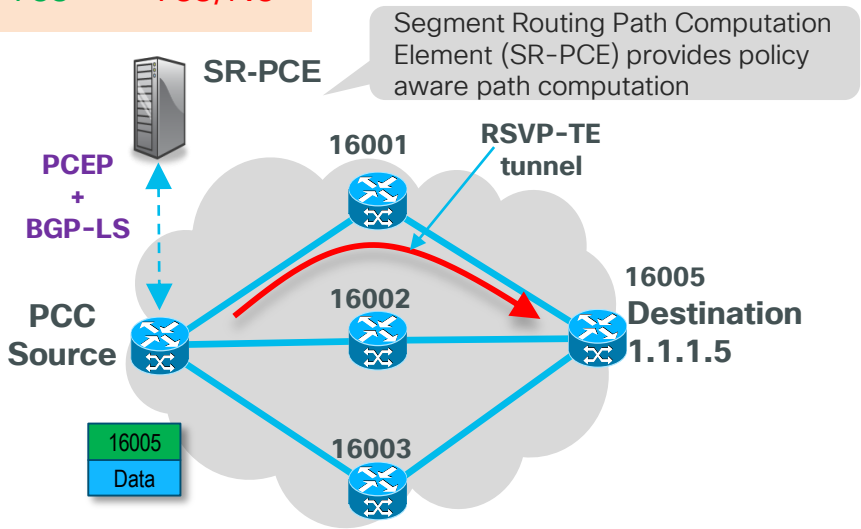
- Source Routing
  - Source chooses a path and encodes in the packet header as an ordered list of segments
  - The rest of the network nodes executes the encoded instructions
- SR-TE Policy Path Control
  - Policy label stack with Node-SID, or Adj-SID
  - Each Policy assigned unique Binding-SID
  - ECMP paths load-balance by IGP Nature
- Topology Independent LFA
  - Automated 1:N path protection
  - Local reroute comparable to MPLS TE Link / Node, but no RSVP or LDP
  - IGP algorithm, support microloop avoidance

SR Centralized Path Computation

	SR-TE	RSVP-TE
TE state only at head-end	Yes	No
ECMP-capability for TE	Yes	No
Engineered for SDN	Yes	Yes/No

```
segment-routing
 traffic-eng
 pcc
   pce address ipv4 192.99.1.1
 !
  policy foo123
   color 10 end-point ipv4 1.1.1.5
   autoroute
   candidate-paths
    preference 100
     dynamic pcep
```

SR Centralized Path Computation



RSVP-TE to SR-TE Seamless Migration

WHY

- Simple, easy and scalable
  - Avoid LDP or RSVP-TE sessions, less protocols to operate
  - Avoid midpoint of RSVP-TE LSP's n^2 scale problem
- Enables Application Driven Programmability:
  - Programmatic interfaces and Orchestration

HOW

- MPLS data plane leveraged without any modification
  - Push, swap and pop: all SR forwarding need
  - Inherit SR label ECMP load balance
- SR Traffic engineering via IGP Source Routing
  - Source routing path control push as a SR label or stack of labels

Solution Overview of Network Migration

SR-TE Policies and Traffic Steering

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Network Migration Approaches

Interworking

- SR and RSVP-TE deployed in non overlapping areas of network
  - Isolated SR domains interconnected over RSVP-TE core
  - Within RSVP-TE domain, SR-TE label stack is carried inside RSVP-TE path

Ships-in-the-night

- SR-TE and RSVP-TE coexist over same network domain
  - Some services are migrated to SR, others retained on existing RSVP-TE
  - RSVP-TE link-management admission-control unaware of SR traffic utilization

RSVP-TE and SR-TE Coexistence

- In control plane: RSVP-TE and SR-TE independently program MPLS label forwarding entries
- In data plane: RSVP-TE and SR-TE use distinct MPLS labels

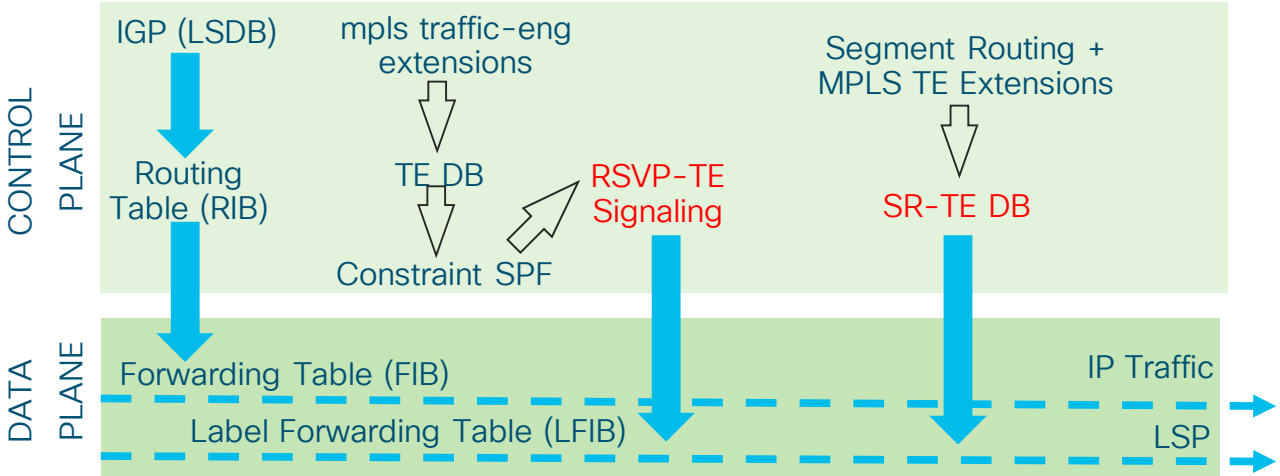
IP and Label Switch Path Install

RSVP-TE

- RSVP-TE Signaling (label distribution)
- Autoroute Announce via IGP
- Fast-reroute link/node protection

SR-TE

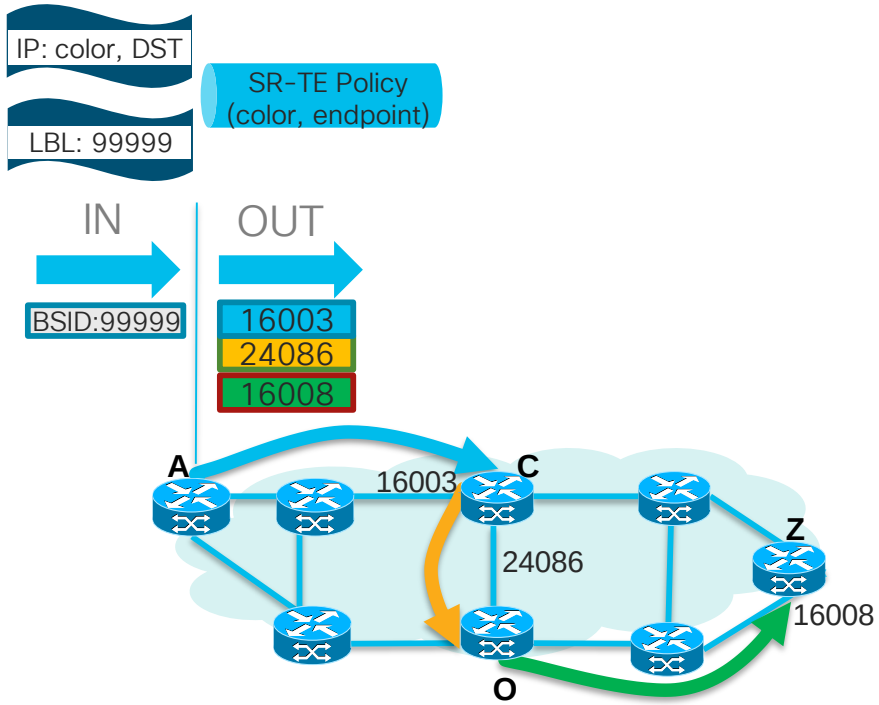
- IGP Label distribution, inherent ECMP
- Auto Steering via BGP Prefix Coloring
- Topology Independent LFA



SR-TE Auto-Steering with BGP Prefix Coloring

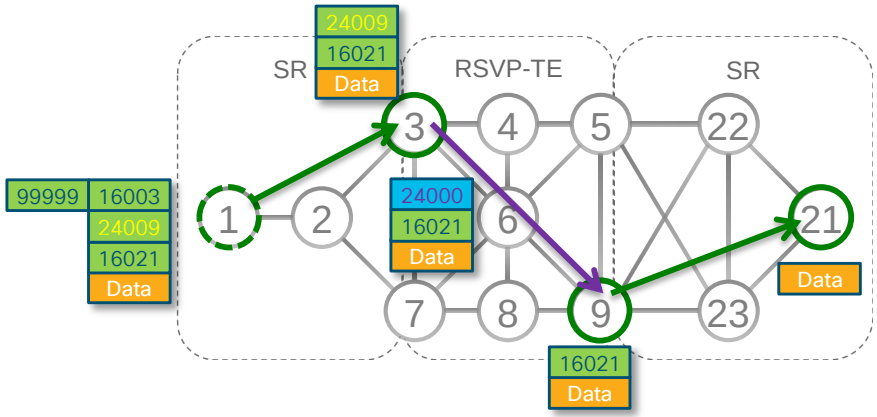
SR-TE provides more granular and automated steering techniques

- Egress BGP route-policy advertised prefixes colors using extended community attributes
- Incoming traffic is steered over SR-TE policy:
  - IP per flow traffic is steered if BGP prefix matches color and endpoint
  - labeled traffic is steered if packet top label matches policy Binding-SID
- Auto-steering applies in same way regardless of local or automatic SR-TE policy types
- If no valid SR-TE policy exists, prefixes will be installed "classically" in the forwarding plane by recursive lookup on the route to next-hop



SR-TE to RSVP-TE Interworking

- Extends an existing network where RSVP-TE is deployed
  - ❖ Enable SR in the network in islands, leave legacy RSVP-TE network in places
  - ❖ SR-TE interwork with RSVP-TE through Binding-SID as part of SRTE label stack
- SR-TE Policy "stitches" RSVP-TE tunnel by using Binding-SID of RSVP-TE tunnel

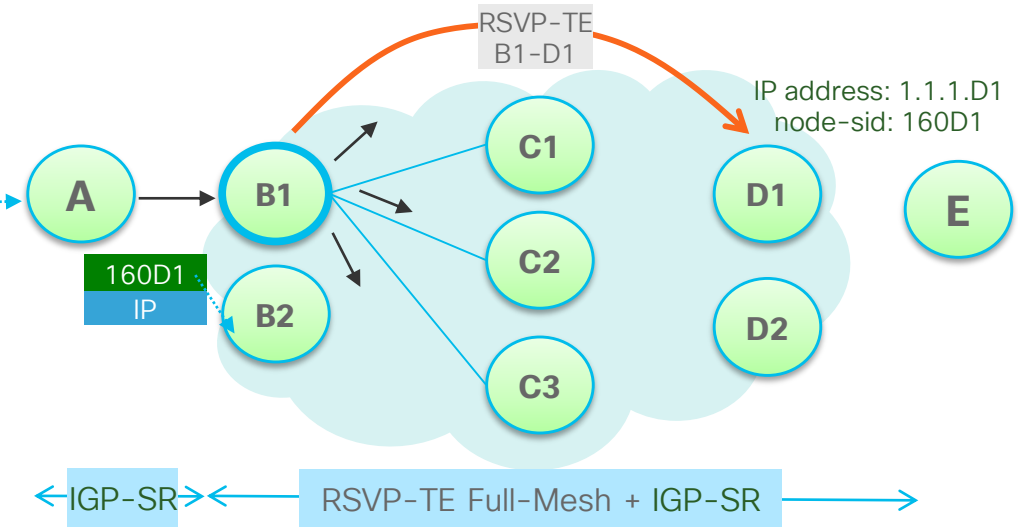


Ships-in-the-night: SR-TE and RSVP-TE Coexist

- Some services deployed over SR, others over existing transport (LDP or RSVP-TE)
- Data plane routes to native IGP SR path or SRTE policy by color and B-SID match
- Gradually move traffic from RSVP-TE Autoroute Announce steering to SR-TE color based Auto-steering

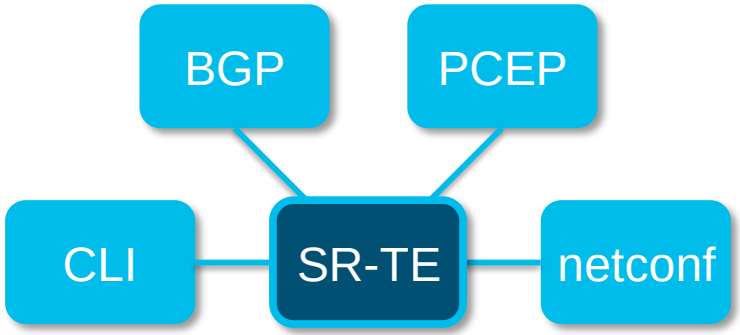
```
int tunnel-te 1000
 destination D1
 autoroute-announce
   exclude-traffic
    segment-routing
```

```
R1# show mpls traffic-eng autoroute
  Destination 1.1.1.5 has 1 tunnels in IS-IS
10 level 2
    tunnel-te1000 (traffic share 0, nexthop
1.1.1.5,  metric 0)
      (IS-IS 10 level-2, IPV4 Unicast)
      Signalled-Name: R1_t1000
        Exclude-traffic: segment-routing
```



Traffic Engineering with Segment Routing

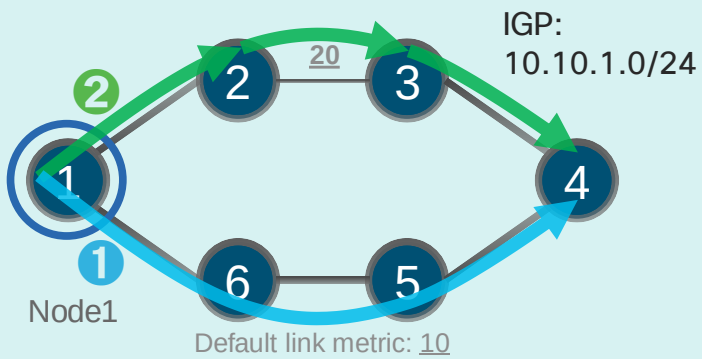
- Automated On-Demand Policy
  - No core state: state in the packet header
  - Automated steering: BGP prefix coloring
  - No tunnel interface: on-demand policy instantiation
- CLI or Controller Based Policy
  - Support constraint-based routing
  - CLI is just one way, more programmable ways
  - Support controller based BGP sr-policy instantiation
- Centralized Multi-Domain Policy
  - SR Path Compute Element (SR-PCE) for path compute
  - Binding-SID (BSID) for traffic steering and scale
  - Supports centralized policy via PCEP provision



Use Case1: CLI SRTE Policy with Autoroute

```
segment-routing
 traffic-eng
  policy POLICY1
   color 2 end-point ipv4 1.1.1.4
   autoroute
    include ipv4 10.10.1.0/24
   binding-sid mpls 999
   candidate-paths
1   preference 100
     dynamic
      metric
       type te
2   preference 200
     explicit segment-list SIDLIST1
   !
   segment-list name SIDLIST1
    index 10 mpls label 16002
    index 20 mpls label 24004
    index 30 mpls label 16004
```

- BGP installs SR-TE policy data path with policy B-SID
  - Path with higher preference is preferred
- SR-TE policy autoroute includes specific prefix
  - Remaining IGP autoroute traffic over RSVP-TE tunnels is not impacted



L2VPN Service Preferred-path Steering

- Use preferred-path configuration to specify SR-TE Policy used to transport Pseudowire traffic

```
l2vpn
 pw-class EoMPLS-PWCLASS
  encapsulation mpls
   preferred-path sr-te policy policy
srte_c_2_ep_1.1.1.4
 !
 xconnect group vpws
  p2p vpws1
   interface Bundle-Ether2.2
   neighbor ipv4 1.1.1.4 pw-id 1
    pw-class EoMPLS-PWCLASS
!
```

```
R1# show l2vpn xc pw-id 1 detail
Group vpws, XC vpws1, state is up; Interworking none
  AC: Bundle-Ether2.2, state is up
...
  PW: neighbor 1.1.1.4, PW ID 1, state is up ( established )
    PW class xc-vpls, XC ID 0xa000001f
    Encapsulation MPLS, protocol LDP
    Source address 1.1.1.1
    PW type Ethernet, control word disabled, interworking
none
    PW backup disable delay 0 sec
    Sequencing not set
    Preferred path Active : SR TE srte_c_2_ep_1.1.1.4,
Statically configured, fallback disabled
    Tunnel: Up
```

```
R1# show segment-routing traffic-eng policy name
srte_c_2_ep_1.1.1.4
Color: 2, End-point: 1.1.1.4
  Name: srte_c_2_ep_1.1.1.4
  Status:
    Admin: up  Operational: up for 02:48:30 (since Apr  1
12:22:57.663)
  Candidate-paths:
    Preference: 200 (configuration) (active)
      Name: POLICY1
      Requested BSID: 999
      PCC info:
        Symbolic name: cfg_ POLICY1_discr_200
        PLSP-ID: 4
      Explicit: segment-list SIDLIST1  (valid)
        Weight: 1, Metric Type: TE
          16002 [Prefix-SID, 1.1.1.2]
          24004 [Adjacency-SID, 10.23.0.1 - 10.23.0.2]
          16004 [Prefix-SID, 1.1.1.4]
    Preference: 100 (configuration)
      Requested BSID: 999
      PCC info:
        Symbolic name: cfg_POLICY1_discr_100
        PLSP-ID: 6
```

Use Case2: On-demand SRTE Policy

- Service source automatically instantiates an SRTE Policy to a BGP next-hop on-demand based on a BGP prefix color-template
  - One binding-sid per auto-policy, no need to pre-configured
- Service headend installs Policy data path based on binding-sid
  - Color match Auto-steering, no impact on RSVP-TE IGP autoroute traffic
- BGP prefix traffic automatically steered over SR-TE Policy based on Color community and BGP next-hop
  - Color community is used as SLA indicator
  - Each SR Policy is defined by (color, endpoint)

Internet Service On-demand Policy Steering

IF

BGP prefix next-hop and color match SR-TE Policy endpoint and color

=>

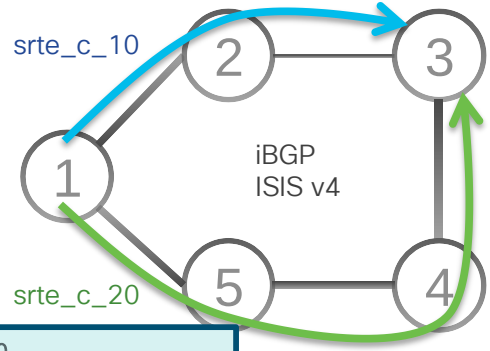
THEN

BGP route is installed and resolved with SR-TE Policy BSID

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

110.1.1.3/32 (color 10, NH 1.1.1.3, srte_c_10)
120.1.1.3/32 (color 20, NH 1.1.1.3, srte_c_20)
```

IGP shortest path

better path with lowest TE metric




```
R1# show bgp ipv4 unicast 120.1.1.0/24 detail | beg C:20
 1.1.1.3 C:20 (bsid:24025) (metric 20) from 1.1.1.3 (1.1.1.3)
     Origin incomplete, metric 0, localpref 100, valid, internal, best, group-best
     Received Path ID 0, Local Path ID 1, version 25
     Extended community: Color:20
     SR policy color 20, up, registered, bsid 24025, if-handle 0x00000270
R1# show cef ipv4 120.1.1.1/32 detail | beg local-label
   via local-label 24025, 3 dependencies, recursive [flags 0x6000]
    Hash  OK  Interface                 Address
    0     Y   srte_c_20_ep_1.1.1.3      point2point
```

```
extcommunity-set opaque BLUE
  10
end-set
!
extcommunity-set opaque GREEN
  20
end-set
!
route-policy SET_COLOR
  if destination in (110.1.1.0/24) then
    set extcommunity color BLUE
  endif
  if destination in (120.1.1.0/24) then
    set extcommunity color GREEN
  endif
  pass
end-policy
!
router bgp 1
 neighbor 1.1.1.1
  remote-as 1
  update-source Loopback0
  address-family ipv4 unicast
   route-policy SET_COLOR out
```

Use Case3: Dynamic VPN SRTE Policy

- Egress PE5 populates a vrf prefix 11.11.1.0/24 requires low latency service

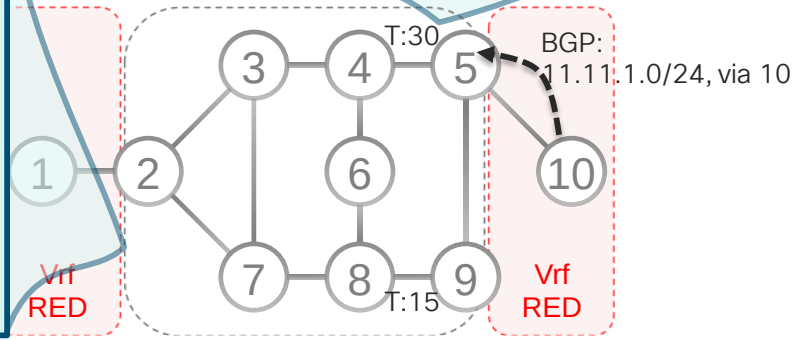
  => PE5 tags with extcommunity “color2”

- Ingress PE2 initiates on-demand policy by color template

  => PE2 finds a path to PE5 with optimized metric latency

```
extcommunity-set opaque color2
  2
end-set
!
route-policy bgp_col
 if destination in (11.11.1.0/24)  then
    set extcommunity color color2
  endif
end-policy
!
router bgp 1
 neighbor 1.1.1.2
  remote-as 1
  address-family vpnv4 unicast
  route-policy bgp_col out
```

```
router bgp 1
 neighbor 1.1.1.5
  address-family vpnv4 unicast
 vrf RED
  rd 2:2
  address-family ipv4 unicast
!
segment-routing
 traffic-eng
  on-demand color 2
   dynamic
     metric
     type latency
!
performance-measurement
 interface GigabitEthernet0/1/1/0
  delay-measurement
```



measure link delay to compute path latency
 # show isis database R1 verbose | inc Delay
Link Average Delay: 7 us
Link Min/Max Delay: 7/7 us

L3VPN Service Policy Work-flow and Steering

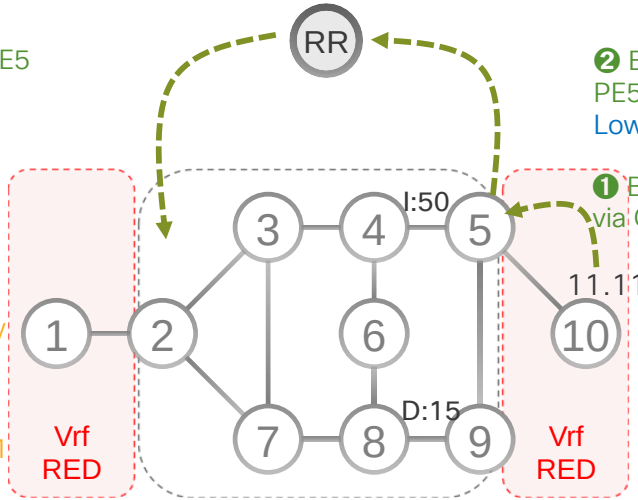
```
R1# show segment-routing traffic-eng policy color 2
Color: 2, End-point: 1.1.1.5
  Name: srte_c_2_ep_1.1.1.5
  Status:
    Admin: up  Operational: up for 00:39:14  (since Mar 31)
  Candidate-paths:
    Preference: 200 (BGP ODN) (active)
      Requested BSID: dynamic
      PCC info:
        Symbolic name: bgp_c_2_ep_1.1.1.5_discr_200
        PLSP-ID: 2
      Dynamic (valid)
        Metric Type: LATENCY,   Path Accumulated Metric: 10
          16005 [Prefix-SID, 1.1.1.5]
    Preference: 100 (BGP ODN)
      Requested BSID: dynamic
      PCC info:
        Symbolic name: bgp_c_2_ep_1.1.1.5_discr_100
        PLSP-ID: 1
      Dynamic
        Metric Type: NONE,   Path Accumulated Metric: 0
  Attributes:
    Binding SID: 24031
    Forward Class: 0
    Steering BGP disabled: no
    IPv6 caps enable: yes

# show cef vrf RED 11.11.1.0/24 | inc local-label
   via local-label 24031, 3 dependencies, recursive
```

❸ BGP: 110/24 via PE5
VPN-LABEL: 24016
Low-Delay (color 2)

❹ PE2 check prefix from PE5 with Low-latency (color 2)

❺ Initiate SRTE policy use template color 2

❻ Policy → SID-list <16005> BSID 24031



❷ BGP: 11.11.1.0/24 via PE5 VPN-LABEL: 24016
Low-Delay (color2)

❶ BGP: 11.11.1.0/24 via CE10

```
R1# show bgp vrf RED 11.11.1.0/24
Paths: (1 available, best #1)
Local
   2.2.2.2 C:2 (bsid:24031) (metric 10) from 2.2.2.2 (2.2.2.2)
     Received Label 24016
...
     Extended community: Color:2 RT:2:2
     SR policy color 2, up, registered, bsid 24031, if-handle 0x02000fe0
     Source AFI: VPNv4 Unicast, Source VRF: RED, Source Route Distinguisher: 2:2
```

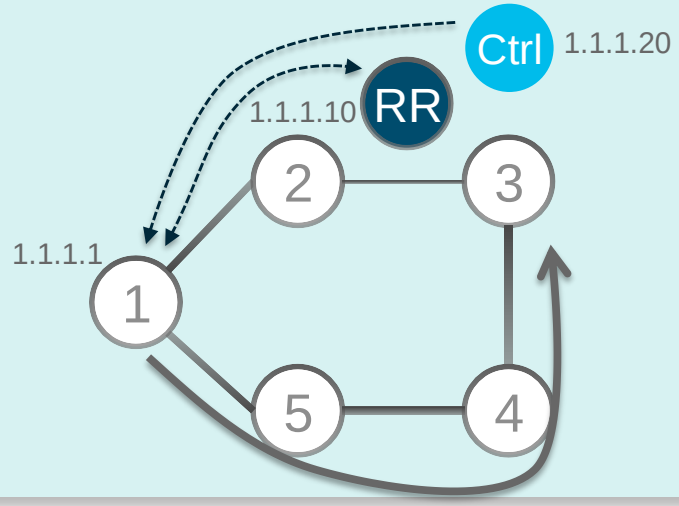
Use Case4: BGP SR-Policy Auto Initiated Policy

```
router bgp 1
 bgp router-id 1.1.1.1
 address-family ipv4 unicast
 address-family vpnv4 unicast
 address-family ipv4 sr-policy
 !
 neighbor 1.1.1.10
  remote-as 1
  update-source Loopback0
  address-family ipv4 unicast
  address-family vpnv4 unicast
 !
 neighbor 1.1.1.20
  remote-as 1
  update-source Loopback0
  address-family ipv4 sr-policy
```

To Service RR

To SRTE Controller

New BGP SAFI “sr-policy” conveys SR-TE policy and NLRI information to signal a candidate paths from controller to headend



IPv4 – SR Policy NLRI
- Color 10
- End-point 1.1.1.3
- Distinguisher 2

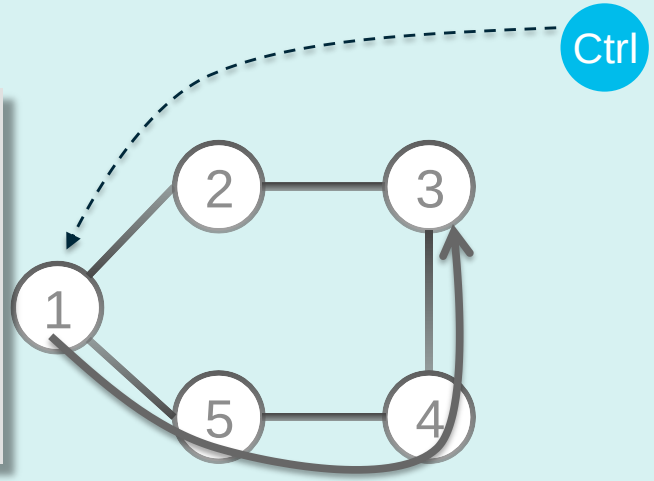
Tunnel encaps attr
- Preference 100
- Binding SID 999
- Segment List
  - Weight: 1
  - <16004, 16003>

```
curl http://1.1.1.1:8088/srpolicy-install -H "Content-Type: application/json" -X POST -d '{"source" : "1.1.1.1", "end-point" : "1.1.1.3", "binding-sid" : 999 "color" : 10, "preference" : 100, "route-distinguisher" : 0, "path-list" : [{"label-stack" : [16400 16300], "metric_te" : 30, "type" : sr-te}]}'
```

Controller Based NLRI Auto-Policy Steering

```
R1# show segment-routing traffic-eng policy
SR-TE policy database
---------------------
Name: bgp_AP_1 (Color: 10, End-point: 1.1.1.3)
   Status:
     Admin: up  Operational: up for 00:08:19 (since Jun 13 21:18:10.469)
   Candidate-paths:
     Preference 100:
       Explicit: segment-list Autolist_3_1* (active)
         Weight: 1, Metric Type: IGP
           16004 [Prefix-SID, 1.1.1.4]
           16003
   Attributes:
     Binding SID: 999
       Allocation mode: explicit
       State: Programmed
       Policy selected: yes
   Auto-policy info:
     Creator: BGP
```

IPv4 – SR Policy NLRI
Color 10
End-point 1.1.1.3
Distinguisher 2
Tunnel encaps attr
Preference 100
Binding SID 999
Segment List
Weight: 1
<16004, 16003>



Use Case5: Controller Multi-domain SRTE Policy

- SR-PCE build inter-domain topology based on the SR-TE DB
  - Learns an attached network domain topology via IGP or BGP-LS
  - Learns a remote domain topology via BGP-LS, directly or through a Route Reflector

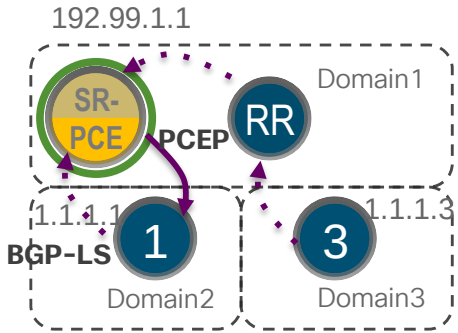
On SR-PCE:

```
pce
 address ipv4 192.99.1.1
!
router bgp 1
 address-family link-state link-state
 neighbor 1.1.1.1
  remote-as 101
  address-family link-state link-state
!
```

BGP-LS: Collection of ISIS / OSPF link state

On PCC:

```
segment-routing traffic-eng pcc
   source-address ipv4 1.1.1.1
   pce address ipv4 192.99.1.1
router isis 1    !! or ospf
 distribute link-state instance-id 101
router bgp 101
 address-family link-state link-state
 neighbor 192.99.1.1
  remote-as 1
  address-family link-state link-state
```



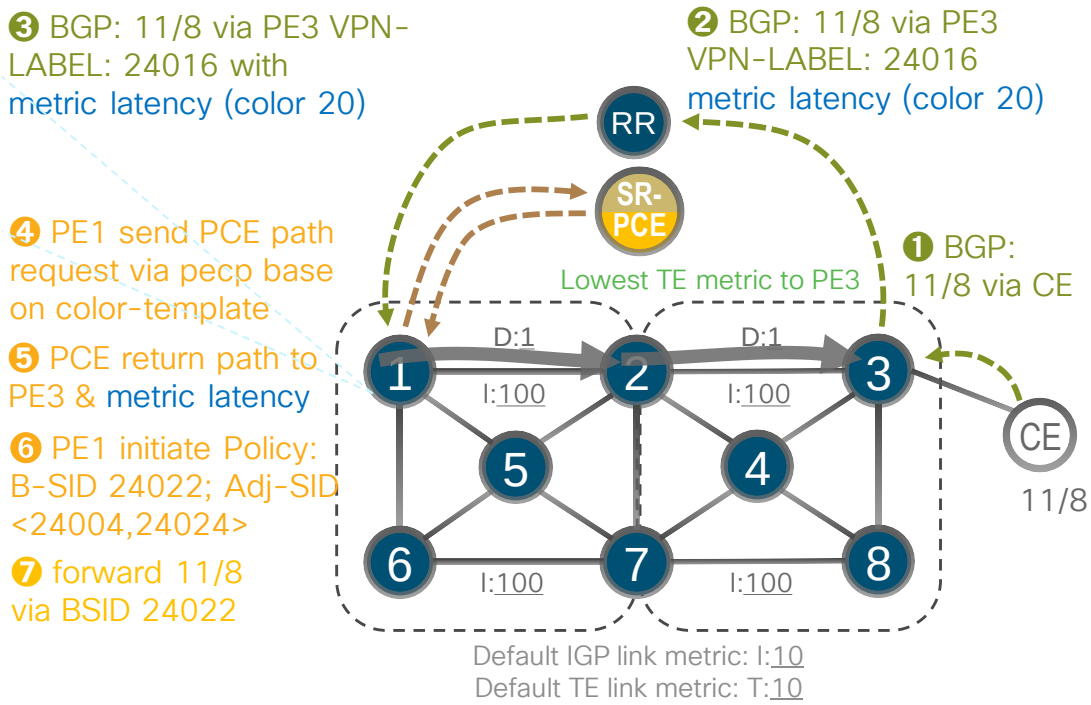

```
curl --raw -vN
"http://192.99.1.1:8080/lsp/create/simple?peer=1.1.1.1&name=rest_1_5&type=sr&
source=1.1.1.1&destination=1.1.1.3&color=10"
```

PCEP used to deploy policy

Centralized Inter-Domain SR-PCE Policy Steering

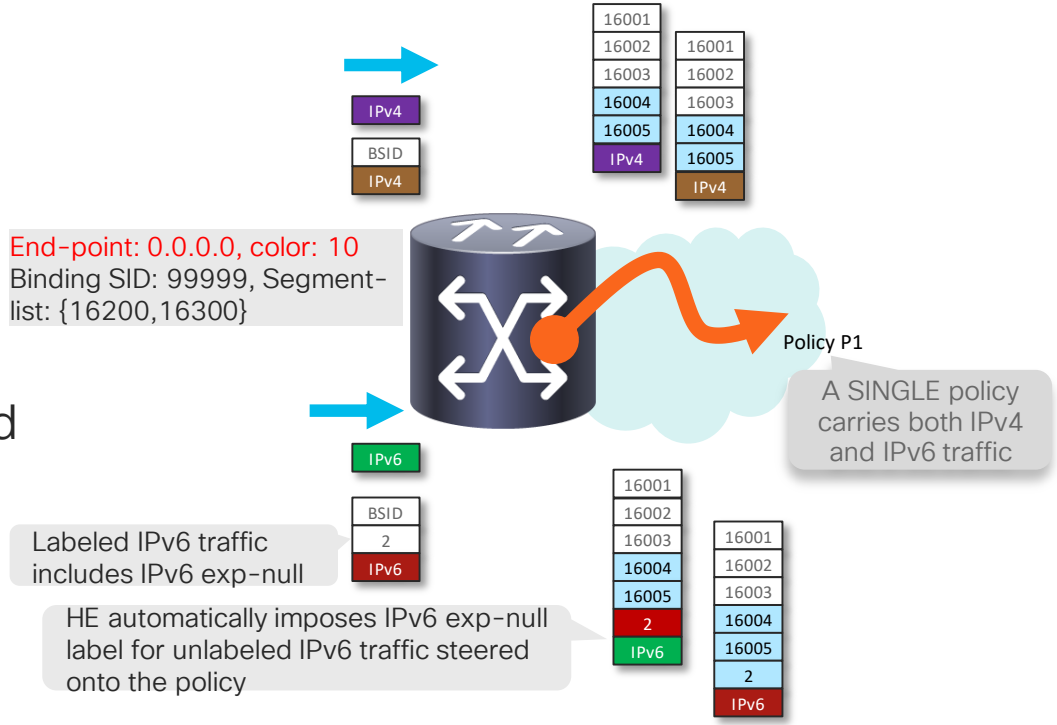
```
segment-routing
 traffic-eng
  policy pcep1
   color 20 end-point ipv4 1.1.1.3
    candidate-paths
     preference 200
      dynamic pcep
        metric type latency
```

```
R1#show segment-routing traffic-eng policy color 20
Color: 20, End-point: 1.1.1.3
  Name: srte_c_20_ep_1.1.1.3
  Status:
    Admin: up  Operational: up for 00:00:05 (Apr  9 09:58:11)
  Candidate-paths:
    Preference: 200 (configuration) (active) (reoptimizing)
      Name: pcep1
      Requested BSID: dynamic
      PCC info:
        Symbolic name: cfg_pcep1_discr_200
        PLSP-ID: 4
      Dynamic (pce 192.99.1.1) (valid)
        Metric Type: LATENCY,   Path Accumulated Metric: 20
          24004 [Adjacency-SID, 10.12.0.1 - 10.12.0.2]
          24024 [Adjacency-SID, 10.23.1.2 - 10.23.1.2]
  Attributes:
    Binding SID: 24022
```



Use Case6: Color-only Null-end Policy

- Single SR policy per color
  - Color-only and IPv6 enabled
  - Address Family Agnostic
- SR policy carries:
  - Labeled v4, Unlabeled v4
  - Labeled v6, Source expected to add v6-exp-null
  - Unlabeled v6, HE performs automatic v6-exp-null label push for unlabeled v6 traffic



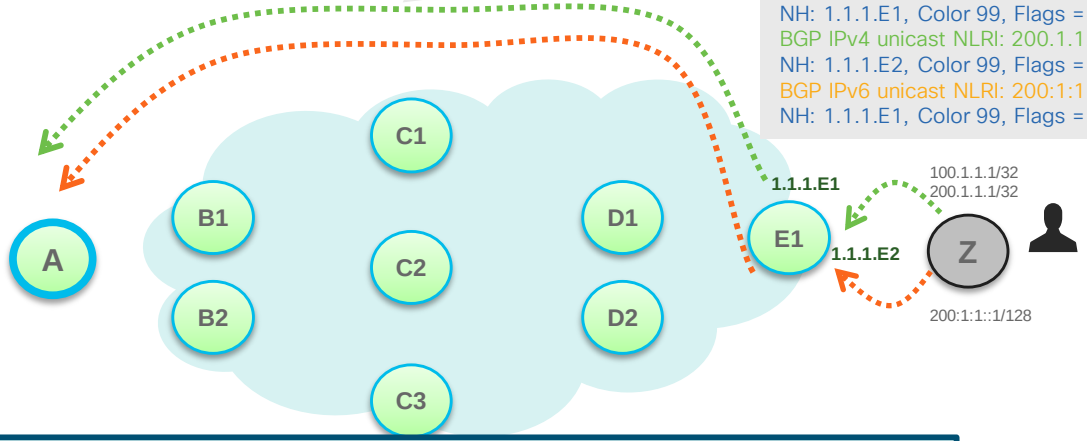
Color-only & AF-agnostic Steering

```
segment-routing
 traffic-eng
  policy c99-null-v4
   binding-sid mpls 999
   color 99 end-point ipv4 0.0.0.0
   ipv6 enable
   candidate-paths preference 111
     explicit segment-list SL-2-via-1
 segment-list name SL-2-via-1
   index 20 mpls label 16200
   index 30 mpls label 16300
```

```
R1# show segment traf policy binding-sid 99999
Color: 99, End-point: 0.0.0.0
  Name: srte_c_99_ep_0.0.0.0
  Status:
    Admin: up  Operational: up for 00:04:40 (since
Apr  9 18:59:37.047)
  Candidate-paths:
    Preference: 111 (configuration) (active)
      Name: c99-null-v4
      Requested BSID: 99999
      Explicit: segment-list SL-2-via-1 (valid)
        Weight: 1, Metric Type: TE
          16200 [Prefix-SID, 2.2.2.2]
          16300
  Attributes:
    Binding SID: 999
    Forward Class: 0
    Steering BGP disabled: no
    IPv6 caps enable: yes
```

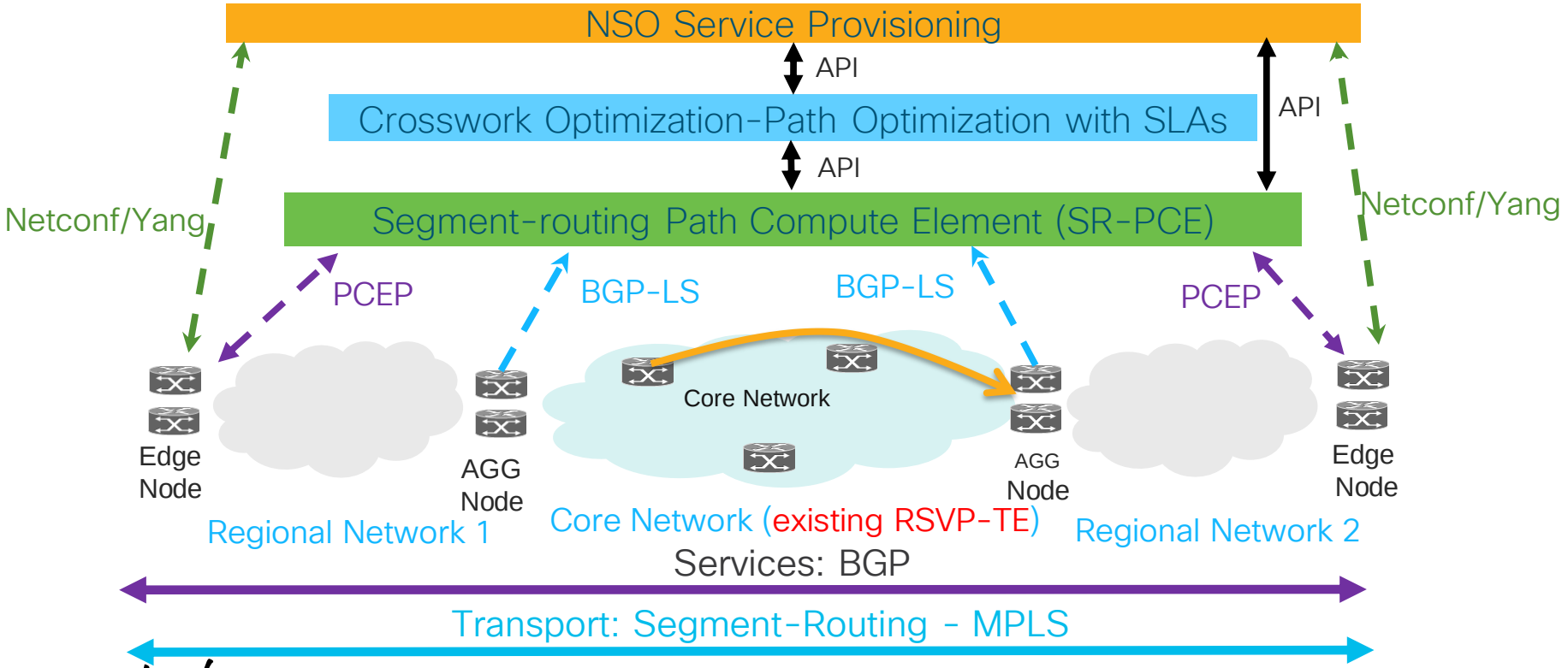
When "co-flag" set to 01, BGP prefix steering first match SR-TE policy color and endpoint. Otherwise, prefix color-only match going steer over a null-end Policy (C, null).

```
extcommunity-set opaque color99
  99 co-flag 01
end-set
!
BGP IPv4 unicast NLRI: 100.1.1.1/32
NH: 1.1.1.E1, Color 99, Flags = 01
BGP IPv4 unicast NLRI: 200.1.1.0/24
NH: 1.1.1.E2, Color 99, Flags = 01
BGP IPv6 unicast NLRI: 200:1:1::1/128
NH: 1.1.1.E1, Color 99, Flags = 01
```




```
R1# show cef 200.1.1.0/24
10.16.3.0/24, version 218468, internal 0x5000001 0x0 (ptr 0x784a1df8) [1], 0x0 (0x0), 0x0 (0x0)
 Updated Apr 10 08:18:57.113
 Prefix Len 24, traffic index 0, precedence n/a, priority 4
   via local-label 99999, 3 dependencies, recursive [flags 0x6000]
    path-idx 0 NHID 0x0 [0x78fbe2b8 0x0]
    recursion-via-label
    next hop via 999/1/21
```

Evolved Network to Unified SR Fabric



RSVP-TE Bandwidth Accounting

SR Accounting & RSVP resvBW Refresh

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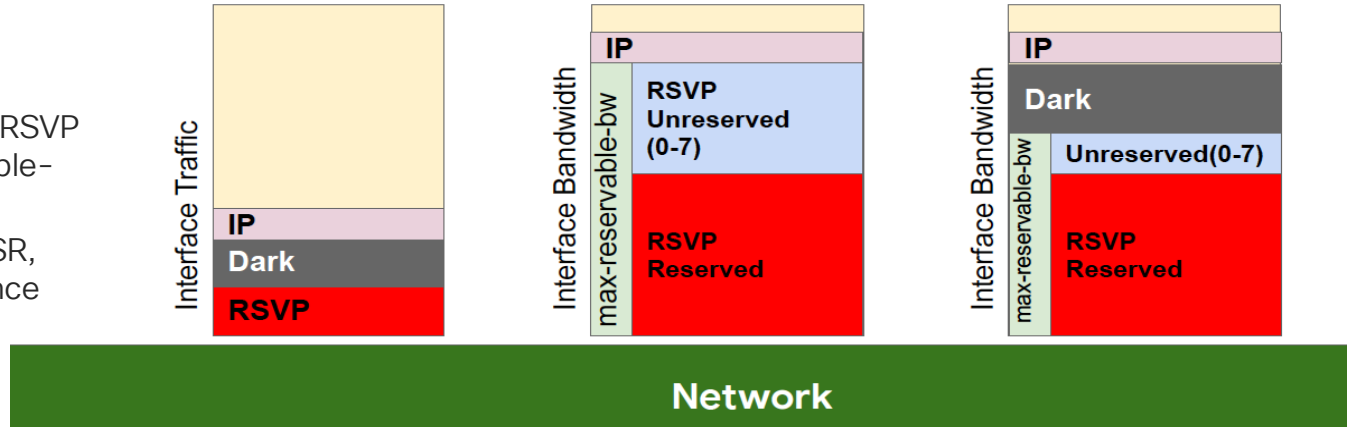
RSVP-TE AdmissionCtrl Aware of SR Accounting

- RSVP-TE non-zero Bandwidth
  - Web/OTT customers: full-mesh rsvp-te + auto-BW
  - Voice/Video Service Providers: full-mesh rsvp-te + auto-BW (or signalled-BW)
- SR-TE and RSVP-TE Coexistence
  - One of Web/OTT customer introduced the network migration base on RSVP-TE Bandwidth Accounting at MPLS World Congress

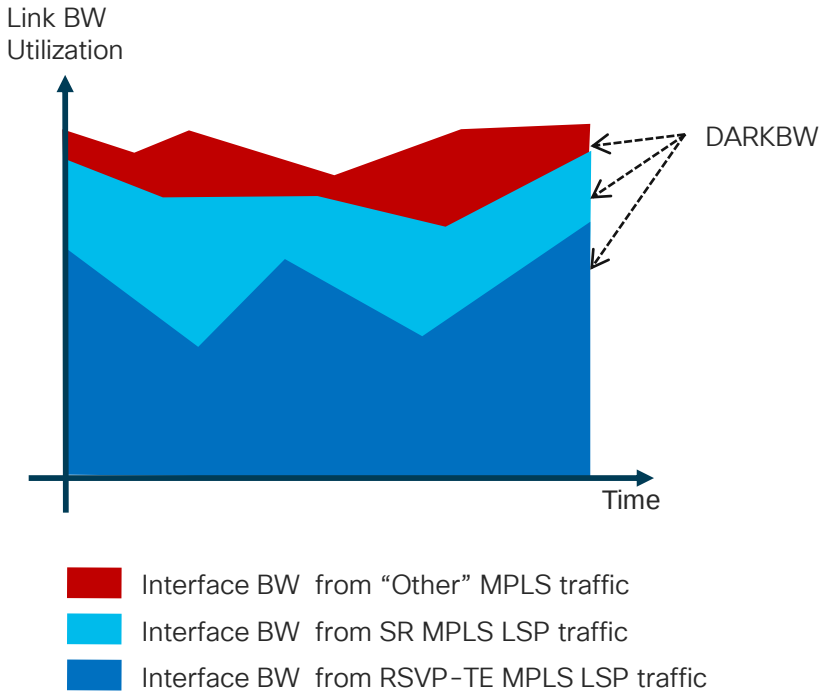
Dark Bandwidth

- SR traffic can alter RSVP Maximum-Reservable-Bandwidth
- Recommended in SR, RSVP-TE coexistence scenarios

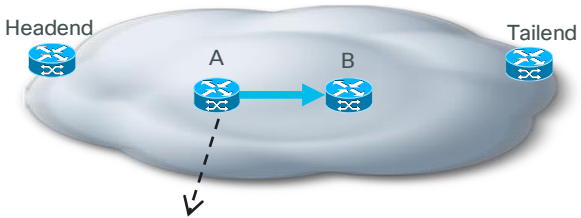


SR Accounting vs RSVP-TE “Dark Bandwidth”

- Subset of the traffic that is not explicitly admission controlled by RSVP-TE
- Those traffic bandwidth isn’t considered during RSVP-TE path computation as well as admission control
- It is assumed that SR traffic has higher priority than any other traffic transport with distributed RSVP-TE LSPs
- SR-accounting on RSVP links to trigger ResvBW refresh and gradually reduce the RSVP-TE bandwidth pool

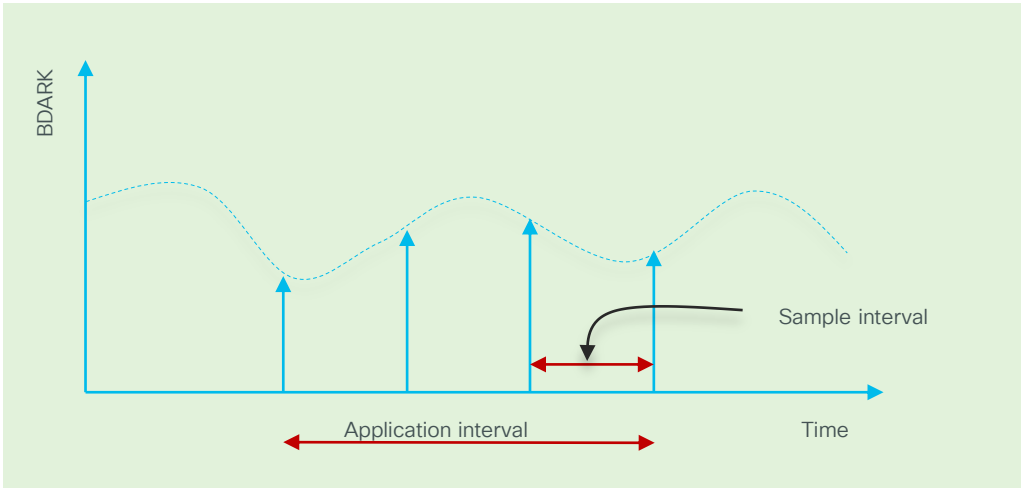


Dark Bandwidth Measurement



SR Traffic Link Utilization Collection

BDARK & “effective” resvBW Calculation

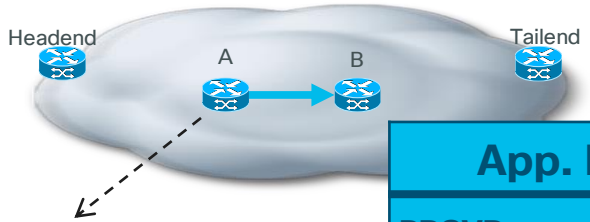


- BDARK @ application interval
  - An average of BDARK [t] samples is calculated
  - Configured Maximum Reservable-Bandwidth (BMRc)
  - “effective” resvBW flooded if change exceed threshold
- BDARK samples & “effective” resvBW (BMRe) calculated:
  - BDARK [t] = SR_IPv4 + SR_IPv6 + SR_MPLS
  - resvBW[t] = BMRc - BDARK [t]

RSVP-TE resvBW and Flooding Threshold

- RSVP-TE resvBW Counters:
  - BMRc = Configured Maximum Reservable Link Bandwidth
  - BMRe = Effective BMR
  - BMRef= last flooded BMRe
- "Effective" BMR (BMRe) collection @ application time [t]:
  - BMRe[t] = BMRc – BDARK[t] * K (K is a configurable adjustment-factor)
- Implementation provides BMRe flooding threshold as:
  - BMRe changes as a percentage of "last flooded BMRe" (BMRef)
  - Calculated as: $\frac{|\mathrm{BMRe} - \mathrm{BMRef}|}{\mathrm{BMRef}}$

Solution Overview – Flooding Action By Timeframe



Interface TenGigE0/0/1/0	
Physical BW	= 1,000
BMRc	= 900
Adjustment factor	= 100%
Flooding thr. Up	= 10%
Flooding thr. Down	= 10%

[1] $BDARK = Avg\ SR\ Samples$
[2] $\boldsymbol{BMRe = BMRc - BDARK}$
[3] $\Delta BMRe = \frac{|BMRe - BMRef|}{BMRef}$
[4] Assumes BMRef of 900 from T_0
[5] (|800 – 900|) / 900
[6] (|860 – 800|) / 800
[7] (|350 – 800|) / 800

App. Interval	T_1	T_2	T_3	T_4
BRSVP – RSVP utilized link BW	→ 200	→ 200	→ 200	→ 200
BDARK – SR utilized link BW	→ 0	↗ 100	↘ 40	↗ 550
BUTIL – Total utilized link BW	→ 200	↗ 300	↘ 240	↗ 750
BResvd – Total reserved link BW	300	300	300	300
BMRe – Effec. max reservable link BW	900	800	860	350
BMRef – Last flooded BMRe	900[4]	→ 900	→ 800	→ 800
ΔBMRe[3] – Change of BMRe	0	11.11%[5]	7.5% [6]	56.2% [7]
Action	No Flooding BMRef= 900	Flooding BMRef= 800	No Flooding BMRef= 800	Flooding BMRef= 350

Migration Solution Building Blocks

SR MPLS

- Source-routing
- Architecture brings right balance of distributed intelligence and centralized optimization
- Lightweight extensions to IP control-plane
- Leverages MPLS data and control plane

Auto-Steering

- Steer SR traffic away from RSVP-TE LSP by IGP sr-prefer, BGP color / endpoint match, and binding SID install

Dark Bandwidth

- Co-existence of non-zero bandwidth RSVP tunnels and SR in the same network domain
- Measure link utilization due to SR MPLS
- Adjust Maximum Link ResvBW (BMR) according to SR accounting

SR Traffic Engineering

- Simple, Automated and Scalable
- No core state – state in the packet header
- No tunnel interface – “SR Policy”
- BGP ODN candidate path
- Explicit local configured candidate paths
- Automate traffic steering
- Color-only match and AF- agnostic automated steering

RSVP-TE Bandwidth Accounting Provision

- BMRe[t] = BMRc – BDARK[t] * K, where:
  - K is a customer configurable adjustment-factor (0% to 200%)
  - K decide how aggressively react to RSVP-TE effective **resvBW** adjustment
  - resvBW refresh like "make before break", gradually reduce the RSVP-TE bandwidth pool

```
accounting interfaces
  segment-routing mpls
   ipv4
   ipv6
!
mpls traffic-eng
 bandwidth-accounting
  application
   enforced
   interval 90
  sampling-interval 10
  adjustment-factor 150
  flooding threshold up 10 down 10
```

K = 150%; by default K = 100%

SR Accounting Statistics

R1# show mpls traffic-eng link-management interfaces Gi0/1/1/0 detail

```
System Information::
   Links Count        : 16 (Maximum Links Supported 800)

Link ID:: GigabitEthernet0/1/1/0 (10.12.110.1)
  Local Intf ID: 22
  Link Status:

    Link Label Type          : PSC
    Physical BW              : 1000000 kbits/sec
    BCID                     : RDM
    Max Reservable BW        : 621981 kbits/sec (reserved: 94% in, 94% out)
    Flooded Max Reservable BW: 621981 kbits/sec
    BC0 (Res. Global BW)     : 529309 kbits/sec (reserved: 94% in, 94% out)
    BC1 (Res. Sub BW)        : 0 kbits/sec (reserved: 100% in, 100% out)
    MPLS TE Link State       : MPLS TE on, RSVP on, admin-up
    IGP Neighbor Count       : 1
    Max Res BW (RDM)         : 900000 kbits/sec
    BC0 (RDM)                : 900000 kbits/sec
    BC1 (RDM)                : 0 kbits/sec
    Max Res BW (MAM)         : 0 kbits/sec
    BC0 (MAM)                : 0 kbits/sec
    BC1 (MAM)                : 0 kbits/sec

    Bandwidth Accounting: Segment-Routing
    Bandwidth Accounting Enforced: Yes

(output continues on the right side)
* ResvBW = BMRc-BMRe = 621981
```

```
Bandwidth Utilization Details:
  Sampling Interval          : 10 sec
  Application Interval       : 90 sec
  Adjustment Factor          : 150%
  Max Reservable BW Up Threshold  : 10
  Max Reservable BW Down Threshold: 10
   Last Application at:  19:41:14 Sun 30 Apr 2017 (51 seconds ago)
    Segment-Routing BW Utilization     : 185346 kbits/sec
    Adjusted BW Utilization            : 278019 kbits/sec
    Enforced BW Utilization            : 278019 kbits/sec
  Next Application at:  19:42:43 Sun 30 Apr 2017 (in 38 seconds)
  Last Collection at :   19:40:42 Sun 30 Apr 2017 (13 seconds ago)
  Next Collection at :  19:40:51 Sun 30 Apr 2017 (in 6 seconds)

      Bandwidth Samples (Kbps):
  Timestamp                              Segment-Routing
       19:40:12 Sun 30 Apr 2017                  187961
       19:40:22 Sun 30 Apr 2017                  180130
       19:40:32 Sun 30 Apr 2017                  187949
       19:40:42 Sun 30 Apr 2017                  180124
Attributes        : 0x0
Ext Admin Group     :
   Length : 256 bits
   Value  : 0x::
Attribute Names     :
Flooding Status: (1 area)
  IGP Area[1]: IS-IS 0 level 2, flooded
    Nbr: ID 0000.0000.0002.00, IP 10.12.110.2 (Up)
    Admin weight: not set (TE), 10 (IGP)
Lockout Status: Never
```

SR Accounting & RSVP resvBW Refresh Monitoring

R1# show mpls traffic-eng link-management summary

```
System Information::
    Links Count         : 16 (Maximum Links Supported 800)
    Flooding System     : enabled
    IGP Areas Count     : 1

IGP Areas
----------

IGP Area[1]:: IS-IS 0 level 2
    Flooding Protocol   : IS-IS
    Flooding Status     : flooded
    Periodic Flooding   : enabled (every 180 seconds)
    Flooded Links       : 7
    IGP System ID       : 0000.0000.0001
    MPLS TE Router ID   : 1.1.1.1
    IGP Neighbors       : 7

Bandwidth accounting:
    Sampling interval: 10 seconds, Next in 9 seconds
    Application interval: 90 seconds, Next in 1 seconds
```

SR accounting intervals when bandwidth-accounting enabled

R1# show mpls traffic-eng link-management advertisements

```
Flooding Status             : Ready
Last Flooding               : 470 seconds ago
Last Flooding Trigger       : Link BW changed
Next Periodic Flooding In   : 136 seconds
Diff-Serv TE Mode           : Not enabled
Configured Areas            : 1

IGP Area[1]:: IS-IS 0 level 2
    Flooding Protocol   : IS-IS
    IGP System ID       : 0000.0000.0001
    MPLS TE Router ID   : 1.1.1.1
    Flooded Links       : 5

    Link ID:: 0 (GigabitEthernet0/1/1/0)
        Link IP Address     : 10.12.110.1
        O/G Intf ID         : 22
        Neighbor            : ID 0000.0000.0002.00, IP 10.12.110.2
        TE Metric           : 10
        IGP Metric          : 10
        Physical BW         : 1000000 kbits/sec
        BCID                : RDM
        Max Reservable BW   : 621981 kbits/sec
        Res Global BW       : 899999 kbits/sec
        Res Sub BW          : 0 kbits/sec
```

Effective BMRe triggers new resvBW flooding

Tunnel Pre-emption When Not Enough ResvBW

```
R1# show mpls traffic-eng link-management admission-control
    System Information::
    Tunnels Count     : 3
    Tunnels Selected  : 3
Bandwidth descriptor legend:
  B0 = bw from pool 0, B1 = bw from pool 1, R = bw locked, H = bw held
TUNNEL ID            UP IF     DOWN IF   PRI STATE        BW (kbits/sec)
----------------------- ---------- ---------- --- ------------ ---------------
1.1.1.1 10_6         -         Gi0/1/1/0   3/3 Resv Admitted 0              B0
1.1.1.1 10_7         -         Te0/3/0/1   3/3 Resv Admitted 800000         RB0

RP/0/RSP0/CPU0:Apr 30 19:43:51.209 : te_control[1178]: %ROUTING-MPLS_TE-5-LSP_REOPT : tunnel-te10 (signalled-name:
SRTE_RTR1_t10, old LSP Id: 6, new LSP Id: 7) has been reoptimized; reason: Soft Preemption.
```

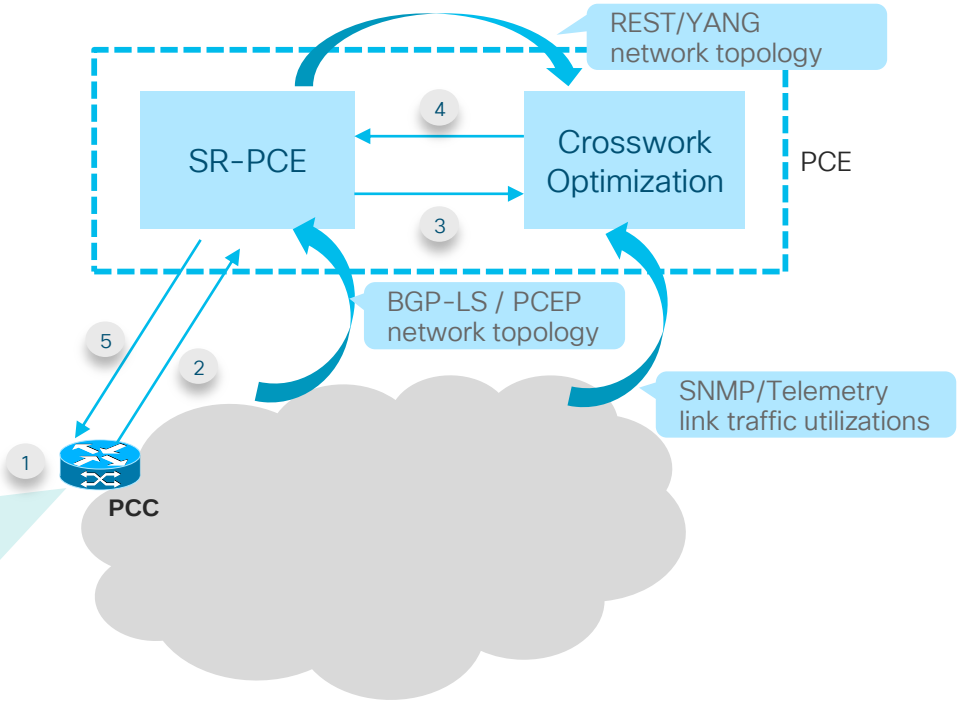
```
R1# show mpls traffic-eng link-management admission-control
            System Information::
    Tunnels Count     : 3
    Tunnels Selected  : 3
Bandwidth descriptor legend:
  B0 = bw from pool 0, B1 = bw from pool 1, R = bw locked, H = bw held
TUNNEL ID            UP IF     DOWN IF   PRI STATE        BW (kbits/sec)
----------------------- ---------- ---------- --- ------------ ---------------
1.1.1.1 10_3         -         Gi0/1/1/0   1/1 Resv Admitted 800000      RB0

RP/0/RSP0/CPU0:Apr 30 19:29:08.551 : te_control[1178]: %ROUTING-MPLS_TE-5-LSP_UPDOWN : tunnel-te10 (signalled-name:
SRTE_RTR1_t10, LSP Id: 3) state changed to down
 RP/0/RSP0/CPU0:Apr 30 19:29:25.131 : te_control[1178]: %ROUTING-MPLS_TE-5-LSP_UPDOWN : tunnel-te10 (signalled-name:
SRTE_RTR1_t10, LSP Id: 4) state changed to up
```

Use Case7: SRTE Policy with Bandwidth OnDemand

1. Operator configures SR-TE policy with bandwidth constraint
2. PCC sends PCReq to SR-PCE controller
3. SR-PCE requests BW-path from Crosswork Optimization
4. Crosswork Optimization returns BW-path (or no-path) to SR-PCE
5. SR-PCE sends BW-path (or no-path) to PCC

```
segment-routing
  traffic-eng
    policy BW123
      bandwidth 888
      color 10 end-point ipv4 3.3.3.3
      candidate-paths
      preference 100
       dynamic pcep
```

CLI inter-domain policy path calculated by PCE



BWoD Policy Configure and Show Output

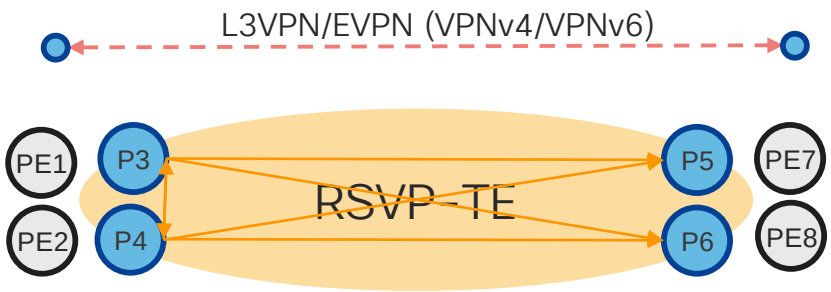
```
segment-routing
 traffic-eng
  pcc
   pce address ipv4 192.99.1.1
  !
  policy BW123
   bandwidth 888
   color 10 end-point ipv4 3.3.3.3
   autoroute
   !
   candidate-paths
    preference 100
     dynamic pcep
      metric
       type te
  !
```

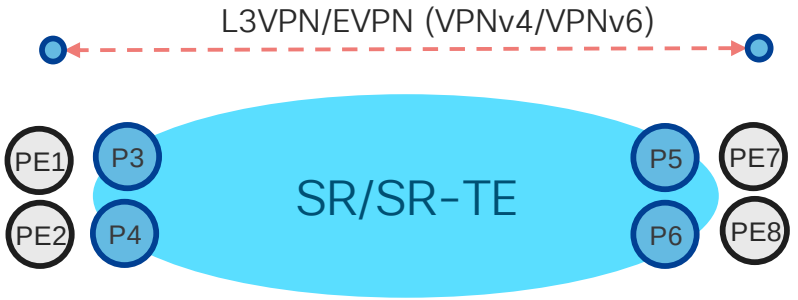
```
pcc# show segment-routing traffic-eng policy
SR-TE policy database
---------------------
Name: BW123 (Color: 10, End-point: 3.3.3.3)  ID: 1
  Status:
    Admin: up  Operational: up for 2d19h (since Jan 27
18:10:16.545)  Candidate-paths:
    Preference 100:
      Dynamic (pce 192.99.1.1) (active), valid yes
        Weight: 0, Metric Type: TE
        IGP area: 0
          16300 [Prefix-SID, 3.3.3.3]
  Attributes:
    Binding SID: 25056
      Allocation mode: dynamic
      State: Programmed
      Policy selected: yes
    Forward Class: 0
    Bandwidth Requested: 888 kbps
    Bandwidth Current: 888 kbps
```

Key Takeaways

You make networking **possible**

Migrate to Scalable and Programmable Network





RSVP-TE

- RSVP-TE Mesh for FRR
- Config+State for N(N-1) Tunnels
- Traffic steering by IGP autoroute

Segment Routing

- Automatic 100% FRR with TI-LFA
- Explicit/Dynamic Stateless Policy
- Traffic steering by policy B-SID

SR Unified Fabric Attributes

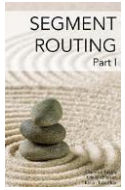
Stay Up-To-Date

http://www.segment-routing.net/

https://www.linkedin.com/groups/8266623

https://twitter.com/SegmentRouting

https://www.facebook.com/SegmentRouting/



Segment Routing, Part I - Textbook

Complete your online session evaluation

- Please complete your session survey after each session. Your feedback is very important.
- Complete a minimum of 4 session surveys and the Overall Conference survey (starting on Thursday) to receive your Cisco Live water bottle.
- All surveys can be taken in the Cisco Live Mobile App or by logging in to the Session Catalog on ciscolive.cisco.com/us.

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Walk-in labs

Meet the engineer 1:1 meetings

Related sessions

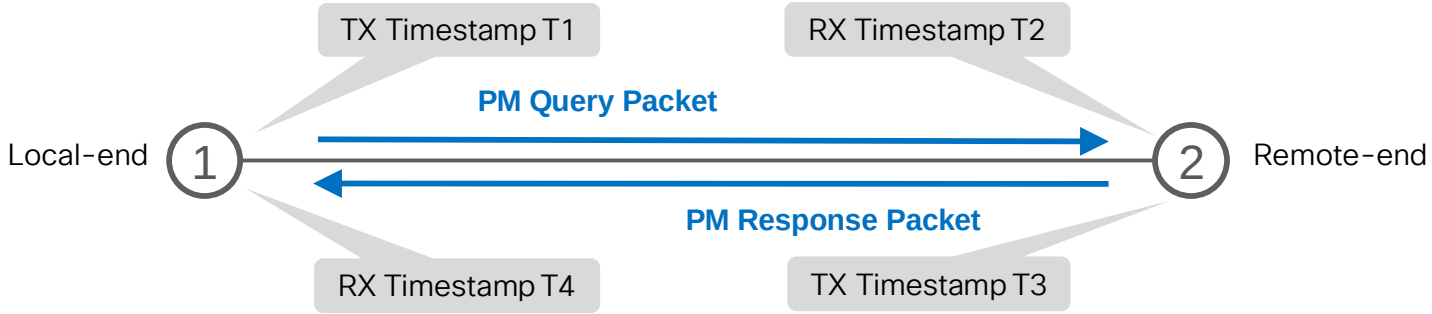
Thank you

You make **possible**

Acronym

- SR-TE — Segment Routing Traffic Engineering
- RSVP-TE — Resource Reservation Protocol Traffic Engineering
- TI-LFA — Path Protection with Topology Independent Loop Free Alternative
- RESTAPI — An application program interface (API) that uses HTTP requests to GET, PUT, POST and DELETE data.
- node-SID — A special type of prefix SID with node flag that identifies a specific node.
- adjacency SID — A dynamically allocated segment SID on an interface
- BSID — Binding SID used to identify an active candidate path of a policy
- PCE — Path Computation Element
- PCC — Path Computation Client
- NLRI — Network Layer Reachability Information
- BMR — Maximum Reservable Link Bandwidth
- BMRc — Configured Maximum Reservable Link Bandwidth
- BMRe — Effective BMR
- BMRef — last flooded BMRe

Link Delay Measurement

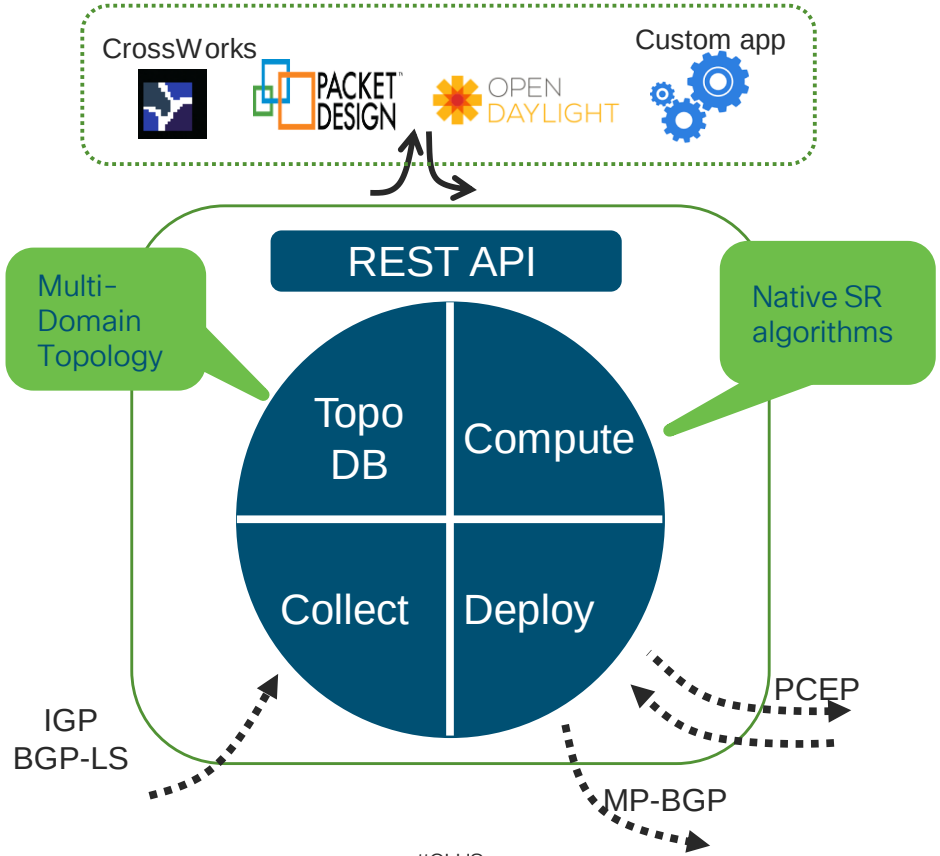


- Two-Way Delay = (T2 – T1) + (T4 – T3)
  = (T4 – T1) – (T3 – T2)
- One-way Delay = (Two-Way Delay)/2

- Measure link delay to compute path latency
- Advertised via IGP TE Metric Extensions
- SRTE optimize path on min-delay

```
# show isis database R1 verbose | i Delay
    Link Average Delay: 7 us
    Link Min/Max Delay: 7/7 us
```

SR-PCE Controller Architecture



Egress Peer Engineering (EPE)

Applicability Examples

Internet Peering

Engineered
Exit Points

Solution

SDN controller based approach to instruct an **ingress PE** to use a **specific egress PE** and a **specific external interface/neighbor** to reach a **particular destination.**

Benefits

Intent-based

SLA-aware BGP service

Optimal decisions based on cost, latency, loss

Optimal use of resources