



Segment Routing: Enterprise Use Cases

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Agenda

- 1 Segment Routing Architecture
- 2 Troubleshooting Simplification
- 3 Traffic Protection with TI-LFA
- 4 Low Latency SR-TE Policy



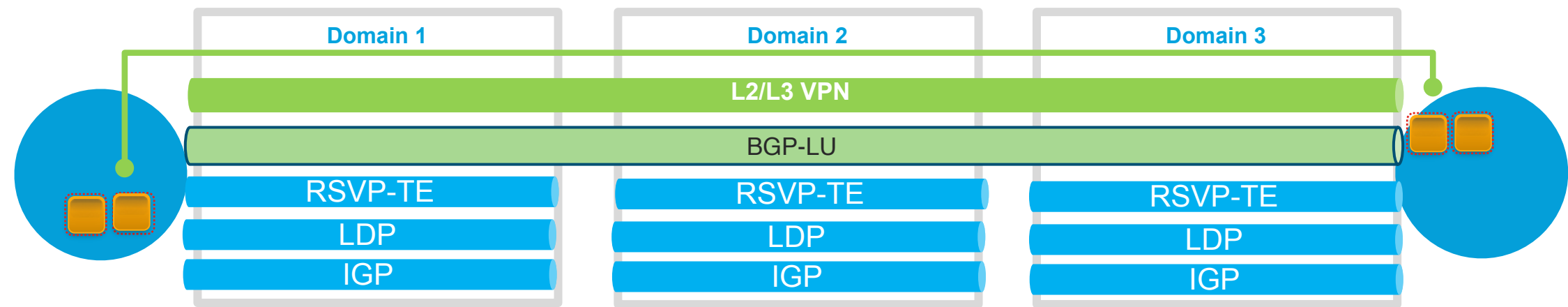
Segment Routing Architecture

Agenda

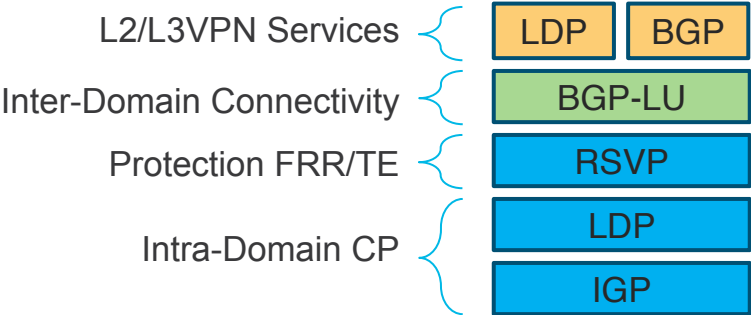
- Why Segment Routing
- SR Data Planes

From Unified MPLS to Segment Routing

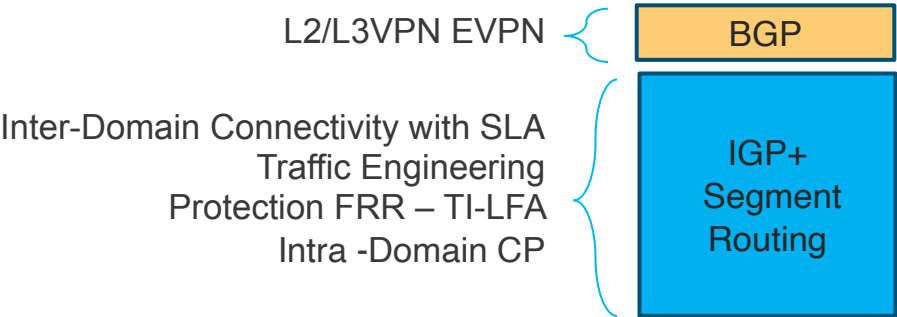
Protocol stack and network **simplification**



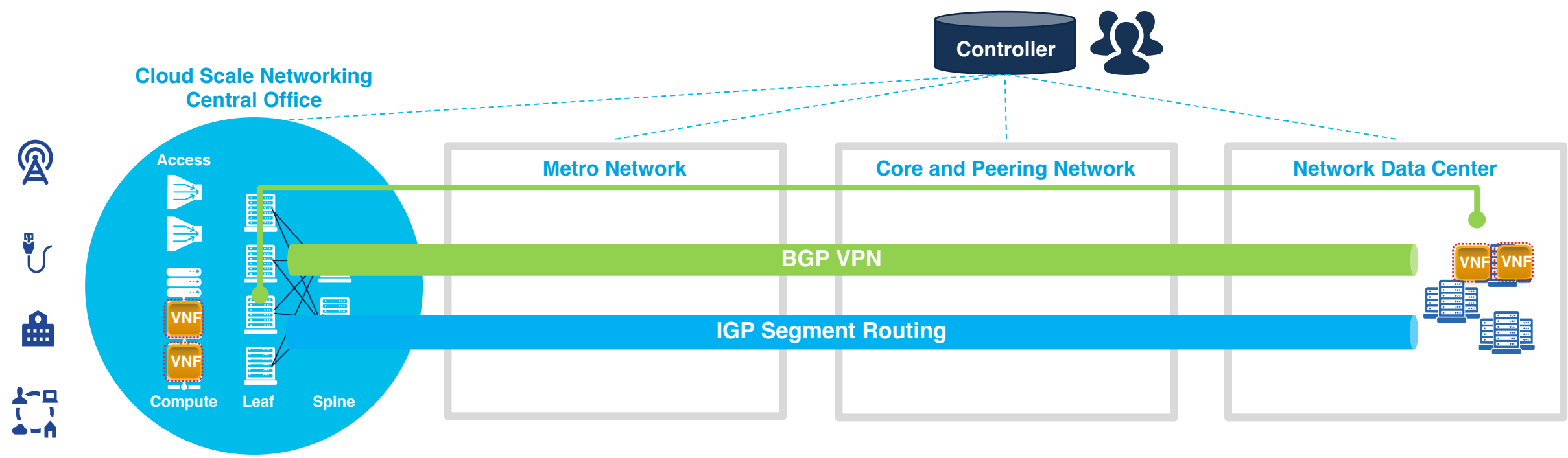
Unified MPLS



Segment Routing Stateless Fabric



Unified “Stateless Fabric” for Service Creation



Simplify

Unified underlay and overlay networks with segment routing and EVPN



Automate

E2E Cross-domain automation with model-driven programmability and streaming telemetry



Virtualize

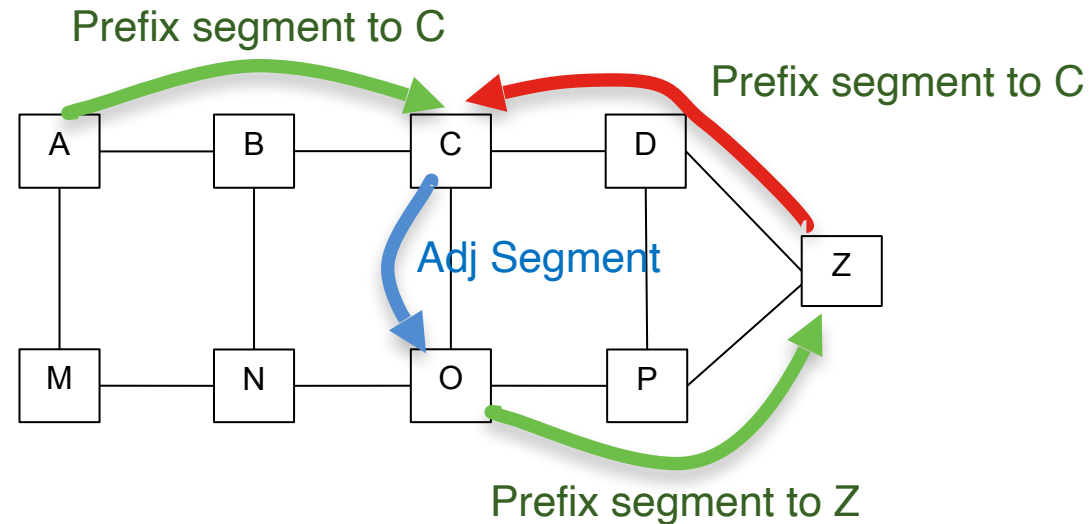
Transform the CO into a data center to enable distributed service delivery and speed up service creation

Segment Routing

- Source Routing
 - the topological and service (NFV) path is encoded in packet header
- Scalability
 - the network fabric does not hold any per-flow state for TE or NFV
- Simplicity
 - automation: TILFA sub-50msec FRR
 - protocol elimination: LDP, RSVP-TE, VxLAN, NSH, GTP, ...
- End-to-End
 - DC, Metro, WAN

Segment Routing – IGP Segments

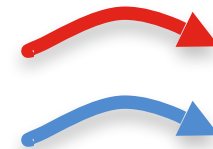
Simple extension to IGP



- Simple extension to IS-IS or OSPF, automatically builds and maintains Segments

Prefix Segment – A Shortest path to the related prefix

Adjacency Segment – One hop through the related adjacency



Two dataplane instantiations

Segment Routing

A diagram showing the text 'Segment Routing' on the left. Two blue curved arrows originate from it: one points upwards and to the right towards the 'MPLS' section, and the other points downwards and to the right towards the 'IPv6' section.

MPLS

- leverage the mature MPLS HW with only SW upgrade
- ✓ • 1 segment = 1 label
- a segment list = a label stack

IPv6

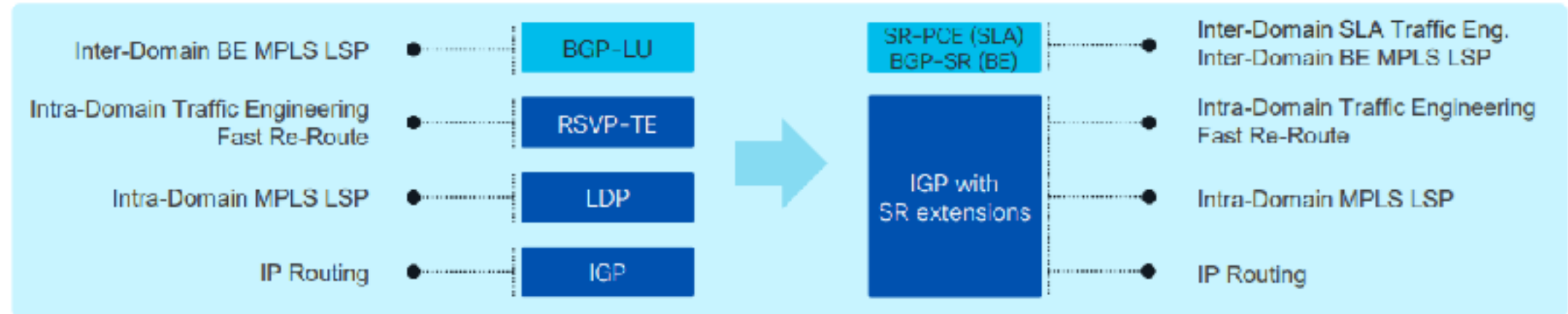
- ✓ • leverages RFC8200 provision for source routing extension header
- 1 segment = 1 address
- a segment list = an address list in the SRH

Network Evolution with SR-MPLS

Service Protocols



Transport Protocols



Data-Plane



Network Evolution with SRv6

Service Protocols



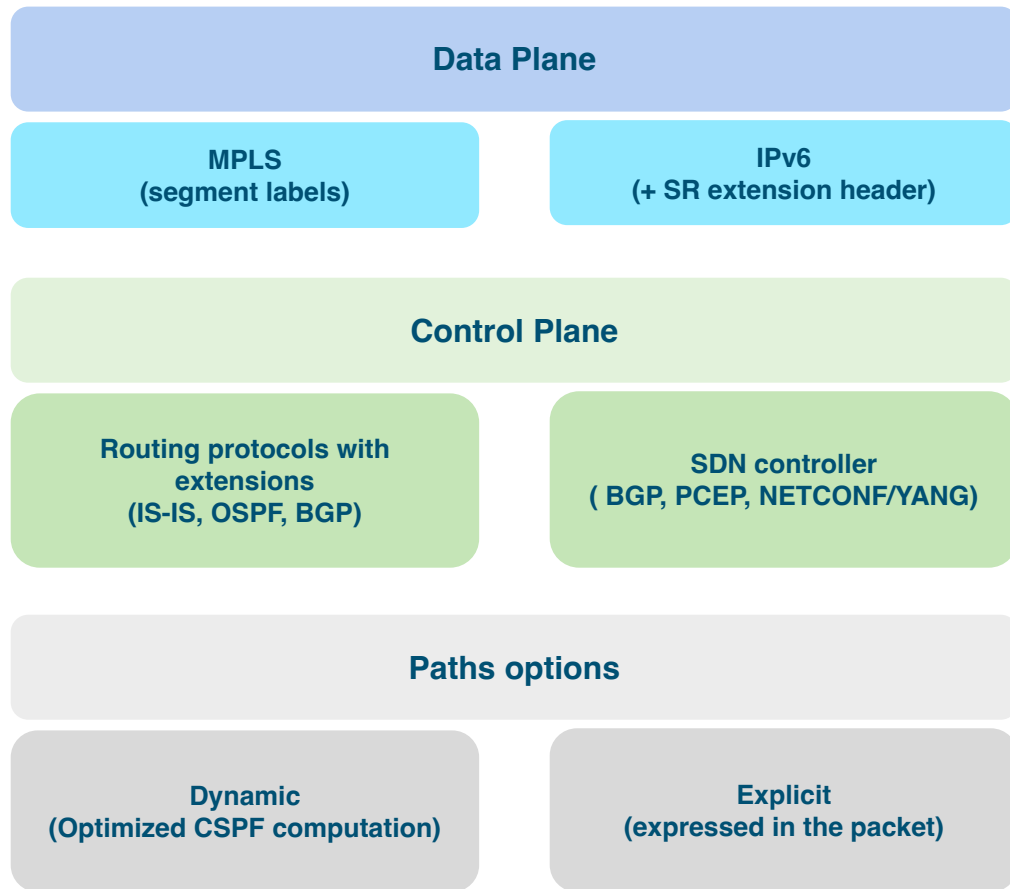
Transport Protocols



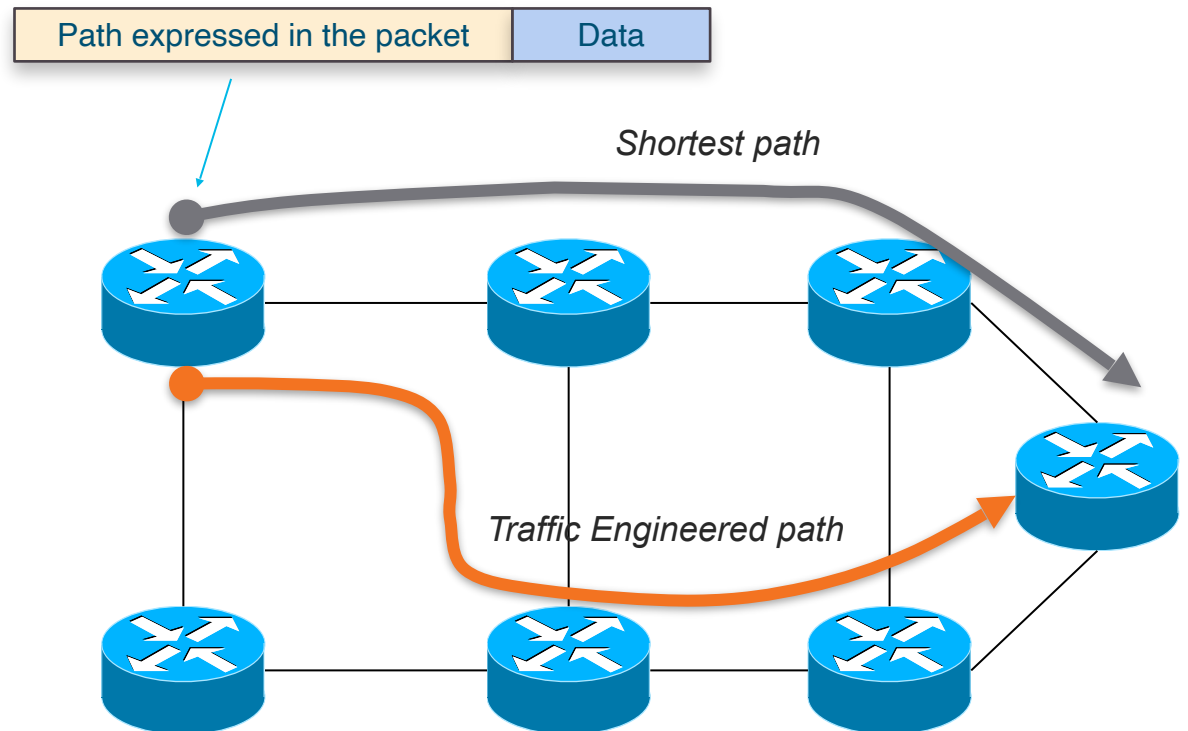
Data-Plane



Segment Routing



- Source Routing paradigm
- Stateless IP fabric !!!



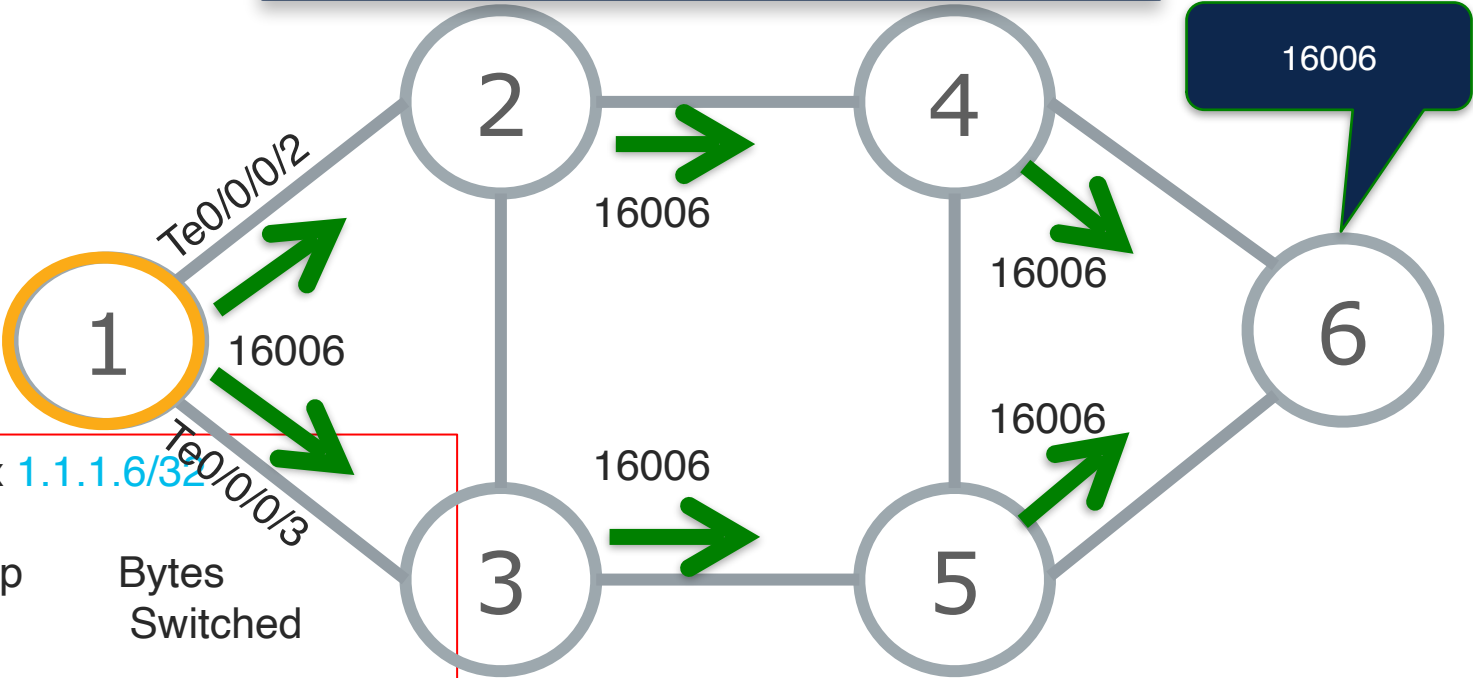
Troubleshooting Simplification

IGP Prefix Segment

Shortest-path to the IGP prefix
Global Segment

```
router isis CORE                                !!R6
address-family ipv4 unicast
metric-style wide level 2
segment-routing mpls
segment-routing mpls sr-prefer
!
interface Loopback0
address-family ipv4 unicast
prefix-sid index 6
!
```

Loopback0
1.1.1.6/32
16006



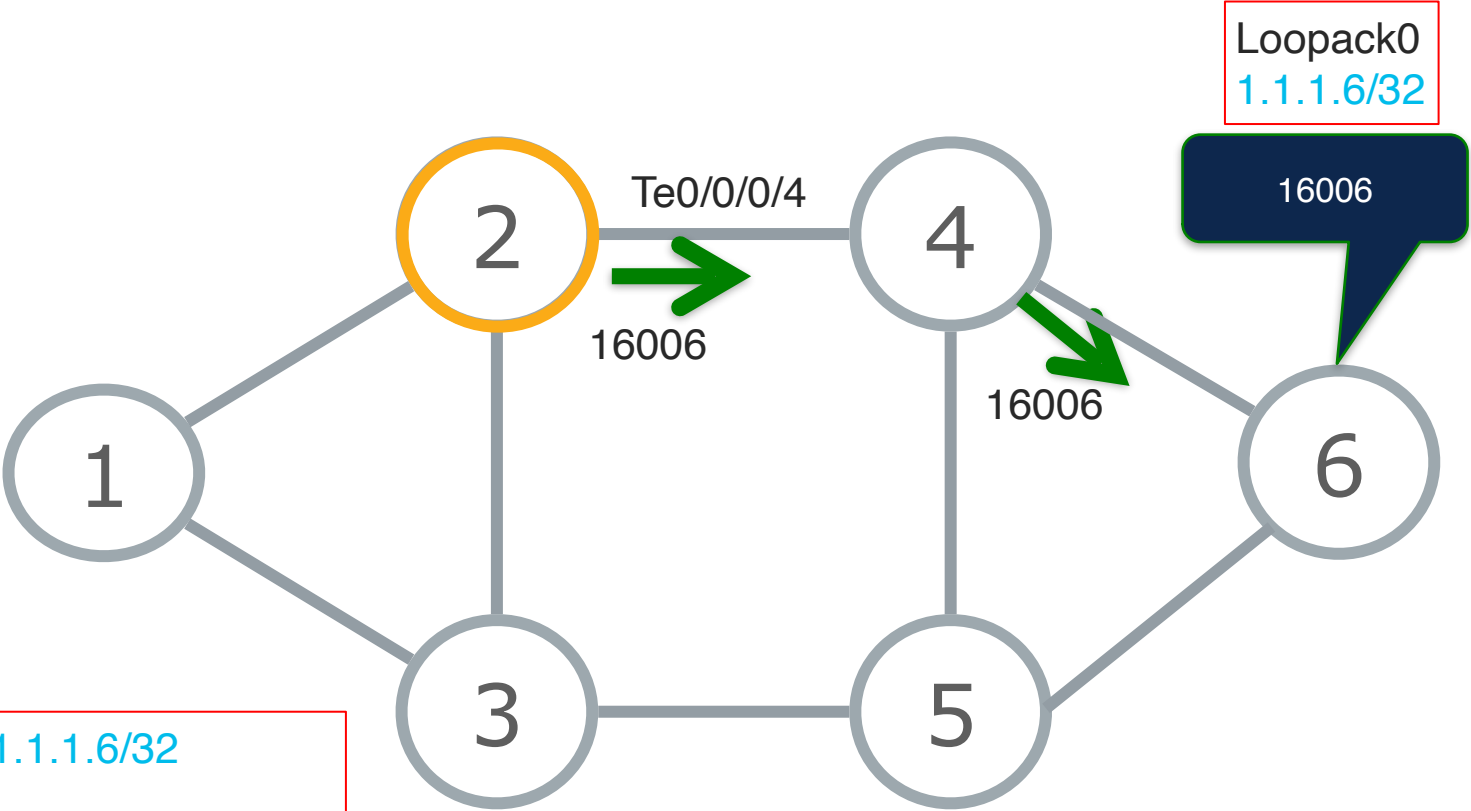
Global Segment

RP/0/RP0/CPU0:Node-1#sh mpls forwarding prefix 1.1.1.6/32
Tue Jan 29 10:30:53.133 UTC

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
16006	16006	1.1.1.6/32	Te0/0/0/2	77.1.2.2	0
	16006	1.1.1.6/32	Te0/0/0/3	77.1.3.3	0

IGP Prefix Segment

Shortest-path to the IGP prefix
Global Segment



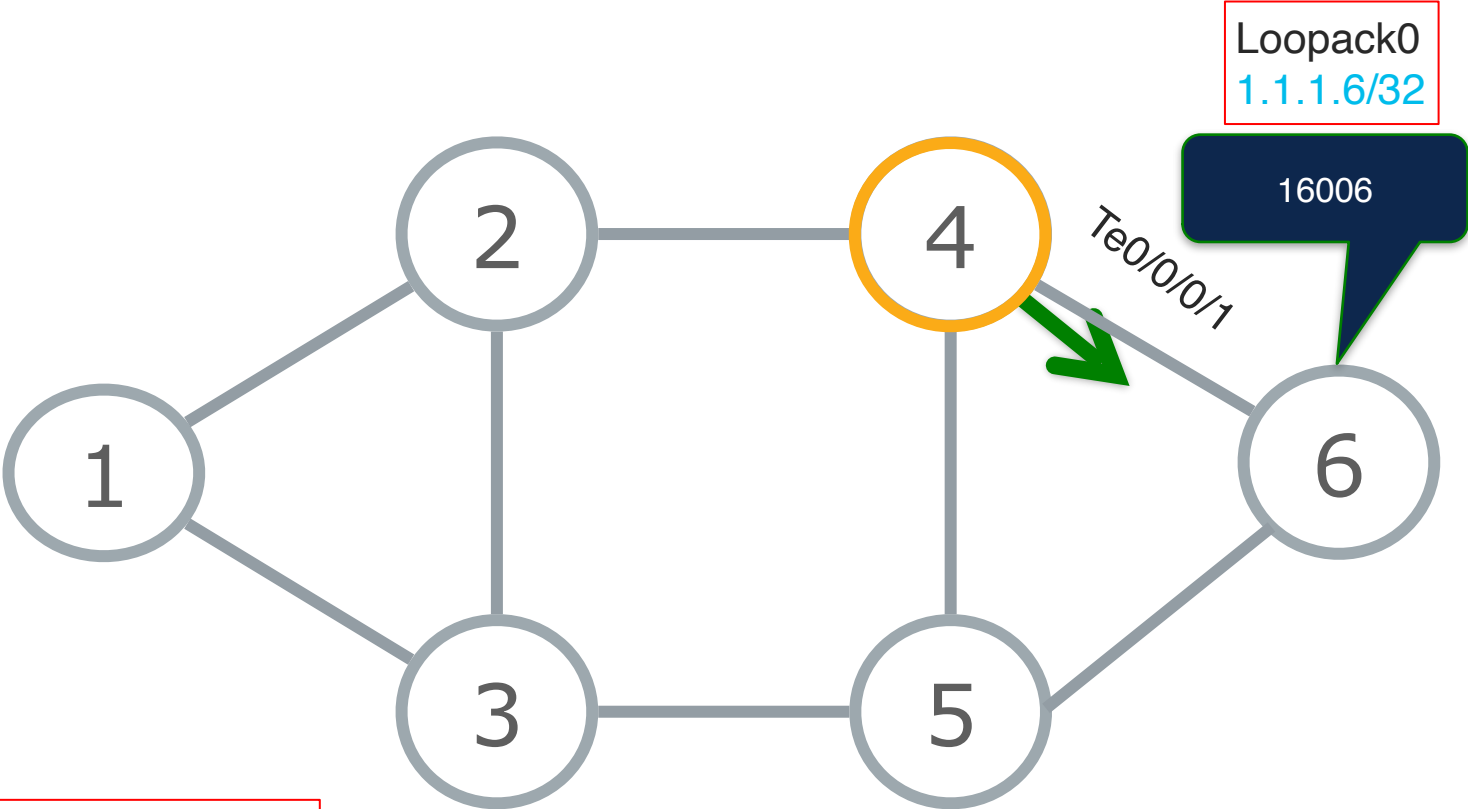
Global Segment

```
RP/0/RP0/CPU0:Node-2#sh mpls forwarding prefix 1.1.1.6/32
Tue Jan 29 10:30:53.133 UTC
```

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
16006	16006	1.1.1.6/32	Te0/0/0/4	77.2.4.4	0

IGP Prefix Segment

Shortest-path to the IGP prefix
Global Segment



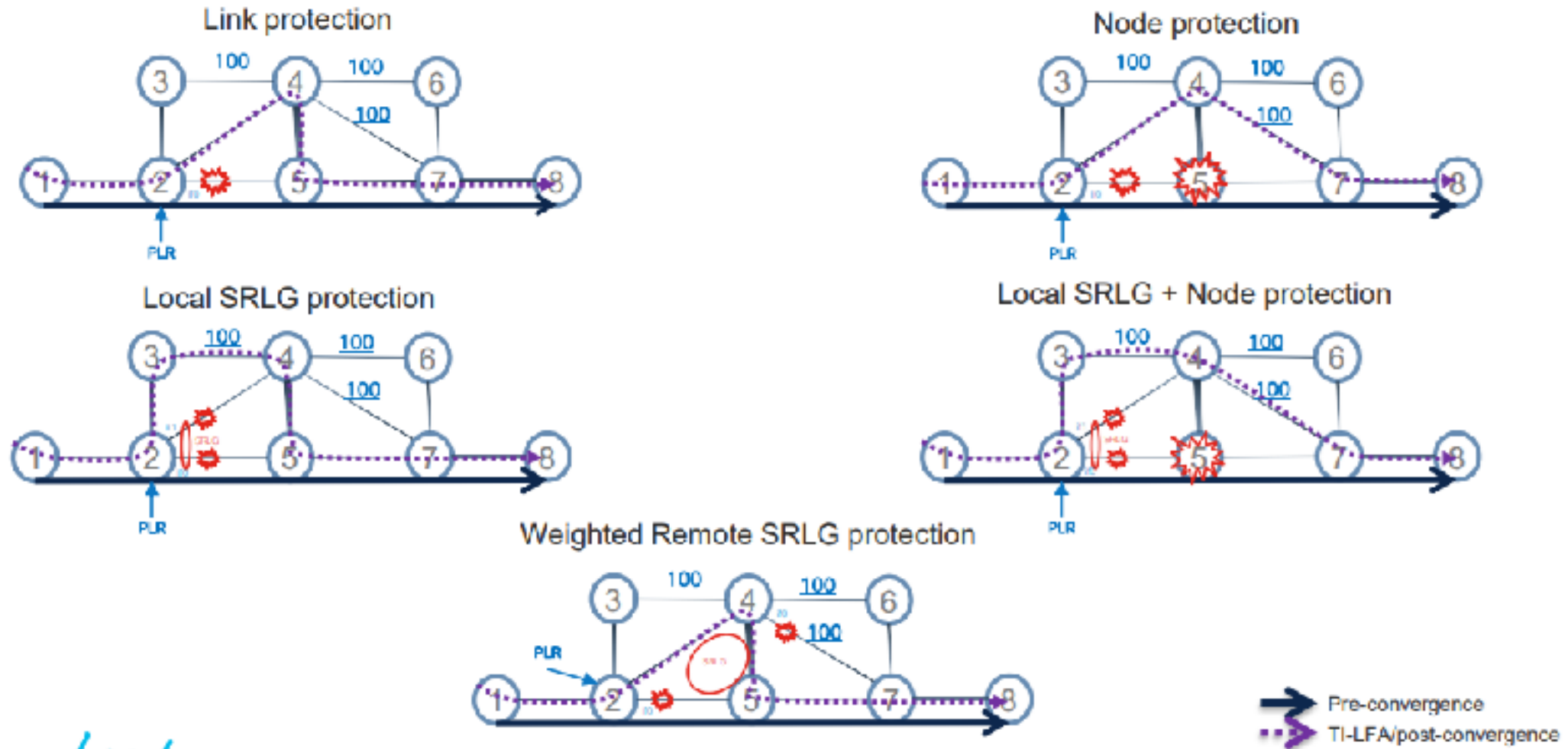
Global Segment

RP/0/RP0/CPU0:Node-3#sh mpls forwarding prefix 1.1.1.6/32
Tue Jan 29 10:30:53.133 UTC

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
16006	Pop	1.1.1.6/32	Te0/0/0/1	77.4.6.4	0

Traffic Protection with TI-LFA

Protect with automatic TI LFA FRR



Topology Independent LFA (TI-LFA) – Benefits

100%-coverage 50-msec link, node, and SRLG protection

Simple to operate and understand

```
!IOS-XR
!  
Router ospf 1  
  segment-routing mpls  
  fast-reroute per-prefix  
  fast-reroute per-prefix ti-lfa enable  
!
```

```
!IOS-XE  
!  
Router ospf 1  
  segment-routing area 0 mpls  
  fast-reroute per-prefix  
  fast-reroute per-prefix ti-lfa enable  
  microloop avoidance segment-routing  
!
```

TI-LFA protection Coverage

```
!IOS-XR
```

```
RP/0/RSP0/CPU0:PE1#sh route 172.27.244.84
```

```
Fri Jun 23 15:01:00.947 MEST
```

```
Routing entry for 172.27.244.84/32
```

```
Known via "ospf 1", distance 110, metric 31, labeled SR, type intra area
```

```
Installed Jun 23 10:53:38.950 for 04:07:22
```

```
Routing Descriptor Blocks
```

```
172.16.1.2, from 172.16.0.6, via TenGigE0/0/0/10, Protected
```

```
Route metric is 31
```

```
172.16.1.26, from 172.16.0.6, via TenGigE0/0/0/8, Backup (TI-LFA)
```

```
Repair Node(s): 172.16.0.41
```

```
Route metric is 52
```

```
No advertising protos.
```

Enabling TI-LFA under IS-IS interface (example)

```
!  
router isis CORE  
  interface GigabitEthernet0/0/0/0  
    address-family ipv4 unicast  
      fast-reroute per-prefix ti-lfa  
  !  
  !  
  interface GigabitEthernet0/0/0/1  
    address-family ipv4 unicast  
      fast-reroute per-prefix ti-lfa  
  !  
  !  
  interface GigabitEthernet0/0/0/3  
    address-family ipv4 unicast  
      fast-reroute per-prefix ti-lfa  
  !
```

TI-LFA protection Coverage

```
RP/0/0/CPU0:XR-1#show isis fast-reroute summary
IS-IS SR-AS-1 IPv4 Unicast FRR summary
```

	Critical Priority	High Priority	Medium Priority	Low Priority	Total
Prefixes reachable in L2					
All paths protected	0	0	4	8	12
Some paths protected	0	0	0	0	0
Unprotected	0	0	0	0	0
Protection coverage	0.00%	0.00%	100.00%	100.00%	100.00%



Low Latency SR-TE Policy

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.

Performance Measurement (PM)

- The PM for link delay uses the IP/UDP packet format defined in RFC 5357 (TWAMP-Light) for probes
- The feature is required on all links over the path
- P2P configuration on IGP is required for flooding the value.
- For link bundles, the hashing function may select a member link for forwarding but the reply may come from the remote line card on a different member link of the bundle.
- For one-way delay measurement, clocks should be synchronized on two end-point nodes of the link using PTP.

OSPF

Value	Sub-TLV
27	Unidirectional Link Delay
28	Min/Max Unidirectional Link Delay
29	Unidirectional Delay Variation

OSPF

- RFC 7471 (OSPF Traffic Engineering (TE) Metric Extensions)
- Used to advertise extended TE metrics – e.g. link delay (in usec)

SR-TE R-MPLS-AREA6-1

```
!IOS-XR
!
Router ospf 65
  distribute link-state
  router-id 10.13.0.11
  segment-routing mpls
  segment-routing sr-prefer
  address-family ipv4 unicast
  area 0
    !mpls traffic-eng
    interface Loopback0
      prefix-sid absolute 16061
      fast-reroute per-prefix
      fast-reroute per-prefix ti-lfa enable
    !
  interface TenGigabitEthernet0/0/1/1
  !
  interface TenGigabitEthernet0/0/1/0
  !
```

show segment-routing traffic-eng policy color 100

```
segment-routing
  global-block 16000 23999
  !
  traffic-eng
    policy SRTE_SACOI_61_71
    color 100 end-point ipv4 10.13.0.13
    candidate-paths
      preference 100
      dynamic
      metric
      type latency
    !
  !
  performance-measurement
    interface TenGigabitEthernet0/0/1/1
      delay-measurement
      next-hop ipv4 10.13.1.74
    !
    interface TenGigabitEthernet0/0/1/0
      delay-measurement
      next-hop ipv4 10.13.1.49
    !
```

SR-TE R-MPLS-AREA6-1

```
!IOS-XR
!  
interface TenGigE0/0/1/2.400 l2transport  
  encapsulation dot1q 400  
  rewrite ingress tag pop 1 symmetric  
  mtu 1518  
!  
l2vpn  
!  
pw-class PW_CLASS_SACOI_61_71  
  encapsulation mpls  
  ipv4 source 10.13.0.11  
  preferred-path sr-te policy SRTE_SACOI_61_71 fallback disable  
!  
!  
!
```

SR-TE R-MPLS-AREA7-1

```
!IOS-XE
!
segment-routing mpls
  set-attributes
    address-family ipv4
    sr-label-preferred
    exit-address-family
  !
  global-block 16000 23999
  !
  connected-prefix-sid-map
    address-family ipv4
    10.13.0.13/32 absolute 16071 range 1
    exit-address-family
  !
router ospf 65
  router-id 10.13.0.13
  segment-routing area 0 mpls
  segment-routing mpls
  fast-reroute per-prefix ti-lfa
  microloop avoidance segment-routing
  distribute link-state
  !
```

```
segment-routing traffic-eng
  policy SRTE_SACOI_71_61
    color 100 end-point 10.13.0.11
    candidate-paths
      preference 100
      constraints
        segments
          dataplane mpls
        !
      !
      dynamic
        metric
          type delay
        !
      performance-measurement
        delay-measurement
    !
  performance-measurement
    interface Ten0/4/1
      delay-measurement
      next-hop ipv4 10.13.1.78
    !
    interface TenGigabitEthernet0/4/2
      delay-measurement
      next-hop ipv4 10.13.1.57
```

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-1#sh performance-measurement sessions

Thu Apr 4 13:41:50.922 CET

Transport type : Interface

Measurement type : Delay Measurement

Interface name : TenGigE0/0/1/0

Nexthop : 10.13.1.49

Delay Measurement session:

Session ID : 1

Last advertisement:

Advertised at: Apr 04 2024 09:46:46.113 (14104.829 seconds ago)

Advertised reason: First advertisement

Advertised delays (uSec): avg: 234, min: 233, max: 234, variance: 1

Next advertisement:

Threshold check scheduled in 2 more probes (roughly every 120 seconds)

Aggregated delays (uSec): avg: 233, min: 233, max: 233, variance: 0

Rolling average (uSec): 233

Current Probe:

Started at: Apr 04 2024 13:41:23.566 (27.376 seconds ago)

Packets Sent: 10, received: 10

Measured delays (uSec): avg: 233, min: 233, max: 233, variance: 0

Next probe scheduled at: Apr 04 2024 13:41:53.499 (in 2.557 seconds)

Next burst packet will be sent in 2.557 seconds

Burst packet sent every 3.0 seconds

Responder IP : 10.13.1.49

Number of Hops : 1

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-1#sh performance-measurement sessions !!second interface

Transport type : Interface
Measurement type : Delay Measurement
Interface name : TenGigE0/0/1/1
Nexthop : 10.13.1.74
Delay Measurement session:
Session ID : 2

Last advertisement:

Advertised at: Apr 04 2024 09:57:31.617 (13459.325 seconds ago)
Advertised reason: First advertisement
Advertised delays (uSec): avg: 10, min: 9, max: 10, variance: 1

Next advertisement:

Threshold check scheduled in 3 more probes (roughly every 120 seconds)
No probes completed
Rolling average (uSec): 9

Current Probe:

Started at: Apr 04 2024 13:41:38.736 (12.206 seconds ago)
Packets Sent: 5, received: 5
Measured delays (uSec): avg: 9, min: 9, max: 9, variance: 0
Next probe scheduled at: Apr 04 2024 13:42:08.661 (in 17.719 seconds)
Next burst packet will be sent in 2.719 seconds
Burst packet sent every 3.0 seconds
Responder IP : 10.13.1.74
Number of Hops : 1

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-1#sh segment-routing traffic-eng policy

Thu Apr 4 14:00:14.404 CET

SR-TE policy database

Color: 100, End-point: 10.13.0.13

Name: srte_c_100_ep_10.13.0.13

Status:

Admin: up Operational: up for 00:01:22 (since Apr 4 13:58:30.921)

Candidate-paths:

Preference: 100 (configuration) (active)

Name: SRTE_SACOI_61_71

Requested BSID: dynamic

Maximum SID Depth: 10

Dynamic (valid)

Metric Type: LATENCY, Path Accumulated Metric: 172

16062 [Prefix-SID, 10.13.0.12]

16072 [Prefix-SID, 10.13.0.14]

16071 [Prefix-SID, 10.13.0.13]

Attributes:

Binding SID: 24187

Forward Class: Not Configured

Steering labeled-services disabled: no

Steering BGP disabled: no

IPv6 caps enable: yes

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-1#sh segment-routing traffic-eng policy

Thu Apr 4 14:21:14.582 CET

SR-TE policy database

Color: 100, End-point: 10.13.0.13

Name: srte_c_100_ep_10.13.0.13

Status:

Admin: up Operational: up for 00:22:23 (since Apr 4 13:58:30.921)

Candidate-paths:

Preference: 100 (configuration) (active)

Name: SRTE_SACOI_61_71

Requested BSID: dynamic

Maximum SID Depth: 10

Dynamic (valid)

Metric Type: LATENCY, Path Accumulated Metric: 299235

16062 [Prefix-SID, 10.13.0.12]

16002 [Prefix-SID, 10.13.0.2]

16001 [Prefix-SID, 10.13.0.1]

16071 [Prefix-SID, 10.13.0.13]

Attributes:

Binding SID: 24187

Forward Class: Not Configured

Steering labeled-services disabled: no

Steering BGP disabled: no

IPv6 caps enable: yes

R-MPLS-PE-AREA7-1#sh segment-routing traffic-eng policy all
Name: SRTE_SACOI_71_61 (Color: 100 End-point: 10.13.0.11)

Owners : CLI

Status:

Admin: up, Operational: up for 00:00:20 (since 04-04 13:59:10.284)

Candidate-paths:

Preference 100 (CLI):

Dynamic (active)

Metric Type: DELAY, Path Accumulated Metric: 239
16061 [Prefix-SID, 10.13.0.11]

Attributes:

Binding SID: 228

Allocation mode: dynamic

State: Programmed

SR-TE R-MPLS-AREA6-2: Tshoot policy down

```
!IOS-XR
!
Router ospf 65
  distribute link-state
  router-id 10.13.0.12
  segment-routing mpls
  segment-routing sr-prefer
  address-family ipv4 unicast
  area 0
    mpls traffic-eng
    interface Loopback0
      prefix-sid absolute 16062
      fast-reroute per-prefix
      fast-reroute per-prefix ti-lfa enable
    !
  interface GigabitEthernet0/0/0/0
  !
```

```
segment-routing
  global-block 16000 23999
!
  traffic-eng
    policy SRTE_SACOI_62_32
      color 100 end-point ipv4 10.13.0.18
      candidate-paths
        preference 100
        dynamic
          metric
            type latency
      !
    !
  performance-measurement
    interface GigabitEthernet0/0/0/0
      delay-measurement
        next-hop ipv4 10.13.1.94
    !
```

show segment-routing traffic-eng policy color 100

Why the policy is Down?

Last error: unresolved first label 16032

```
RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-2#show segment-routing traffic-eng policy state down
Thu Mar 28 13:45:01.207 CET

SR-TE policy database
-----

Color: 100, End-point: 10.13.0.18
Name: srte_c_100_ep_10.13.0.18
Status:
  Admin: up Operational: down for 01:03:15 (since Mar 28 12:41:26.159)
Candidate-paths:
  Preference: 100 (configuration)
  Name: SRTE_SACOI_62_32
  Requested BSID: dynamic
  Maximum SID Depth: 10
  Dynamic (invalid)
  Last error: unresolved first label (16032)
  Metric Type: LATENCY, Path Accumulated Metrics: 293
  16032 [Prefix-SID, 10.13.0.18]
Attributes:
  Forward Class: 0
  Steering labeled-services disabled: no
  Steering BGP disabled: no
  IPv6 caps enable: no
```

SR-TE R-MPLS-AREA6-2

```
Policy Down : troubleshooting
show mpls forwarding
show mpls forwarding labels 16032
detail
show cef 10.13.0.18/32 detail
show segment-routing traffic-eng
policy
```

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-2#show mpls forwarding
Tue Apr 2 11:25:43.332 CET

Local Label	Outgoing Label	Prefix or ID	Outgoing Interface	Next Hop	Bytes Switched
16001	16001	SR Pfx (idx 1)	Te0/0/1/0	10.13.1.53	0
	16001	SR Pfx (idx 1)	Te0/0/1/1	10.13.1.73	0
16002	Pop	SR Pfx (idx 2)	Te0/0/1/0	10.13.1.53	803428
[deleted output]					
16061	Pop	SR Pfx (idx 61)	Te0/0/1/1	10.13.1.73	799204
16071	16071	SR Pfx (idx 71)	Te0/0/1/0	10.13.1.53	0

RP/0/RSP1/CPU0:R-MPLS-PE-AREA6-2#show mpls forwarding labels 16032 detail

Tue Apr 2 11:26:02.685 CET
!empty output

We found a misconfiguration for prefix sid : on the router we had a typo 16132

REFERENCES

Performance measurement configuration guidelines

https://www.cisco.com/c/en/us/td/docs/iosxr/ncs5500/segment-routing/72x/b-segment-routing-cg-ncs5500-72x/configure-performance-measurement.html#id_118505

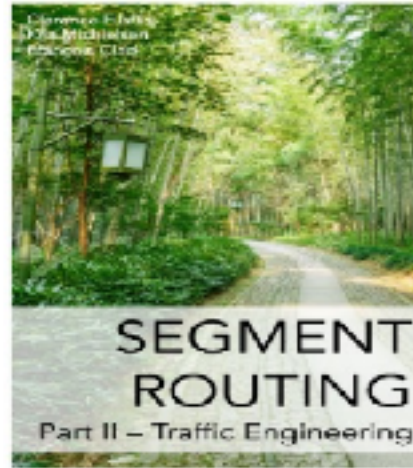
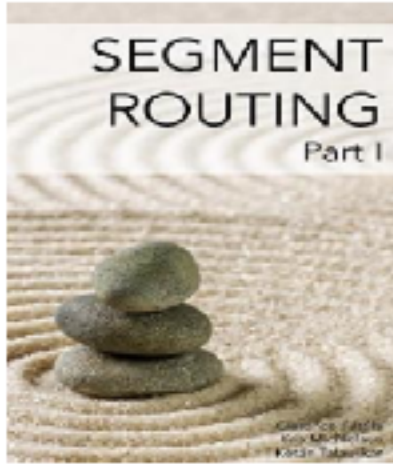
https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/seg_routing/configuration/xe-17/segrrt-xe-17-book/m-sr-performance-measurement.html

Configure SR TE policy Cisco IOS-XR

<https://www.cisco.com/c/en/us/td/docs/iosxr/ncs560/segment-routing/79x/b-segment-routing-cg-79x-ncs560/m-configure-sr-te-policy-new-cli-ncs5xx.pdf>

SR MPLS – Performance Monitoring

<https://www.segment-routing.net/images/tutorials/sr-mpls-pm-rev1g-km1.pdf>



Segment Routing Part I by Clarence Filsfils (Author), Kris Michielsen (Author), Ketan Talaulikar (Author)

Segment Routing Part II – traffic Engineering by Clarence Filsfils (Author), Kris Michielsen (Author), Francois Clad (Author), Daniel Voyer (Author)