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KHNOG
Cambodia Network Operators Group

MPLS LDP/RSVP-TE Migration to Segment Routing MPLS(SR-MPLS)

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Agenda

MPLS Historical Information

- **MPLS** is a Technology Framework that Transforms Traditional TCP/IP Networks through the introduction of a **label switching** mechanism rather than **destination-based lookup** hop-by-hop basic.
- **MPLS** can allow core routers to switch packets based on some simplified header.
- **MPLS** significantly improves the efficiency and scalability of network routing.

Applications of MPLS

- **ISPs: E**nabling flexible, scalable services with multi-protocol capabilities and efficient traffic engineering, ensuring optimal network performance for customers.
- **Mobile Networks:** The utilization of MPLS in mobile backhaul networks is on the rise, effectively managing the surge in traffic from the increasing number of mobile devices. This ensures a secure and smooth user experience, with the ability to separate internet, voice, signaling, and management traffic over a shared infrastructure.
- **Enterprise Networks:** Enterprises benefit from MPLS by establishing secure and streamlined (WANs) for various services. This enables reliable, high-speed data transmission across multiple locations, ensuring scalability, flexibility, and optimized traffic engineering for improved network performance.

What’s Segment Routing MPLS (SR-MPLS)?

- **Segment Routing** is a Routing Technology that fundamentally transforms the Routing Framework, allowing the Source Node to determine the entire path of a packet, including all intermediate hops, from its origin to the final destination.
- Simple to deploy and operate
    - Leverage MPLS services & hardware
    - straightforward ISIS/OSPF extension to distribute labels LDP/RSVP not required
    - Provide for optimum scalability, resiliency and virtualization
    - SDN enabled ready
        - simple network, highly programmable, highly responsive

What's Segment Routing MPLS (SR-MPLS)?

Label Range:	Reserved Label:	Use For:
0 – 15	Base special-purpose MPLS labels	0 = IPv4 Explicit NULL 3 = Implicit NULL
16 – 15,999	Static MPLS labels	LDP assigned
16,000 - 23,999	SRGB	Global Segments (i.e., SR)
24,000 - 1,048,575	Dynamic allocation	Adjacency Segments

Remark:

- **Label = 16000 + Index values**
- **Advertised as index**
- **Distributed by IGP (OSPF/IS-IS)**

As you can see label (16006), it's mean SRGB + Index (16000+6) = 16006

Applications of SR-MPLS

- **SR** introduces label distribution through only IGP and BGP, allowing for greater flexibility and simplified label management.
- **SR-MPLS** operates in a stateless manner. It relies on source-based forwarding instructions encoded in the MPLS header, simplifying the control plane, ensuring efficient scalability, and providing flexibility for network changes.
- **Traffic engineering:** Built-in support for SR-Traffic Engineering (SR-TE), allowing operators to direct traffic through specific paths for optimized network performance.
- **SR** fits smoothly into current networks, making it easy to move from traditional MPLS networks to SR-MPLS networks.
- **Hardware support:** SR-MPLS utilizes the existing hardware-based data forwarding support inherent in MPLS.

Goals and Requirements of SR-MPLS

- **Make Engineer or operators life easier**
  - Improve Scalability, Simplify Operations
  - Enhance service offering potential through programmability
  - Leverage the efficient MPLS Data Plane that we have today
    - Push, Swap and Pop
    - Maintain existing label structure
    - Leverage all the services supported over MPLS
    - Explicit Routing, FRR, Layer 3 VPNv4/6, Layer 2VPNs (VPWS, VPLS, EVPN).

Why we need to migrate MPLS to SR-MPLS?

- The **Headend** chooses a path and encodes it in the packet header as an ordered list of segments
  - The rest of the nodes executes the encoded instructions (In Stack of labels)
  - **No State are required in SR-MPLS networks**
- Segment: an identifier for any type of instruction
  - forwarding or service
- Forwarding state (segment) is established by IGP
  - **LDP and RSVP-TE are not required**
  - Data Plane: MPLS or IPv6 (SRv6)
- MPLS Data Plane is leveraged without any modification
  - push, swap and pop: all that we need

Why we need to migrate MPLS to SR-MPLS?

Network Element	Legacy Networks		Converged SDN Transport with Routed Optical Networking
xVPN Services	LDP	BGP	✔ BGP for all L2VPN/L3VPN
IP Network Scaling	BGP-LU		SR Segment Routing
TE, FRR	RSVP-TE		
MPLS Overlay Protocol	RSVP-TE	LDP	
IPv6 Transport Overlay	None		
[redacted]	[redacted]		[redacted]

[redacted]

Benefits of SR-MPLS over MPLS (Classic)

Features:	MPLS LDP:	MPLS RSVP-TE:	Segment Routing:
Overview	Multipoint to point	Point-to-point	Multipoint to point
Operation	Simple	LSP per Destination/TE-Path	Simple
Dependencies	Based on IGP (OSPF/IS-IS)	Based on IGP (OSPF/IS-IS) TE	Relies on IGP + Offline TE
Labels Allocation	Local Significant per node	Local Significant per node	**Global**
Traffic Engineering	N/A	IGP-TE/RSVP-TE	SR-TE, SR policy, Flex-Algo IGP-TE with CSPF, SDN Controller
Scaling	1 LBL per node	Nx(N-1)	**1 LBL per node/ local interface**
Fast Reroute	LFA, LFA Policies, RLFA - <100% coverage	Link/Node protection (detour/facility) – 100% coverage	LFA, LFA Policies, RLFA/DLFA can get to **100% coverage** (better than LDP with RLFA)
Multicast	mLDP	P2MP RSVP	Extensions being defined(Build-In)
IPv6	Extensions required	Extensions required	**Native**
Egress Peering	N/A	N/A	Supported

Segment Routing Migration Guidelines

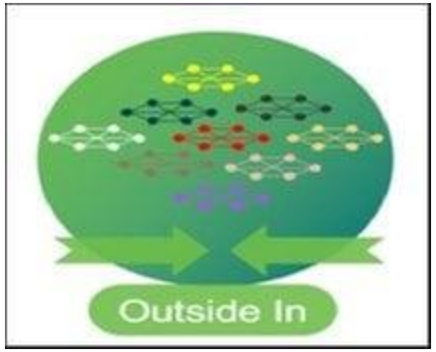
Remark:

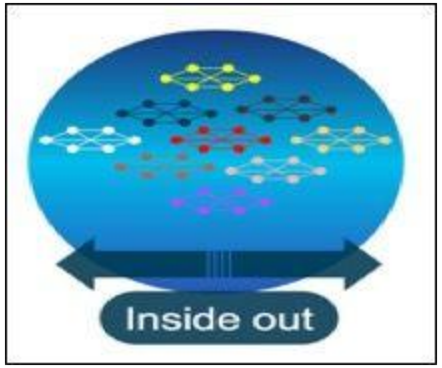
- When we plan to deploy **SR**, they won't have to swap out network hardware. Sometimes it's just the software upgrade to make the network SR capable. For the brownfield environment, SR can be enabled in current **MPLS** networks without any RIP and replace strategy and as stated previously, can **co-exist with LDP/RSVP-TE** with no changes to existing Control or Data Plane operation.
- Migration to a new technology especially in the brown-field deployment depends on the availability of seamless migration strategies that allows an Operator to migrate from legacy to new technology with minimal or zero impact in the production network. SR allows an Operator to incrementally upgrade from LDP to SR without breaking any control/data plane for existing traffic.

Segment Routing Migration Guidelines (Continue)

Segment Routing Migration has 3 approach:

- Outside-In Strategy - Inside-Out Strategy - Ship in the Night Strategy

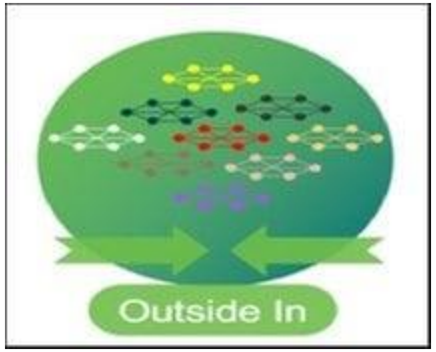




Segment Routing Migration Guidelines (Continue)

Segment Routing Migration has 3 approach:

➢ Outside-In Strategy



- SR migration is started from the access network.
- Make the aggregation and core SR ready while migrating the Access circles to SR.
- Work gradually into Aggregation and then into Core segments to make the network fully SR-IGP fabric

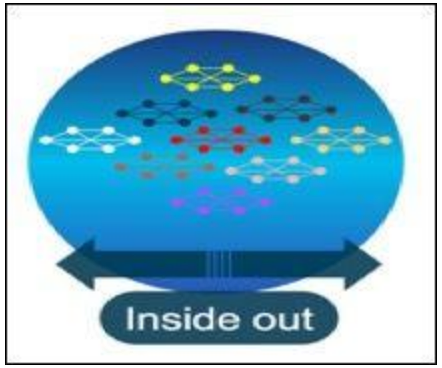
Why choose Outside In Migration:

- Low Risk: Service disruptions not widespread
- More devices, but divided into manageable islands e.g. Rings
- Allows operators to gain more experience while moving into Aggregation and Core

Segment Routing Migration Guidelines (Continue)

Segment Routing Migration has 3 approach:

➢ Inside-Out Strategy



- Start SR migration from Core network
- Start making the aggregation and access network ready for SR deployment while the migration work in the core is in progress.
- Work outside into aggregation and then into access segments

Why choose Inside Out Migration:

- High Impact: Operator can make use of BW optimization in the core
- The lower number of devices provides an opportunity to migrate the whole segment relatively quickly.
- Typically for more experienced operators.

Segment Routing Migration Guidelines (Continue)

Segment Routing Migration has 3 approach:

- Ship in the Night Strategy

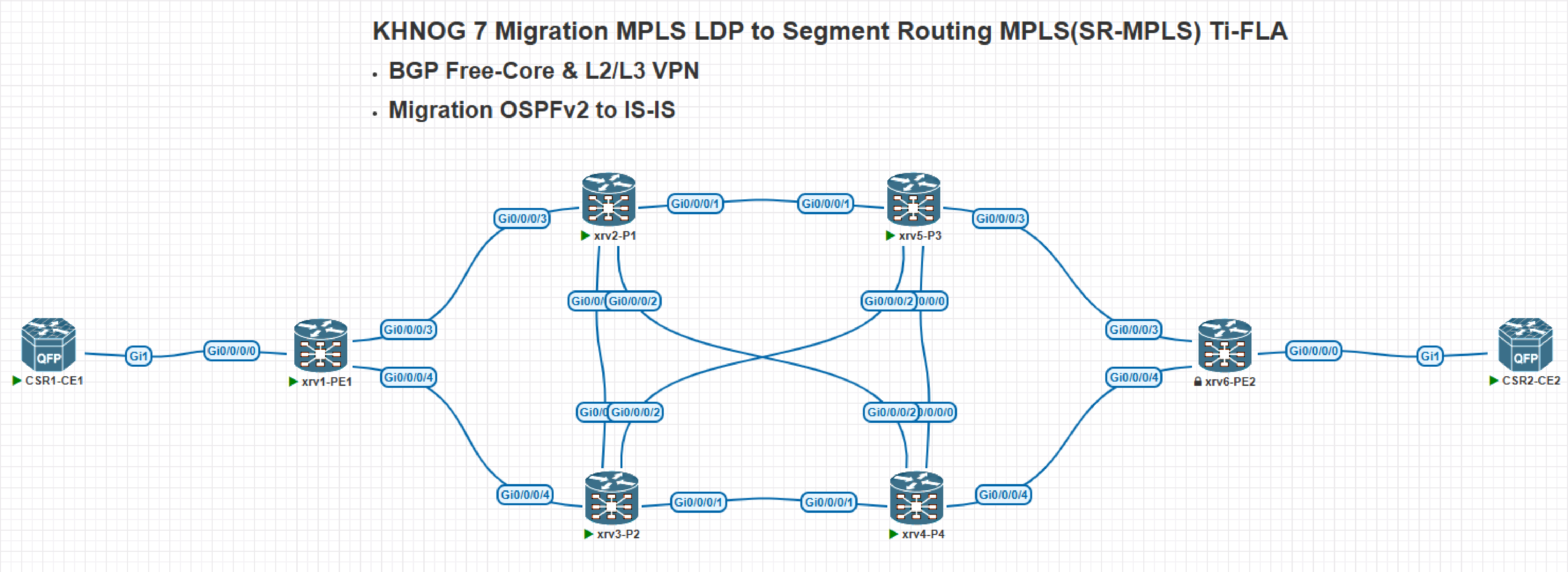
  - Allows for “make before break” verification
  - SR control verification before making the switchover
  - Segment Routing Control Plane is enabled on existing LDP network
  - LDP and SR are kept independent
  - SR and LDP PE can interwork seamlessly

Segment Routing Migration Phase:

The implementation will be split into three phases.

- **Phase 1:** SR and LDP co-existence by configuring SR and let LDP be the preferred label imposition method.
- **Phase 2:** Preferring SR over LDP as a label imposition method.
- **Phase 3:** Remove LDP and followed by RSVP-TE if configured.

High Level Topology



Configuration Best Practices:

Cisco IOS XE (OSPF)	Cisco IOS XE (IS-IS)	Cisco IOS XR (OSPF)	Cisco IOS XR (IS-IS)
mpls oam ! segment-routing mpls global-block 16000 23999 local-block 15000 15999 ! connected-prefix-sid-map address-family ipv4 1.1.1.1/32 index 1 range 1 exit-address-family ! interface Loopback0 ip address 1.1.1.1 255.255.255.255 ! interface GigabitEthernet1 ip address 10.10.1.1 255.255.255.252 ip ospf network point-to-point ip ospf 100 area 0 ! router ospf 100 router-id 1.1.1.1 **segment-routing area 0 mpls** **segment-routing mpls** mpls ldp sync mpls ldp autoconfig mpls traffic-eng router-id Loopback0	mpls oam ! segment-routing mpls global-block 16000 23999 local-block 15000 15999 ! connected-prefix-sid-map address-family ipv4 1.1.1.1/32 index 1 range 1 exit-address-family ! interface Loopback0 ip address 1.1.1.1 255.255.255.255 ip router isis ISIS-SR ! interface GigabitEthernet1 ip address 10.10.1.1 255.255.255.252 ip router isis ISIS-SR isis circuit-type level-2-onlyisis network point-to-point ! router isis ISIS-SR net 49.0000.0000.0000.0001.00 is-type level-2-only metric-style wide **segment-routing mpls** passive-interface default mpls traffic-eng router-id Loopback0!	mpls oam ! segment-routing global-block 16000 23999 local-block 15000 15999 ! router ospf KHNOG7-SR-MPLS distribute link-state log adjacency changes detail router-id 1.1.1.1 **segment-routing mpls** passive enable mpls ldp sync mpls ldp auto-config fast-reroute per-prefix fast-reroute per-prefix ti-lfa enable prefix-suppression mpls ldp sync-igp-shortcuts **segment-routing sr-prefer** area 0 mpls traffic-eng interface Loopback0 **prefix-sid index 1** ! interface GigabitEthernet0/0/0/1 network point-to-point passive disable !	mpls oam ! segment-routing global-block 16000 23999 local-block 15000 15999 ! router isis KHNOG7-SR-MPLS distribute link-state is-type level-2-only net 49.0001.0000.0000.0001.00 address-family ipv4 unicast metric-style wide advertise passive-only mpls traffic-eng level-2-only mpls traffic-eng router-id Loopback0 **segment-routing mpls** segment-routing mpls **sr-prefer** mpls ldp auto-config interface Loopback0 passive address-family ipv4 unicast **prefix-sid index 1** ! interface GigabitEthernet0/0/0/1 circuit-type level-2-only point-to-point hello-padding disable address-family ipv4 unicast fast-reroute per-prefix fast-reroute per-prefix ti-lfa level 2 !

Commands Reference Guidelines

```
RP/0/0/CPU0:XRV1-PE1#sh isis neighbors
Thu Nov  6 06:37:02.826 UTC
IS-IS KHNOG7-SR-MPLS neighbors:
System Id      Interface        SNPA           State Holdtime Type IETF-NSF
XRV2-P1        Gi0/0/0/3        *PtoP*         Up    23       L2   Capable
XRV3-P2        Gi0/0/0/4        *PtoP*         Up    28       L2   Capable

Total neighbor count: 2
RP/0/0/CPU0:XRV1-PE1#
RP/0/0/CPU0:XRV1-PE1#sh isis fast-reroute summary
Thu Nov  6 06:38:45.539 UTC
IS-IS KHNOG7-SR-MPLS IPv4 Unicast FRR summary

                          Critical   High       Medium     Low        Total
                          Priority   Priority   Priority   Priority
Prefixes reachable in L2
  All paths protected     0          0          5          0          5
  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%
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#sh route 6.6.6.6
Thu Nov  6 06:40:47.290 UTC

Routing entry for 6.6.6.6/32
  Known via "isis KHNOG7-SR-MPLS", distance 115, metric 30, labeled SR, type level-2
  Installed Nov  6 06:40:39.061 for 00:00:08
  Routing Descriptor Blocks
    10.10.1.2, from 6.6.6.6, via GigabitEthernet0/0/0/3, Protected, Backup (Local-LFA)
      Route metric is 30
    10.10.2.2, from 6.6.6.6, via GigabitEthernet0/0/0/4, Protected, Backup (Local-LFA)
      Route metric is 30
  No advertising protos.
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#sh route 6.6.6.6 detail
Thu Nov  6 06:45:01.093 UTC
Routing entry for 6.6.6.6/32
  Known via "isis KHNOG7-SR-MPLS", distance 115, metric 30, labeled SR, type level-2
  Installed Nov  6 06:40:39.061 for 00:04:22
  Routing Descriptor Blocks
    10.10.1.2, from 6.6.6.6, via GigabitEthernet0/0/0/3, Protected, Backup (Local-LFA)
      Route metric is 30
      Label: 0x3e86 (16006)
      Tunnel ID: None
      Binding Label: None
      Extended communities count: 0
      Path id:2       Path ref count:1
      NHID:0x1(Ref:5)
      Backup path id:1
```

```
10.10.2.2, from 6.6.6.6, via GigabitEthernet0/0/0/4, Protected, Backup (Local-LFA)
    Route metric is 30
    Label: 0x3e86 (16006)
    Tunnel ID: None
    Binding Label: None
    Extended communities count: 0
    Path id:1       Path ref count:1
    NHID:0x2(Ref:5)
    Backup path id:2
Route version is 0xb0 (176)
 Local Label: 0x3e86 (16006)
 IP Precedence: Not Set
 QoS Group ID: Not Set
 Flow-tag: Not Set
 Fwd-class: Not Set
 Route Priority: RIB_PRIORITY_NON_RECURSIVE_MEDIUM (7) SVD Type RIB_SVD_TYPE_LOCAL
 Download Priority 1, Download Version 1364
 No advertising protos.
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#sh mpls forwarding | include SR
Thu Nov  6 06:47:32.582 UTC
16002  Pop             SR Pfx (idx 2)    Gi0/0/0/3    10.10.1.2      392
       16002           SR Pfx (idx 2)    Gi0/0/0/4    10.10.2.2      0          (!)
16003  Pop             SR Pfx (idx 3)    Gi0/0/0/4    10.10.2.2      824
       16003           SR Pfx (idx 3)    Gi0/0/0/3    10.10.1.2      0          (!)
16004  16004           SR Pfx (idx 4)    Gi0/0/0/3    10.10.1.2      0
       16004           SR Pfx (idx 4)    Gi0/0/0/4    10.10.2.2      0
16005  16005           SR Pfx (idx 5)    Gi0/0/0/3    10.10.1.2      0
       16005           SR Pfx (idx 5)    Gi0/0/0/4    10.10.2.2      0
16006  16006           SR Pfx (idx 6)    Gi0/0/0/3    10.10.1.2      0
       16006           SR Pfx (idx 6)    Gi0/0/0/4    10.10.2.2      58006
24000  Pop             SR Adj (idx 1)    Gi0/0/0/3    10.10.1.2      0
       16002           SR Adj (idx 1)    Gi0/0/0/4    10.10.2.2      0          (!)
24001  Pop             SR Adj (idx 3)    Gi0/0/0/3    10.10.1.2      0
24002  Pop             SR Adj (idx 1)    Gi0/0/0/4    10.10.2.2      0
       16003           SR Adj (idx 1)    Gi0/0/0/3    10.10.1.2      0          (!)
24003  Pop             SR Adj (idx 3)    Gi0/0/0/4    10.10.2.2      0
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#sh mpls  interfaces
Thu Nov  6 06:49:52.043 UTC
Interface                  LDP      Tunnel   Static   Enabled
-------------------------- -------- -------- -------- --------
GigabitEthernet0/0/0/3     No       Yes      No       Yes
GigabitEthernet0/0/0/4     No       Yes      No       Yes
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#ping sr-mpls 6.6.6.6/32 source 1.1.1.1 verbose
Thu Nov  6 06:51:32.486 UTC
Sending 5, 100-byte MPLS Echos to 6.6.6.6/32,
     timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

!      size 100, reply addr 10.10.10.2, return code 3
!      size 100, reply addr 10.10.10.2, return code 3
!      size 100, reply addr 10.10.10.2, return code 3
!      size 100, reply addr 10.10.10.2, return code 3
!      size 100, reply addr 10.10.10.2, return code 3

Success rate is 100 percent (5/5), round-trip min/avg/max = 20/34/50 ms
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#traceroute sr-mpls 6.6.6.6/32 source 1.1.1.1 verbose
Thu Nov  6 06:52:13.943 UTC

Tracing MPLS Label Switched Path to 6.6.6.6/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

  0 10.10.2.1 10.10.2.2 MRU 1500 [Labels: 16006 Exp: 0]
L 1 10.10.2.2 10.10.6.2 MRU 1500 [Labels: 16006 Exp: 0] 10 ms, ret code 8
L 2 10.10.6.2 10.10.10.2 MRU 1500 [Labels: implicit-null Exp: 0] 20 ms, ret code 8
! 3 10.10.10.2 90 ms, ret code 3
RP/0/0/CPU0:XRV1-PE1#
```

```
RP/0/0/CPU0:XRV1-PE1#traceroute mpls multipath ipv4 6.6.6.6/32 source 1.1.1.1
Thu Nov  6 06:53:17.489 UTC
Starting LSP Path Discovery for 6.6.6.6/32
Type escape sequence to abort.
LL!
Path 0 found,
 output interface GigabitEthernet0/0/0/3 nexthop 10.10.1.2
 source 1.1.1.1 destination 127.0.0.4
L!
Path 1 found,
 output interface GigabitEthernet0/0/0/3 nexthop 10.10.1.2
 source 1.1.1.1 destination 127.0.0.0
LL!
Path 2 found,
 output interface GigabitEthernet0/0/0/4 nexthop 10.10.2.2
 source 1.1.1.1 destination 127.0.0.0
L!
Path 3 found,
 output interface GigabitEthernet0/0/0/4 nexthop 10.10.2.2
 source 1.1.1.1 destination 127.0.0.2
Paths (found/broken/unexplored) (4/0/0)
 Echo Request (sent/fail) (10/0)
 Echo Reply (received/timeout) (10/0)
 Total Time Elapsed 259 ms
RP/0/0/CPU0:XRV1-PE1#
```

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References Document:
https://www.cisco.com/c/en/us/support/docs/multiprotocol-label-switching-mpls/mpls/215215-segment-routing-overview-and-migration-g.html
https://www.segment-routing.net/

Thank You so much!

Any Questions please feel free to ask!