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Multicast over Segment Routing

Deployment and Troubleshooting

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Mankamana Mishra, Technical Leader

BRKMPL-2257

Speaker Introduction

I am a **Principal Engineer** with the CX team, leading / co-leading various innovation activities around **Future of Work** and **Full Stack Observability**.

I have been with Cisco for more than 10 years playing different roles. I am one of the contributing architect for various technologies and co-invented various solutions implemented in different Cisco and other vendor products.

I am the co-inventor of more than **150 patent applications** and have co-authored various **Internet Standards and RFCs**.

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Speaker Introduction

I am Sr. Technical leader in the Engineering working on Multicast, BGP and MPLS. I have been involved in Multicast for about 10 years working on many different aspects of multicast, like PIM, IGMP, MSDP, MVPN and EVPN. I have worked on the integration of Multicast and EVPN SR MPLS. I am (co)author of many IETF drafts related to Multicast, MPLS and mVPN , EVPN technologies.

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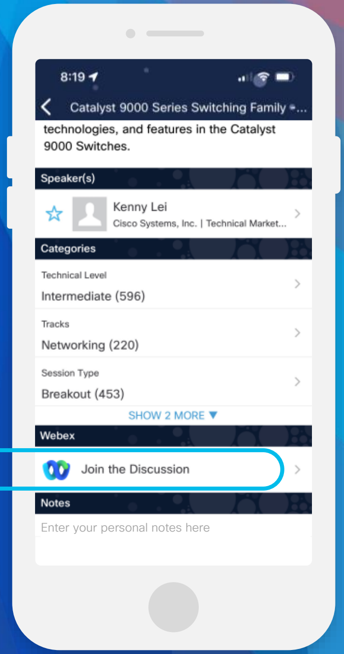

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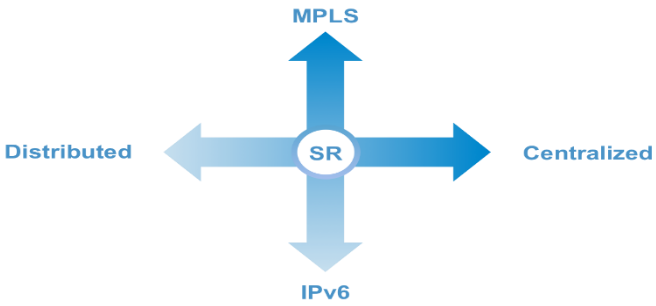
Agenda

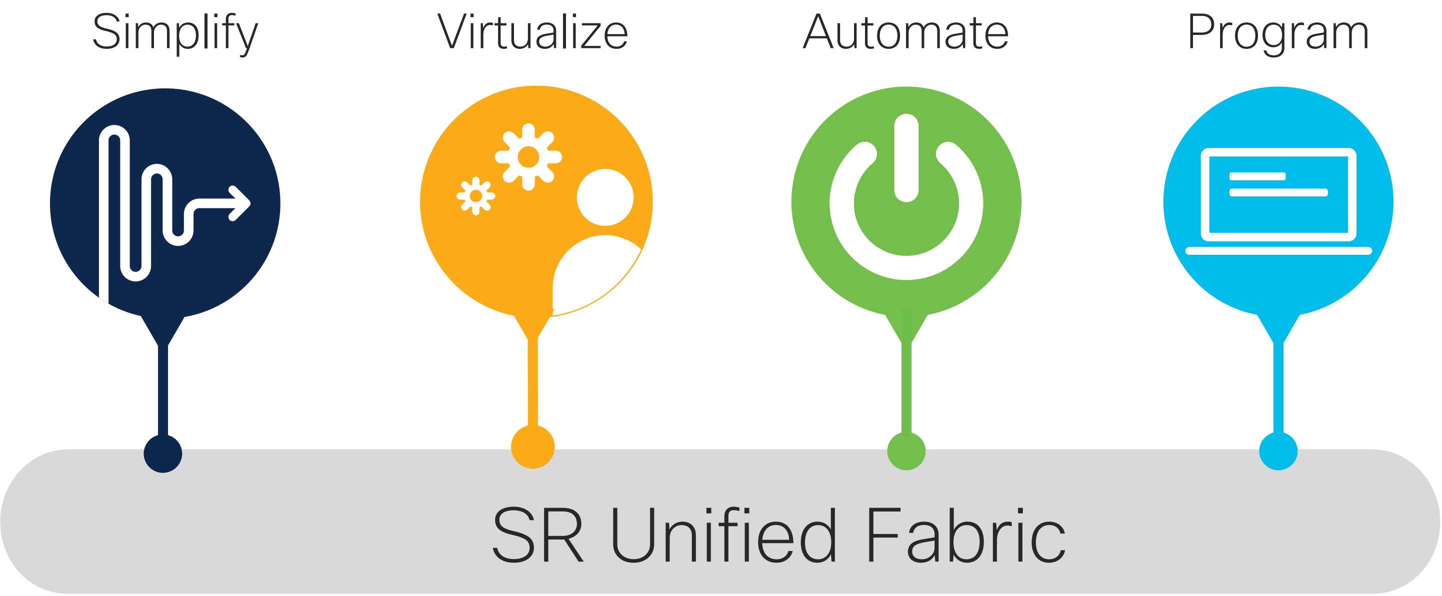
- Segment Routing Primer
- SR P2MP Policy
- SR P2MP Policy Configuration
- mLDP P2MP
- mVPN Primer
- Troubleshooting mLDP

Segment Routing



- Source Routing
  - Source chooses a path and encodes it in the packet header as an ordered list of segments
  - Rest of the network executes the encoded instructions without any further per-flow state
- Segment ID
  - Identifier for any type of instruction
  - Forwarding or service
- Control Plane Paradigm
  - Distributed intelligence is used to build these segments
  - Centralized intelligence maps application to path for resource optimization

Segment Routing Unified Fabric



New business capabilities built on the network as the platform;
Enabling customers to achieve business outcomes faster with ruthless ease

IGP Prefix Segment

- Aka Node Segment ID
- Shortest-path to the IGP prefix
- Global
- Signaled by ISIS/OSPF
- Manually assigned or using centralized controller.

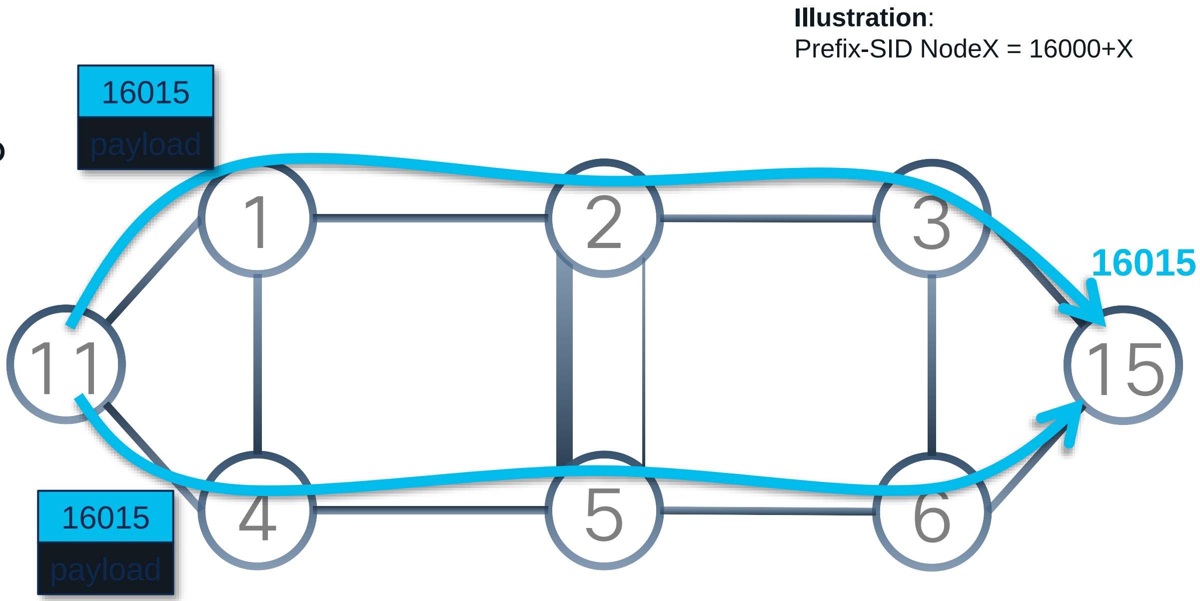
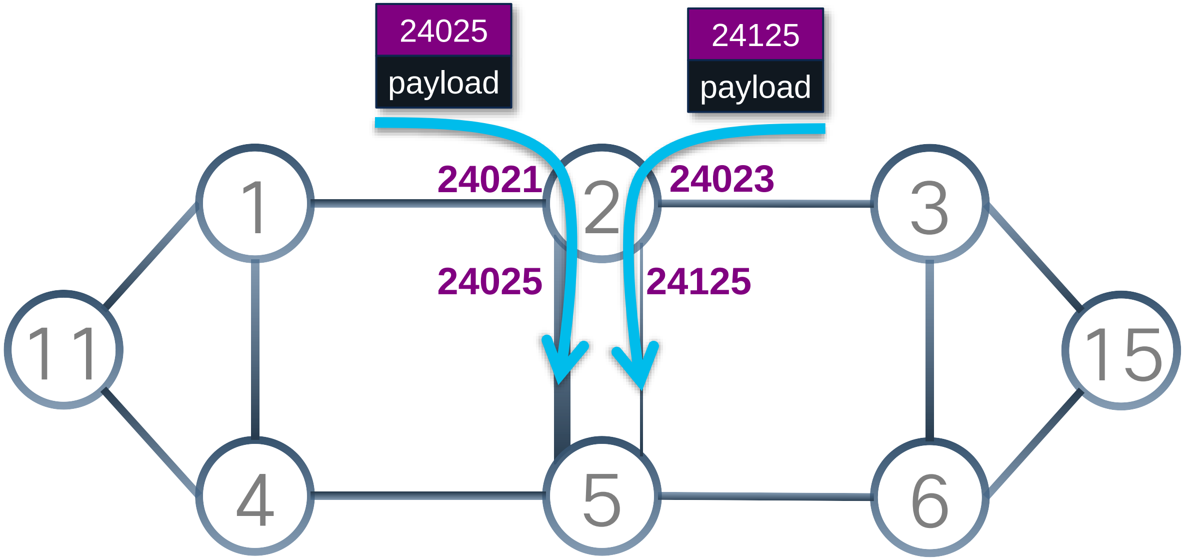


Illustration:
Adj-SID X→Y = 24nXY, n is index

IGP Adjacency Segment

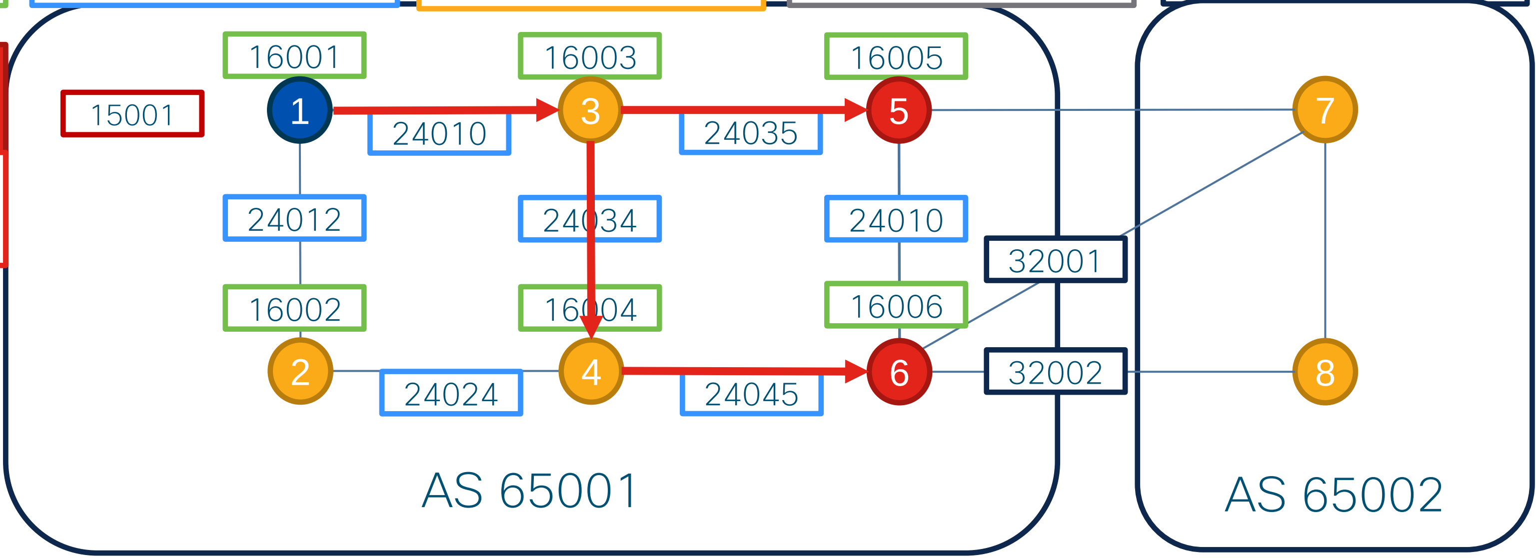
- Forward on the IGP adjacency
- Locally Assigned
- Local significance
- Signaled by ISIS/OSPF
- Programmed only in originator’s forwarding table



Segment Routing – Technology Overview

Node SID (Prefix SID)	Adjacency SID	Anycast SID	Binding SID	Peering SID (EPE)
Globally Significant	Locally Significant Unidirectional	Globally Significant	Globally or Locally Significant	Locally Significant

Tree SID
Locally Significant



SR Control Plane – Path Computation Element

SRTE Head-End

Distributed Mode – SR-TE Head-End
Visibility is limited to its own IGP domain

Solution

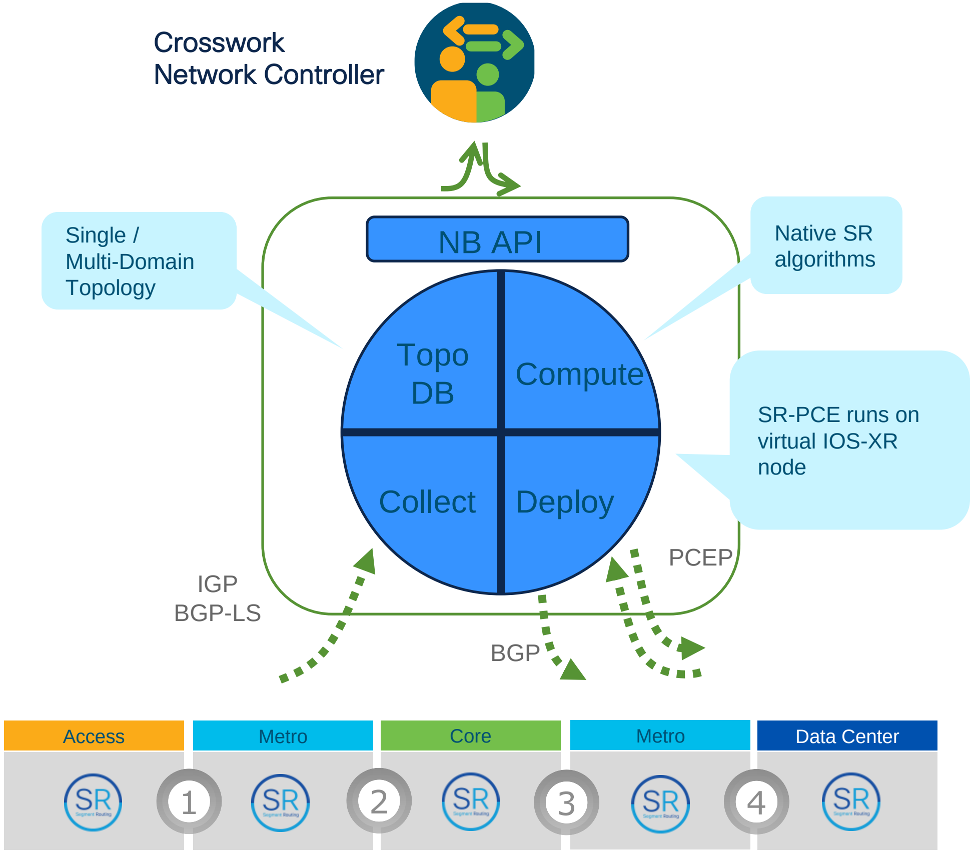
Multi-Domain SRTE Visibility
Centralized SR-PCE for Multi-Domain Topology view

Integration with Applications
North-bound APIs for topology/deployment

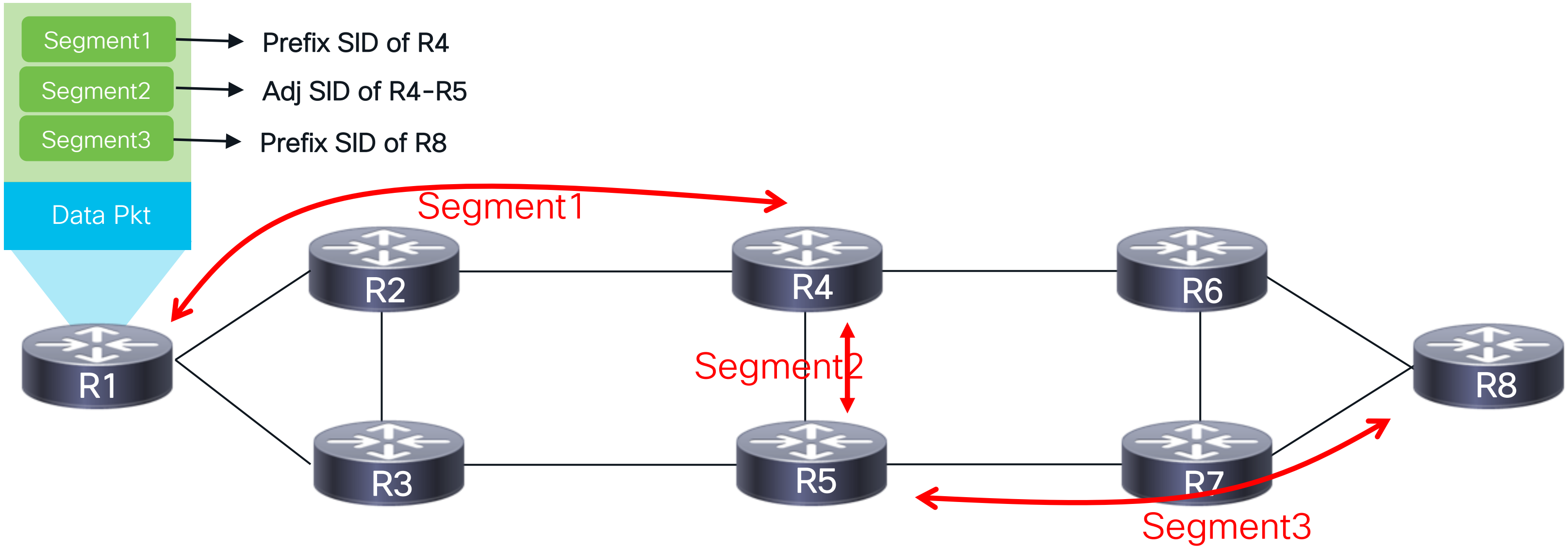
Delivers **across the unified SR Fabric** the SLA requested by the service

Benefits

Simplicity and Automation
End-to-End network topology awareness
SLA-aware path computation across network domains

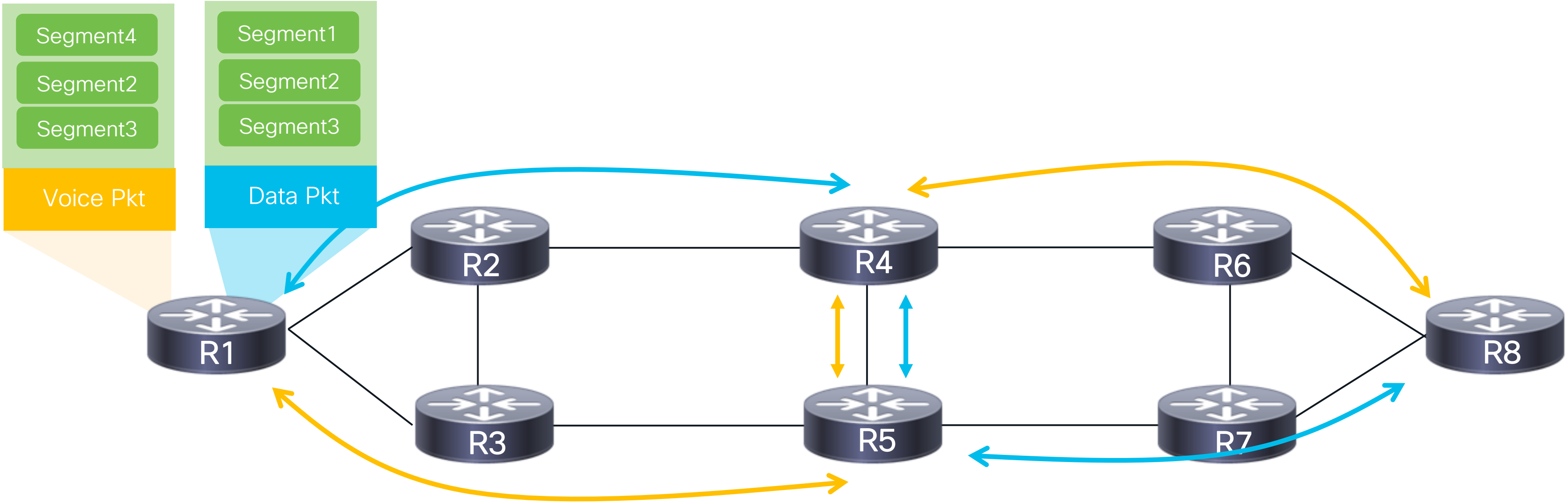


SR Header – Path Encoding



- Path Information is encoded as stack of segments in the header.
- Each segment is an instruction that will be executed by the transit devices.

Traffic Engineering using SR



- Traffic is classified based on the path attributes requested
  - Low Latency vs High BW
- Packet is encoded with relevant segment list to steer the traffic

Segment Routing Data Plane

Segment Routing

MPLS

Control Plane: IGP with SR
Data Plane: MPLS
SID replaces Label
Label Stack → SID Stack

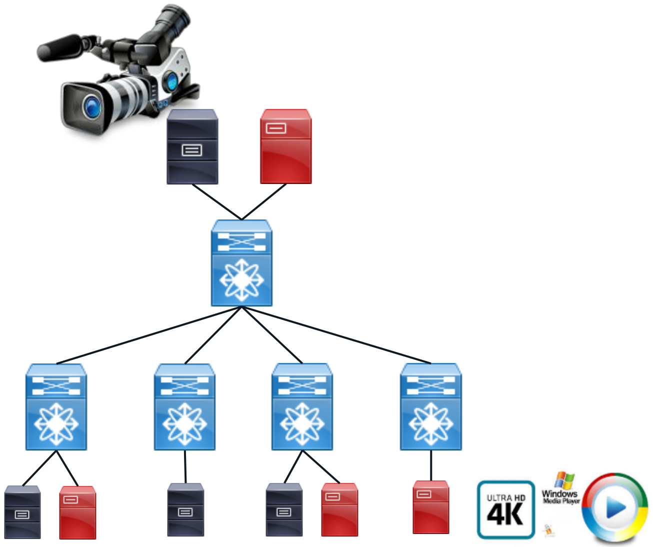
IPv6

Control Plane: IGP with SR
Data Plane: IPv6
Source Routing Extension Header
SID = IPv6 Address
SRH Extension → SID Stack

Segment = **Instructions** such as
"go to node N using the shortest path"

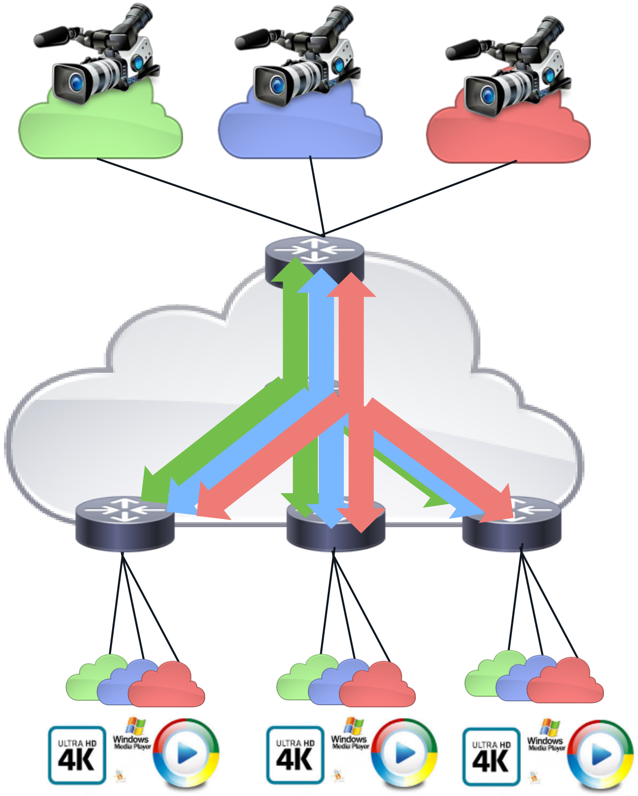
Why Multicast?

- Various End Applications leverages multicast for data synchronization, backup etc.
  - Video and Collaboration Solutions
  - Distributed File systems
  - Data Replication and Synchronization
  - Media conferencing
  - Video Surveillance
- Common to see servers deployed in Datacenters.
  - Servers acting as multicast source
- Hosts can be senders or receivers.

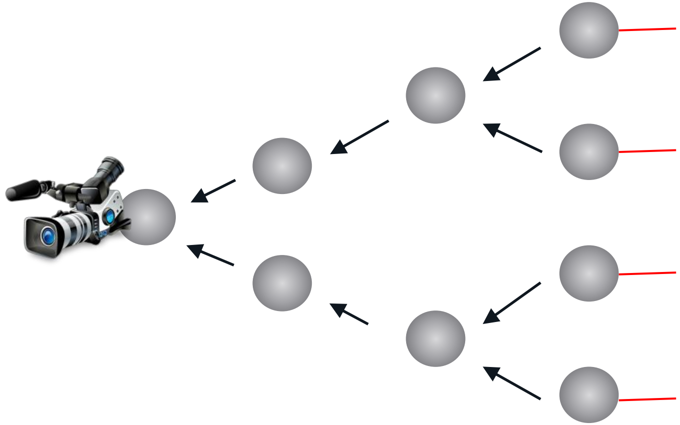


Why Multicast?

- Multicast VPN (MVPN) is one of the service offered by most of the Service Provider.
  - Enterprise Applications
  - IPTV Streaming
  - Financial Applications
  - Internet of Things
- Multicast Distribution Tree (MDT) are created for each VRF tenants.



Traditional Multicast Solution



- Different control plane protocol used for multicast tree building
- Different Data plane used for traffic forwarding
  - IP lookup
  - GRE Encapsulation

Traditional Multicast Options

- Deploying SR for unicast is **orthogonal** to solution used for Multicast.
- Nothing prevents existing protocols to continue to work, like:
  - Ingress Replication (IR)
  - PIM
  - mLDP
  - RSVP-TE
- In that sense, there is no requirement to change the Multicast deployment.
  - However, if there is a technology that would benefit from being simplified and scale improved, it is Multicast ☺

Session Focus

SR P2MP Policy
Centralized Approach

Multipoint LDP
Distributed Approach

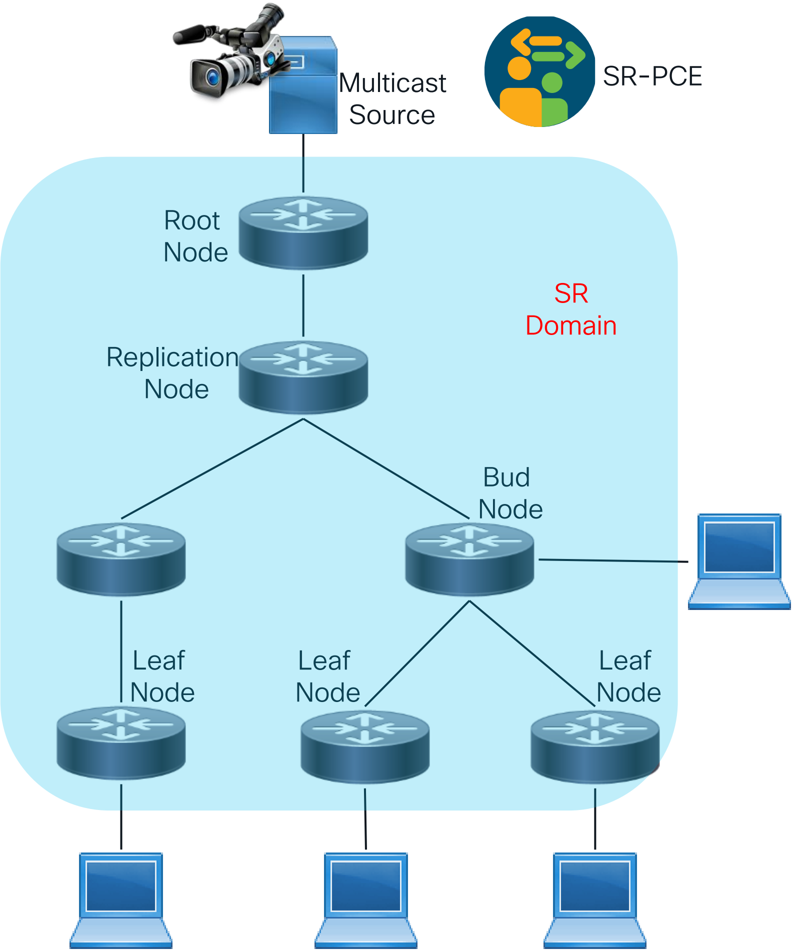
SR
Segment Routing

Segment Routing P2MP Policy

SR P2MP Policy

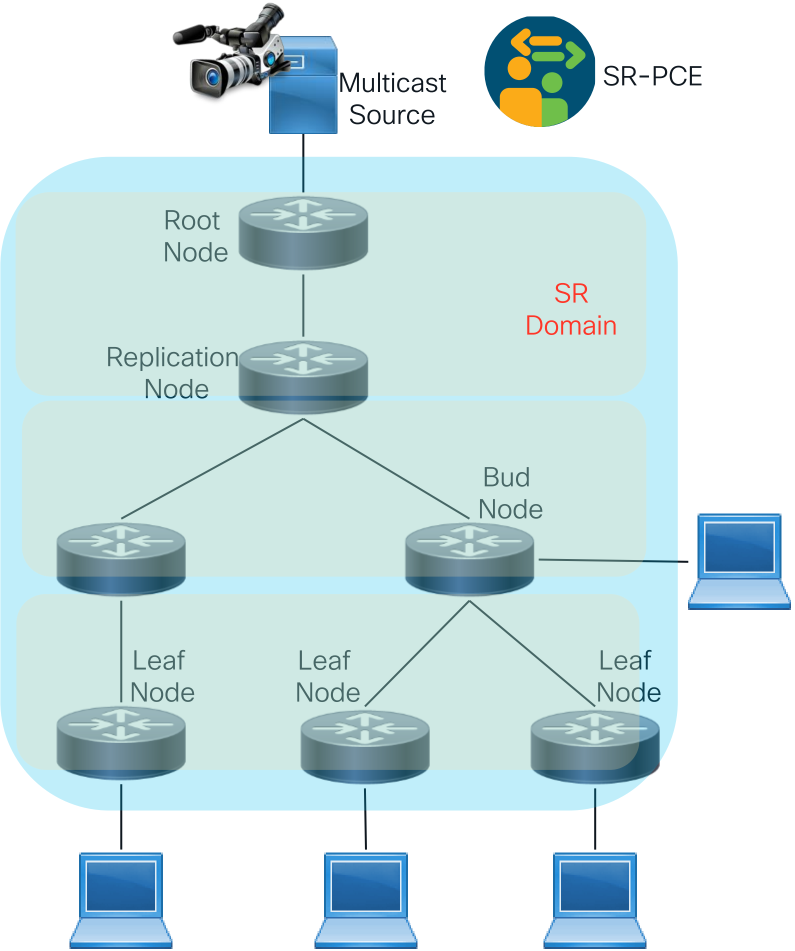
- SR P2MP Policy is a SDN controller-based approach to building P2MP trees in a SR domain
  - SR-PCE computes and instantiates the Tree
- A tree can be built using Traffic Engineering criteria (like TE metric optimization or affinity constraints).
- Static Tree-SID
  - User-defined root, leaves and multicast flow mapping
- Dynamic Tree-SID Policies
  - Dynamic discovery of root, leaves and multicast flow mapping using BGP mVPN

Use cases: IPTV / Streaming media / Business mVPN

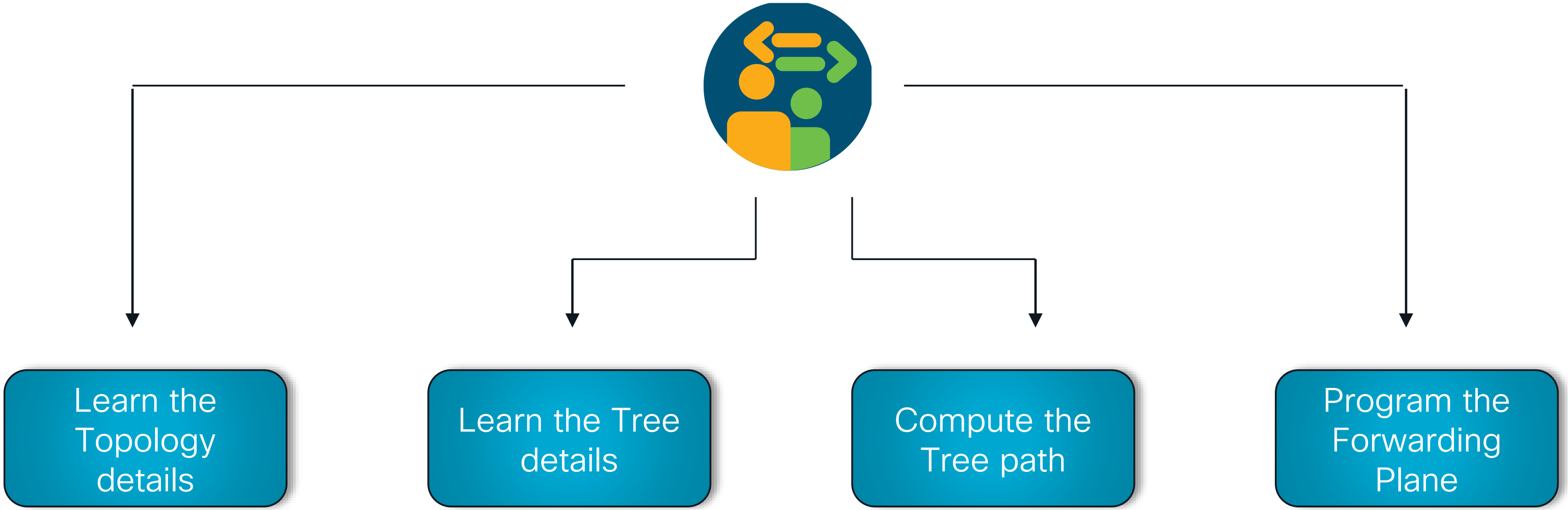


SR Replication Segment

- Replication segment allows node (Replication Node) to replicate packets to a set of other nodes (Downstream Nodes) in a Segment Routing Domain
- Replication segments provide building blocks for Point-to-Multipoint Service delivery via SR Point-to-Multipoint (SR P2MP) policy
- A Replication segment can replicate packet to directly connected nodes or to downstream nodes (without need for state on the transit routers)
- The use of one or more stitched Replication segments constructed for SR P2MP Policy tree

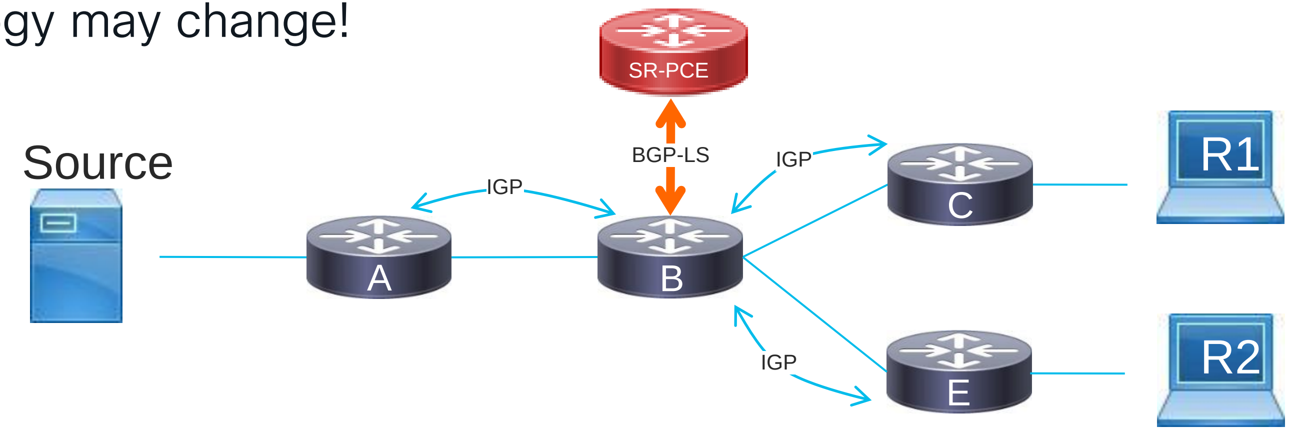


SR PCE Functionalities



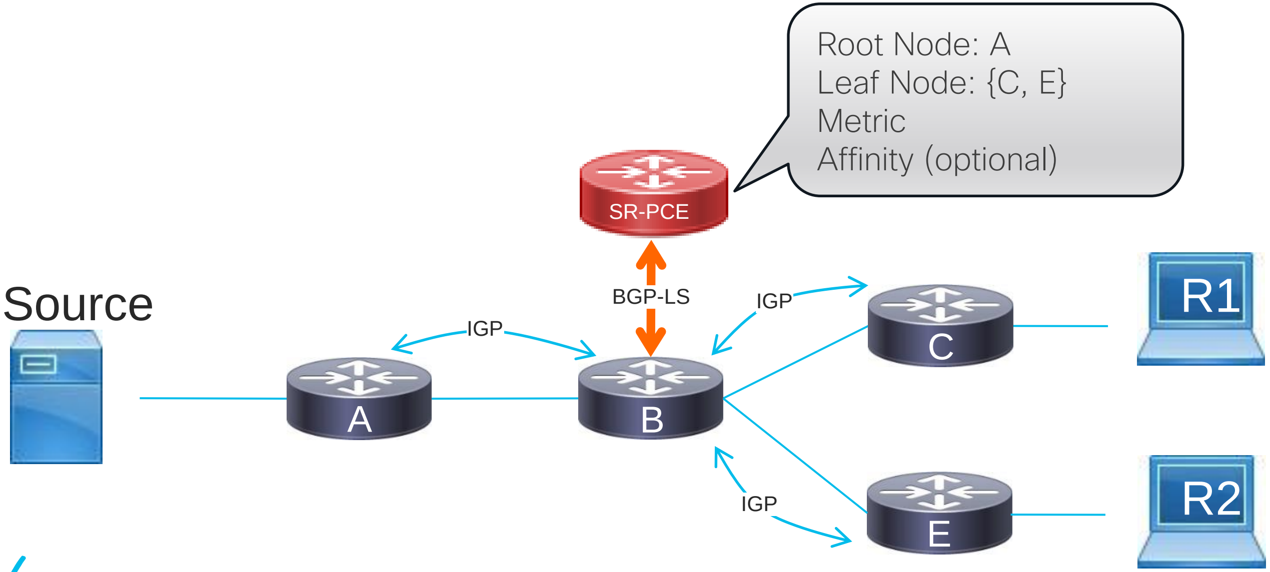
Learning the Topology

- A common mechanism to learn the topology is using BGP Link State (LS).
- Through BGP-LS, the controller sucks up the Link State database.
- Through the LS database, the controller can use any sort of algorithm (like Dijkstra) to calculate paths.
- Topology may change!



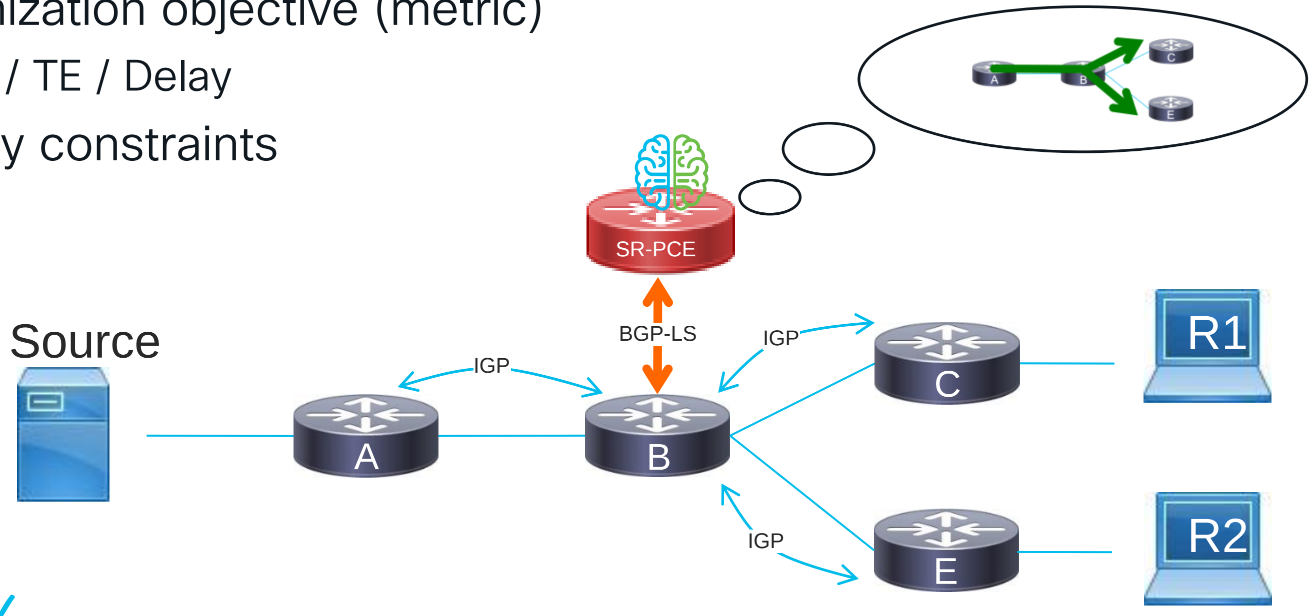
Learning the Tree

- SR-PCE also needs to know the Tree Root and End-points.
  - This can be defined by an operator.
  - Dynamically through a protocol, like BGP Auto Discovery (AD).

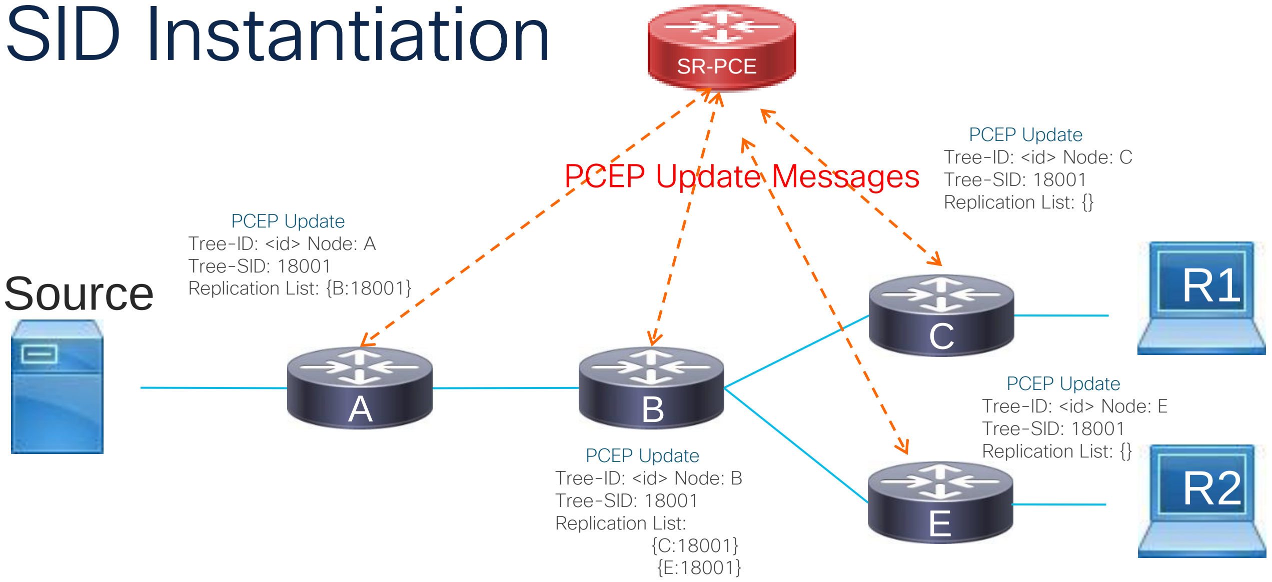


Computing the Multipoint Path

- With the central knowledge at the controller, the tree can be computed according to different metrics and constraints.
  - Optimization objective (metric)
    - IGP / TE / Delay
  - Affinity constraints

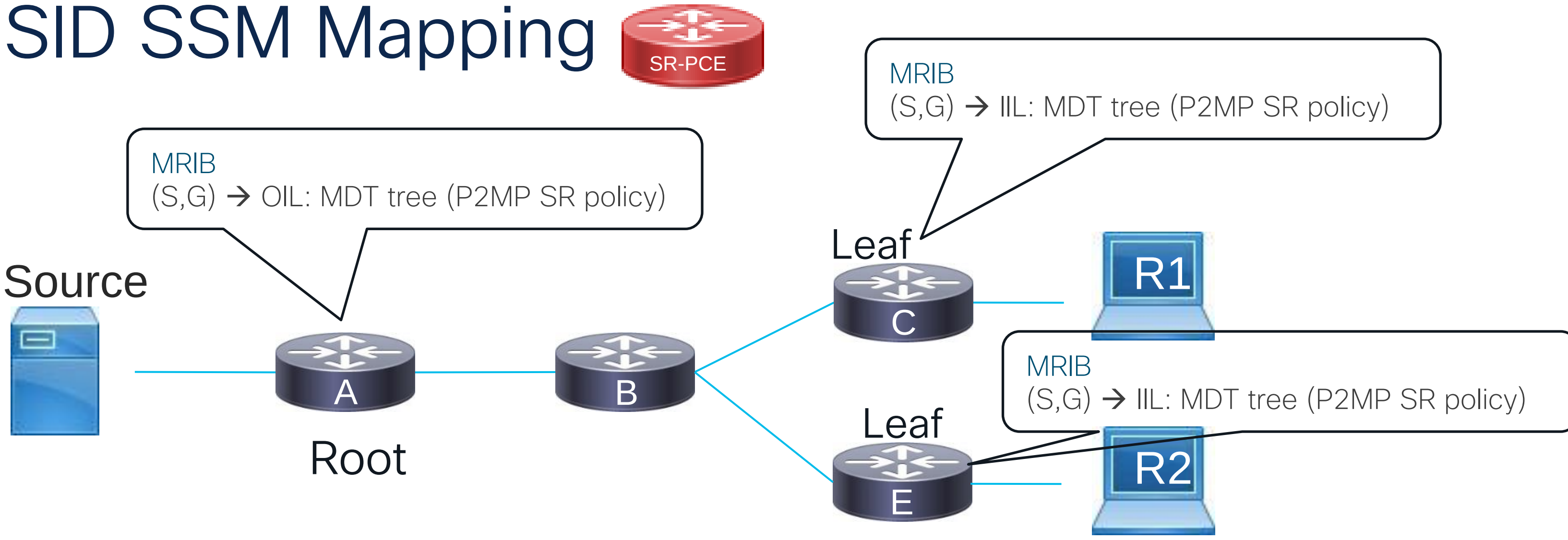


Tree SID Instantiation



- PCEP is used to program the relevant devices with the Tree SID forwarding information.
- Forwarding Plane is programmed with replication semantics

Tree SID SSM Mapping



- The MRIB of the root node is programmed by mapping the P2MP SR Policy as the OIL to the (S,G)
- The MRIB of the leaf node is programmed by mapping the P2MP SR Policy as the incoming interface for (S,G)

Tree SID Policy Configuration

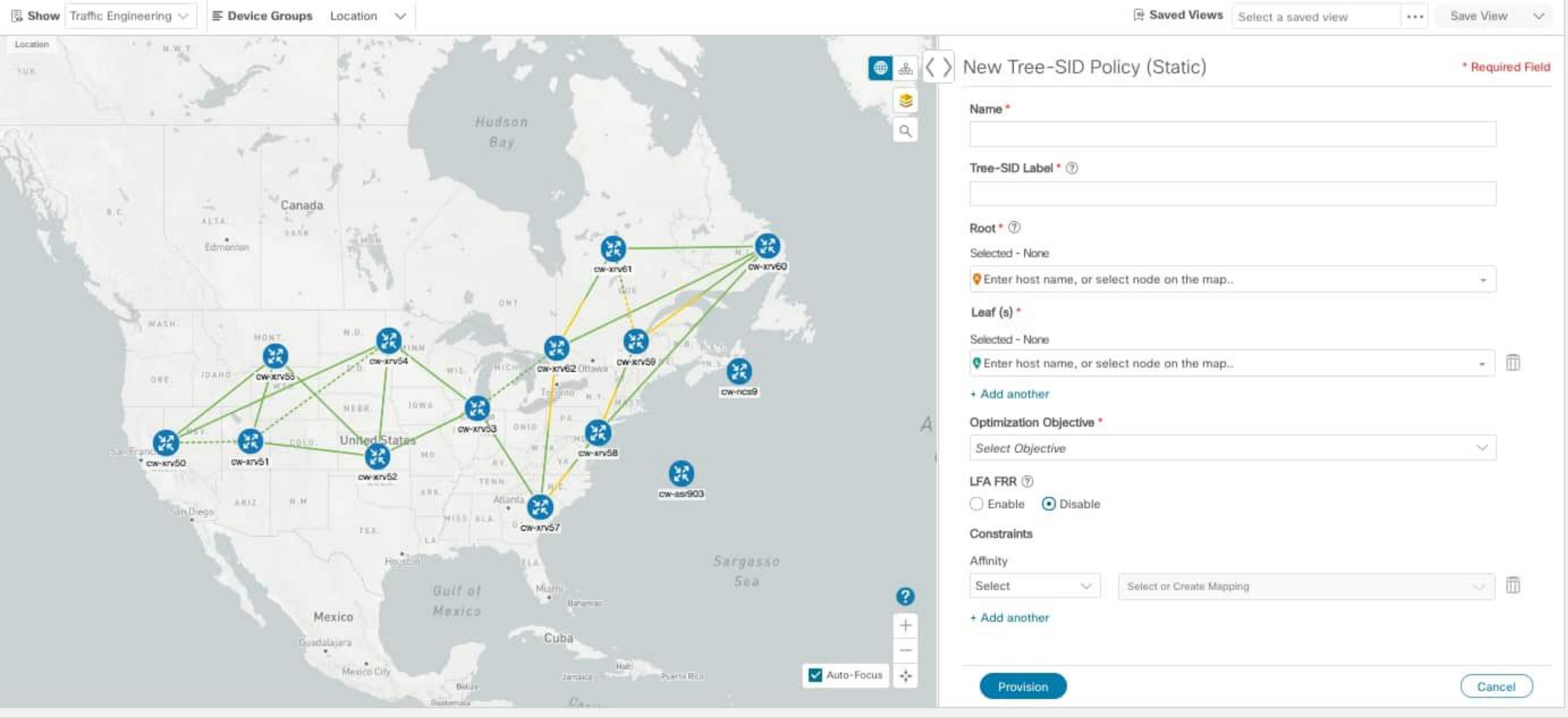
Static Tree


```
pce
 address ipv4 <pce>
!
 segment-routing
  traffic-eng
   p2mp
    endpoint-set tree-1
     ipv4 <endpoint>
     ipv4 <endpoint>
    !
    policy p2mp-tree-1
     …
```

```
policy p2mp-tree-1
    source ipv4 <addr>
    color 10 endpoint-set tree-1
    treesid mpls 18001
    candidate-paths
     constraints
      affinity
       include-any | include-all | exclude
        color1
       !
      !
     !
     preference 100
      dynamic
       metric
        type igp | te | latency
```

- User defines the Tree SID policy (Root, endpoint)
- SR-PCE computes the P2MP path
  - Metrics Optimization
  - Affinity Constraints

Tree SID Configuration



Sample ROOT node Configuration

```
multicast-routing
 address-family ipv4
  mdt source Loopback0
  interface all enable
  mdt static segment-routing
 !
!
router pim
 address-family ipv4
  sr-p2mp-policy p2mp-tree-1
   static-group 232.101.1.1 inc-mask 0.0.0.1 count 200 192.101.1.2
  !
 !
!
 vrf vpn1
  address-family ipv4
   sr-p2mp-policy p2mp-vpn1-1
    static-group 232.1.2.1 192.201.1.2
   !
   sr-p2mp-policy p2mp-vpn1-2
    static-group 232.1.3.1 inc-mask 0.0.0.1 count 200 192.201.1.2 inc-mask 0.0.0.1 count 200
   !
```

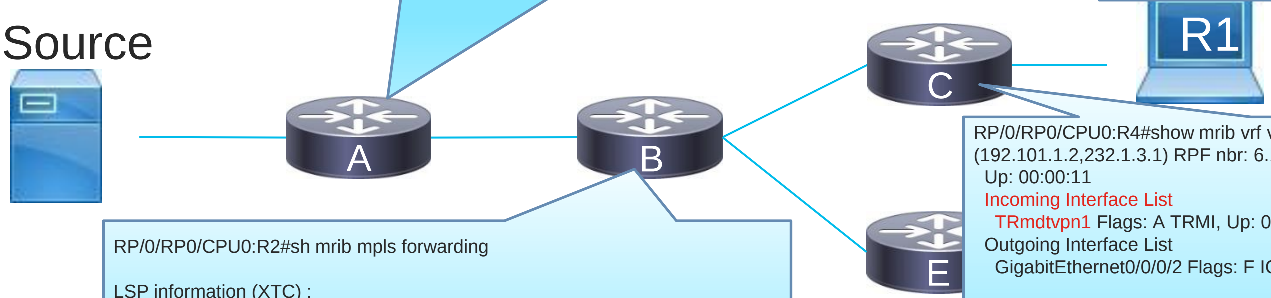
Sample Leaf Node Configuration

```
multicast-routing
 address-family ipv4
  mdt source Loopback0
  interface all enable
  static sr-policy p2mp-tree-1
  mdt static segment-routing
 !
 vrf vpn1
  address-family ipv4
   interface all enable
   static sr-policy p2mp-vpn1-1
   static sr-policy p2mp-vpn1-2
   mdt static segment-routing
  !
 !
```

Tree SID State Entries

```
RP/0/RP0/CPU0:R1#show mrib vrf vpn1 ipv4 route detail
(192.101.1.2,232.1.4.1) Ver: 0xad8a RPF nbr: 192.101.1.2 Flags: RPF EID,
<snip>
 Incoming Interface List
  GigabitEthernet0/0/0/0 Flags: A, Up: 08:10:24
 Outgoing Interface List
  TRmdtvpn1 Flags: F NS TRMI, Up: 02:11:26, Head LSM-ID: 0x0000c

RP/0/RP0/CPU0:A#sh mrib mpls forwarding
<snip>
LSP information (XTC) :
 LSM-ID: 0x0000C, Role: Head, Head LSM-ID: 0x0000C
  Incoming Label      : (18101)
<snip>
 Outsegment Info #1 [M/Swap]:
    OutLabel: 18001, NH: 192.1.2.2, IF: GigabitEthernet0/0/0/0
```

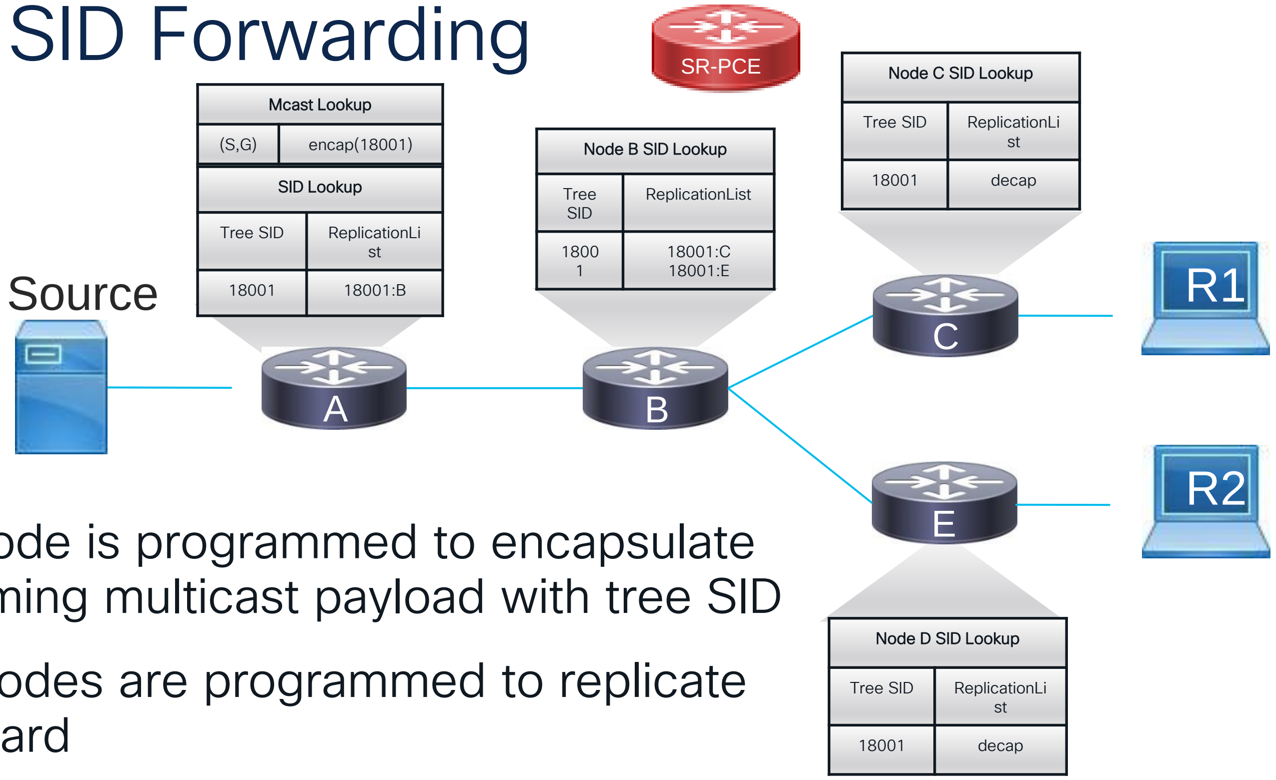
```
RP/0/RP0/CPU0:SR-PCE1#sh pce lsp p2mp

Tree: <>
 Label:   18001    Operational: up  Admin: up
Source: <>
 Destinations<Leaf-Nodes>
 Nodes:
Role: Transit
  Hops:
   Incoming: 18001 CC-ID: 137
   Outgoing: 18001 CC-ID: 137
 Node[2]: <>
  Role: Ingress
  Hops:
   Incoming: 18001 CC-ID: 138
   Outgoing: 18001 CC-ID: 138 (192.1.2.1)
   Outgoing: 18001 CC-ID: 138 (192.1.3.1)
 Node[3]: <>
  Role: Egress
  Hops:
   Incoming: 18101 CC-ID: 139
…
```




```
RP/0/RP0/CPU0:R2#sh mrib mpls forwarding

LSP information (XTC) :
 LSM-ID: 0x0006F, Role: Mid
  Incoming Label      : 18001
  Transported Protocol : <unknown>
  Explicit Null       : None
  IP lookup           : disabled

 Outsegment Info #1 [M/Swap]:
    OutLabel: 18001, NH: 192.2.5.2, IF: GigabitEthernet0/0/0/3
 Outsegment Info #2 [M/Swap]:
    OutLabel: 18001, NH: 192.2.6.2, IF: GigabitEthernet0/0/0/4
```

```
RP/0/RP0/CPU0:R4#show mrib vrf vpn1 ipv4 route detail
(192.101.1.2,232.1.3.1) RPF nbr: 6.1.1.101 Flags: RPF
 Up: 00:00:11
 Incoming Interface List
  TRmdtvpn1 Flags: A TRMI, Up: 00:00:11
 Outgoing Interface List
  GigabitEthernet0/0/0/2 Flags: F IC NS II LI, Up: 00:00:11

RP/0/RP0/CPU0:E#sh mrib mpls forwarding

LSP information (XTC) :
 LSM-ID: 0x0006F, Role: Tail, Peek
 RPF-ID: 0x00003, Assoc-TIDs: 0xe0000002/0x0, MDT: TRmdtvpn1
  Incoming Label      : 18001
  Transported Protocol : <unknown>
  Explicit Null       : None
  IP lookup           : enabled

  Outsegment Info #1 [T/Pop]:
```

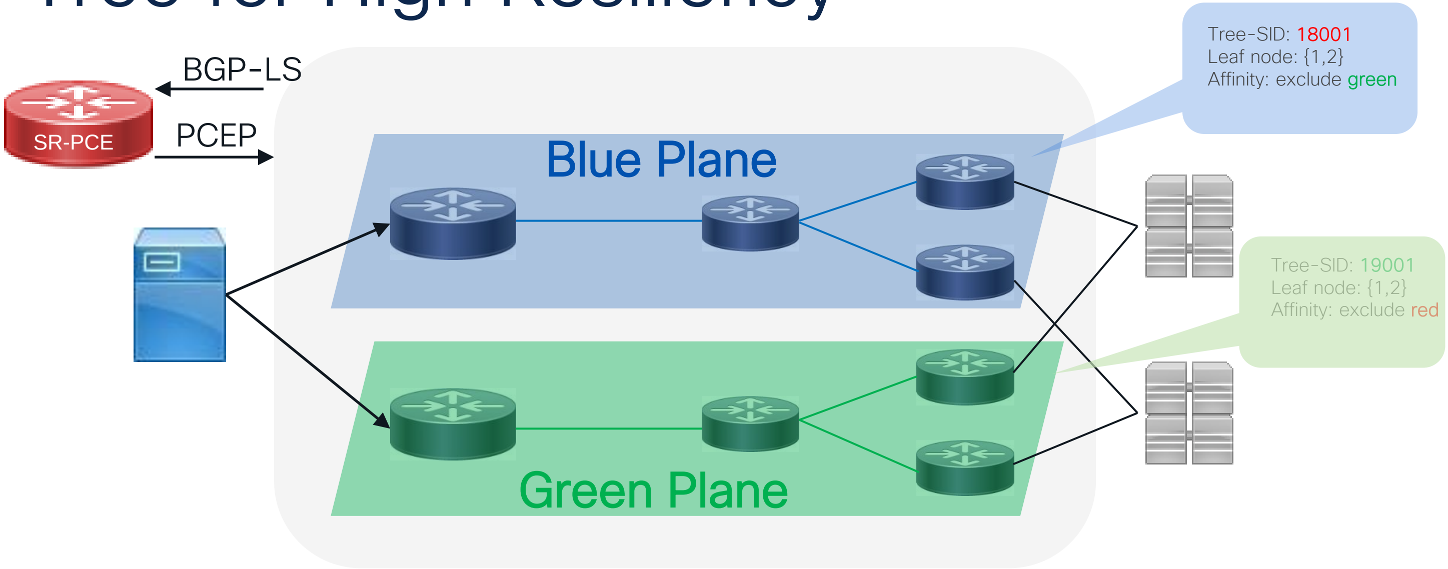
Tree SID Forwarding



- ROOT Node is programmed to encapsulate the incoming multicast payload with tree SID
- Transit nodes are programmed to replicate and forward
- Leaf nodes are programmed to decapsulate the tree SID.

Disjointed Tree for High Resiliency

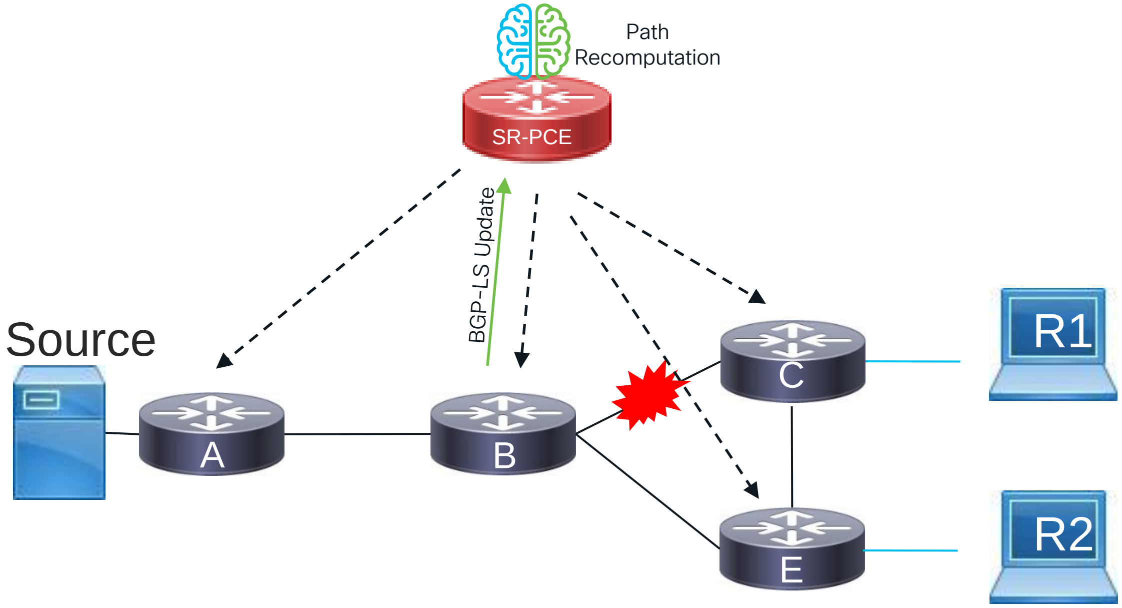
```
policy p2mp-igp-green-vpn1
  source ipv4 <root>
  color 200 endpoint-set <leafset>
  treesid mpls 18101
  candidate-paths
    constraints
      affinity
        include-any
          GREEN
!

policy p2mp-igp-blue-vpn1
  source ipv4 <root>
  color 201 endpoint-set <leafset>
  treesid mpls 18201
  candidate-paths
    constraints
      affinity
        include-any
          BLUE
!
```



- Multi Plane Topology using link affinity colors
  - Green and Blue planes.
- SR-PCE learns link affinities via BGP-LS
- Path computation satisfying the constrains with link affinity

P2MP SR Path Make-Before-Break

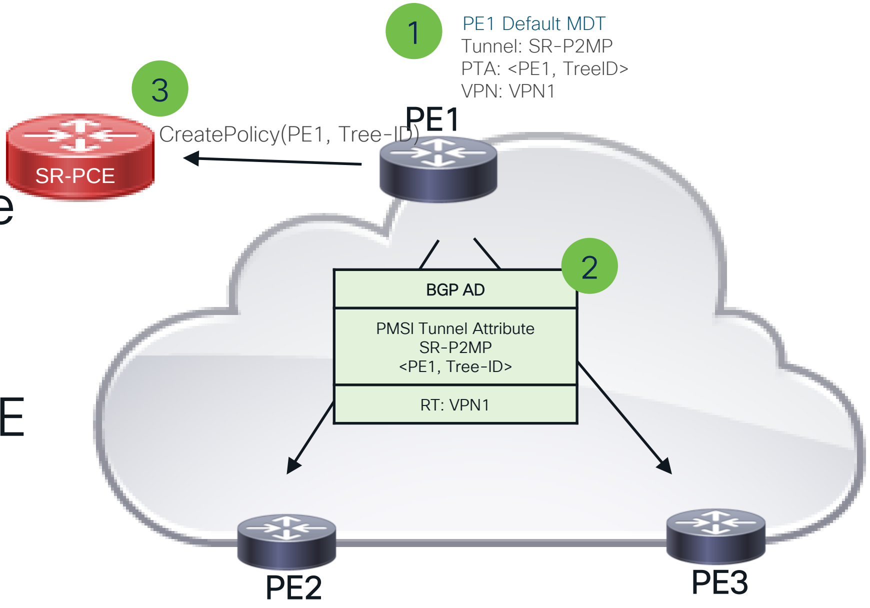
- Event occurs in the network.
- Topology change is notified to SR-PCE
- SR-PCE recomputes the path based on the new topology
- SR-PCE Updates the transit and leaf nodes with new Tree SID.
  - Old entries are retained as stale entry.
- SR-PCE updates the ROOT to use the new Tree SID
- ROOT confirms the update
- SR-PCE updates all the nodes to remove the stale entries.



Dynamic SR P2MP Policy

Default MDT SR P2MP tree

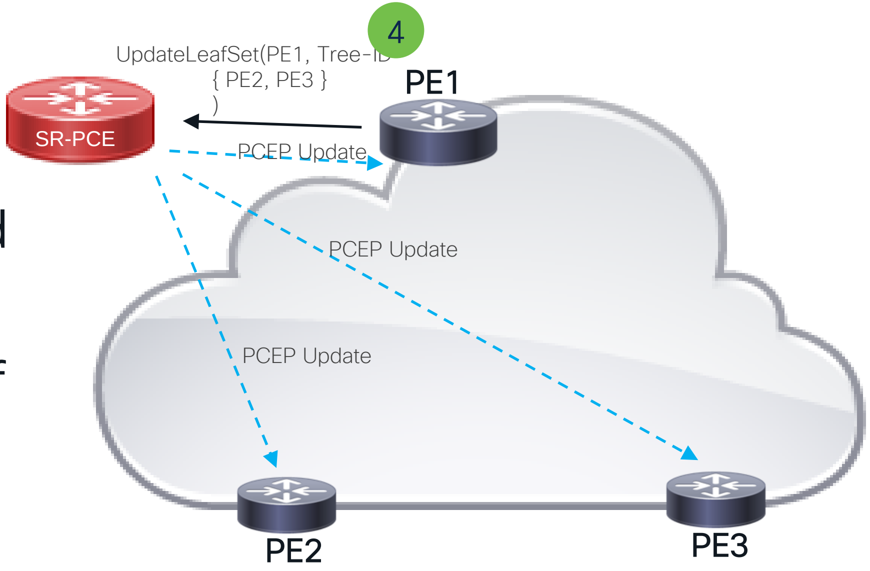
- PE1 assigns a unique Tree ID for the default MDT of VPN1.
- PE1 creates a P2MP policy by invoking CreatePolicy API of the PCE
- PMSI route advertised by PE1 to all remote Pes via BGP-AD



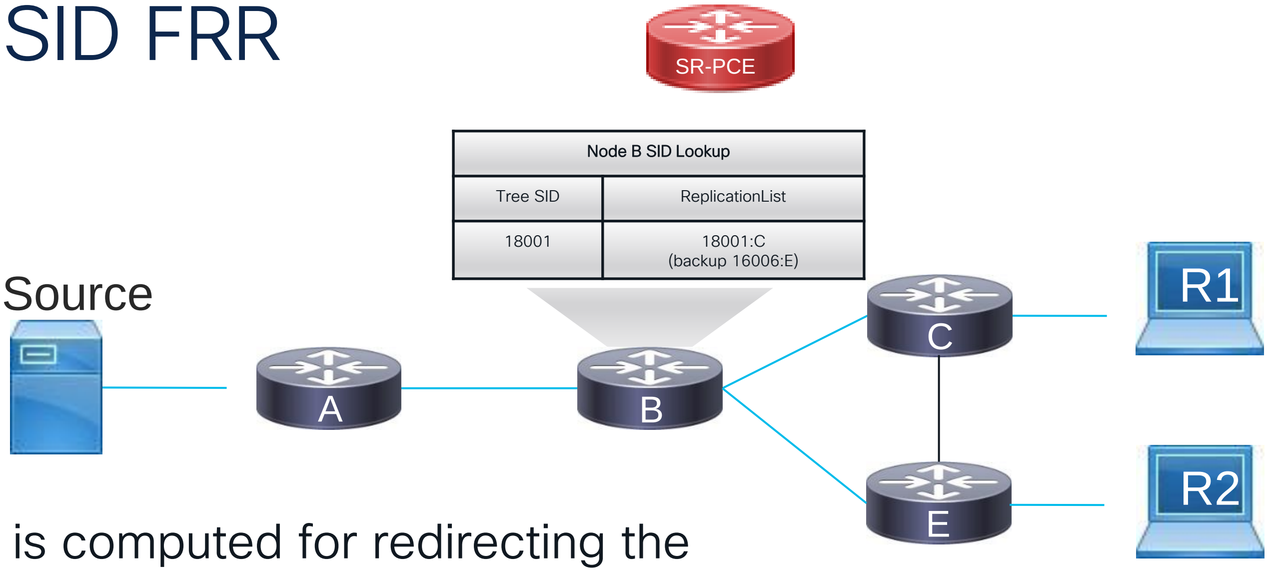
Dynamic SR P2MP Policy

Default MDT SR P2MP tree

- PE1 discovers remote Pes participating in the VPN via received BGP-AD routes.
- PE1 request the PCE to add the leaf nodes to the tree by invoking UpdateLeafSet API of the PCE.
- PCE computes the replication segments and programs the relevant nodes.



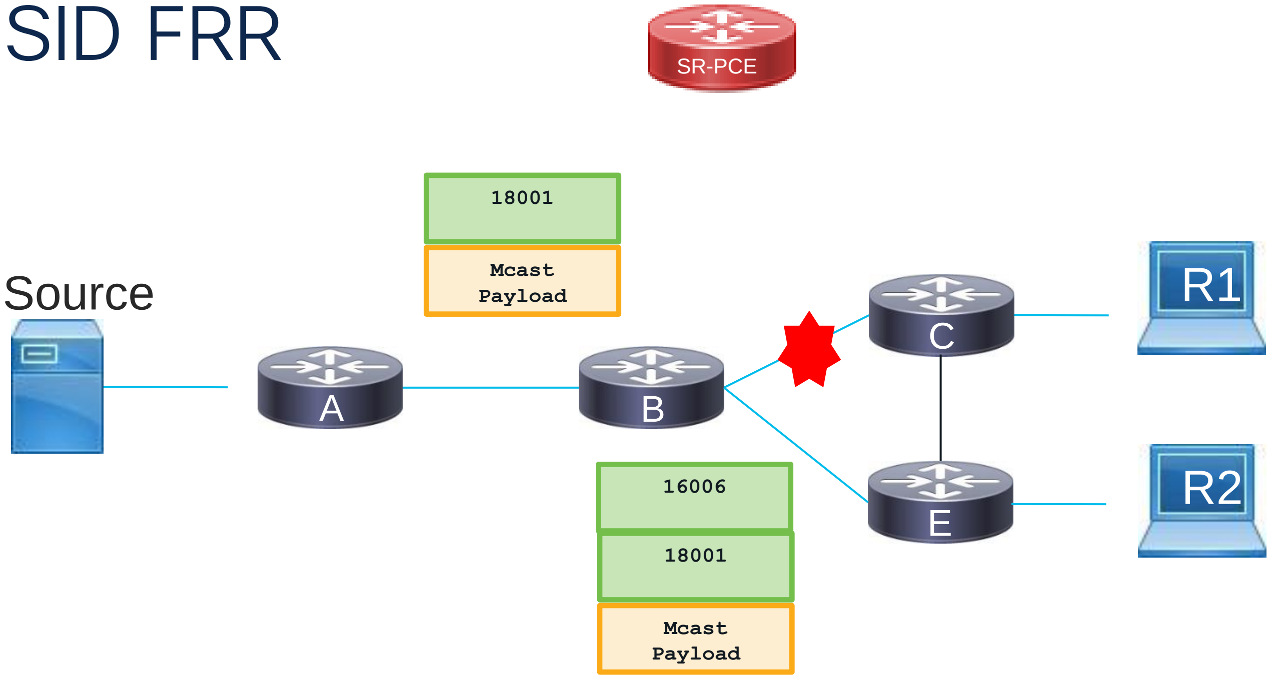
Tree SID FRR



Node B SID Lookup	
Tree SID	ReplicationList
18001	18001:C (backup 16006:E)

- LFA path is computed for redirecting the traffic over backup path.
- Appends Prefix SID to unicast the traffic to the downstream node via backup path.

Tree SID FRR



- LFA path is computed for redirecting the traffic over backup path.
- Appends Prefix SID to unicast the traffic to the downstream node via backup path.

Session Focus

Multipoint LDP
Distributed Approach

SR
Segment Routing

mLDP based P2MP Trees

mLDP-only SAC

- RFC 7473: State Advertisement Control for Non-negotiated LDP apps
- Have an LDP peer negotiate to advertise label bindings for certain MPLS apps or not by means of capability exchange at LDP session establishment
- Configure LDP to negotiate the label advertisement for IPv4, IPv6, FEC128, FEC129, and mLDP
- Request: run (m)LDP for advertisement of mLDP label bindings, but not for unicast label bindings
  - Use-case: Segment Routing network (no LDP for unicast is needed)

```
RP/0/0/CPU0:PE(config-ldp)#capabilities sac ?

  fec128-disable  Disable exchanging PW FEC128 label bindings
  fec129-disable  Disable exchanging PW FEC129 label bindings
  ipv4-disable    Disable exchanging IPv4 prefix label bindings
  ipv6-disable    Disable exchanging IPv6 prefix label bindings
  mldp-only       Only exchange mLDP label bindings
  <cr>
```

LDP without mLDP-only SAC


```
RP/0/0/CPU0:PE1#show running-config mpls ldp
mpls ldp
mldp
 router-id 192.168.0.2
 interface Bundle-Ether1
 interface GigabitEthernet0/0/0/0
 interface GigabitEthernet0/0/0/1
 interface GigabitEthernet0/0/0/2
```

```
RP/0/0/CPU0:P#show running-config mpls ldp
mpls ldp
 mldp
router-id 192.168.0.1
 interface Bundle-Ether1
interface Bundle-Ether2
interface GigabitEthernet0/0/0/0
```

```
RP/0/0/CPU0:PE2#show running-config mpls ldp
mpls ldp
mldp
router-id 192.168.0.3
 interface Bundle-Ether2
 interface GigabitEthernet0/0/0/0
 !
 interface GigabitEthernet0/0/0/1
 !
```

```
RP/0/0/CPU0:PE1#show mpls ldp summary
  AFIs       : IPv4
  Routes     : 6 prefixes
  Bindings   : 7 prefixes
      Local      : 6
      Remote     : 6
  Neighbors : 1
  Adj Groups: 1
  Hello Adj : 1
  Addresses : 3
  Interfaces: 1 LDP configured
```

```
RP/0/0/CPU0:P#show mpls ldp summary
  AFIs       : IPv4
  Routes     : 6 prefixes
  Bindings   : 8 prefixes
      Local      : 6
      Remote     : 12
  Neighbors : 2
  Adj Groups: 2
  Hello Adj : 2
  Addresses : 4
  Interfaces: 2 LDP configured
```

```
RP/0/0/CPU0:PE2#show mpls ldp summary
  AFIs       : IPv4
  Routes     : 6 prefixes
  Bindings   : 7 prefixes
      Local      : 6
      Remote     : 6
  Neighbors : 1
  Adj Groups: 1
  Hello Adj : 1
  Addresses : 3
  Interfaces: 1 LDP configured
```

Impact of mLDP-only SAC


```
RP/0/0/CPU0:PE1#show running-config mpls ldp
mpls ldp
capabilities sac mldp-only
mldp
 router-id 192.168.0.2
 interface Bundle-Ether1
 interface GigabitEthernet0/0/0/0
 interface GigabitEthernet0/0/0/1
 interface GigabitEthernet0/0/0/2
```

```
RP/0/0/CPU0:P#show running-config mpls ldp
mpls ldp
capabilities sac mldp-only
 mldp
router-id 192.168.0.1
 interface Bundle-Ether1
interface Bundle-Ether2
interface GigabitEthernet0/0/0/0
```

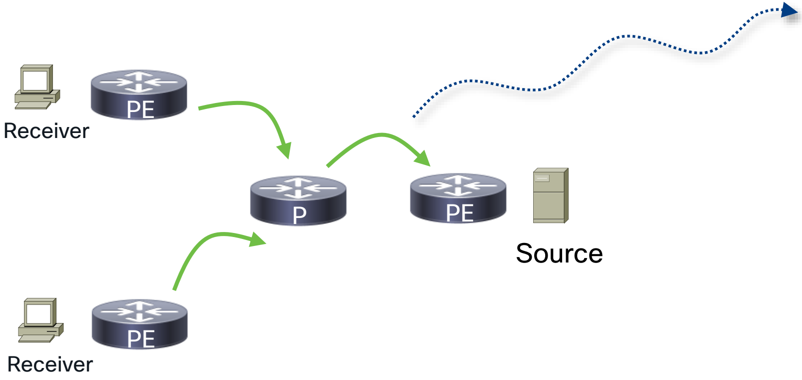
```
RP/0/0/CPU0:PE2#show running-config mpls ldp
mpls ldp
capabilities sac mldp-only
mldp
router-id 192.168.0.3
 interface Bundle-Ether2
 interface GigabitEthernet0/0/0/0
 !
 interface GigabitEthernet0/0/0/1
 !
```

```
RP/0/0/CPU0:PE1#show mpls ldp summary
 AFIs       : IPv4
  Routes    : 0 prefixes
  Bindings  : 0 prefixes
     Local     : 0
     Remote    : 0
  Neighbors : 1
  Adj Groups: 1
  Hello Adj : 1
  Addresses : 3
  Interfaces: 1 LDP configured
```

```
RP/0/0/CPU0:P#show mpls ldp summary
 AFIs       : IPv4
  Routes    : 0 prefixes
  Bindings  : 0 prefixes
     Local     : 0
     Remote    : 0
  Neighbors : 2
  Adj Groups: 2
  Hello Adj : 2
  Addresses : 4
  Interfaces: 2 LDP configured
```

```
RP/0/0/CPU0:PE2#show mpls ldp summary
 AFIs       : IPv4
  Routes    : 0 prefixes
  Bindings  : 0 prefixes
     Local     : 0
     Remote    : 0
  Neighbors : 1
  Adj Groups: 1
  Hello Adj : 1
  Addresses : 3
  Interfaces: 1 LDP configured
```

LDP Label Mapping Message: 4 Important Fields



LDP Label Mapping Message

FEC TLV

FEC Element
FEC Type 0x100

these 3 items uniquely identify the mLDP tree

1	Type	P2MP
2	Root	Ingress PE
3	Opaque	Global Identifier P routers do not interpret this value
4	Label TLV	MPLS label!

Replication in Core

- Core (P) routers signal mLDP
- Replicate MPLS Multicast packets

Control plane | mLDP

Modified LDP
1 additional FEC for LDP Label Mapping Message

Data plane | MPLS

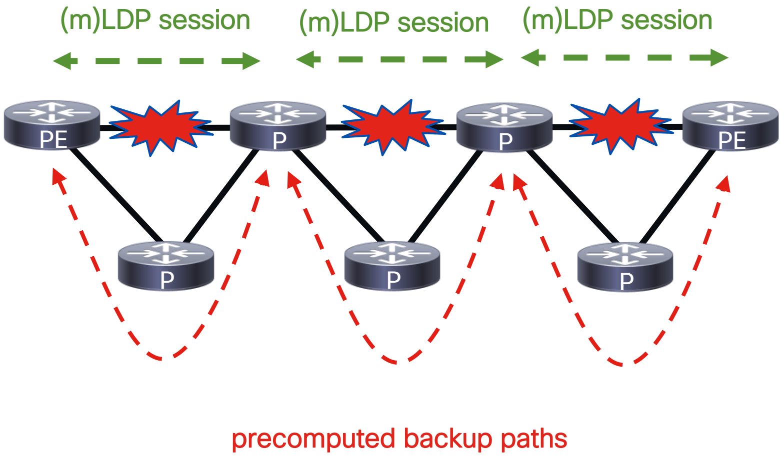
Replication list programmed in data plane

replication

```
RP/0/0/CPU0:P#show mpls forwarding p2mp
Local   Outgoing    Prefix              Outgoing      Next Hop
Label   Label       or ID               Interface
------  ----------- ------------------- ------------- --------
24006   24004       mLDP/IR: 0x00001    Gi0/0/0/0     10.1.4.1
        24009       mLDP/IR: 0x00001    Gi0/0/0/2     10.3.4.3
```

mLDP Protection in Underlay

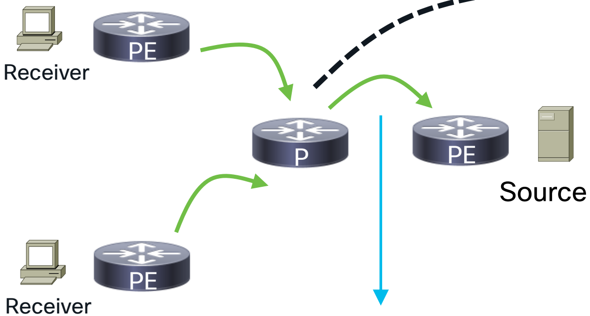
- Backup path is precomputed
- Two possibilities
  - LFA and Ti-LFA (aka FRR)
    - Loop Free Alternate
    - Per-prefix FRR
    - No signalling involved
    - Link protection only (no node protection)



mLDP -> LFIB

mLDP Signaling

- mLDP signalling hop-per-hop
- Label binding, FEC 0x100
- Egress PE towards ingress PE (root)




```
RP/0/0/CPU0:P#show mpls mldp bindings
mLDP MPLS Bindings database

LSP-ID: 0x00001 Paths: 3 Flags:
 0x00001 P2MP   10.0.0.2 [global-id 1]
   Local Label: 24006 Active
   Remote Label: 24004 NH: 10.1.4.1 Inft: GigabitEthernet0/0/0/0
   Remote Label: 24009 NH: 10.3.4.3 Inft: GigabitEthernet0/0/0/2
```

mLDP DB

- 1 mLDP DB entry per tree

```
mLDP database
LSM-ID: 0x00001  Type: P2MP
  FEC Root                : 10.0.0.2
  Opaque decoded        : [global-id 1]
  Upstream neighbor(s)  :
  Is CSI accepting     : N
    10.0.0.2:0 [Active] Uptime: 00:28:37
      Local Label (D) : 24006
  Downstream  client(s):
    LDP 10.0.0.1:0
      Next Hop          : 10.1.4.1
      Interface         : GigabitEthernet0/0/0/0
        Remote label  (D)  : 24004
    LDP 10.0.0.3:0      Uptime: 00:20:31
      Next Hop          : 10.3.4.3
      Interface         : GigabitEthernet0/0/0/2
       Remote label  (D)  : 24009
```

LFIB

- 1 LFIB entry per tree

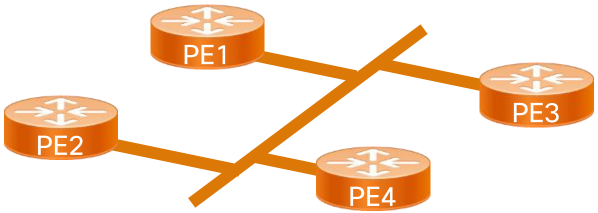
```
RP/0/0/CPU0:P#show mpls forwarding p2mp
Local  Outgoing    Prefix             Outgoing     Next Hop
Label  Label       or ID              Interface
------ ----------- ------------------ ------------ --------
24006  24004       mLDP/IR: 0x00001   Gi0/0/0/0    10.1.4.1
       24009       mLDP/IR: 0x00001   Gi0/0/0/2    10.3.4.3
```

Packet replication

mVPN Basics

Core Tree Types

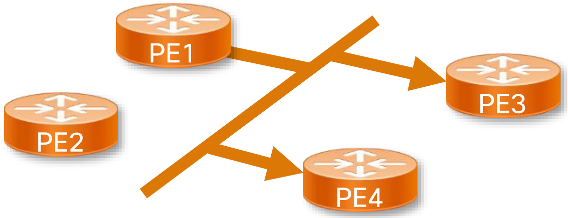
Default MDT



- Connects all PEs
- Bidirectional
- Always present

Multi-Directional Inclusive PMSI
MI-PMSI

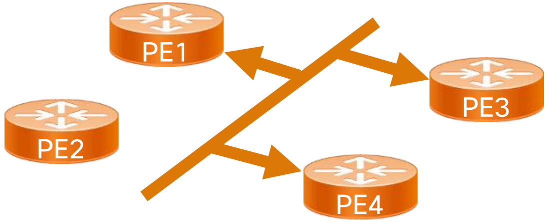
Data MDT



- Connects subset of PEs
- Unidirectional
- On-demand

Selective PMSI
S-PMSI

Partitioned MDT

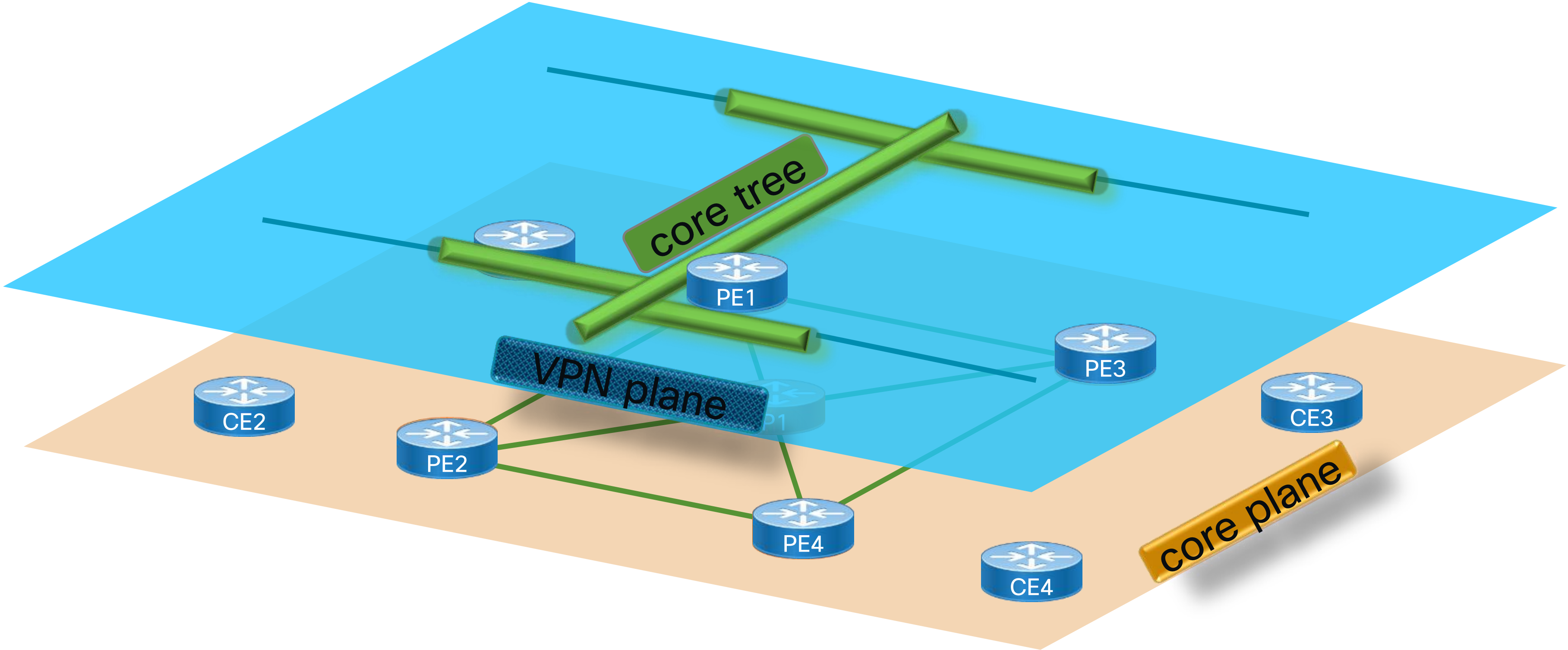


- Connects subset of PEs
- Uni- or Bidirectional
- On-demand

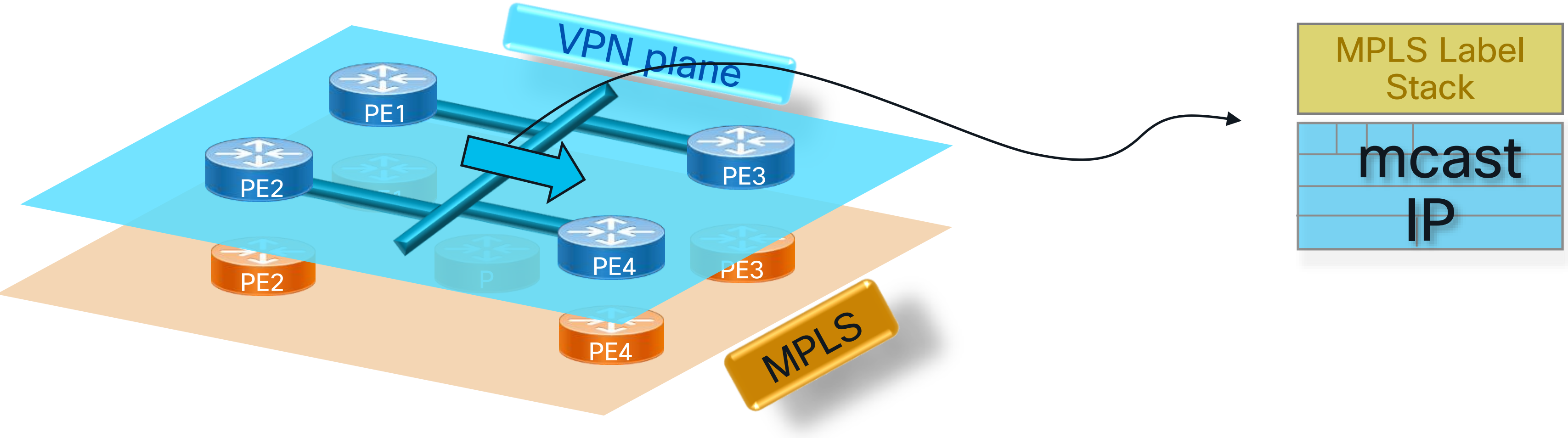
Multidirectional Selective PMSI
MS-PMSI

MDT = Multicast Distribution Tree
PMSI = Provider Multicast Service Interface

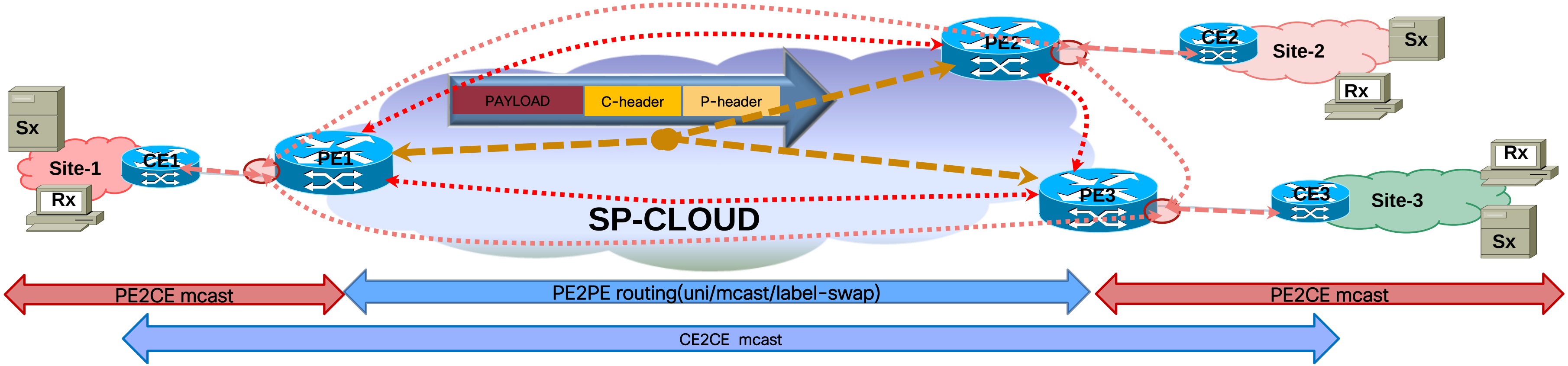
Planes – Overlay Signaling



Encapsulation



Why so many mVPN profiles ?

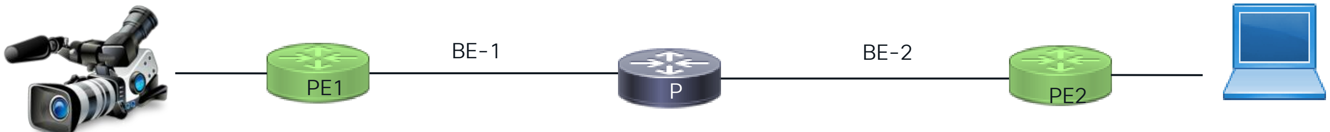


	CLASSICAL-support		NG-support
ENCAPSULATION OPTIONS IN CORE	IP/GRE	+	MPLS
OPTIONS TO DISCOVER PEs	PIM	+	BGP
CORE/PROVIDER-TREE	PIM-ASM/SSM/BIDIR	+	mLDP, P2MP-TE, INGRESS-REPLICATION
C-MCAST ROUTING OPTIONS (PE-PE)	PIM	+	BGP
PE-CE MCAST ROUTING	PIM-ASM/SSM/BIDIR	+	mLDP, BGP
BINDING BTW FLOW & P-TREE	PIM	+	BGP

Global mLDP inBand Signaling

mVPN profile 7

Global mLDP inBand Signaling base config




```
RP/0/0/CPU0:PE1#show running-config multicast-routing
Fri Jun  2 10:25:19.829 PDT
multicast-routing
 address-family ipv4
  mdt source Loopback0
  rate-per-route
  interface all enable
  mdt mldp in-band-signaling ipv4
```

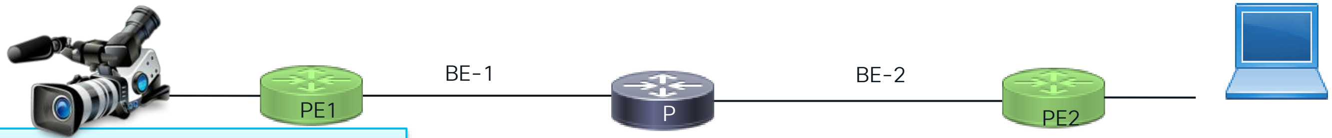
```
RP/0/0/CPU0:PE1#show mpls ldp neighbor  brief
Fri Jun  2 11:34:34.518 PDT

Peer              GR  NSR  Up Time     Discovery   Addresses     Labels
                                       ipv4  ipv6  ipv4  ipv6  ipv4   ipv6
----------------- --  ---  ----------  ----------  ----------  -------
-----
192.168.0.1:0     N   N    01:44:30    1     0     4     0     6      0

RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show mpls ldp neighbor  brief
Fri Jun  2 11:34:47.317 PDT

Peer              GR  NSR  Up Time     Discovery   Addresses     Labels
                                       ipv4  ipv6  ipv4  ipv6  ipv4   ipv6
----------------- --  ---  ----------  ----------  ----------  -----
-------
192.168.0.2:0     N   N    01:44:43    1     0     3     0     6      0
192.168.0.3:0     N   N    01:44:41    1     0     3     0     6      0

RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show running-config multicast-routing
Fri Jun  2 10:14:25.675 PDT
multicast-routing
 address-family ipv4
  mdt source Loopback0
  rate-per-route
  interface all enable
  mdt mldp in-band-signaling ipv4
```

```
RP/0/0/CPU0:PE2#show mpls ldp neighbor  brief
Fri Jun  2 11:34:51.670 PDT

Peer              GR  NSR  Up Time     Discovery   Addresses     Labels
                                       ipv4  ipv6  ipv4  ipv6  ipv4   ipv6
----------------- --  ---  ----------  ----------  ----------  --------
----
192.168.0.1:0     N   N    01:44:45    1     0     4     0     6      0

RP/0/0/CPU0:PE2#
```

Validate if LDP is running for mLDP




```
RP/0/0/CPU0:PE1#show mpls ldp summary
Sat Jun  3 18:57:08.242 PDT

 AFIs      : IPv4
 Routes    : 0 prefixes
 Bindings  : 0 prefixes
    Local     : 0
    Remote    : 0
 Neighbors : 1
 Adj Groups: 1
 Hello Adj : 1
 Addresses : 3
 Interfaces: 1 LDP configured
```

```
RP/0/0/CPU0:P#show mpls ldp summary
Sat Jun  3 18:57:28.900 PDT

 AFIs      : IPv4
 Routes    : 0 prefixes
 Bindings  : 0 prefixes
    Local     : 0
    Remote    : 0
 Neighbors : 2
 Adj Groups: 2
 Hello Adj : 2
 Addresses : 4
 Interfaces: 2 LDP configured
```

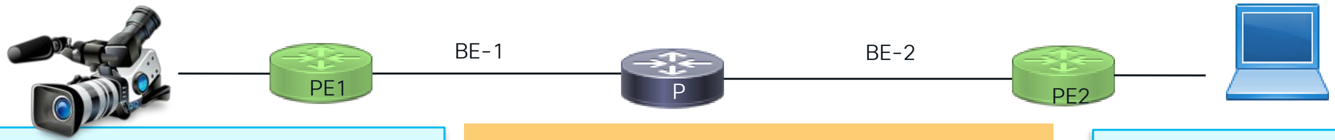
```
RP/0/0/CPU0:PE2#show mpls ldp summary
Sat Jun  3 18:57:35.598 PDT

 AFIs      : IPv4
 Routes    : 0 prefixes
 Bindings  : 0 prefixes
    Local     : 0
    Remote    : 0
 Neighbors : 1
 Adj Groups: 1
 Hello Adj : 1
 Addresses : 3
 Interfaces: 1 LDP configured
```

```
RP/0/0/CPU0:PE1#show mpls ldp capabilities
Sat Jun  3 18:54:25.993 PDT
 Type    Description                                 Owner
 ------  ------------------------------------------  ------------
 0x50b   Typed Wildcard FEC                          LDP
 0x3eff  Cisco IOS-XR                                LDP
 0x508   MP: Point-to-Multipoint (P2MP)              mLDP
 0x509   MP: Multipoint-to-Multipoint (MP2MP)        mLDP
 0x50c   MP: Multi-Topology (MT)                     mLDP
 0x50d   State Advertisement Control                 LDP
 0x703   P2MP PW                                     L2VPN-AToM
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show mpls ldp capabilities
Sat Jun  3 18:54:45.953 PDT
 Type    Description                                 Owner
 ------  ------------------------------------------  ------------
 0x50b   Typed Wildcard FEC                          LDP
 0x3eff  Cisco IOS-XR                                LDP
 0x508   MP: Point-to-Multipoint (P2MP)              mLDP
 0x509   MP: Multipoint-to-Multipoint (MP2MP)        mLDP
 0x50c   MP: Multi-Topology (MT)                     mLDP
 0x50d   State Advertisement Control                 LDP
 0x703   P2MP PW                                     L2VPN-AToM
RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show mpls ldp capabilities
Sat Jun  3 18:54:39.573 PDT
 Type    Description                                 Owner
 ------  ------------------------------------------  ------------
 0x50b   Typed Wildcard FEC                          LDP
 0x3eff  Cisco IOS-XR                                LDP
 0x508   MP: Point-to-Multipoint (P2MP)              mLDP
 0x509   MP: Multipoint-to-Multipoint (MP2MP)        mLDP
 0x50c   MP: Multi-Topology (MT)                     mLDP
 0x50d   State Advertisement Control                 LDP
 0x703   P2MP PW                                     L2VPN-AToM
RP/0/0/CPU0:PE2#
```

mLDP neighborship

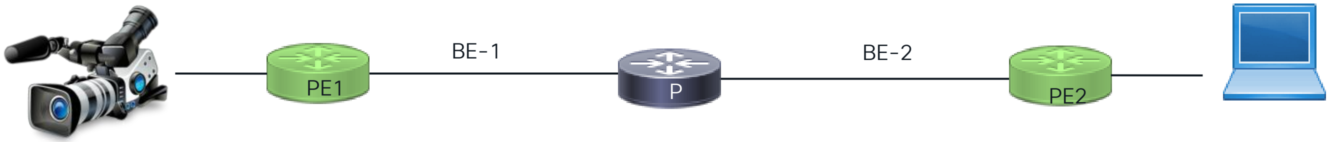



```
RP/0/0/CPU0:PE1#show mpls mldp neighbors
Sat Jun  3 19:01:50.522 PDT
mLDP neighbor database
 MLDP peer ID      : 192.168.0.1:0, uptime 00:08:28 Up,
  Capabilities     : Typed Wildcard FEC, P2MP, MP2MP
  Target Adj       : No
  Upstream count   : 0
  Branch count     : 1
  Label map timer  : never
  Policy filter in :
  Path count       : 1
  Path(s)          : 1.0.0.1          Bundle-Ether1 LDP
  Adj list         : 1.0.0.1          Bundle-Ether1
  Peer addr list   : 10.10.10.1
                   : 192.168.0.1
                   : 1.0.0.1
                   : 2.0.0.1
```

```
RP/0/0/CPU0:P#show mpls mldp neighbors
Sat Jun  3 19:02:18.165 PDT
mLDP neighbor database
 MLDP peer ID      : 192.168.0.2:0, uptime 00:08:56 Up,
  Capabilities     : Typed Wildcard FEC, P2MP, MP2MP
  Target Adj       : No
  Upstream count   : 1
  Branch count     : 0
  Label map timer  : never
  Policy filter in :
  Path count       : 1
  Path(s)          : 1.0.0.2          Bundle-Ether1 LDP
  Adj list         : 1.0.0.2          Bundle-Ether1
  Peer addr list   : 11.11.11.2
                   : 192.168.0.2
                   : 1.0.0.2

 MLDP peer ID      : 192.168.0.3:0, uptime 00:09:00 Up,
  Capabilities     : Typed Wildcard FEC, P2MP, MP2MP
  Target Adj       : No
  Upstream count   : 0
  Branch count     : 1
  Label map timer  : never
  Policy filter in :
  Path count       : 1
  Path(s)          : 2.0.0.3          Bundle-Ether2 LDP
  Adj list         : 2.0.0.3          Bundle-Ether2
  Peer addr list   : 12.12.12.3
                   : 192.168.0.3
                   : 2.0.0.3
RP/0/0/CPU0:P#
```

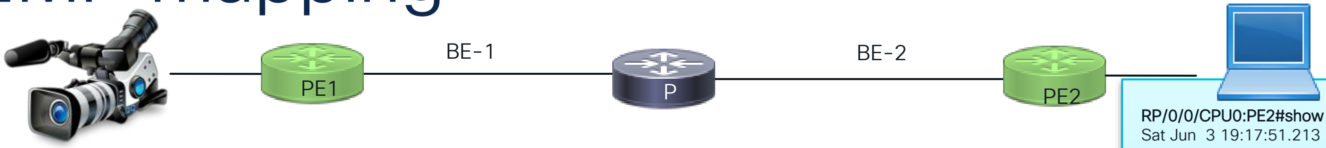
```
RP/0/0/CPU0:PE2#show mpls mldp neighbors
Sat Jun  3 19:02:26.713 PDT
mLDP neighbor database
 MLDP peer ID      : 192.168.0.1:0, uptime 00:09:09 Up,
  Capabilities     : Typed Wildcard FEC, P2MP, MP2MP
  Target Adj       : No
  Upstream count   : 1
  Branch count     : 0
  Label map timer  : never
  Policy filter in :
  Path count       : 1
  Path(s)          : 2.0.0.1          Bundle-Ether2 LDP
  Adj list         : 2.0.0.1          Bundle-Ether2
  Peer addr list   : 10.10.10.1
                   : 192.168.0.1
                   : 1.0.0.1
                   : 2.0.0.1
RP/0/0/CPU0:PE2#
```

Originate IGMP join from receiver



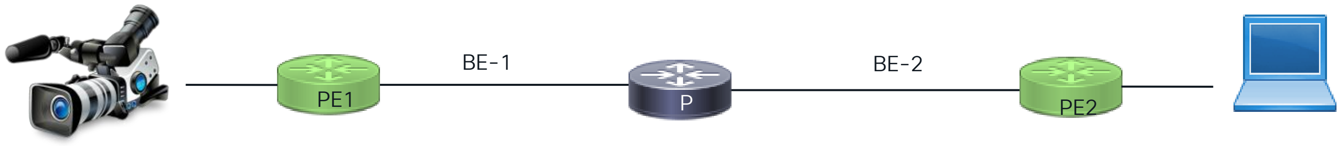

```
RP/0/0/CPU0:PE2#show running-config router igmp
Sat Jun  3 19:14:53.958 PDT
router igmp
 interface GigabitEthernet0/0/0/3
  static-group 232.1.1.1 11.11.11.2
 !
!

RP/0/0/CPU0:PE2#
```


Processing at last hop router before creating P2MP mapping




```
RP/0/0/CPU0:PE2#show ip route 11.11.11.2
Sat Jun  3 19:17:51.213 PDT

Routing entry for 11.11.11.0/24
  Known via "bgp 100", distance 200, metric 0, type internal
  Installed Jun  2 09:50:18.217 for 1d09h
  Routing Descriptor Blocks
    192.168.0.2, from 192.168.0.2
      Route metric is 0
  No advertising protos.
RP/0/0/CPU0:PE2#show bgp ipv4 unicast 11.11.11.2
Sat Jun  3 19:18:10.819 PDT
BGP routing table entry for 11.11.11.0/24
Versions:
  Process           bRIB/RIB  SendTblVer
  Speaker                  7           7
Last Modified: Jun  2 09:50:18.000 for 1d09h
Paths: (1 available, best #1)
  Not advertised to any peer
  Path #1: Received by speaker 0
  Not advertised to any peer
  Local
    192.168.0.2 (metric 3) from 192.168.0.2 (192.168.0.2)
      Origin incomplete, metric 0, localpref 100, valid, internal, best, group-best
      Received Path ID 0, Local Path ID 1, version 7
RP/0/0/CPU0:PE2#show ip route 192.168.0.2
Sat Jun  3 19:18:53.230 PDT

Routing entry for 192.168.0.2/32
  Known via "ospf 100", distance 110, metric 3, type intra area
  Installed Jun  2 09:50:07.884 for 1d09h
  Routing Descriptor Blocks
    2.0.0.1, from 192.168.0.2, via Bundle-Ether2
      Route metric is 3
  No advertising protos.
RP/0/0/CPU0:PE2#show ip int brief | in 2.0.0.1
Sat Jun  3 19:20:19.790 PDT
RP/0/0/CPU0:PE2#
```

Verifying mLDP state end to end

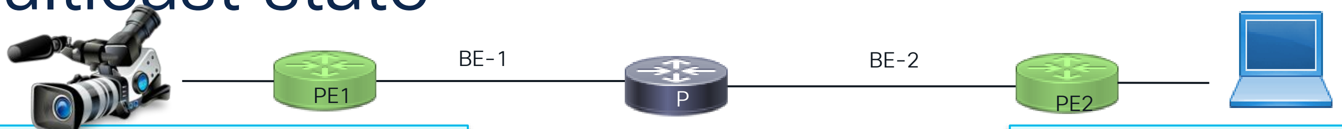



```
RP/0/0/CPU0:PE1#show mpls mldp database p2mp
Sat Jun  3 19:05:57.306 PDT
mLDP database
LSM-ID: 0x00002  Type: P2MP  Uptime: 00:12:35
  FEC Root           : 192.168.0.2 (we are the root)
  Opaque decoded     : [ipv4 11.11.11.2 232.1.1.1]
  Upstream neighbor(s) :
    None
  Downstream  client(s):
    LDP 192.168.0.1:0  Uptime: 00:12:35
      Next Hop         : 1.0.0.1
      Interface        : Bundle-Ether1
      Remote label (D) : 24002
    Local              Uptime: 00:12:35
      Local Label      : 24003 (internal)
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show mpls mldp database p2mp
Sat Jun  3 19:06:14.735 PDT
mLDP database
LSM-ID: 0x00002  Type: P2MP  Uptime: 00:12:57
  FEC Root           : 192.168.0.2
  Opaque decoded     : [ipv4 11.11.11.2 232.1.1.1]
  Upstream neighbor(s) :
  Is CSI accepting   : N
    192.168.0.2:0 [Active] Uptime: 00:12:53
      Local Label (D) : 24002
  Downstream  client(s):
    LDP 192.168.0.3:0  Uptime: 00:12:57
      Next Hop         : 2.0.0.3
      Interface        : Bundle-Ether2
      Remote label (D) : 24003
RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show mpls mldp database p2mp
Sat Jun  3 19:06:40.961 PDT
mLDP database
LSM-ID: 0x00002  Type: P2MP  Uptime: 1d06h
  FEC Root           : 192.168.0.2
  Opaque decoded     : [ipv4 11.11.11.2 232.1.1.1]
  Upstream neighbor(s) :
  Is CSI accepting   : N
    192.168.0.1:0 [Active] Uptime: 00:13:23
      Local Label (D) : 24003
  Downstream  client(s):
    PIM MDT            Uptime: 1d06h
      Egress intf      : lmdtdefault
      Table ID         : IPv4: 0xe0000000
      RPF ID           : 3
RP/0/0/CPU0:PE2#
```

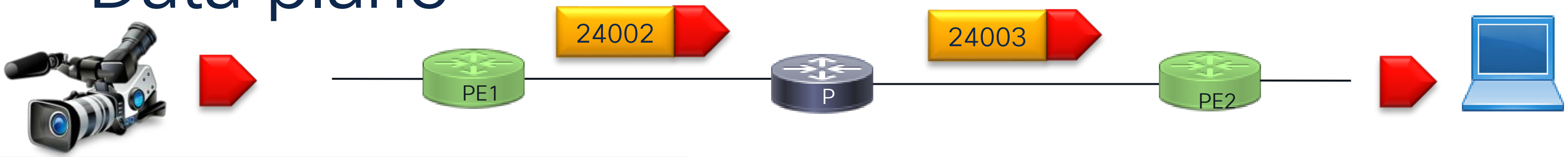
Multicast state




```
RP/0/0/CPU0:PE1#show mrib route 11.11.11.2 232.1.1.1 detail
Sun Jun  4 09:04:59.433 PDT

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
    C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
    IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
    MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface
handle
    CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
    MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
    MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
    NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
    II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
    LD - Local Disinterest, DI - Decapsulation Interface
    EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
    EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
    MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE
MDT Interface
    IRMI - IR MDT Interface, TRMI - TREE SID MDT Interface, MH - Multihome
Interface

(11.11.11.2,232.1.1.1) Ver: 0x19ac RPF nbr: 11.11.11.2 Flags: RPF EID,
FMA: 0x10000
  Up: 14:11:37
  RPF-ID: 0, Encap-ID: 1
  Incoming Interface List
    GigabitEthernet0/0/0/3 Flags: A, Up: 14:11:37
  Outgoing Interface List
    Imdtdefault Flags: F LMI, Up: 14:11:37, Head LSM-ID: 0x00002
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show mrib route 11.11.11.2 232.1.1.1 detail
Sat Jun  3 19:34:23.108 PDT

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
    C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
    IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
    MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface
handle
    CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
    MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
    MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
    NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
    II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
    LD - Local Disinterest, DI - Decapsulation Interface
    EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
    EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
    MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE
MDT Interface
    IRMI - IR MDT Interface, TRMI - TREE SID MDT Interface, MH - Multihome
Interface

(11.11.11.2,232.1.1.1) Ver: 0xe5a RPF nbr: 2.0.0.1 Flags: RPF RPFID, FMA:
0x10000
  Up: 1d07h
  RPF-ID: 3, Encap-ID: 0
  Incoming Interface List
    Imdtdefault Flags: A LMI, Up: 1d07h
  Outgoing Interface List
    GigabitEthernet0/0/0/3 Flags: F NS LI, Up: 1d07h
RP/0/0/CPU0:PE2#
```

Data plane




```
RP/0/0/CPU0:PE1#show mpls forwarding p2mp
Wed Jun  7 08:35:35.115 PDT
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
24003  24002       mLDP/IR: 0x00002   BE1          1.0.0.1         0
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show mpls forwarding p2mp
Wed Jun  7 08:35:47.604 PDT
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
24002  24003       mLDP/IR: 0x00002   BE2          2.0.0.3         0
```

```
RP/0/0/CPU0:PE2#show mpls forwarding p2mp
Wed Jun  7 08:35:52.876 PDT
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
24003  Unlabelled  mLDP/IR: 0x00002
```

mLDP profile 14

A New-Found Role for BGP

Auto-Discovery

Customer Multicast Signalling

Discoverying PE endpoints automatically

- Replacing some PIM signalling, signalling Data MDT

Control plane replacing PIM

- Shared tree (*,G)
- Source tree (S,G)

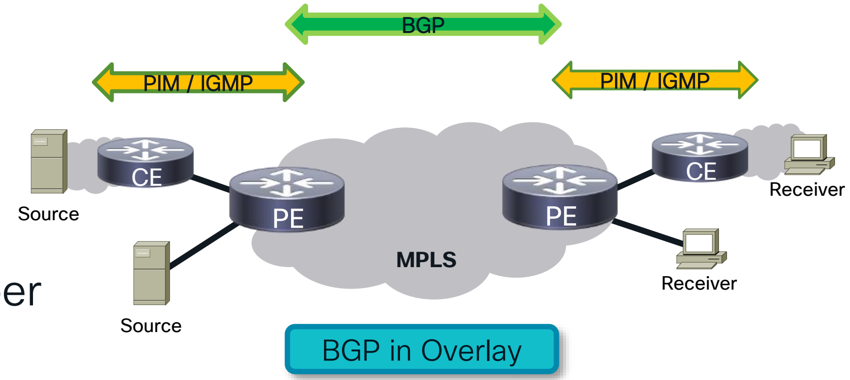
replacing PIM Joins, Prunes, Hellos

- New BGP address family: IPv4 mVPN
- PMSI Tunnel Attribute (PTA) information
  - Describes the core tree (PIM, mLDP, MPLS TE, IR)
- Prefix (NLRI)
  - Describes multicast state
  - Source, Group, Originator, Route Distinguisher

* PMSI = Provider Multicast Service Instance

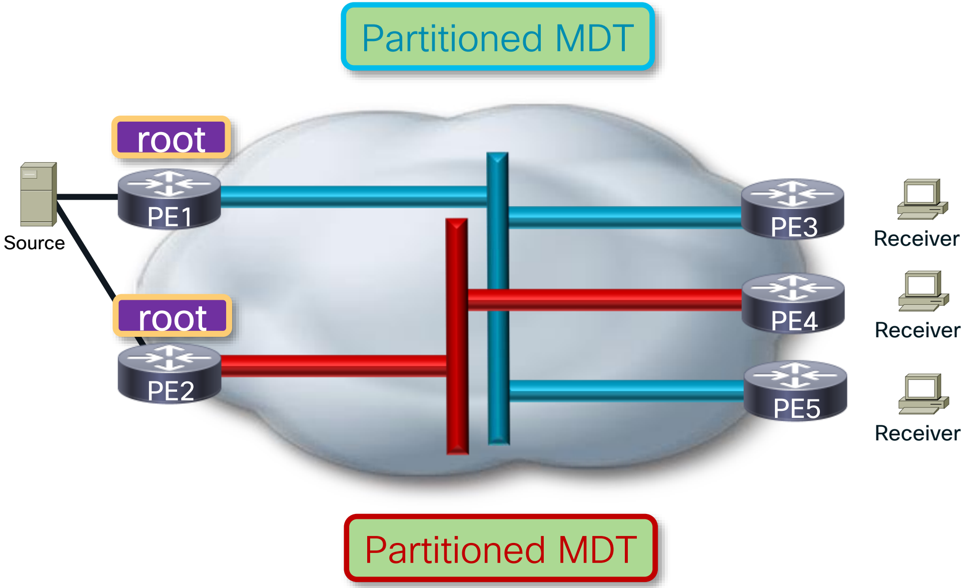
BGP in Overlay

- PE-CE is PIM signaling
- PE-PE is BGP signaling



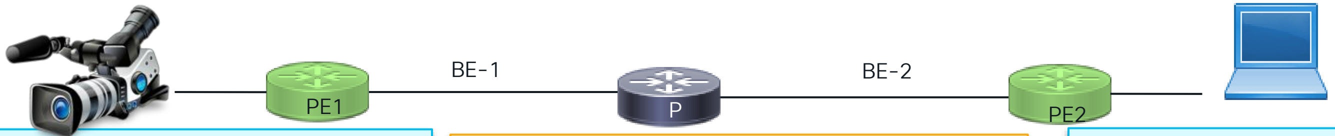
- BGP scales well
- BGP is not a multicast signaling protocol per design
  - Receiver to Source signaling …
  - PIM Sparse Mode works differently in BGP → new procedures
- New address family “IPv4 mVPN”
  1. Signal Auto-Discovery (AD)
  2. Signal multicast information
     - (*,G) or (S,G)
     - Which tunnel to use (core tree protocol and tunnel type: mLDP and Partitioned MDT)

Partitioned MDT



- Unidirectional
- Connects subset of PEs
- BGP AD is needed
- BGP Overlay signaling for (*,G) and (S,G)
- MDT built on-demand when customer traffic is present
  - Optimized for sources mostly co-located in few sites

Initial underlay config to enable mLDP profile 14




```
RP/0/0/CPU0:PE1#show running-config multicast-routing vrf p14_v4_1400
multicast-routing
 vrf p14_v4_1400
  address-family ipv4
   interface all enable
   bgp auto-discovery mldp
   mdt partitioned mldp ipv4 p2mp
   mdt data 10
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE1#show running-config mpls ldp
mpls ldp
 capabilities sac mldp-only
 mldp
 router-id 192.168.0.2
 interface Bundle-Ether1
```

```
RP/0/0/CPU0:PE1#show running-config router pim vrf p14_v4_1400
router pim
 vrf p14_v4_1400
  address-family ipv4
   rpf topology route-policy rpf-for-p14_v4_1400
   mdt c-multicast-routing bgp
```

```
RP/0/0/CPU0:P#show running-config router pim
Sun Jun  4 09:34:32.224 PDT
% No such configuration item(s)

RP/0/0/CPU0:P#
```

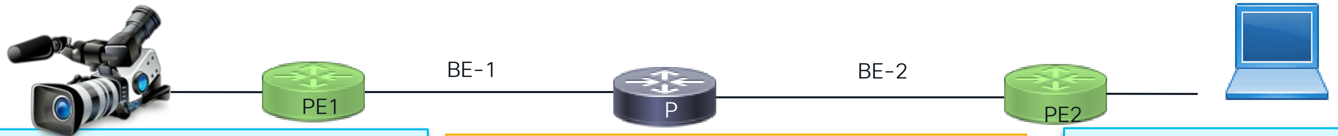
```
RP/0/0/CPU0:P#show running-config mpls ldp
Sun Jun  4 09:39:20.991 PDT
mpls ldp
 capabilities sac mldp-only
 mldp
 !
 router-id 192.168.0.1
 interface Bundle-Ether1
 !
 interface Bundle-Ether2
 !
```

```
RP/0/0/CPU0:PE2#show running-config multicast-routing
multicast-routing
vrf p14_v4_1400
  address-family ipv4
   interface all enable
   bgp auto-discovery mldp

   mdt partitioned mldp ipv4 p2mp
   mdt data 10
```

```
RP/0/0/CPU0:PE2#show running-config mpls ldp
mpls ldp
 capabilities sac mldp-only
mldp
 router-id 192.168.0.3
 interface Bundle-Ether2
```

```
RP/0/0/CPU0:PE2#show running-config router pim
router pim
 vrf p14_v4_1400
  address-family ipv4
   rpf topology route-policy rpf-for-p14_v4_1400
   mdt c-multicast-routing bgp
```

BGP overlay config




```
RP/0/0/CPU0:PE1#show running-config router bgp
router bgp 100
 mvpn
 bgp router-id 192.168.0.2
address-family ipv4 unicast
 address-family vpnv4 unicast
 address-family ipv4 mvpn
 neighbor 192.168.0.3
  remote-as 100
  update-source Loopback0
  address-family ipv4 unicast
  address-family vpnv4 unicast
  address-family ipv4 mvpn
vrf p14_v4_1400
  rd 1400:1
  address-family ipv4 unicast
  address-family ipv4 mvpn

RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show running-config router bgp
Sun Jun  4 09:50:56.634 PDT
% No such configuration item(s)

RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show running-config router bgp
router bgp 100
 mvpn
 bgp router-id 192.168.0.3
address-family ipv4 unicast
 address-family vpnv4 unicast
 address-family ipv4 mvpn
 neighbor 192.168.0.2
  remote-as 100
  update-source Loopback0
  address-family ipv4 unicast
  address-family vpnv4 unicast
  address-family ipv4 mvpn
 vrf p14_v4_1400
  rd 1400:1
  address-family ipv4 unicast
  address-family ipv4 mvpn
```

Verify BGP AF IPv4 mVPN


```
RP/0/0/CPU0:PE1#show bgp ipv4 mvpn summary
.....
Process       RcvTblVer   bRIB/RIB   LabelVer  ImportVer  SendTblVer  StandbyVer
Speaker             12         12         12         12          12          0

Neighbor        Spk    AS MsgRcvd MsgSent   TblVer  InQ OutQ  Up/Down  St/PfxRcd
192.168.0.3       0   100      40      37       12    0    0 00:25:41          2

RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn summary
.....
Process       RcvTblVer   bRIB/RIB   LabelVer  ImportVer  SendTblVer  StandbyVer
Speaker             11         11         11         11          11          0

Neighbor        Spk    AS MsgRcvd MsgSent   TblVer  InQ OutQ  Up/Down  St/PfxRcd
192.168.0.2       0   100      37      40       11    0    0 00:25:59          2

RP/0/0/CPU0:PE2#
```

Verify BGP AD for mVPN


```
RP/0/0/CPU0:PE1#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 1
.........
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 12
*> [1][192.168.0.2]/40
                   0.0.0.0                              0 i
*>i[1][192.168.0.3]/40
                   192.168.0.3                 100      0 i

Processed 2 prefixes, 2 paths
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 1
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 11
*>i[1][192.168.0.2]/40
                   192.168.0.2                 100      0 i
*> [1][192.168.0.3]/40
                   0.0.0.0                              0 i

Processed 2 prefixes, 2 paths
RP/0/0/CPU0:PE2#
```

Verify BGP AD for (*,*)


```
RP/0/0/CPU0:PE1#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 3
..........
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 12
*> [3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120
                   0.0.0.0                              0 i
*>i[3][0][0.0.0.0][0][0.0.0.0][192.168.0.3]/120
                   192.168.0.3                100       0 i

Processed 2 prefixes, 2 paths
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 3
........
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 11
*>i[3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120
                   192.168.0.2                100       0 i
*> [3][0][0.0.0.0][0][0.0.0.0][192.168.0.3]/120
                   0.0.0.0                              0 i

Processed 2 prefixes, 2 paths
RP/0/0/CPU0:PE2#
```

[0][0.0.0.0][0][0.0.0.0] means (*,*) in multicast speak. So, any source, and any group.

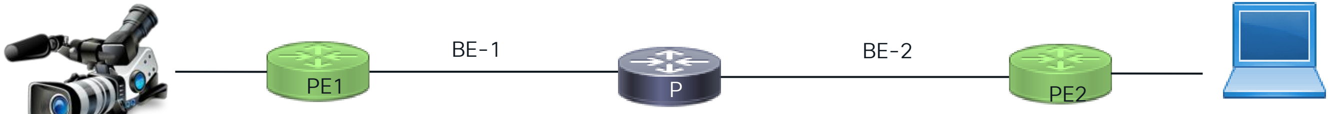
This means that each PE is willing to do Partitioned MDT for any source, any group.

Decoding (*,*) route

FEC Element
FEC Element Type : 6 : P2MP
AF Type : 1
Address Length : 4
Root Address : 192.168.0.2
MP Opaque Length : 7
MP Opaque Value Element
Opaque Type:1 :LSP ID Global
Opaque Length : 4
Global ID : 1

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 [3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120 det
Sun Jun  4 10:48:10.813 PDT
BGP routing table entry for [3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120, Route Distinguisher: 1400:1
Versions:
  Process           bRIB/RIB  SendTblVer
  Speaker                  9           9
    Flags: 0x00041001+0x00000000;
Last Modified: Jun  4 09:29:09.000 for 01:19:02
Paths: (1 available, best #1, not advertised to EBGP peer)
  Not advertised to any peer
  Path #1: Received by speaker 0
  Flags: 0x2000000085060005+0x00, import: 0x39f
  Not advertised to any peer
  Local
    192.168.0.2 (metric 3) from 192.168.0.2 (192.168.0.2), if-handle 0x00000000
      Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
      Received Path ID 0, Local Path ID 1, version 9
      Community: no-export
      Extended community: RT:1400:1
      PMSI: flags 0x00, type 2, label 0, ID 0x06000104c0a80002000701000400000001
      PPMP: label 24000
      Source AFI: IPv4 MVPN, Source VRF: p14_v4_1400, Source Route Distinguisher: 1400:1
RP/0/0/CPU0:PE2#
```

Initial MPLS mLDP database

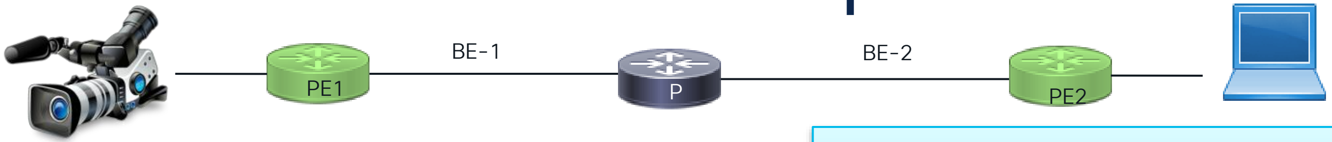



```
RP/0/0/CPU0:PE1#show mpls mldp database
Sun Jun  4 10:14:33.838 PDT
mLDP database
LSM-ID: 0x00001  Type: P2MP  Uptime: 00:46:14
  FEC Root           : 192.168.0.2 (we are the root)
  Opaque decoded     : [global-id 1]
  Upstream neighbor(s) :
    None
  Downstream  client(s):
    PIM MDT          Uptime: 00:46:14
      Egress intf     : Lmdtp14/v4/1400
      Table ID        : IPv4: 0xe0000011 IPv6: 0xe0800011
      HLI             : 0x00001
      Ingress         : Yes
      PPMP            : Yes
      Local Label     : 24000 (internal)
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show mpls mldp database
Sun Jun  4 10:14:10.959 PDT
mLDP database
LSM-ID: 0x00001  Type: P2MP  Uptime: 00:45:51
  FEC Root           : 192.168.0.3 (we are the root)
  Opaque decoded     : [global-id 1]
  Upstream neighbor(s) :
    None
  Downstream  client(s):
    PIM MDT          Uptime: 00:45:51
      Egress intf     : Lmdtp14/v4/1400
      Table ID        : IPv4: 0xe0000011 IPv6: 0xe0800011
      HLI             : 0x00001
      Ingress         : Yes
      PPMP            : Yes
      Local Label     : 24000 (internal)
RP/0/0/CPU0:PE2#
```

```
RP/0/0/CPU0:P#show mpls mldp database
Sun Jun  4 10:15:28.376 PDT
No entries in the table to display
RP/0/0/CPU0:P#
```

Multicast membership & Tree building

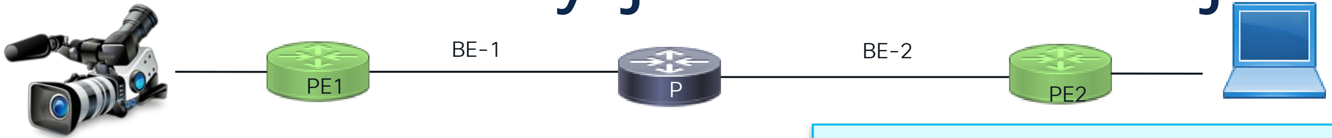



```
RP/0/0/CPU0:PE2#show running-config router igmp
Sun Jun  4 10:27:29.974 PDT
router igmp
 vrf p14_v4_1400
  interface GigabitEthernet0/0/0/3.1400
   static-group 232.1.1.1 11.5.120.20
  !
```

```
RP/0/0/CPU0:PE2#show ip route vrf p14_v4_1400 11.5.120.20
Sun Jun  4 10:29:43.940 PDT

Routing entry for 11.5.120.0/24
  Known via "bgp 100", distance 200, metric 0, type internal
  Installed Jun  4 09:29:09.244 for 01:00:34
  Routing Descriptor Blocks
    192.168.0.2, from 192.168.0.2
      Nexthop in Vrf: "default", Table: "default", IPv4 Unicast, Table Id:
0xe0000000
      Route metric is 0
  No advertising protos.
RP/0/0/CPU0:PE2#
```

```
RP/0/0/CPU0:PE2#show ip route 192.168.0.2
Sun Jun  4 10:31:51.426 PDT

Routing entry for 192.168.0.2/32
  Known via "ospf 100", distance 110, metric 3, type intra area
  Installed Jun  4 09:28:57.276 for 01:02:54
  Routing Descriptor Blocks
    2.0.0.1, from 192.168.0.2, via Bundle-Ether2
      Route metric is 3
  No advertising protos.
RP/0/0/CPU0:PE2#
```

mLDP underlay join with first join



Join underlay mLDP to root from (*,*)

Verifies, if we have unicast route

```
RP/0/0/CPU0:PE2#show running-config router igmp
Sun Jun  4 10:27:29.974 PDT
router igmp
 vrf p14_v4_1400
  interface GigabitEthernet0/0/0/3.1400
   static-group 232.1.1.1 11.5.120.20
```

Verifies, if we (*,*) route

```
RP/0/0/CPU0:PE2#show ip route vrf p14_v4_1400 11.5.120.20
Sun Jun  4 10:29:43.940 PDT

Routing entry for 11.5.120.0/24
  Known via "bgp 100", distance 200, metric 0, type internal
  Installed Jun  4 09:29:09.244 for 01:00:34
  Routing Descriptor Blocks
    192.168.0.2, from 192.168.0.2
      Nexthop in Vrf: "default", Table: "default", IPv4 Unicast, Table Id:
0xe0000000
      Route metric is 0
  No advertising protos.
RP/0/0/CPU0:PE2#
```

```
RP/0/0/CPU0:PE2#  show bgp ipv4 mvpn vrf p14_v4_1400 route-type 3
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 14
*>i[3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120
                   192.168.0.2                    100      0 i
*> [3][0][0.0.0.0][0][0.0.0.0][192.168.0.3]/120
                   0.0.0.0                            0 i

Processed 2 prefixes, 2 paths
RP/0/0/CPU0:PE2#
```

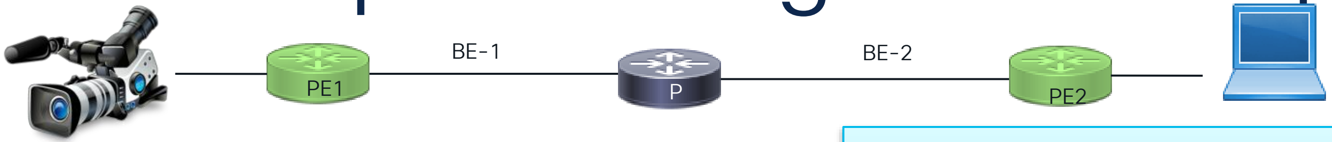
Verify mLDP underlay join


```
RP/0/0/CPU0:PE1#show mpls mldp database
Sun Jun  4 11:09:53.804 PDT
mLDP database
LSM-ID: 0x00001  Type: P2MP  Uptime: 01:41:34
  FEC Root            : 192.168.0.2 (we are the root)
  Opaque decoded      : [global-id 1]
  Upstream neighbor(s) :
    None
  Downstream  client(s):
    LDP 192.168.0.1:0  Uptime: 00:42:51
      Next Hop          : 1.0.0.1
      Interface         : Bundle-Ether1
      Remote label (D) : 24000
    PIM MDT            Uptime: 01:41:34
      Egress intf       : Lmdtp14/v4/1400
      Table ID          : IPv4: 0xe0000011 IPv6: 0xe0800011
      HLI               : 0x00001
      Ingress           : Yes
      PPMP              : Yes
      Local Label       : 24000 (internal)
RP/0/0/CPU0:PE1#
```

```
P/0/0/CPU0:P#show mpls mldp database
un Jun  4 11:09:06.572 PDT
LDP database
SM-ID: 0x00002  Type: P2MP  Uptime:
):42:04
FEC Root            : 192.168.0.2
Opaque decoded      : [global-id 1]
Upstream neighbor(s) :
s CSI accepting     : N
 192.168.0.2:0 [Active] Uptime: 00:42:04
   Local Label (D) : 24000
Downstream  client(s):
 LDP 192.168.0.3:0  Uptime: 00:42:04
   Next Hop          : 2.0.0.3
   Interface         : Bundle-Ether2
   Remote label (D) : 24001
P/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show mpls mldp database
mLDP database
LSM-ID: 0x00003  Type: P2MP  Uptime: 00:40:40
  FEC Root            : 192.168.0.2
  Opaque decoded      : [global-id 1]
  Upstream neighbor(s) :
  Is CSI accepting     : N
    192.168.0.1:0 [Active] Uptime: 00:40:40
      Local Label (D) : 24001
  Downstream  client(s):
    PIM MDT            Uptime: 00:40:40
      Egress intf       : Lmdtp14/v4/1400
      Table ID          : IPv4: 0xe0000011 IPv6: 0xe0800011
      RPF ID            : 3
      RD                : 1400:1
```

Multicast processing at Last hop router




```
RP/0/0/CPU0:PE2#show mrib vrf p14_v4_1400 route 11.5.120.20 232.1.1.1
........
(11.5.120.20,232.1.1.1) RPF nbr: 192.168.0.2 Flags: RPF
  Up: 00:51:42
  Incoming Interface List
    Lmdtp14/v4/1400 Flags: A LMI, Up: 00:51:42
  Outgoing Interface List
    GigabitEthernet0/0/0/3.1400 Flags: F NS LI, Up: 00:51:42
RP/0/0/CPU0:PE2#
```

```
RP/0/0/CPU0:PE2#show pim vrf p14_v4_1400 rpf
Sun Jun  4 11:21:25.870 PDT

Table: IPv4-Unicast-default
* 11.5.120.20/32 [200/0]
    via Lmdtp14/v4/1400 with rpf neighbor 192.168.0.2
    Connector: 1400:1:192.168.0.2, Nexthop: 192.168.0.2
RP/0/0/CPU0:PE2#
```

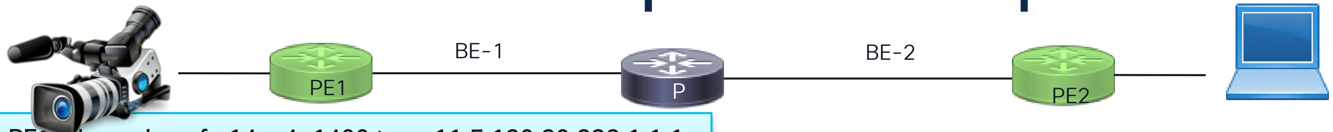
```
RP/0/0/CPU0:PE2#show pim vrf p14_v4_1400 topo 11.5.120.20 232.1.1.1
.........
(11.5.120.20,232.1.1.1)SPT SSM Up: 00:52:44
JP: Join(BGP) RPF: Lmdtp14/v4/1400,192.168.0.2 Flags:
  GigabitEthernet0/0/0/3.1400 00:52:44  fwd LI LH
RP/0/0/CPU0:PE2#
```

Multicast Overlay join


```
RP/0/0/CPU0:PE1#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 7
Sun Jun  4 11:15:25.507 PDT
BGP router identifier 192.168.0.2, local AS number 100
BGP generic scan interval 15 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0
BGP table nexthop route policy:
BGP main routing table version 17
BGP NSR Initial initsync version 2 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
              i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 17
*>i[7][1400:1][100][32][11.5.120.20][32][232.1.1.1]/184
                      192.168.0.3                  100      0 i

Processed 1 prefixes, 1 paths
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 7
Sun Jun  4 11:13:11.513 PDT
BGP router identifier 192.168.0.3, local AS number 100
BGP generic scan interval 15 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0
BGP table nexthop route policy:
BGP main routing table version 14
BGP NSR Initial initsync version 2 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
BGP scan interval 60 secs
Status codes: s suppressed, d damped, h history, * valid, > best
              i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 14
*> [7][1400:1][100][32][11.5.120.20][32][232.1.1.1]/184
                      0.0.0.0                                0 i

Processed 1 prefixes, 1 paths
RP/0/0/CPU0:PE2#
```

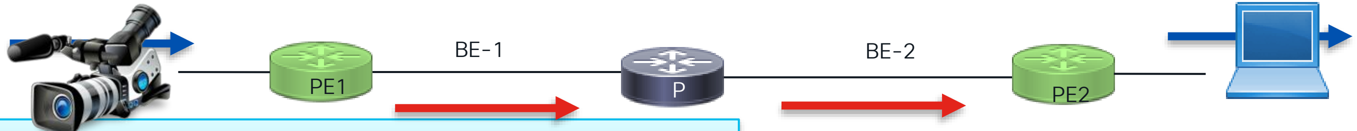
Multicast First hop router processing




```
RP/0/0/CPU0:PE1#show pim vrf p14_v4_1400 topo 11.5.120.20 232.1.1.1
Sun Jun  4 11:24:17.305 PDT
......
(11.5.120.20,232.1.1.1)SPT SSM Up: 00:57:43
JP: Join(00:00:05) RPF: GigabitEthernet0/0/0/3.1400,11.5.120.20* Flags:
  Lmdtp14/v4/1400            00:57:15  fwd BGP
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE1#show mrib vrf p14_v4_1400 route 11.5.120.20 232.1.1.1

(11.5.120.20,232.1.1.1) RPF nbr: 11.5.120.20 Flags: RPF
  Up: 01:10:20
  Incoming Interface List
    GigabitEthernet0/0/0/3.1400 Flags: A, Up: 01:10:20
  Outgoing Interface List
    Lmdtp14/v4/1400 Flags: F LMI TR, Up: 01:09:51
RP/0/0/CPU0:PE1#
```

End to End MPLS P2MP forwarding

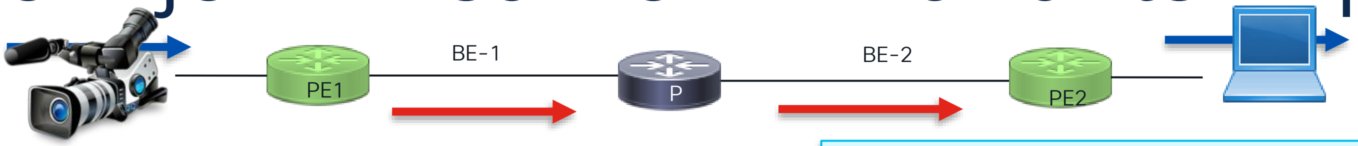



```
RP/0/0/CPU0:PE1#show mpls forwarding p2mp
Sun Jun  4 11:42:42.627 PDT
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- --
----------
24000  24000       mLDP/IR: 0x00001   BE1          1.0.0.1         0
RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:P#show mpls forwarding p2mp
Sun Jun  4 11:45:28.614 PDT
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- --
----------
24000  24001       mLDP/IR: 0x00002   BE2          2.0.0.3         0
RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show mpls forwarding p2mp
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- --
----------
24000  Unlabelled  mLDP/IR: 0x00001
24001  Unlabelled  mLDP/IR: 0x00003
RP/0/0/CPU0:PE2#
```

New join in same VRF and its impact




```
RP/0/0/CPU0:PE2#show running-config router igmp
router igmp
 vrf p14_v4_1400
  interface GigabitEthernet0/0/0/3.1400
   static-group 232.1.1.1 11.5.120.20
   static-group 233.1.1.1 11.5.120.21
  !
```

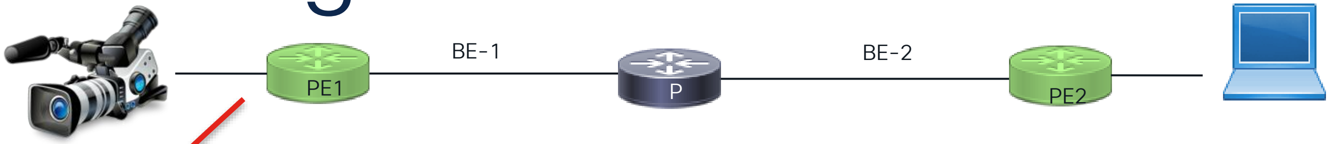
```
RP/0/0/CPU0:PE2#show mpls mldp database
Sun Jun  4 12:04:29.156 PDT
mLDP database
LSM-ID: 0x00003  Type: P2MP  Uptime: 01:37:27
  FEC Root           : 192.168.0.2
  Opaque decoded     : [global-id 1]
  Upstream neighbor(s) :
  Is CSI accepting   : N
    192.168.0.1:0 [Active] Uptime: 01:37:27
      Local Label (D) : 24001
  Downstream  client(s):
    PIM MDT           Uptime: 01:37:27
      Egress intf     : Lmdtp14/v4/1400
      Table ID        : IPv4: 0xe0000011 IPv6: 0xe0800011
      RPF ID          : 3
      RD              : 1400:1
```

```
RP/0/0/CPU0:PE2#show mrib vrf p14_v4_1400 route
(11.5.120.20,232.1.1.1) RPF nbr: 192.168.0.2 Flags: RPF
  Up: 01:38:35
  Incoming Interface List
    Lmdtp14/v4/1400 Flags: A LMI, Up: 01:38:35
  Outgoing Interface List
    GigabitEthernet0/0/0/3.1400 Flags: F NS LI, Up: 01:38:35

(11.5.120.21,233.1.1.1) RPF nbr: 192.168.0.2 Flags: RPF
  Up: 00:02:43
  Incoming Interface List
    Lmdtp14/v4/1400 Flags: A LMI, Up: 00:02:43
  Outgoing Interface List
    GigabitEthernet0/0/0/3.1400 Flags: F NS LI, Up: 00:02:43
```

Data MDT (S-PMSI) Processing

- With current approach, every flow rooted at Ingress PE is being delivered using same underlay tree
- What would be option if we need to create multiple optimal tree ?

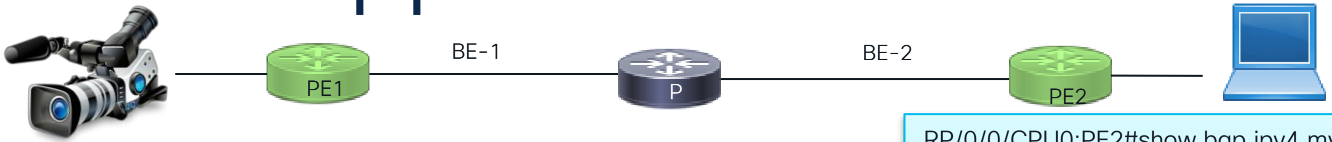
Switching to Data MDT




```
RP/0/0/CPU0:PE1(config-mcast-p14_v4_1400-ipv4)#mdt data 10 ?
  WORD             ACL for Customer VRF groups allowed to do Data MDT
  immediate-switch  Switch to Data MDT immediately
  route-policy      DATA MDT Route policy
  threshold         Traffic rate threshold in Kbps to trigger Data MDT
  <cr>
RP/0/0/CPU0:PE1(config-mcast-p14_v4_1400-ipv4)#mdt data 10
```

```
RP/0/0/CPU0:PE1#show running-config multicast-routing
multicast-routing
vrf p14_v4_1400
  address-family ipv4
  interface all enable
   bgp auto-discovery mldp
   mdt partitioned mldp ipv4 p2mp
   mdt data 10 immediate-switch

RP/0/0/CPU0:PE1#
```


Flows mapped to MDT




```
RP/0/0/CPU0:PE1#show pim vrf p14_v4_1400 mdt cache
Sun Jun  4 12:23:27.842 PDT

Core Source     Cust (Source, Group)        Core Data      Expires  Name
192.168.0.2     (11.5.120.20, 232.1.1.1)     [global-id 4]  00:02:44


192.168.0.2     (11.5.120.21, 233.1.1.1)     [global-id 6]  00:02:44


RP/0/0/CPU0:PE1#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 route-type 3
Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1400:1 (default for vrf p14_v4_1400)
Route Distinguisher Version: 27
*>i[3][0][0.0.0.0][0][0.0.0.0][192.168.0.2]/120
                   192.168.0.2                  100      0 i
*> [3][0][0.0.0.0][0][0.0.0.0][192.168.0.3]/120
                   0.0.0.0                           0 i
*>i[3][32][11.5.120.20][32][232.1.1.1][192.168.0.2]/120
                   192.168.0.2                  100      0 i
*>i[3][32][11.5.120.21][32][233.1.1.1][192.168.0.2]/120
                   192.168.0.2                  100      0 i

Processed 4 prefixes, 4 paths
RP/0/0/CPU0:PE2#
```

```
RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 [3][32][11.5.120.20][32][232.1.1.1][192.168.0.2]/120 det
PMSI: flags 0x00, type 2, label 0, ID 0x06000104c0a80002000701000400000004

RP/0/0/CPU0:PE2#show bgp ipv4 mvpn vrf p14_v4_1400 [3][32][11.5.120.21][32][233.1.1.1][192.168.0.2]/120 det
PMSI: flags 0x00, type 2, label 0, ID 0x06000104c0a80002000701000400000006
```

Flows mapped to MDT


```
RP/0/0/CPU0:P#show mpls mldp database opaquetype global-id 4
Sun Jun  4 12:31:19.065 PDT
mLDP database
LSM-ID: 0x00005  Type: P2MP  Uptime: 00:18:08
  FEC Root            : 192.168.0.2
  Opaque decoded      : [global-id 4]
  Upstream neighbor(s) :
```

```
RP/0/0/CPU0:P#show mpls mldp database opaquetype global-id 6
Sun Jun  4 12:32:01.903 PDT
mLDP database
LSM-ID: 0x00006  Type: P2MP  Uptime: 00:18:51
  FEC Root            : 192.168.0.2
  Opaque decoded      : [global-id 6]
  Upstream neighbor(s) :
  Is CSI accepting    : N
    192.168.0.2:0 [Active] Uptime: 00:18:51
      Local Label (D) : 24002
  Downstream  client(s):
    LDP 192.168.0.3:0  Uptime: 00:18:51
      Next Hop         : 2.0.0.3
      Interface        : Bundle-Ether2
      Remote label (D) : 24003
RP/0/0/CPU0:P#
```

```
RP/0/0/CPU0:PE2#show mpls mldp database opaquetype  global-id 4
Sun Jun  4 12:29:42.839 PDT
mLDP database
LSM-ID: 0x00006  Type: P2MP  Uptime: 00:16:32
  FEC Root            : 192.168.0.2
  Opaque decoded      : [global-id 4]
  Upstream neighbor(s) :
```

```
RP/0/0/CPU0:PE2#show mpls mldp database opaquetype  global-id 6
Sun Jun  4 12:30:08.231 PDT
mLDP database
LSM-ID: 0x00007  Type: P2MP  Uptime: 00:16:57
  FEC Root            : 192.168.0.2
  Opaque decoded      : [global-id 6]
  Upstream neighbor(s) :
  Is CSI accepting    : N
    192.168.0.1:0 [Active] Uptime: 00:16:57
      Local Label (D) : 24003
  Downstream  client(s):
    PIM MDT           Uptime: 00:16:57
      Egress intf     : Lmdtp14/v4/1400
      Table ID        : IPv4: 0xe0000011 IPv6: 0xe0800011
      RPF ID          : 3
      RD              : 1400:1
RP/0/0/CPU0:PE2#
```

Try out in Lab

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mVPN: Profile 14 - LABMPL-2012

Luc De Ghein, Technical Leader, Cisco Systems, Inc. - **Distinguished Speaker**

JC Rode, Principal Engineer, Cisco Systems, Inc. - **Distinguished Speaker**

mVPN is popular and profile 14 is by far the most popular multicast VPN solution today. This profile is based on the core tree protocol mLDP and uses BGP as customer signalling protocol. You will learn how this profile works, and how to configure and troubleshoot mVPN profile 14 in this lab on IOS-XR devices.

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NOTE: Interested in this session? Add it to your Personal Time and select a day/time that fits your schedule.
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Wednesday: 8:30 a.m. - 5 p.m.
Thursday: 8:30 a.m. - 1 p.m.

Session Type: Walk-in Lab

Technical Level: Intermediate

Technology: Routing, Service Provider

Track: Service Provider

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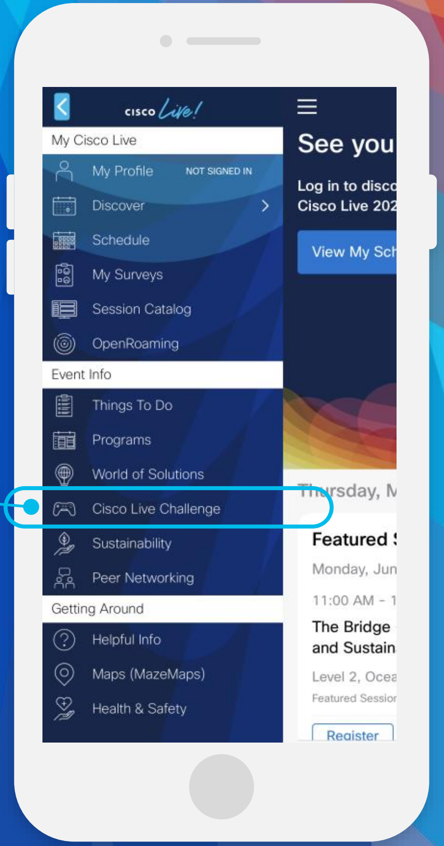

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