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The bridge to possible

SR IGP Flex-Algo

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BRKMPL-2129

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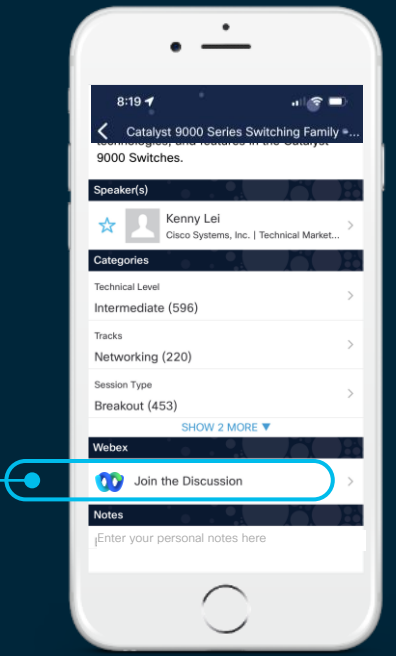

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Why are we here?

- Wouldn’t it be nice to be able to manipulate the IGP to our own specific needs? If we could add our own attribute or constraint?
  - Only use a route with a cumulative delay based on a measured per link delay
  - Have a highly reliable network achieving 5 or even 6 9’s of uptime.
  - If we only want to use a secure path. Such as paths with MACsec only
  - Define a path traversing high speed links for bandwidth sensitive traffic
  - Only use a subset of the routers in your network

Agenda

- MPLS Traffic Engineering Evolution
- SR IGP Flexible-Algorithm (Flex-Algo)
- SRTE ODN Policy using Flex-Algo
- Use Cases
- Conclusion

What we won't be able to cover

- Basics of Segment Routing
- ISIS or OSPF basics of label transport

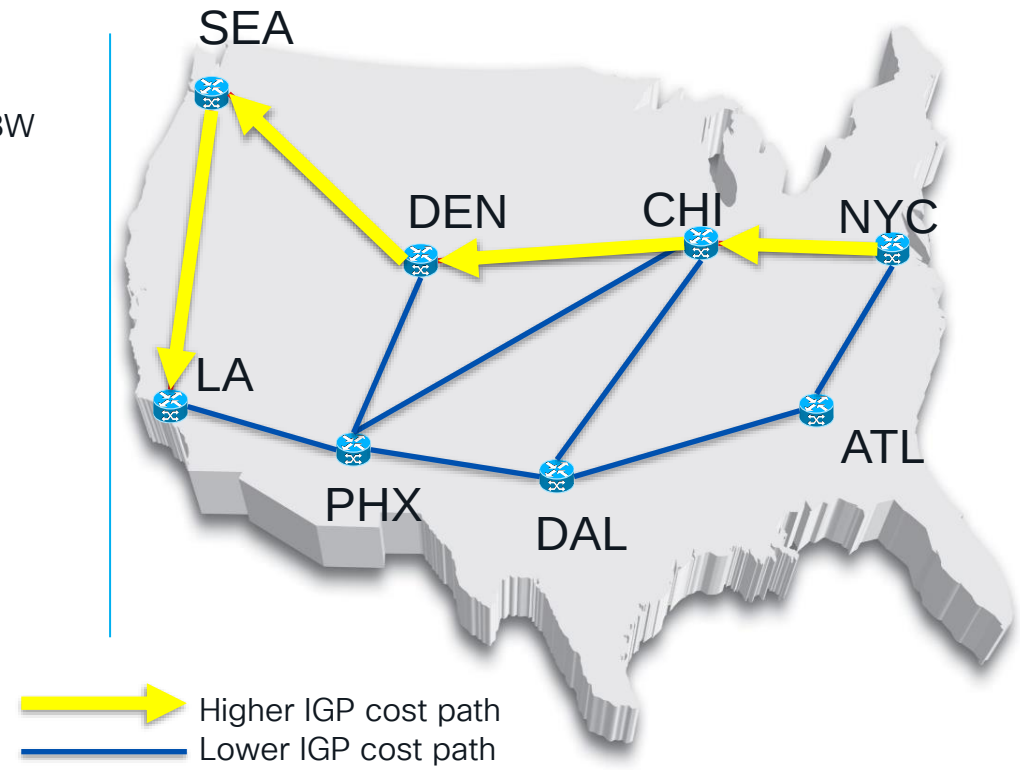
Recommended Sessions to review or attend

- BRKMPL-2137 Designing MPLS based IP VPNs
- BKRMPL-2131 Deploying VPNs Over Segment Routed Networks Made Easy
- BRKMPL-2117 SRv6 based IP Transport-Design, Deployment Best Practices & Challenge
- BRKMPL-2123 Multicast Segment Routing & Traffic Engineering
- BRKMPL-2119 Traffic-Engineering with SR and SRv6 Evolution

MPLS Traffic Engineering Evolution

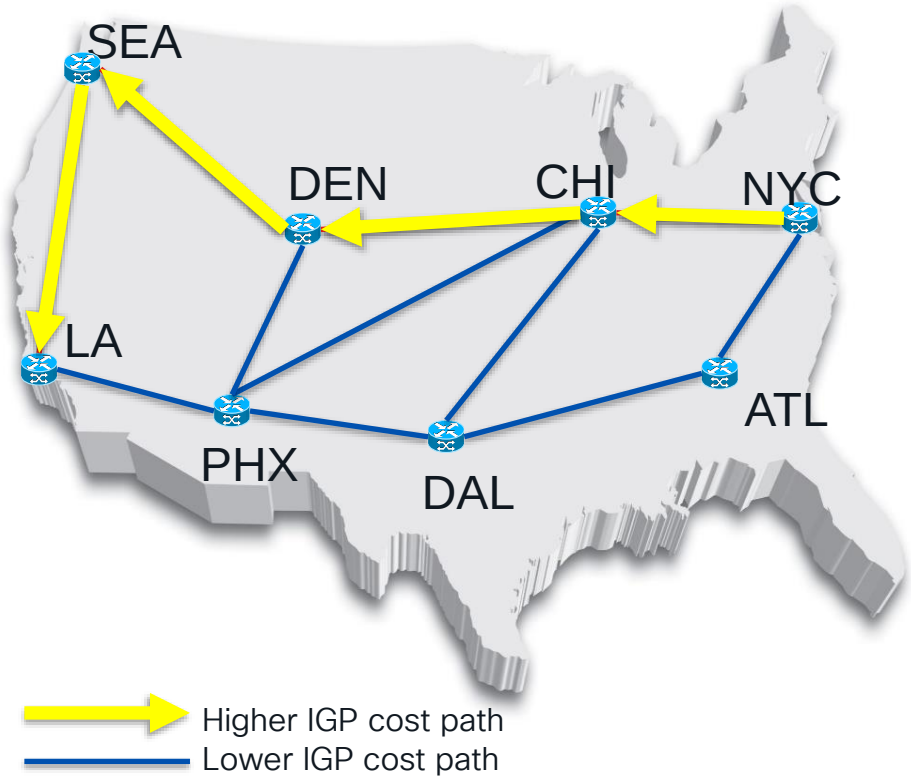
MPLS TE with RSVP

- In addition to MPLS and IGP
  - RSVP use for path signaling, label distribution, BW control, etc.
- TE Path
  - TE tunnel from NYC to LA via DEN and SEA
- Path computation is complex & lack of scalability
  - RSVP control plane is complex
  - To protect the primary TE path, required FRR backup tunnels for link/node protection
  - TE states build in all the nodes from head-end tail-end
  - RSVP-TE is not ECMP friendly



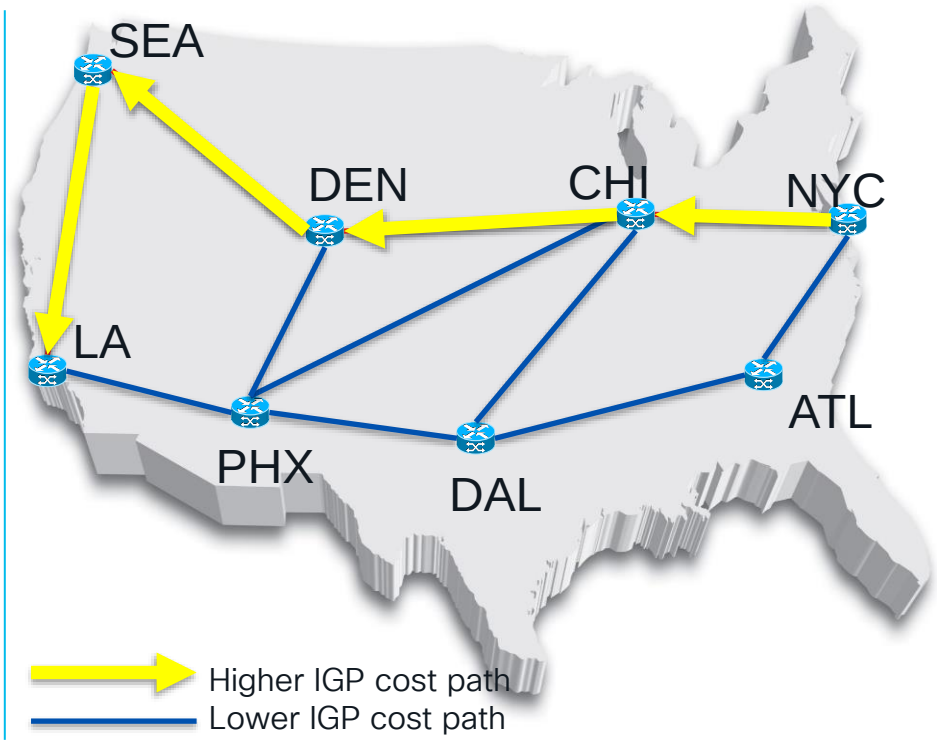
MPLS TE with Segment-Routing / SR-TE Policy

- No additional Protocol i.e., No RSVP except IGP and MPLS
  - Source-based routing
  - SR Labels (SID) are distributed by IGP
- TE Path
  - TE tunnel from NYC to LA via DEN and SEA
- Simplify and Scale Better
  - Head-end accumulates labels to reach destination, align with centralized controller concept
  - TE states build only at head-end node
  - TI-LFA natively support sub 50ms link/node protection and uLoop avoidance
  - Inherent support of ECMP and UCMP



SR ODN Policy using Flex-Algo

- In addition to SR-TE benefits, Flex-Algo brings the following added capabilities:
  - On-Demand Next-hop (ODN) Policy
  - Automated Steering (AS) based on intent
  - Support Inter-domain latency and SRLG for disjoint path
  - Use Flex-algo label, no Adj label i.e., decrease number of labels in packet header



SR IGP Flex-Algo

SR IGP Flex-Algo (Flexible-Algorithm)

- Flex-Algo is a mechanism that allows a network operator to influence a path computation by associating Metric and Constraints to Flex-Algo instead of using link-cost based SFP
- Flex-Algo instance (K) is defined as
  - Metric: IGP or Latency or TE
  - Constraints: Exclude/Include Link-affinity (Link color), Shared Risk Link Group (SRLG) for path dis-jointness,
- TI-LFA honors Flex-algo constraints for backup path
- Flex-algo is distributed by ISIS/OSPF

Currently Defined Flex-Algo(s)

- Flex-Algo(s): 0-255, 0-127 are reserved, 128-255 are Operator Useable

- Algo 0: Shortest Path First (SPF) algorithm based on IGP metric

  This is the well-known shortest path algorithm as computed by the IS-IS decision process. consistent with the deployed practice for link-state protocols, algorithm 0 permits any node to overwrite the SPF path with a different path based on local policy

- Algo 1: Strict Shortest Path First (SPF) algorithm based on IGP metric

  The algorithm is identical to algorithm 0 but algorithm 1 requires that all nodes along the path will honor the SPF routing decision. Local policy MUST NOT alter the forwarding decision computed by algorithm 1 at the node claiming to support algorithm

Flex-Algo Prefix-SID

- Flex-Algo Participation Advertisement - node wants to participate in Flex-algo
- No additional loopback address is needed

Node belongs to Flex-algo(FA):

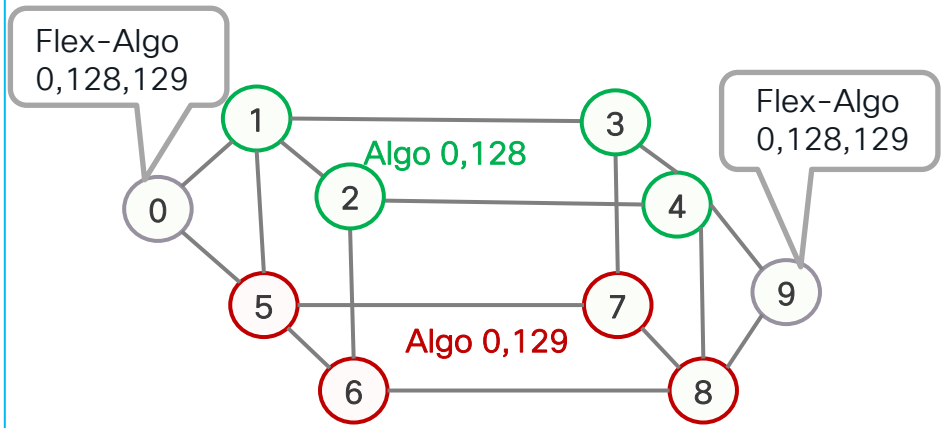
Nodes 0 and 9 participate to Algo 0, 128 and 129
Nodes 1,2,3 and 4 participate to Algo 0 and 128
Nodes 5,6,7 and 8 participate to Algo 0 and 129

Node 3 FA Participation Adv:

Prefix-SID for FA 0 = loopback0 +FA 0 + 16300
Prefix-SID for FA 128 = loopback0 +FA 128 + 16308

Node 9 FA Participation Adv:

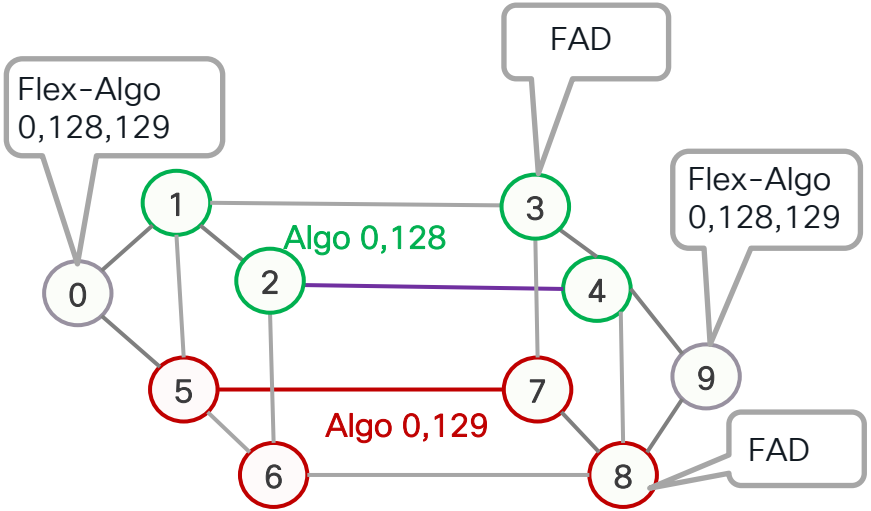
Prefix-SID for FA 0 = loopback0 + FA0 +16900
Prefix-SID for FA 128 = loopback0 + FA128 +16908
Prefix-SID for FA 129 = loopback0 + FA129 +16909



Flex-algo(s) - 128-255, operator useable
Default SRGB is 16000 - 23999

Flex-Algo Definition (FAD)

- Operator can associate the desired metric type, and constraints to Flex-algo(s)
  - IGP metric or latency metric or TE metric
  - Link affinity and/or SRLG
- All nodes MUST agree on same definition of the Flex-Algo(s) for loop free forwarding
  - Example, Node 3 and 8 Advertisement:
  - FA 128 = metric is IGP + exclude purple link
  - FA 129 = metric is delay + exclude red link
- Multiple FAD nodes are recommended for redundancy



Flex-Algo Computation and Install Prefix-SID

- Let's say node N needs to compute a path using Flex-Algo 128
  - Node N is needed to enable Flex-algo 128 for participation
  - Node N has a consistent definition for algo 128
  - Node N supports the definition for algo 128

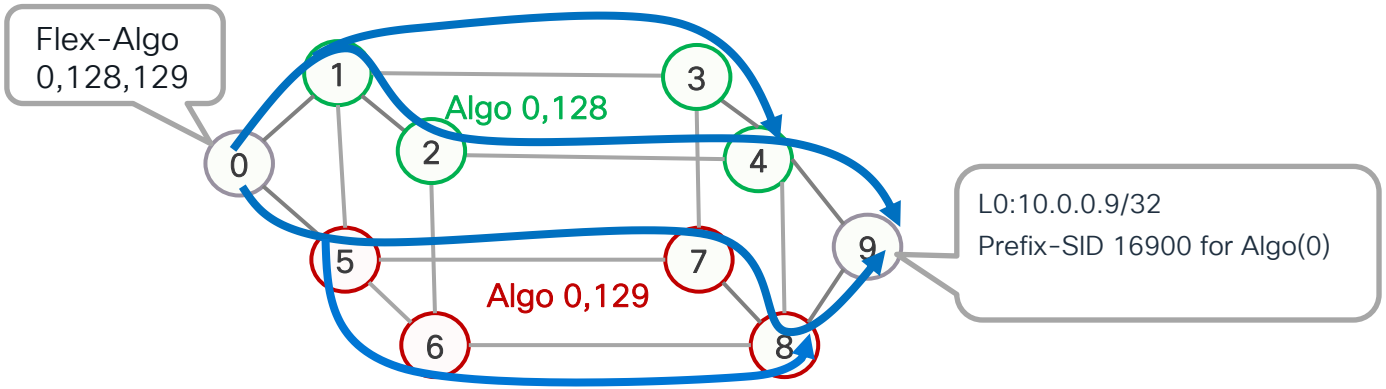
- 1st step is to define the topology for algo 128
  - Node N prunes any node that is not advertising participation to algo 128
  - Node N prunes any link that is excluded by the algorithm of algo 128

    e.g., if 128 excludes link-affinity RED then any link with link-affinity RED is pruned

Flex-Algo Computation and Prefix-SID installation

- 2nd step is to compute shortest-path tree for Topo(128) with the metric defined by 128
  - it could be the IGP metric, the TE metric or the delay
- 3rd step is to install reachability for Prefix-SID Flex-Algo 128 in the forwarding table

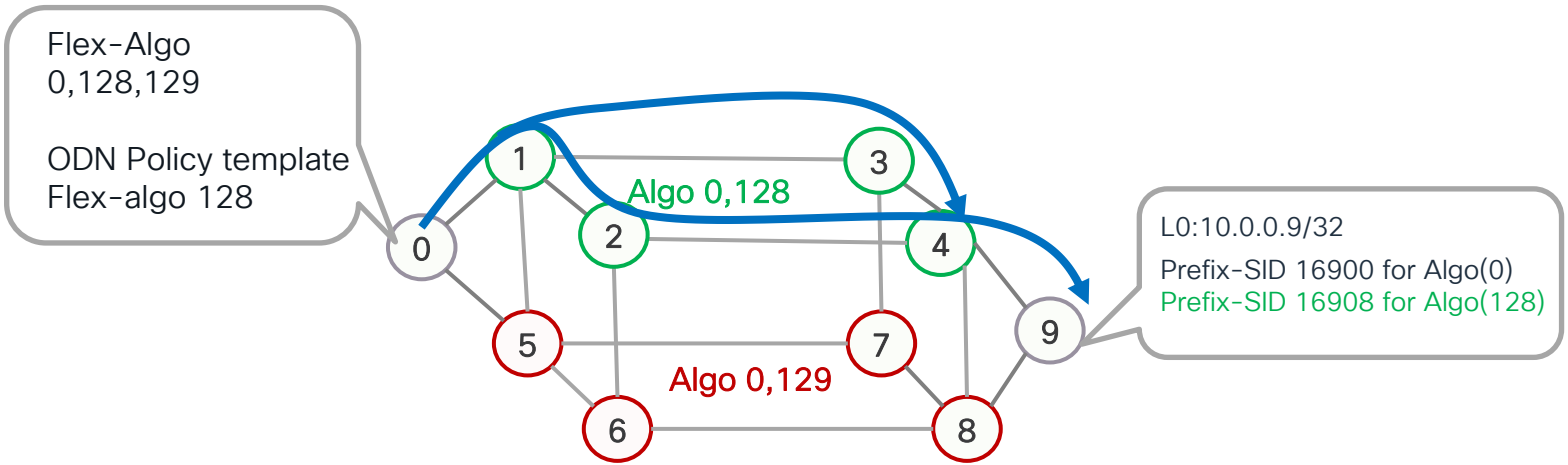
Example – Prefix-SID 16900 of Algo(0)



Let's say same IGP metric in all links, will follow ECMP

- Algo 0 is default flex-algo and metric type is IGP, will use entire topology
- SR leverage TI-LFA and uLoop

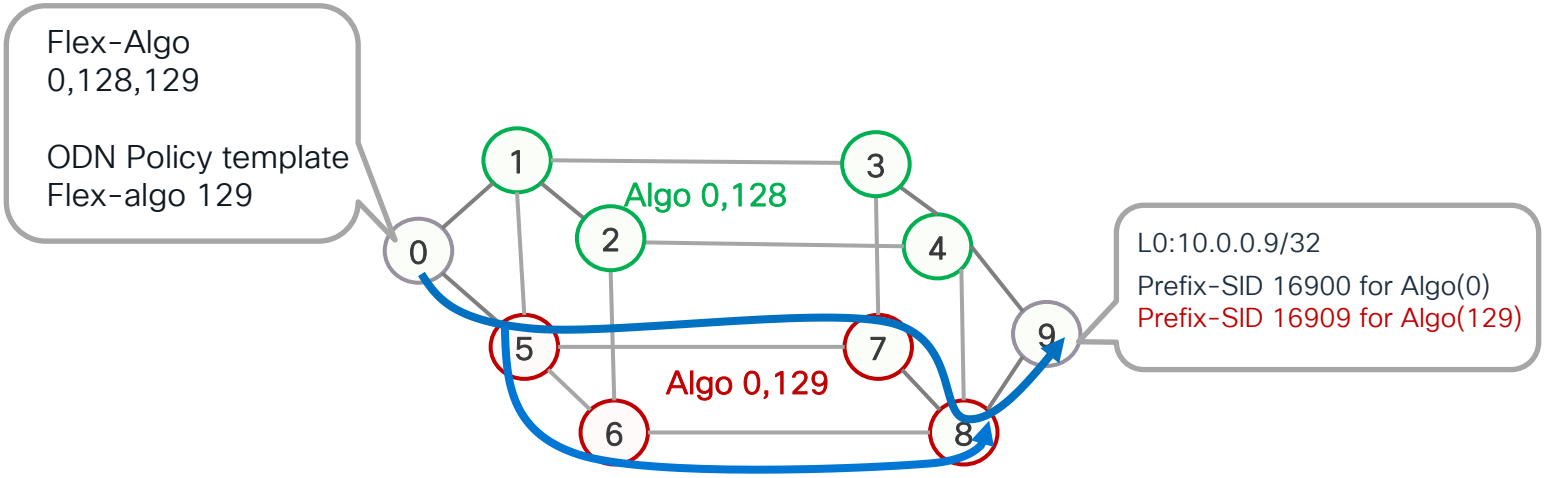
Example – Prefix-SID 16908 of Algo(128)



Let's say same IGP metric in all links, will follow ECMP

- Algo 128 is operator defined, compute path thru the nodes participate to algo 128
- TI-LFA backup path honor constraints and uLoop

Example – Prefix-SID 16909 of Algo(129)



Let's say same IGP metric in all links, will follow ECMP

- Algo 129 is operator defined, compute path thru nodes participate to algo 129
- TI-LFA backup path honor constraints and uLoop

SR ODN Policy using Flex-Algo

SR ODN Policy

- Per-Destination policy
  - Steer traffic based on next-hop and color of a BGP service route
  - Color is a BGP extended community attribute
  - Color is used for transport SLA indicator, for instance min-delay or min-cost
- Per-Flow policy
  - Steer traffic based on incoming packets classification (IPP, DSCP, ACL, EXP etc.)
  - Then set local Forward-Class up to 8, range 0-7
  - An ingress PBR policy applied to an input interface

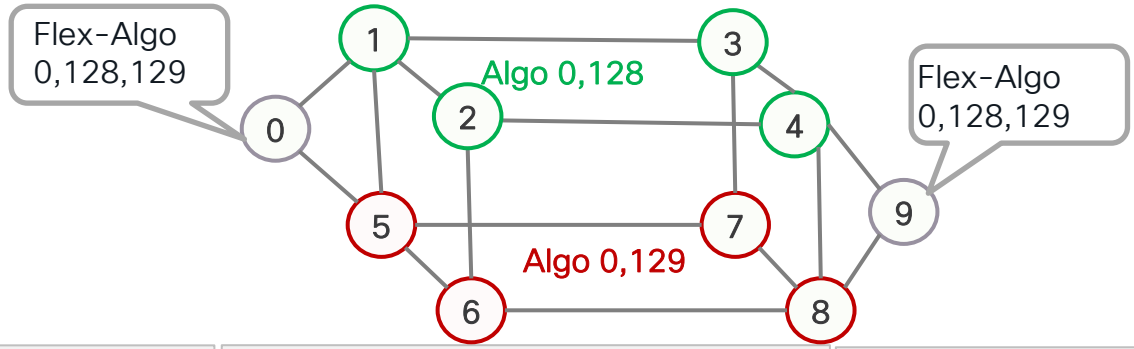
SR ODN Policy – Per Destination

- Steps to build SR ODN policy

1. Flex-Algo Prefix-SID, node wants to participate in Flex-algo
2. Flex-Algo Link Affinity-map, exclude or include a link for path computation by Flex-algo
3. Flex-Algo Definition (FAD), associate metric & link constraints to Flex-algo
4. BGP Extended Color Community, add color to BGP prefix for intended ODN path
5. Finally, SR ODN Policy, auto dynamic path computation based on intended SLA

1. Flex-Algo Prefix-SID

- Flex-Algo Prefix-SID is the node that wants to participate in Flex-algo(s)
- Use existing loopback address



Node3: IOS-XR

```
router isis 1
Flex-algo 128
interface Loopback0
 passive
 address-family ipv4 unicast
   prefix-sid absolute 16300
   prefix-sid algorithm 128 absolute 16308
```

Node7: IOS-XE

```
router isis 1
Flex-algo 129
!
segment-routing mpls
connected-prefix-sid-map
  address-family ipv4
   10.0.0.7/32 absolute 16700 range 1
  exit-address-family
  address-family ipv4 algorithm 129
   10.0.0.7/32 absolute 16709 range 1
  exit-address-family
```

Node9: IOS-XR

```
router isis 1
Flex-algo 128
Flex-algo 129
interface Loopback0
 passive
 address-family ipv4 unicast
   prefix-sid absolute 16900
   prefix-sid algorithm 128 absolute 16908
   prefix-sid algorithm 129 absolute 16909
```

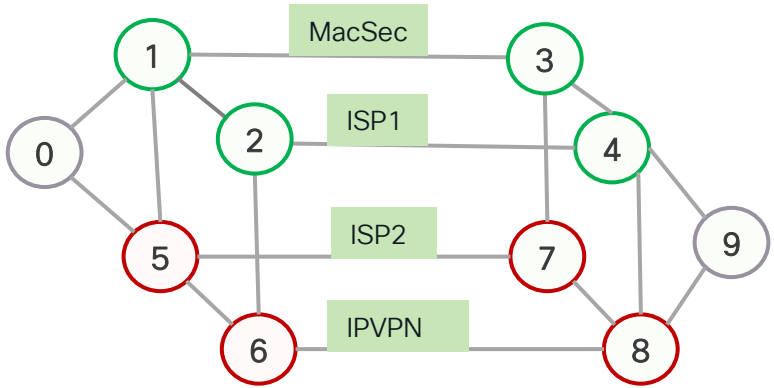
2. Flex-Algo Link affinity-map (Link color)

Node 1 # IOS-XR

```
Router isis 1
affinity-map MACSec bit-position 1
affinity-map ISP1 bit-position 2
affinity-map ISP2 bit-position 3
affinity-map IPVPN bit-position 4
!
interface tenG0/0/0/1
affinity flex-algo MACSec
```

Node 5 # IOS-XE

```
Router isis 1
affinity-map MACSec bit-position 1
affinity-map ISP1 bit-position 2
affinity-map ISP2 bit-position 3
affinity-map IPVPN bit-position 4
!
interface tenG0/0/0/1
Isis affinity flex-algo
name ISP2
```



Link affinity-map bit-position MUST be matched in all the nodes within the path computation domain.

3. Flex-Algo Definition (FAD)

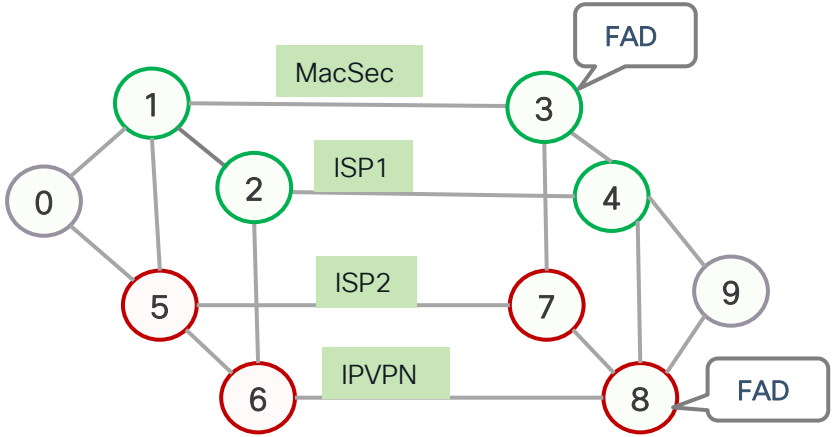
- ISIS uses Sub-TLV and OSPF uses TLV to advertise FAD

Node 3 # IOS-XR

```
router isis 1
flex-algo 128
priority 250
(By-default metric-type is IGP)
advertise-definition
affinity exclude-any ISP1
!
```

Node 8 # IOS-XE

```
router isis 1
flex-algo 129
  advertise-definition
  metric-type delay
  priority 250
```

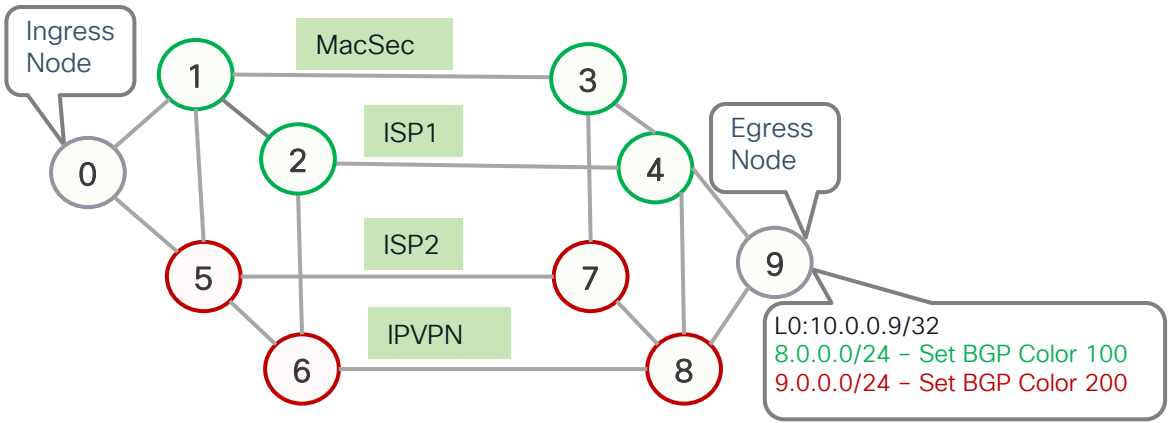


Select more than one node to advertise FAD with priority for active and standby FAD

4. BGP Extended Color Community

- Setup BGP extended color community for SLA

```
Node9 # IOS-XR
extcommunity-set opaque COLOR_100
  100
end-set
extcommunity-set opaque COLOR_200
  200
end-set
prefix-set PREFIX_8
  8.0.0.0/24
end-set
prefix-set PREFIX_9
  9.0.0.0/24
end-set
!
route-policy BGP_COLOR
  if destination in PREFIX_8 then
    set extcommunity color COLOR_100
  else
    if destination in PREFIX_9 then
      set extcommunity COLOR_200
    else
      pass
end-policy
```

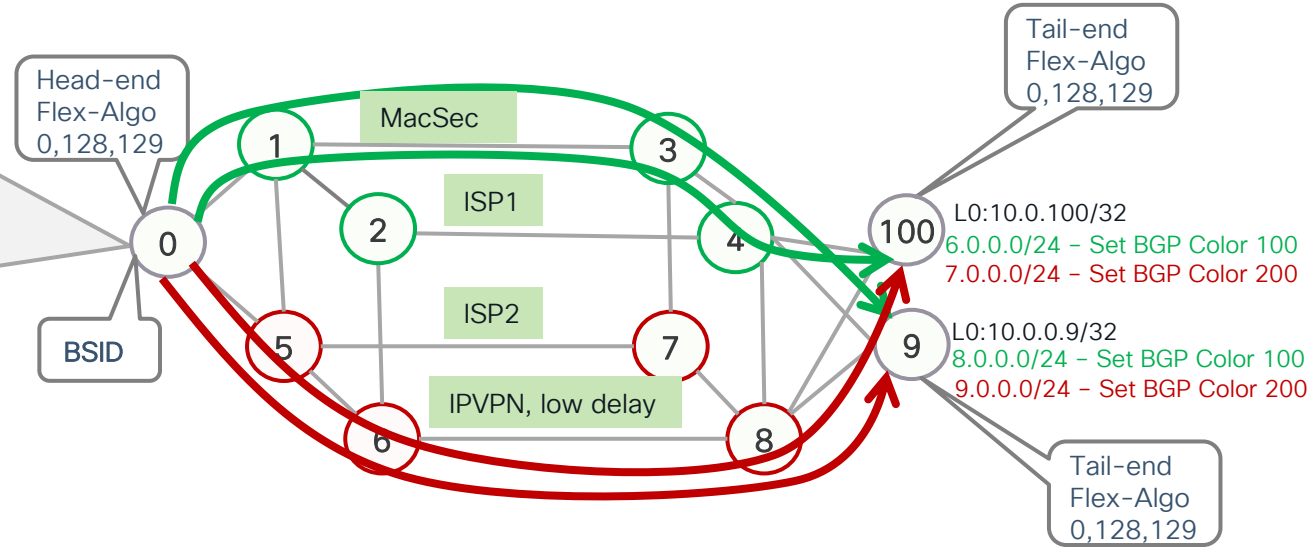


5.1 SR ODN Policy – Candidate Path

- Automated Steering by leveraging IGP Flex-Algo

Node0 # IOS-XR

```
segment-routing
 traffic-eng
!
 on-demand color 100
  steering
    path-invalidation drop
    restrict IP_ACL
   dynamic
    sid-algorithm 128
!
on-demand color 200
   dynamic
    sid-algorithm 129
```



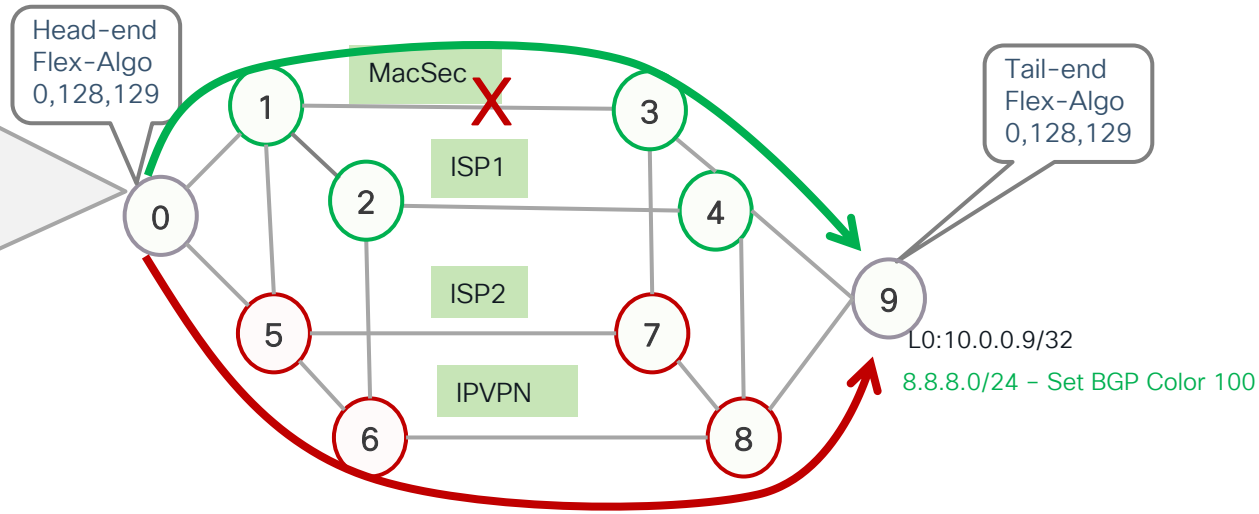
- Flex-algo 128, metric is IGP, excluded ISP1 link, Prefix color 100, label 16908
- Flex-algo 129, metric is delay, Prefix color 200, label 16909
- The BGP next-hop IP address and Prefix-SID IP address must be same Loopback

5.2 SR ODN Policy – Multi-Candidate Paths

- Automated Steering by leveraging IGP Flex-Algo

Node0 # IOS-XE

```
segment-routing traffic-eng
on-demand color 100
authorize
  candidate-paths
   preference 100
constraints
     segments
      dataplane mpls
      algorithm 128
!
preference 90
constraints
     segments
      dataplane mpls
      algorithm 129
```

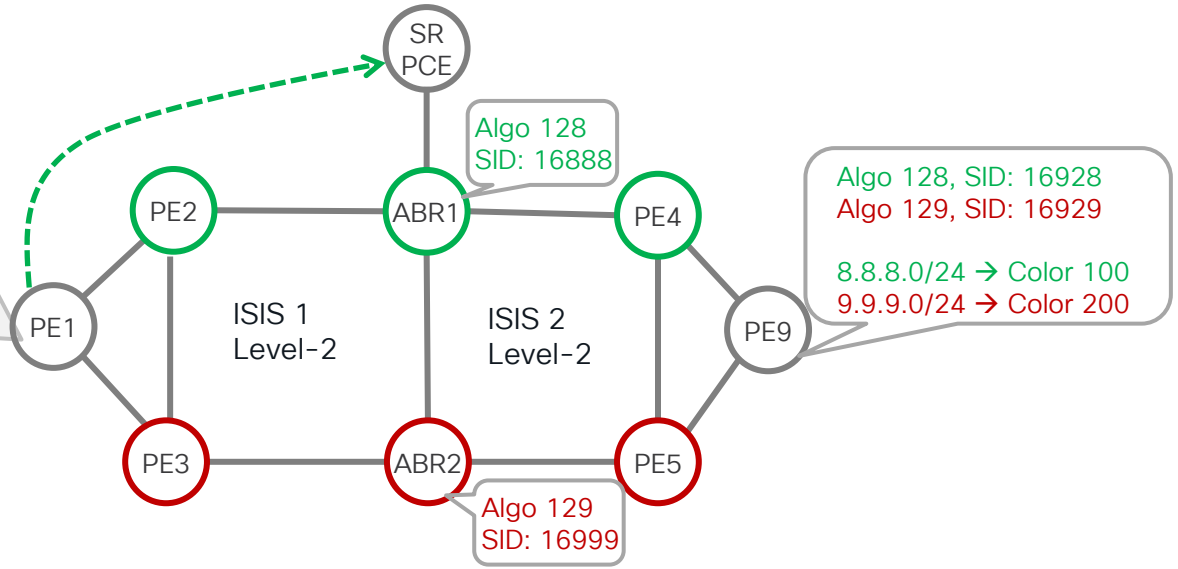


- Flex-algo 128, metric is IGP, excluded ISP1 link, Prefix color 100, label 16908
- Flex-algo 129, metric is IGP, exclude ISP1, Prefix color 200, label 16909

5.3 SRTE ODN Policy – Inter-Domain

IOS-XR:

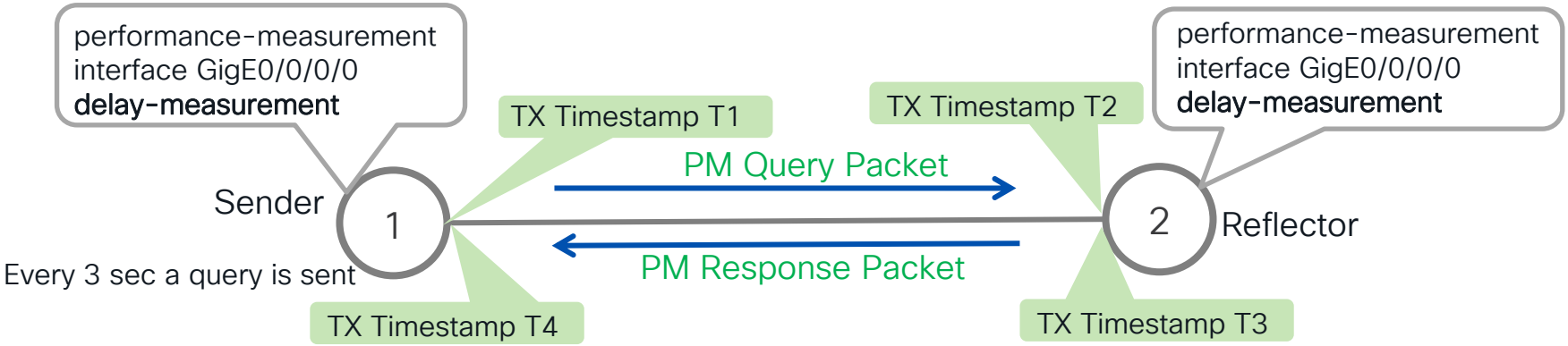
```
segment-routing
 traffic-eng
  on-demand color 100
   dynamic
    sid-algorithm 128
   !
on-demand color 200
   dynamic
bounds
     cumulative
      type igp <>
      type te <>
      type hopcount <>
      type latency <>
    sid-algorithm 129
   !
pcc
   source-address ipv4 192.168.0.1
   pce address ipv4 192.168.0.10
    precedence 100
```



- PCE supports Inter-domain policy using Flex-algo
- Inter-domain ODN Policy without PCE is in progress

Performance Measurement

Per-link Delay Measurement



- Router discover per-link DM and flood to IGP also can report to centralized controller via telemetry
- Two-way delay = (T2-T1)+(T4-T3) is by default, no clock synchronization is required
- One-way delay = Two-way delay/2, clock synchronization is required
- Sender and Reflector required HW Timestamping
- Two-Way Active Measurement Protocol (TWAMP-Light) uses RFC 5357 with IP/UDP encapsulation

Per-link delay Measurement

- Over a measurement internal
  - Minimum
  - Average
  - Maximum
  - Variance

Used as delay metric for SR ODN Policy

Not used by SR ODN Policy

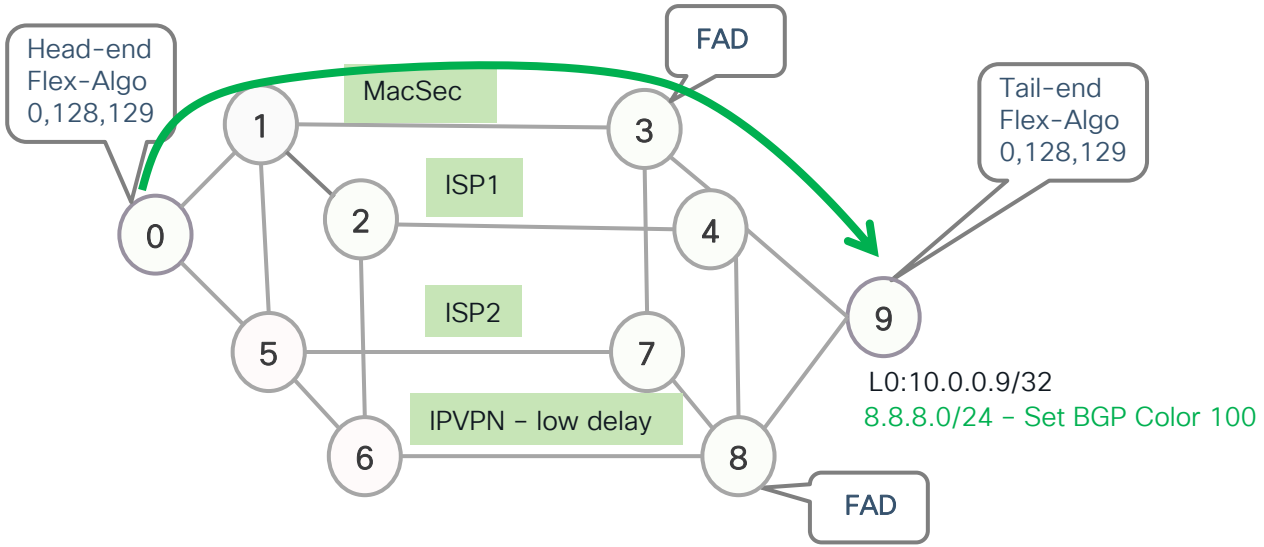
Use Cases

So why are we here?

- We want to be able to manipulate the IGP to our own specific needs using attribute or constraints that *we* decide are important?
  - Only use a route with a cumulative delay based on a measured per link delay
  - If we only want to use a secure path. Such as paths with MACsec only
  - Define a path traversing high speed links for bandwidth sensitive traffic
  - Only use a subset of the routers in your network

Use Case 1 – Secure Path

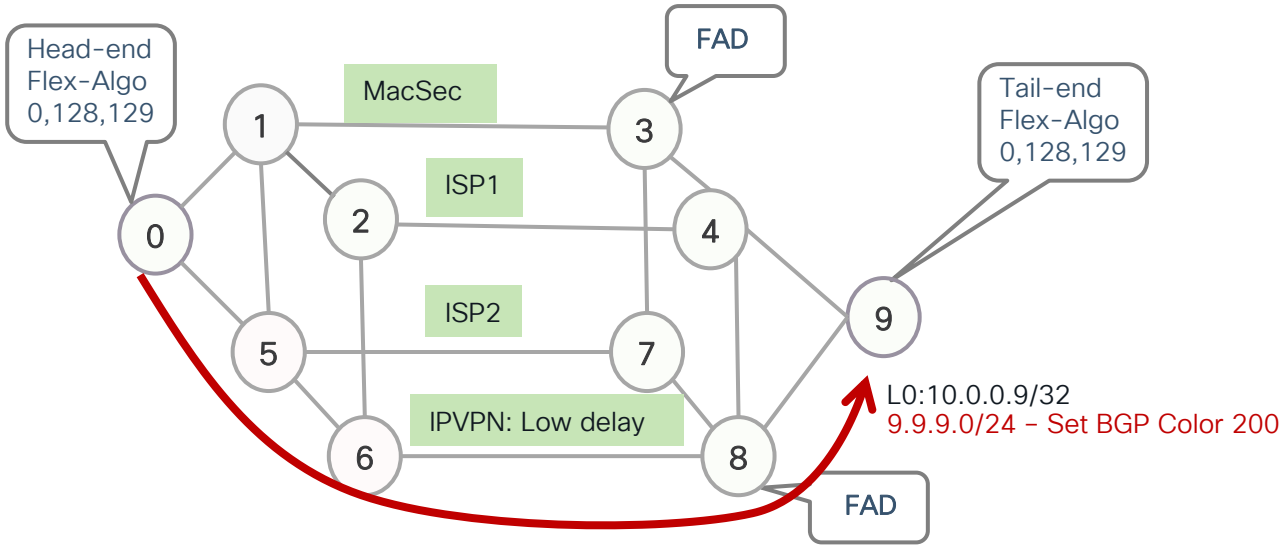
```
Node 0 IOS-XR#
router isis 1
 flex-algo 128
!
 address-family ipv4 unicast
  router-id Loopback0
  segment-routing mpls
 !
 interface Loopback0
  address-family ipv4 unicast
   prefix-sid absolute 16000
   prefix-sid algorithm 128 absolute 16800
!
segment-routing
 traffic-eng
!
 on-demand color 100
dynamic
    sid-algorithm 128
!
```



- All nodes support Algo 0, 128 and 129
- Algo 128 is associated with IGP metric and exclude ISP1, ISP2

Use Case 2- Real-time communications and applications

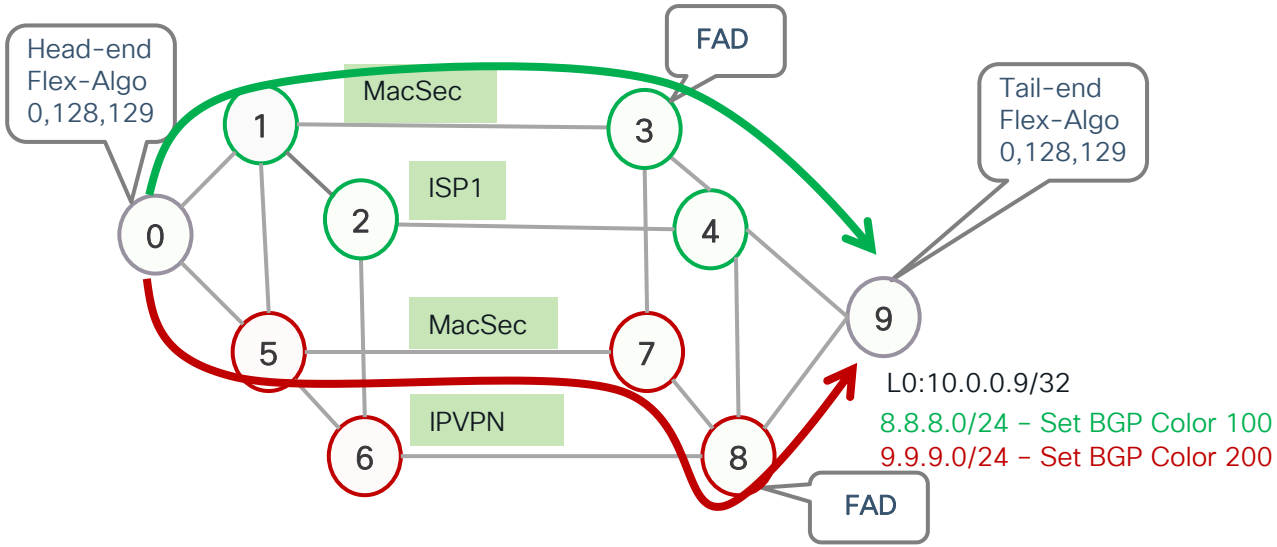
```
Node 0 IOS-XR#
router isis 1
 flex-algo 129
!
 address-family ipv4 unicast
  router-id Loopback0
  segment-routing mpls
 !
 interface Loopback0
  address-family ipv4 unicast
   prefix-sid absolute 16000
   prefix-sid algorithm 129 absolute 16900
!
performance-measurement
 interface GigabitEthernet0/0/0/X
  delay-measurement
  !
segment-routing
 traffic-eng
!
 on-demand color 200
dynamic
    sid-algorithm 129
!
```



- All nodes participating Algo 0, 128 and 129
- Algo 129 is associated with delay metric and no link affinity included or excluded
- Per-link delay measurement is flood to IGP

Use Case 3- Dual Plane / Multi-plane

```
Node 0 IOS-XR#
router isis 1
 flex-algo 128
!
 address-family ipv4 unicast
  router-id Loopback0
  segment-routing mpls
 !
 interface Loopback0
  address-family ipv4 unicast
   prefix-sid absolute 16000
   prefix-sid algorithm 128 absolute 16800
!
segment-routing
 traffic-eng
!
 on-demand color 100
dynamic
    sid-algorithm 128
!
on-demand color 200
dynamic
    sid-algorithm 129
```



- Algo 128 is associated with IGP metric and exclude ISP1
- Algo 129 is associated with IGP metric and exclude IPVPN

Additional Use Cases

- Only use a subset of the routers in your network
- Define a path traversing high speed links for bandwidth sensitive traffic

Flex-Algo support Highlights

- ISIS Flex-Algo
- OSPF Flex-Algo
- MPLS-PM: per-link delay measurement
- MPLS-PM: end-to-end SR Policy delay measurement
- SR Data Plane Monitoring (SR-DPM)
- Inter-domain ECMP and UCMP

SR ODN Support Highlights

- The SR ODN Policy supports the following services:
  - IPv4 BGP global routes
  - IPv6 BGP global routes (6PE)
  - VPNv4
  - VPNv6 (6vPE)
  - EVPN-VPWS (single-homing)
  - EVPN-VPWS (multi-homing)
  - EVPN (single-homing/multi-homing)

IETF

- draft-ietf-spring-segment-routing
  - Prefix-SID per Algorithm
- draft-filsfils-spring-segment-routing-policy
  - SRTE architecture, ODN, AS
- draft-hegdeppsenak-isis-sr-flex-algo
  - Customization of Algo and consistency
- draft-ietf-isis-te-app
  - Used to flood Flex-Algo specific link affinities
- RFC7810 (IS-IS Traffic Engineering (TE) Metric Extensions)
  - Used to advertise extended TE metrics – e.g., link delay

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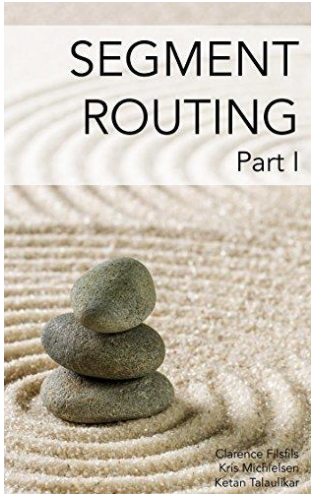

segment-routing.net

linkedin.com/groups/8266623

twitter.com/SegmentRouting

facebook.com/SegmentRouting/

Technical Session Surveys

- Attendees who fill out a minimum of four session surveys and the overall event survey will get Cisco Live branded socks!
- Attendees will also earn 100 points in the Cisco Live Game for every survey completed.
- These points help you get on the leaderboard and increase your chances of winning daily and grand prizes.

Conclusion

Q&A

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Cisco Digital Learning
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Cisco Modeling Labs
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Cisco Learning Network
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Intensive team & individual automation and technology training programs

Cisco Learning Partner Program
Authorized training partners supporting Cisco technology and career certifications

Cisco Instructor-led and Virtual Instructor-led training
Accelerated curriculum of product, technology, and certification courses

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Additional Flex-Algo Slides

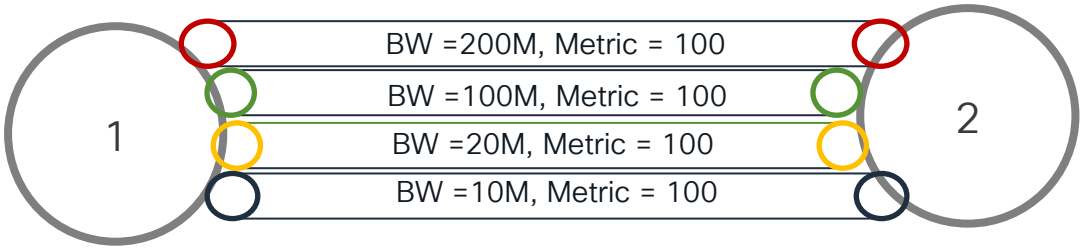
SR IGP Flex-Algo

- Leverages the SR-TE benefits of simplicity, automation and scalable
  - Automated sub-50msec FRR (TILFA), backup path honors Flex-Algo constraints
  - On-Demand Policy (ODN) and Automated Steering (AS)
  - Scale, no core state: state at the headend only
  - Supports Inter-domain latency and disjointed path
  - Use Prefix-SID label, no Adjacency label

- Example
  - Operator1 defines Flex-Algo(128) as “minimize IGP metric and avoid link-affinity *green*”
  - Operator2 defines Flex-Algo(128) as “minimize delay metric and avoid link-affinity *blue*”

UCMP – Unequal Cost Multi-Path

- UCMP = ECMP + Bandwidth, Per destination
  - Same IGP metric but different BW



Unequal Cost Multi-path

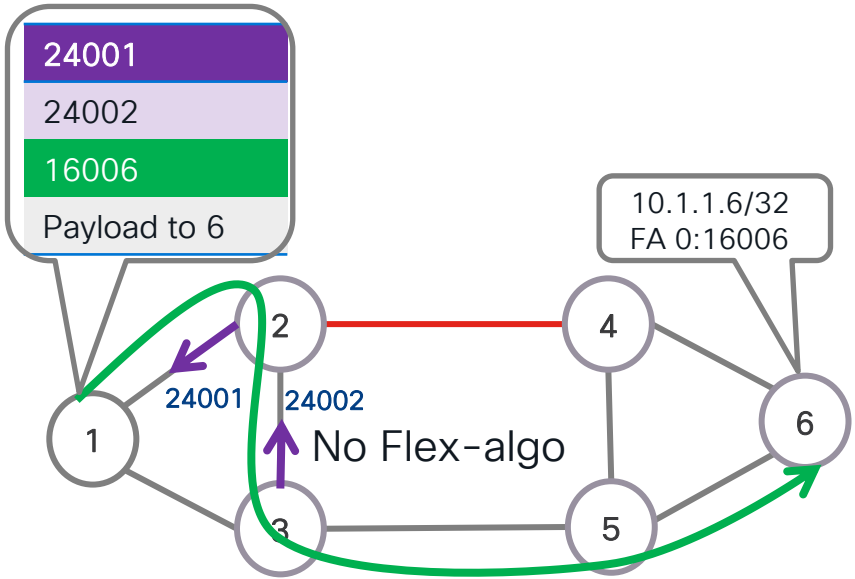
UCMP – Unequal Cost Multi-Path

- UCMP = ECMP + Bandwidth, Per destination
- Apply ”ucmp local” under ISIS process

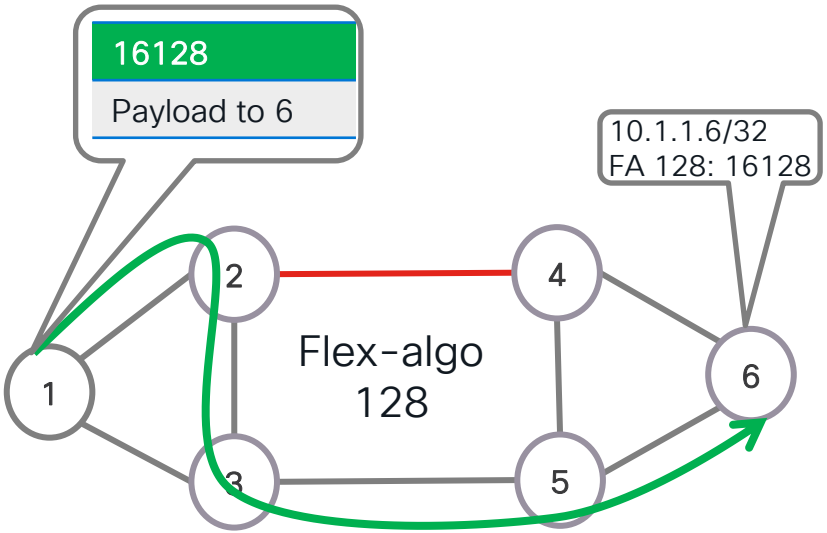
```
#show mpls forwarding-table labels 26042 detail | in Tu|load

Label      Label      or Tunnel Id     Switched      interface
                            0           Tu3002161   point2point
   Per-destination load-sharing, slots: 0
                            0           Tu3002141   point2point
   Per-destination load-sharing, slots: 1
                            0           Tu3002151   point2point
   Per-destination load-sharing, slots: 2
                            0           Tu3002131   point2point
   Per-destination load-sharing, slots: 3 6
                            0           Tu3002111   point2point
   Per-destination load-sharing, slots: 4 7 9 11 13 15
                            0           Tu3002121   point2point
   Per-destination load-sharing, slots: 5 8 10 12 14
```

Destination Prefix-SID

SRTE Path Computation without and with Flex-Algo



(a) Path Computation without Flex-algo



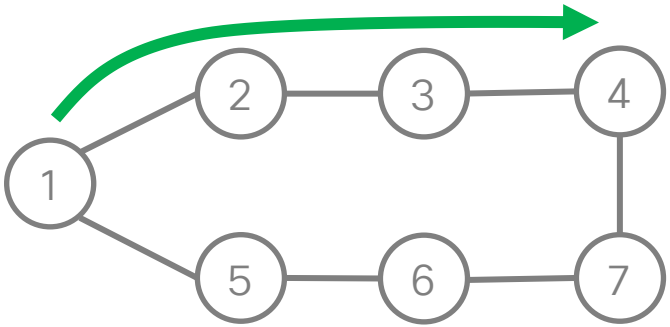
(b) Path Computation with Flex-algo, no adjacency label

Automated Steering – ODN Policy

- An on-demand SR policy is created dynamically for BGP or VPN
- On-Demand Next-hop (ODN) Policy
  - Intent based dynamic path computation
  - The ODN solution is solely related to dynamic instantiation of a candidate path
- An SR Policy is identified by three attributes, tuple:
  - Head-end: where the policy is instantiated
  - End-point: where the policy ends, the BGP next-hop address
  - Color: a numerical value assigned to a BGP prefix, represents an intent for SRTE policy

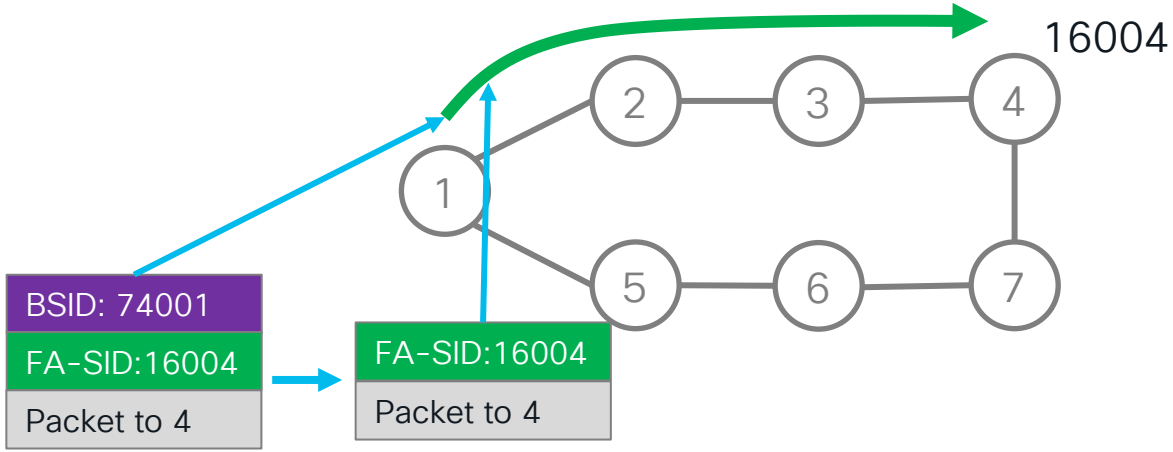
SR ODN Policy

Head-end: 1
Color: Green
End-point: 4



Binding SID (BSID)

- Binding SID is a local Segment ID or label bound to an SRTE Policy
- A BSID is associated with a single SRTE Policy
- By default, the head-end dynamically allocates the BSID, but the BSID can also be explicitly defined
- A BSID identifies a SRTE policy
  - Packet received with BSID as Top Label is steered into the SRTE Policy associated with the BSID
  - BSID label is popped, SRTE Flex-algo prefix-SID is pushed



BSID – Binding SID

- BSID is a local label that is auto generated, so right prefix can take the right SR ODN Policy

```
#sh segment-routing traffic-eng policy
end-point ipv4 10.101.1.4

SR-TE policy database
---------------------
Color: 850, End-point: 10.101.1.4
 Binding SID: 76623
```

```
#  sh bgp vpnv4 unicast vrf CUSTOMER1 11.103.1.1

10.101.1.4 C:850 (bsid:76623) (metric 200040) from
10.100.0.1 (10.101.1.4)

SR policy color 850, up, registered, bsid 76623, if-handle
0x3c0080d4 Local, (received-only)

10.101.1.4 C:850 (bsid:76623) (metric 200040) from
10.100.0.1 (10.101.1.4
```

SR ODN Policy Color

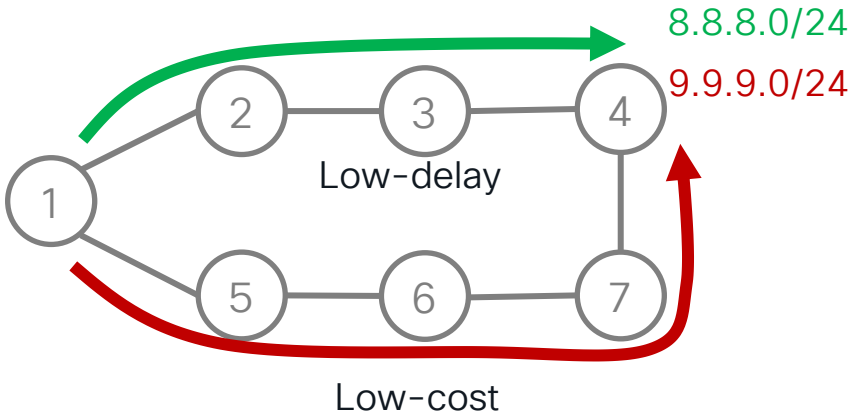
- Each SR Policy has a color
  - BGP color is used to provide certain treatment (SLA) to some applications by SR ODN policy
  - Each SRTE ODN Policy has a unique triplet (H,C,E)
  - A prefix with multiple colors will choose highest numerical value to steer traffic

SR ODN Policy

1,green,4
steer 8.8.8.0/24 via low delay path

SR ODN Policy

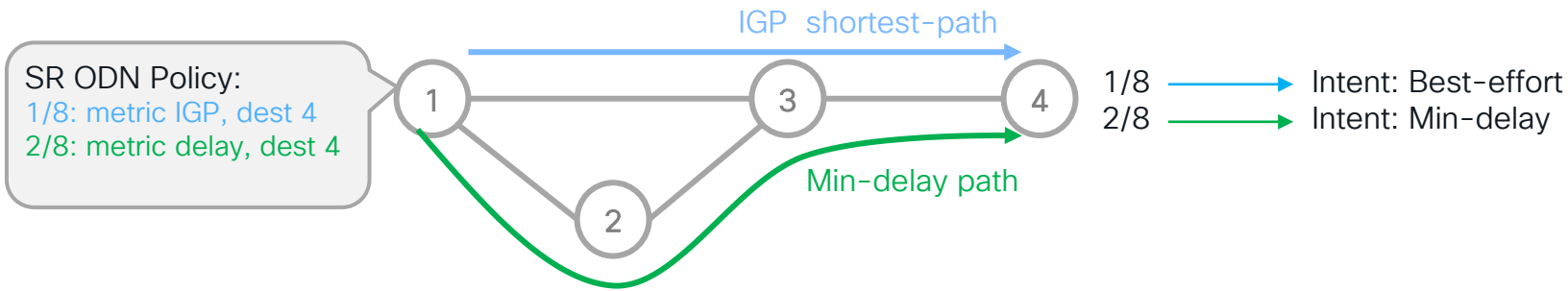
1,red,4
steer 9.9.9.0/24 via Low-cost path



The BGP color extended community is specified in RFC5512

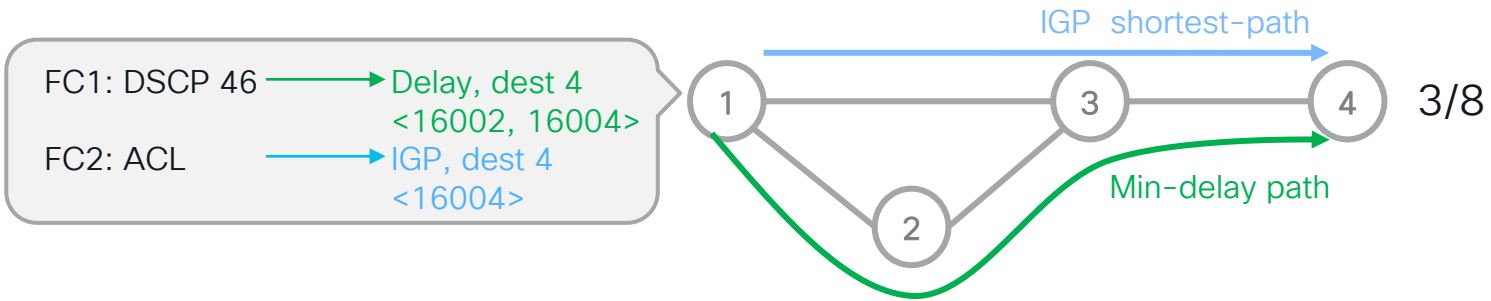
Automated Steering - Per-Destination Policy (PDP)

- Per-destination policy
  - Steer traffic based on next-hop and color of a BGP service route
  - Color is a BGP extended community attribute
  - Color is used for transport SLA indicator, for instance min-delay or min-cost



Automated Steering - Per-Flow Policy (PFP)

- Per-flow policy
  - Steer traffic based on incoming packets classification (IPP, DSCP, ACL, EXP etc.)
  - Then set local Forward-Class up to 8, range 0-7
  - An ingress PBR policy applied to an input interface



Automated Steering - Per-Flow Policy (PFP)

Traffic Classification:

```
class-map type traffic match-any MinDelay
match dscp46
end-class-map
!
class-map type traffic match-any PremiumHosts
match access-group ipv4 PrioHosts
end-class-map
```

```
policy-map type pbr  MyPFP
class type traffic MinDelay
set forward-class 1
!
class type traffic PremiumHosts
set forward-class 2
!
class type traffic class-default
set forward-class 0
```

```
interface GigabitEthernet0/0/0/0
description PE_Ingress_Interface
service-policy type pbr input MyPFP
```

Per-Flow Policy:

```
segment-routing
 traffic-eng

  on-demand color 10
   dynamic
    sid-algorithm 128
   !
```

```
on-demand color 20
   dynamic
    sid-algorithm 129
!
on-demand color 30
   dynamic
    sid-algorithm 130
```

```
on-demand color 1000
  per-flow
    forward-class 0 color 10
    forward-class 1 color 20
    forward-class 2 color 30
```

Headend SRTE DB – IGP Config

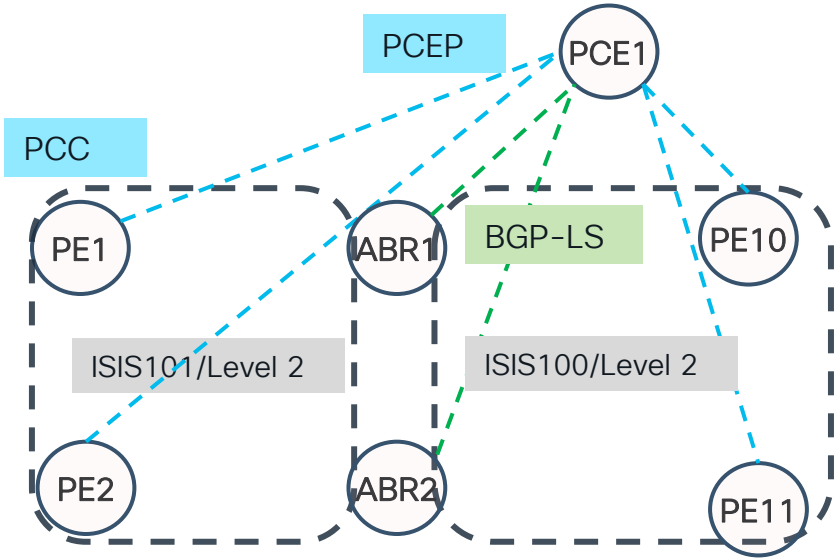
- Enable the following command under ISIS/OSPF to feed the SRTE DB on the head-end:

```
router isis 1
distribute link-state
```

```
router ospf 1
distribute link-state
```

PCE – Path Computation Element

- IGP principle is to keep the node and link-state info within its own IGP area
- ABR redistribute node and link-state info from ISIS to BGP-LS address-family
- PE run path computation element protocol (PCEP) with the PCE for inter-domain node and link-state info



PCC: Path computation client
PCE: Path computation element
PCEP: PCE protocol
BGP-LS: BGP link-state

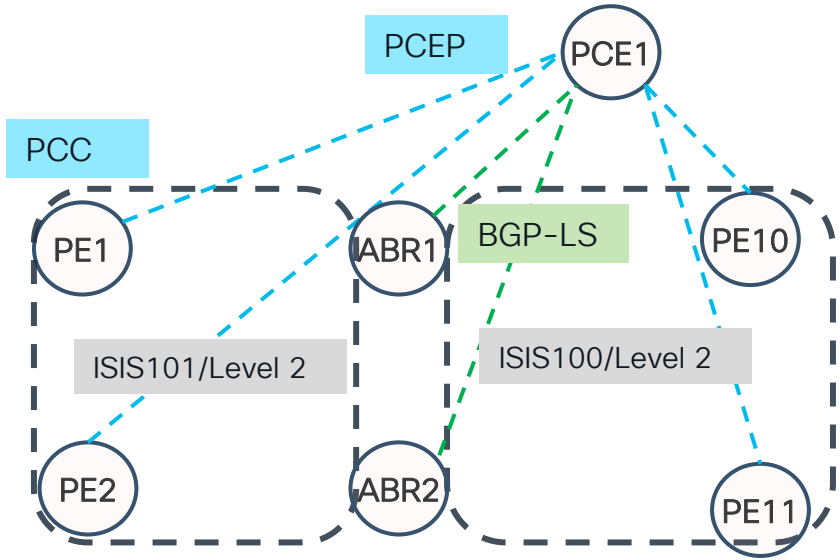
PCE – Path Computation Element

IOS-XR:

PCC#
```
segment-routing
 traffic-eng
 pcc
   source-address ipv4 x.x.x.x
   pce address ipv4 x.x.x.y
    precedence 100
```

ABR#
```
router isis 1
 distribute link-state instance-id 1 level X
```

PCE#
```
pce
 address ipv4 x.x.x.z
```



PCC: Path computation client
PCE: Path computation element
PCEP: PCE protocol
BGP-LS: BGP link-state

ODN Policy – Per-Destination (Inter-Domain)

IOS-XR:

```
PE1#show segment-routing traffic-eng policy color 100
SR-TE policy database
---------------------
Color: 100, End-point: 192.168.0.9
  Name: srte_c_100_ep_192.168.0.9
  Status:
    Admin: up  Operational: up
Candidate-paths:
    Preference: 200 (BGP ODN) (inactive)
    Preference: 100 (BGP ODN) (active)
      Requested BSID: dynamic
Constraints:
       Prefix-SID Algorithm: 128
 Dynamic (pce 192.168.0.10) (valid)
         16888 [Prefix-SID, 192.168.0.11]
         16928 [Prefix-SID, 192.168.0.9]
  Attributes:
    Binding SID: 24010

PE1#  sh bgp vrf GREEN 8.8.8.1
BGP routing table entry for 8.8.8.0/24, Route Distinguisher: 1:1
Local
    192.168.0.9 C:100 (bsid:24010) (metric 120) from 192.168.0.10
(192.168.0.9)
```

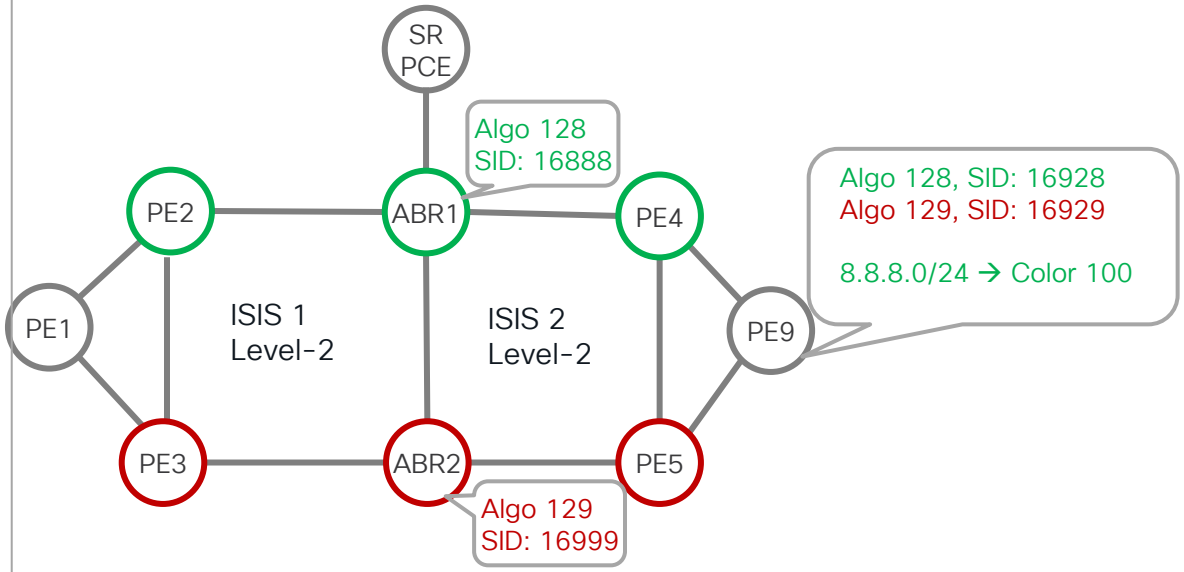
Pref 200 is failed because for Inter-domain ODN policy, the local DB has no link info for other domain and then it moved to PCE with pref 100 and succeed.

For inter-domain it uses two prefix-SIDs, 1st SID for head-end to ABR router and 2nd SID for ABR to tail-end.

SRTE ODN Policy– Multi-Candidate Paths

IOS-XE:

```
segment-routing traffic-eng
 !
 on-demand color 100
  authorize
  candidate-paths
   preference 200
    constraints
     segments
      dataplane mpls
      algorithm 128
     !
dynamic
      pcep
    !
   preference 100
    constraints
     segments
      dataplane mpls
      algorithm 129
     !
dynamic
      pcep
    !
pcc
  pce address 192.168.0.10 source-address 192.168.0.1
```



- For network 8.8.8.0/24, Flex-algo 128 Green nodes are primary
- path and Flex-algo 129 Red nodes are backup path.

SRTE ODN Policy– Multi-Candidate Paths

IOS-XE:

```
PE1#sh segment-routing traffic-eng policy all

Name: *192.168.0.9|100 (Color: 100 End-point: 192.168.0.9))
  Candidate-paths:
    Preference 200 (BGP):
      Constraints:
        Algorithm: 128
      Dynamic (pce 192.168.0.10) (active)
          16011 [Prefix-SID, 192.168.0.11]
          16008 [Prefix-SID, 192.168.0.9]
Preference 100 (BGP):
      Constraints:
        Algorithm: 129
      Dynamic (pce 192.168.0.10) (inactive)
          16012 [Prefix-SID, 192.168.0.12]
          16009 [Prefix-SID, 192.168.0.9]
  Attributes:
    Binding SID: 22
      Allocation mode: dynamic
      State: Programmed
  IPv6 caps enabled
```

IOS-XE:

```
PE1#sh bgp vrf GREEN 8.8.8.1
BGP routing table entry for 1:1:8.8.8.0/24, version 64
Paths: (1 available, best #1, table GREEN)
  Not advertised to any peer
  Refresh Epoch 1
  Local
    192.168.0.9 (metric 120) (via default) from 192.168.0.10 (192.168.0.10)
      Origin incomplete, metric 0, localpref 100, valid, internal, best
      Extended Community: RT:1:10 Color:100
      Originator: 192.168.0.9, Cluster list: 192.168.0.10
      mpls labels in/out nolabel/24000
      binding SID: 22 (color - 100) (state - UP)
      rx pathid: 0, tx pathid: 0x0
      Updated on Apr 21 2022 01:49:24 UTC
```

Default

- Every 3 second, a query
  - a two-way query is sent
- Every 30 seconds, a probe
  - min, avg, max, var are computed over the last 10 queries
  - Last-Probe EDT trigger with (min, avg, max, var)
- Every 120 seconds, an aggregation
  - min, avg, max, var over the last 4 probes are computed
  - Last-Aggregation Even Driven Telemetry trigger with (min, avg, max, var)
  - IF [abs(min-F.min)/F.min >= 10%] and [abs(min-F.min)>=1000usec]
    THEN an LSDB change is triggered to flood the new link delay values
    a last-advertisement EDT is triggered with these values

F.min is the last flooded value of min-delay. This is what the rest of the network thinks of this link min delay.

Minimum delay is of interest for SRTE

- Minimum delay provides the propagation delay
  - fiber length / speed of light
- A property of the topology
  - with awareness of DWDM circuit change
- SRTE (Policy or Flex-Algo) can optimize on min delay

Average, Max and Variance are dealt with by QoS

- Depends on congestion
  - (traffic burst over line rate) / line rate
- Highly variable at any time scale
- Not controlled by routing optimization
- Controller by QoS
  - Priority queue, WRR, WFQ…
  - Tail-Drop, RED…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