You make **possible**

Next Generation Network Architectures

Design, Deployment and Operations

Kashif Islam – Sr. Solutions Architect
Syed Hassan – Sr. Solutions Architect

TECSPG-2801

Cisco live!
June 9-13, 2019 · San Diego, CA

#CLUS

Agenda

- Architectural Transformation Landscape
- Fundamentals of Next Generation Architecture
  - Intent Based Programmable Transport
  - Application based Forwarding Architectures
  - BGP Based VPN
- Operational Efficiency Through Orchestration and Automation
- Summary

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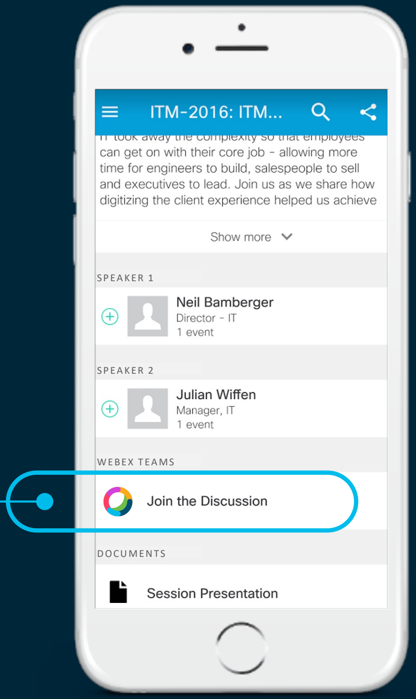

ITM-2016: ITM...

IT took away the complexity so that employees can get on with their core job – allowing more time for engineers to build, salespeople to sell and executives to lead. Join us as we share how digitizing the client experience helped us achieve

Show more

SPEAKER 1

Neil Bamberger
Director - IT
1 event

SPEAKER 2

Julian Wiffen
Manager, IT
1 event

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DOCUMENTS

Session Presentation

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Architectural Transformation Landscape

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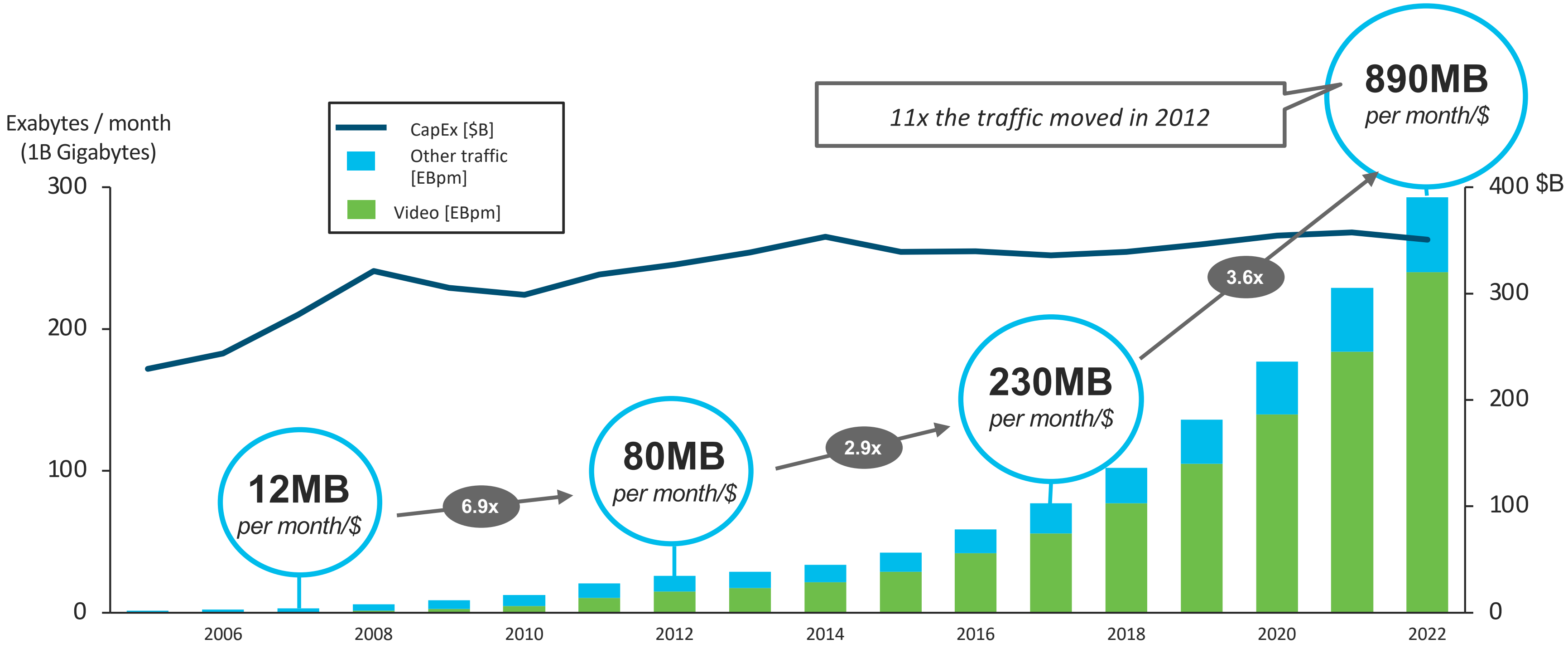
Need for Architectural and Operation Transformation:
Bandwidth Growth Finally ‘Breaking the Bank’



Sources: IHS Technology, “Service Provider CapEx, OpEx, Revenue, and Subscribers Database, Q1 2017”; Cisco Visual Networking Index (VNI)

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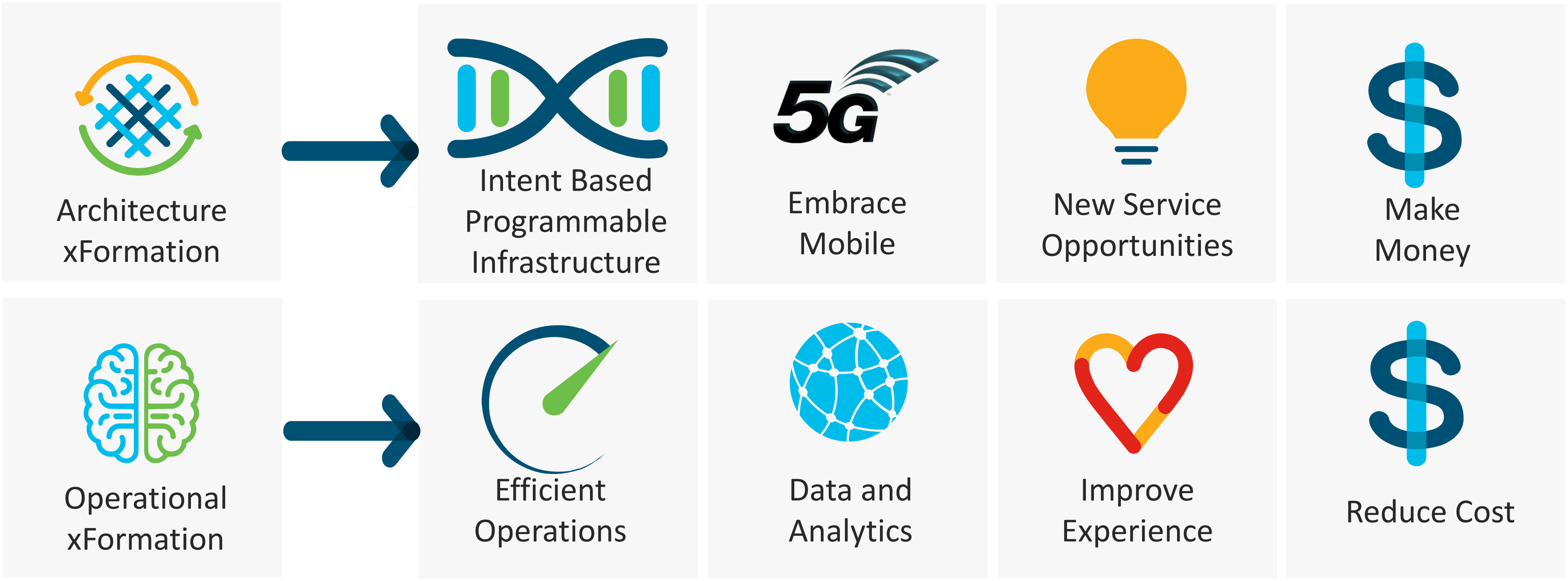
Happening Now: Network Transformation



Architecture xFormation

Intent Based Programmable Infrastructure

Embrace Mobile

New Service Opportunities

Make Money

Operational xFormation

Efficient Operations

Data and Analytics

Improve Experience

Reduce Cost

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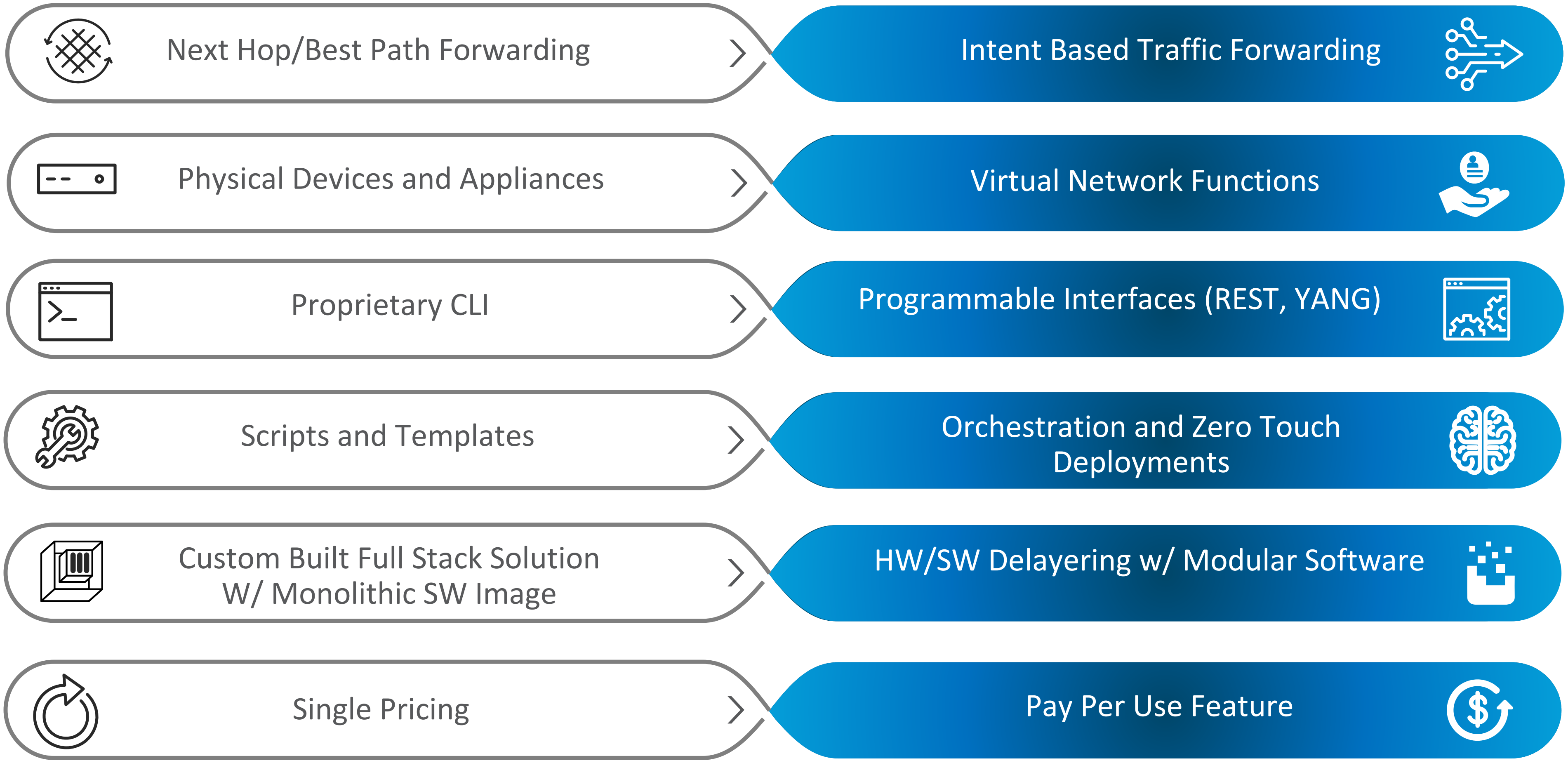
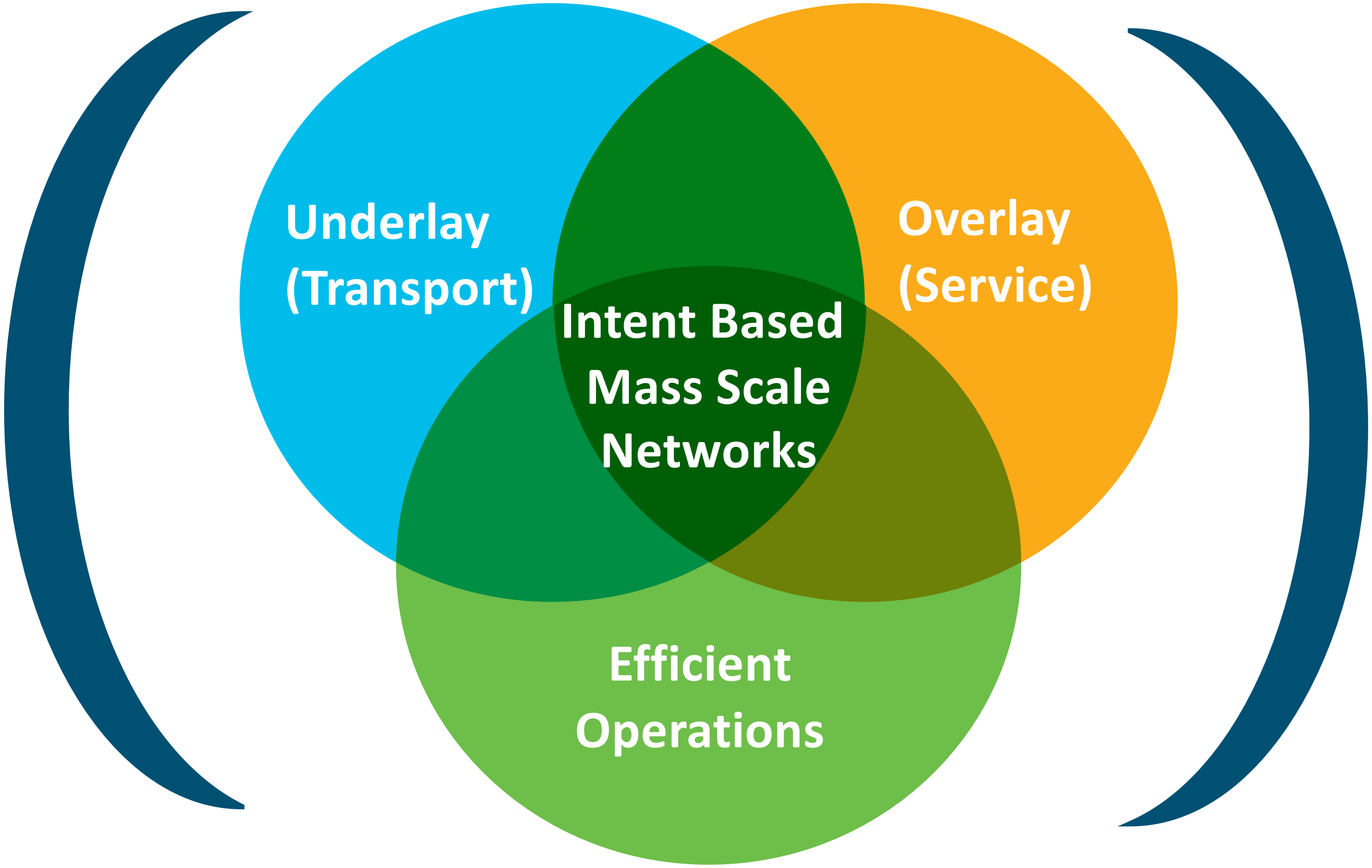
Transformation Accelerants (Some of them anyway…)



Next Hop/Best Path Forwarding	Intent Based Traffic Forwarding
Physical Devices and Appliances	Virtual Network Functions
Proprietary CLI	Programmable Interfaces (REST, YANG)
Scripts and Templates	Orchestration and Zero Touch Deployments
Custom Built Full Stack Solution W/ Monolithic SW Image	HW/SW Delayering w/ Modular Software
Single Pricing	Pay Per Use Feature

Wholistic Network View – Summary

Intent Based Programmable Networks



Underlay (Transport)

Overlay (Service)

Intent Based Mass Scale Networks

Efficient Operations

Automation, Machine Learning, AI

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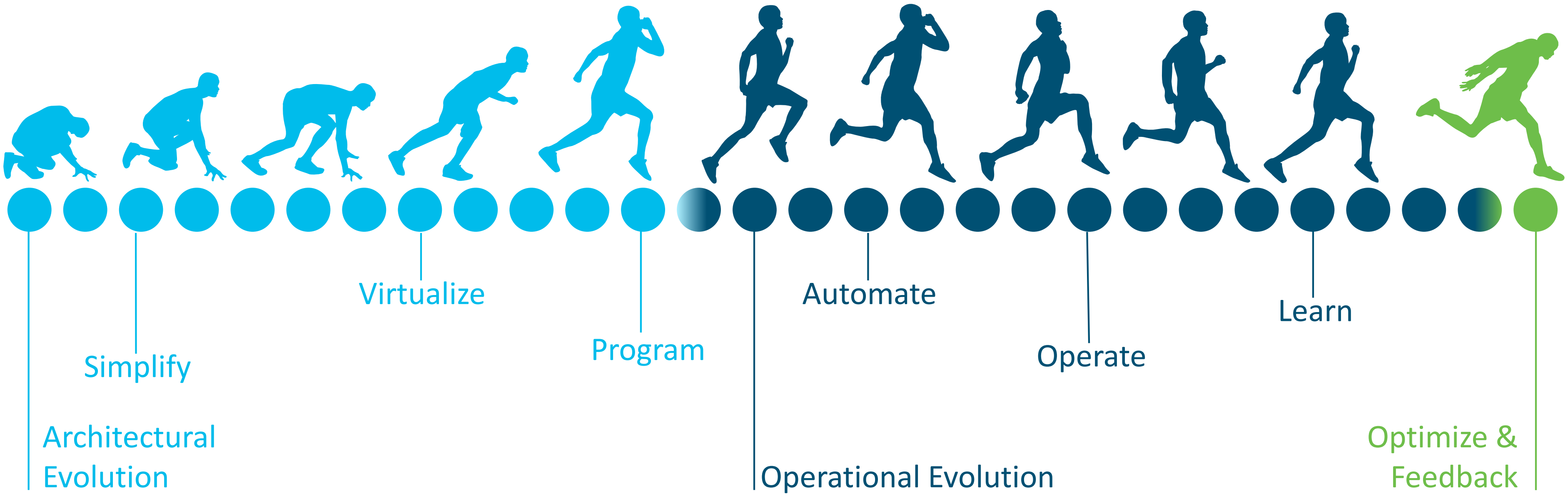
Get Your (Transformation) Priorities Straight



It all starts with Simplification …. at all layers of the Network

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Network Evolution and Simplification Journey

	Legacy	Existing	Next Gen
Technology Arch.	IP/MPLS	Unified MPLS	Segment Routing
Provisioning			
Programmability			
Services (L2/L3 VPN)	LDP BGP		
Scaling Mechanism			
TE, FRR	RSVP		
Overlay Protocol	LDP		
Connectivity Protocol	IGP		

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Network Evolution and Simplification Journey

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Services (L2/L3 VPN)	LDP BGP	LDP BGP	
Scaling Mechanism		BGP-LU	
TE, FRR	RSVP	RSVP	
Overlay Protocol	LDP	LDP	
Connectivity Protocol	IGP	IGP	

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Network Evolution and Simplification Journey

	Legacy		Existing		Next Gen
Technology Arch.	IP/MPLS		Unified MPLS		Segment Routing
Provisioning					NETCONF, YANG
Programmability					Path Control Element (PCE)
Services (L2/L3 VPN)	LDP	BGP	LDP	BGP	BGP
Scaling Mechanism			BGP-LU		Segment Routing w/ IGP
TE, FRR	RSVP		RSVP		
Overlay Protocol	LDP		LDP		
Connectivity Protocol	IGP		IGP		

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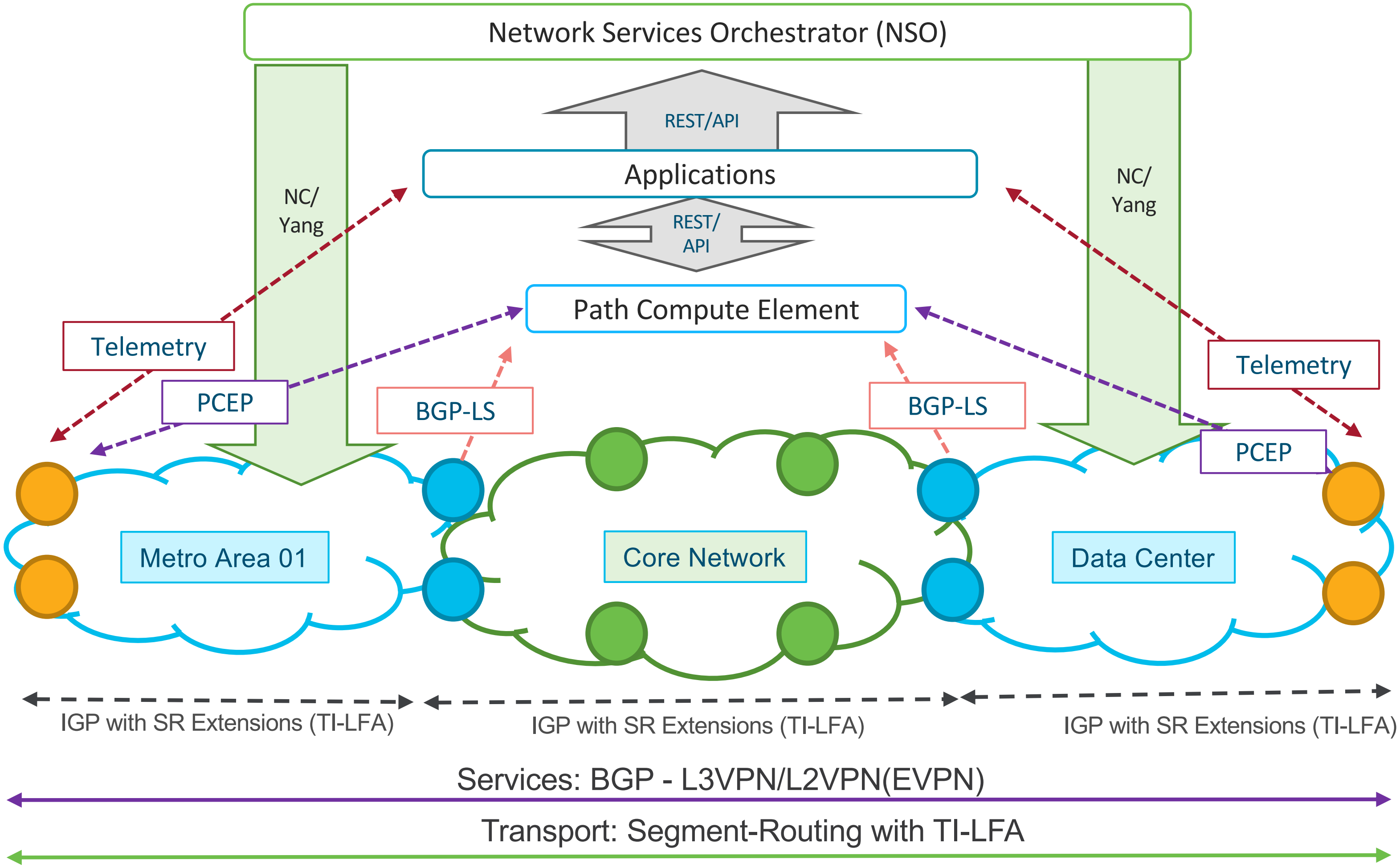
Intent Based, SDN Ready Network Infrastructure



Network Services Orchestrator (NSO)

REST/API

Applications

REST/
API

Path Compute Element

NC/
Yang

NC/
Yang

Telemetry

PCEP

BGP-LS

BGP-LS

Telemetry

PCEP

Metro Area 01

Core Network

Data Center

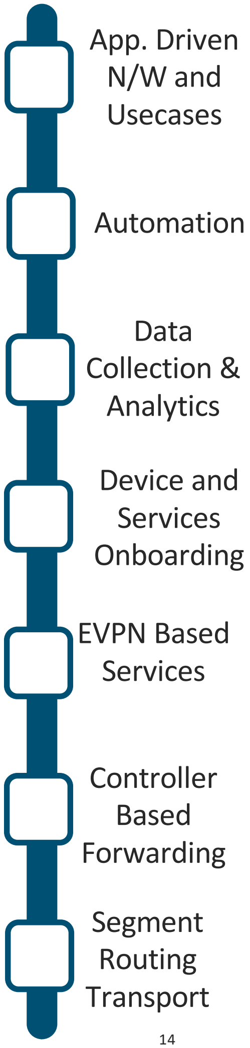
IGP with SR Extensions (TI-LFA)

IGP with SR Extensions (TI-LFA)

IGP with SR Extensions (TI-LFA)

Services: BGP - L3VPN/L2VPN(EVPN)

Transport: Segment-Routing with TI-LFA



App. Driven
N/W and
Usecases

Automation

Data
Collection &
Analytics

Device and
Services
Onboarding

EVPN Based
Services

Controller
Based
Forwarding

Segment
Routing
Transport

Fundamentals of Next Gen Network Architectures:

Intent Based Programmable Transport

Application Based Forwarding Architecture

BGP Based VPNs

You make security **possible**

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Programmable Network Infrastructure – How?

Network Forwarding –

Today

- Routed based on Next Hop Forwarding
  i.e No route control once packet leaves the source

Optimal path (mostly) but not suited for
“Network Programmability”

Network Forwarding –

Intent Based and Programmable

- Ability to define “Intent” for traffic
- Source Influences Exact Traffic Path
- Requires Source Routing for MPLS

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Segment Routing – Technology Overview

Segment ID (SID) is used as label in MPLS-SR

Globally unique Prefix-SID identifies the router

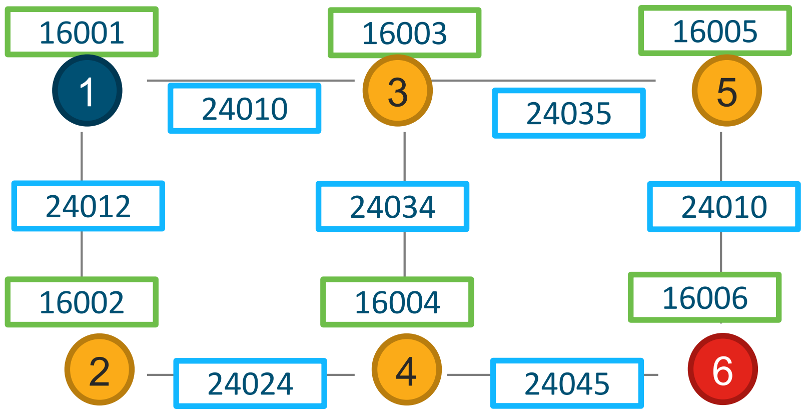
Locally unique Adjacency-SID identifies link on a router

Simple extension to IS-IS or OSPF to propagate SIDs through the network

Builds & Maintains ”Segment”

Segment Routing – Technology Overview

Prefix SID (Node SID)	Adjacency SID
Globally Significant	Locally Significant Unidirectional



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

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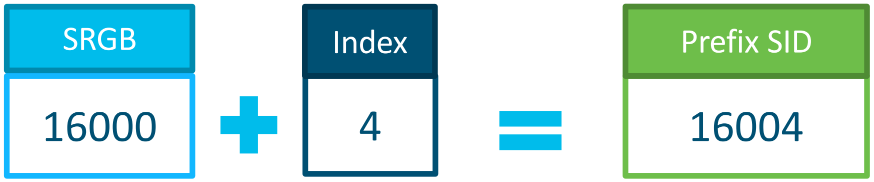
Segment Routing – Configuration Concepts

- Configured under IGP Routing Protocol
- Requires: Enabling SR & Configuring Prefix-SID
  - Configure "Absolute Value" or "Index"
- Optional: Configure SR-Global-Block (SRGB).
  - Default 16000 - 23999
- SRGB & Index advertised using IGP



SRGB 16000 + Index 4 = Prefix SID 16004

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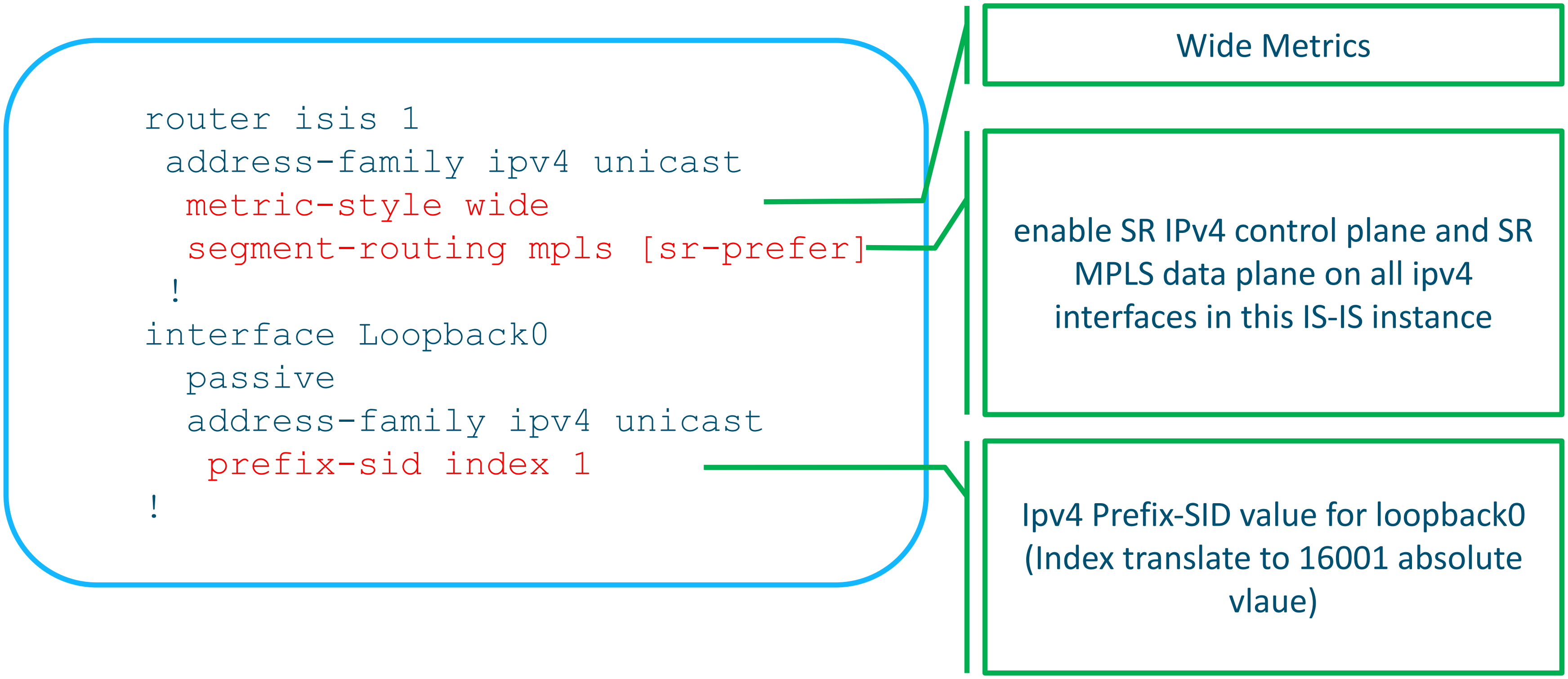
Segment Routing Configuration Example



```
router isis 1
 address-family ipv4 unicast
  metric-style wide
  segment-routing mpls [sr-prefer]
 !
interface Loopback0
  passive
  address-family ipv4 unicast
   prefix-sid index 1
!
```

Wide Metrics

enable SR IPv4 control plane and SR MPLS data plane on all ipv4 interfaces in this IS-IS instance

Ipv4 Prefix-SID value for loopback0 (Index translate to 16001 absolute vlaue)

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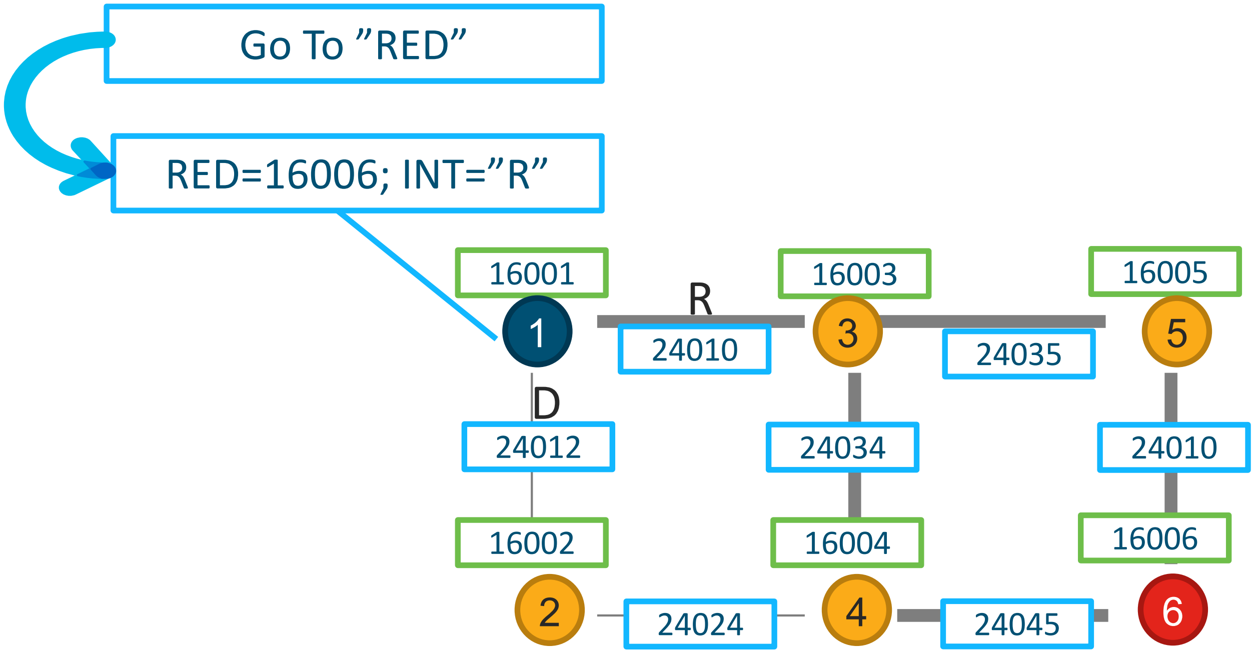
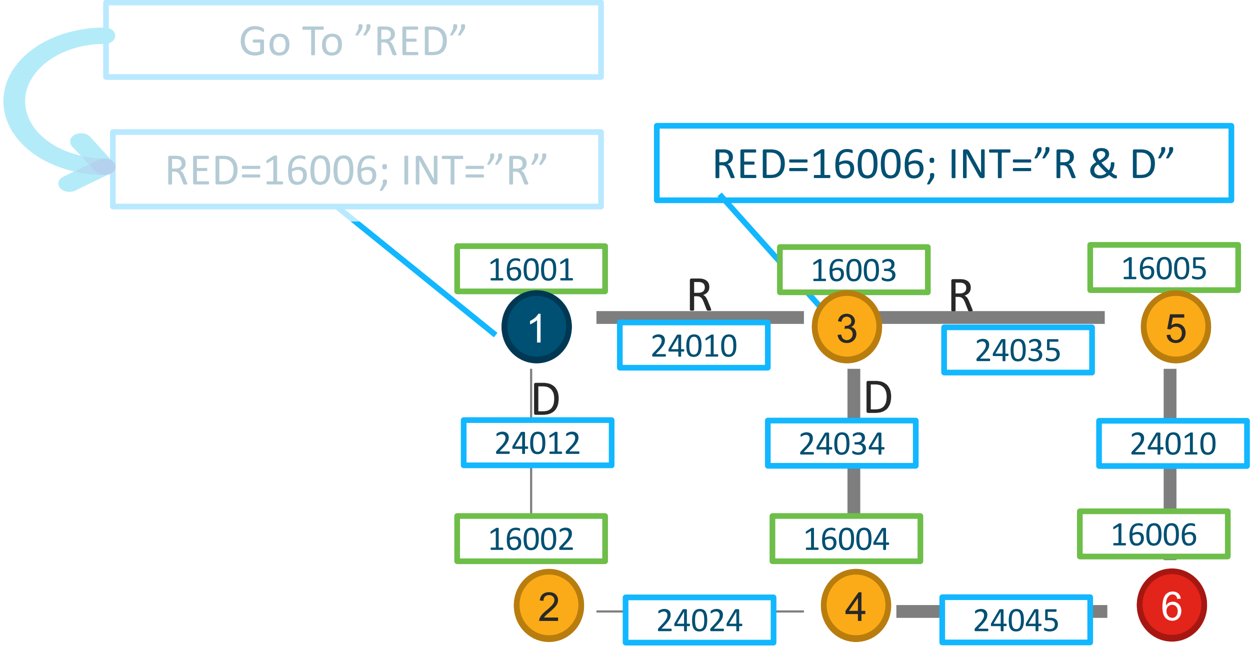
Segment Routing – Technology Overview



Segment Routing – Technology Overview



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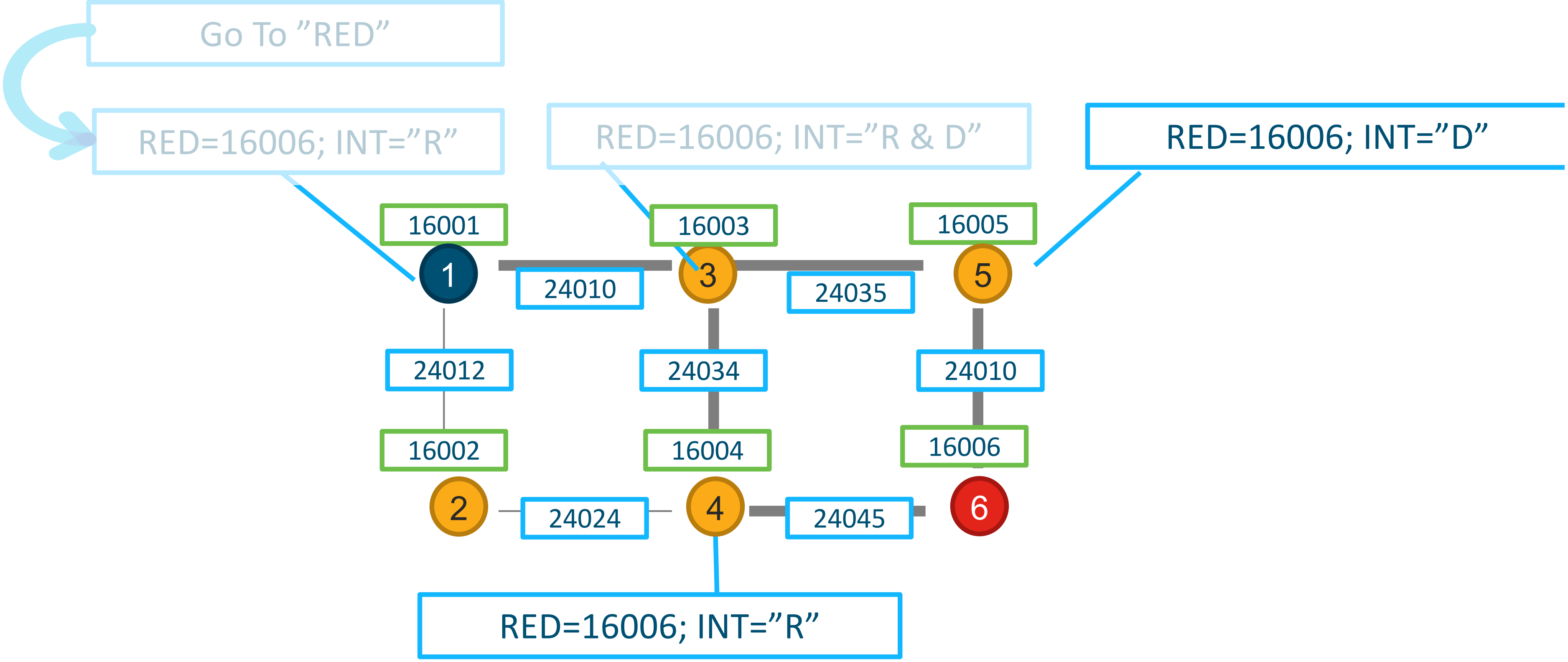
Segment Routing – Technology Overview



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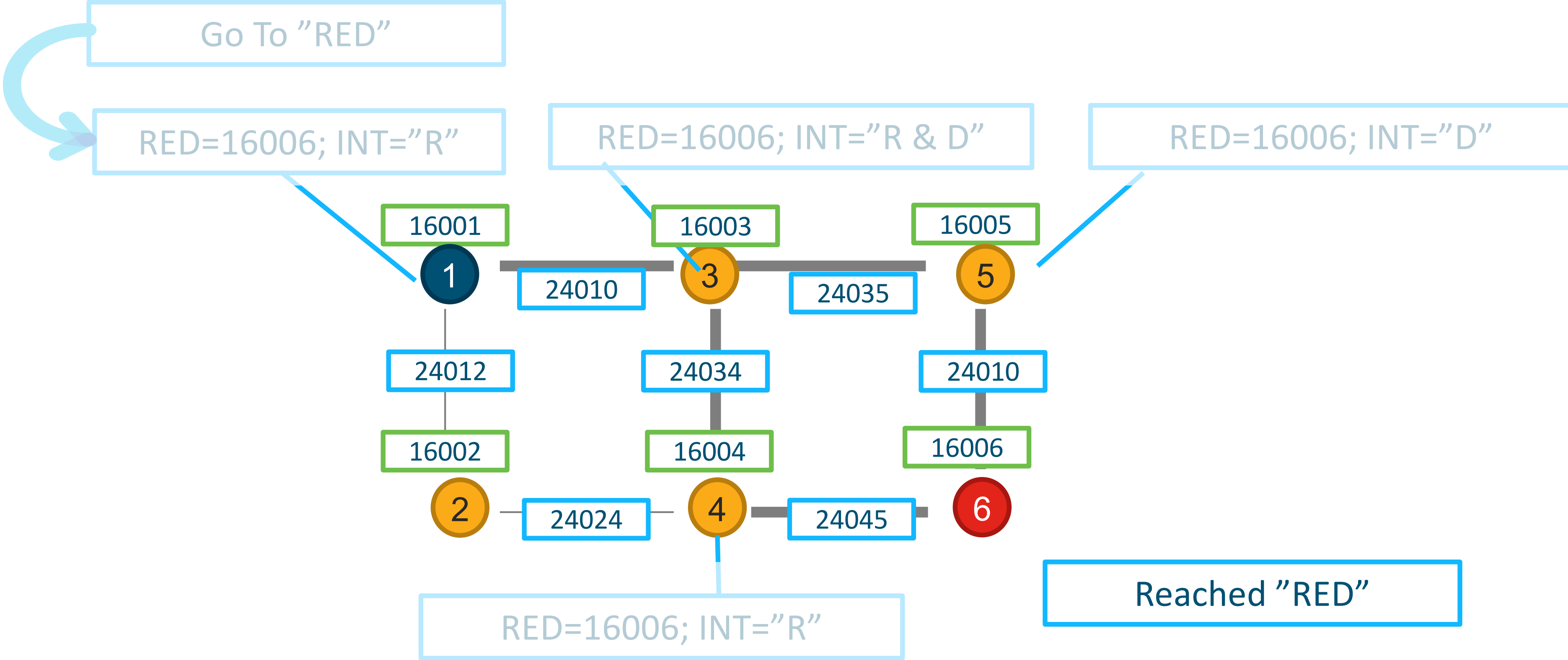
Segment Routing – Technology Overview



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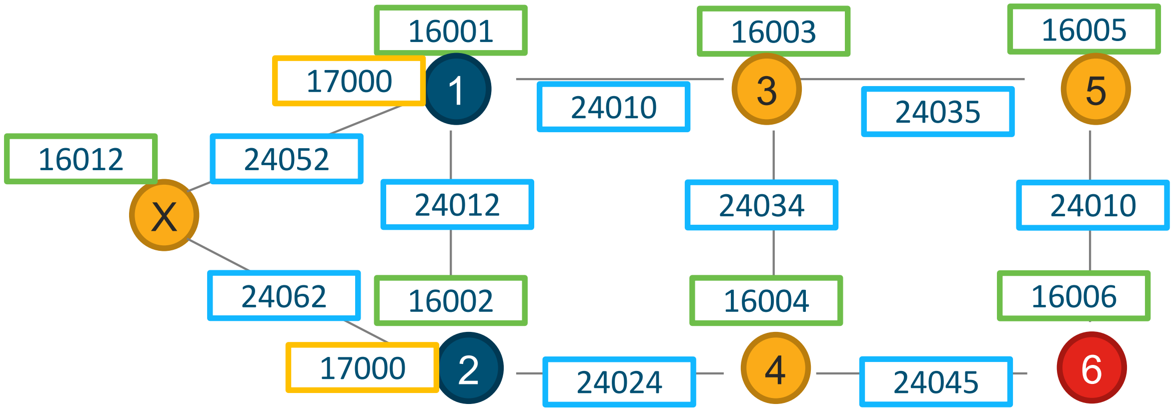
Segment Routing – Technology Overview

Prefix SID	Adjacency SID	Anycast SID
Globally Significant	Locally Significant Unidirectional	Globally Significant



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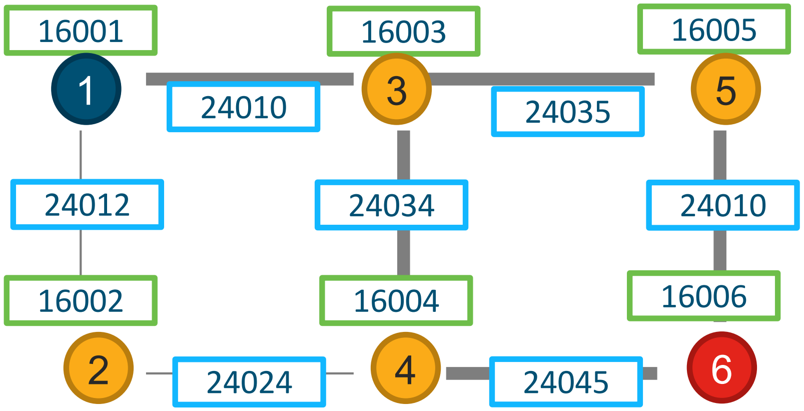
Segment Routing – Programming The Path

Go To ”RED”; Desired Path 1→2→4→3→5→6

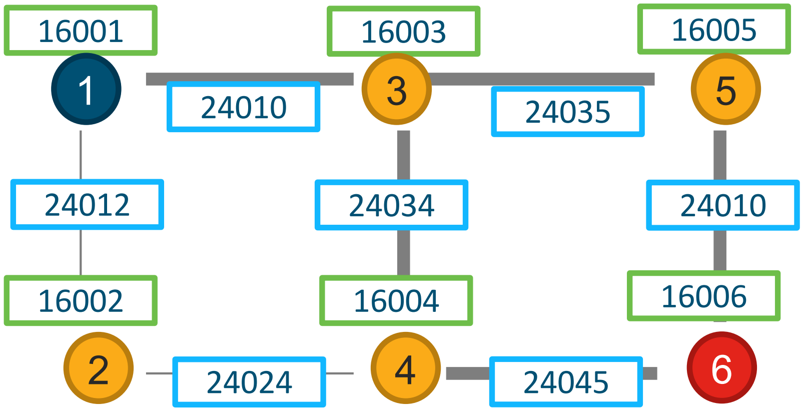


Segment Routing – Programming The Path

Go To ”RED”; Desired Path 1→2→4→3→5→6

SID-List:

24012
24024
16003
16005
16006



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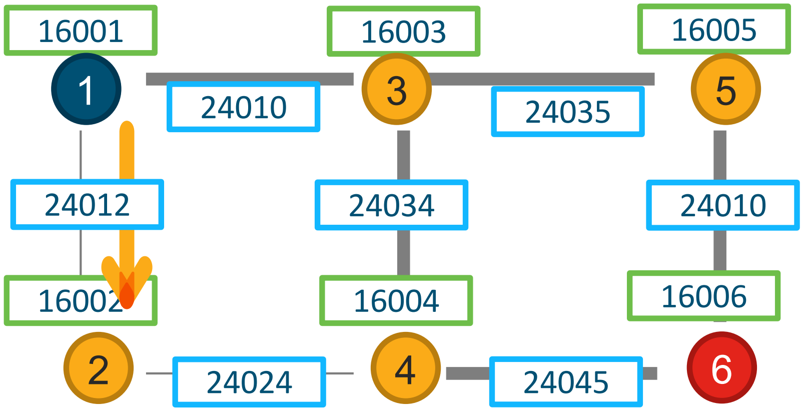
Segment Routing – Programming The Path

Go To ”RED”; Desired Path 1→2→4→3→5→6

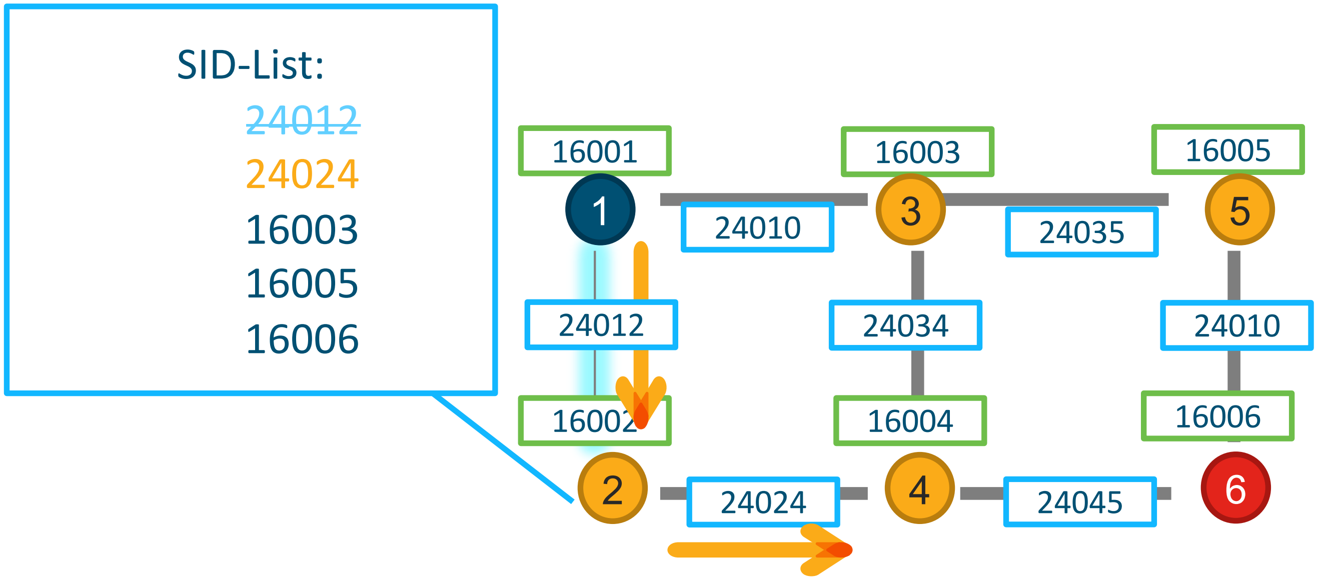
SID-List:

24012
24024
16003
16005
16006

24012; INT=”D”



Segment Routing – Programming The Path



SID-List:

~~24012~~

24024

16003

16005

16006

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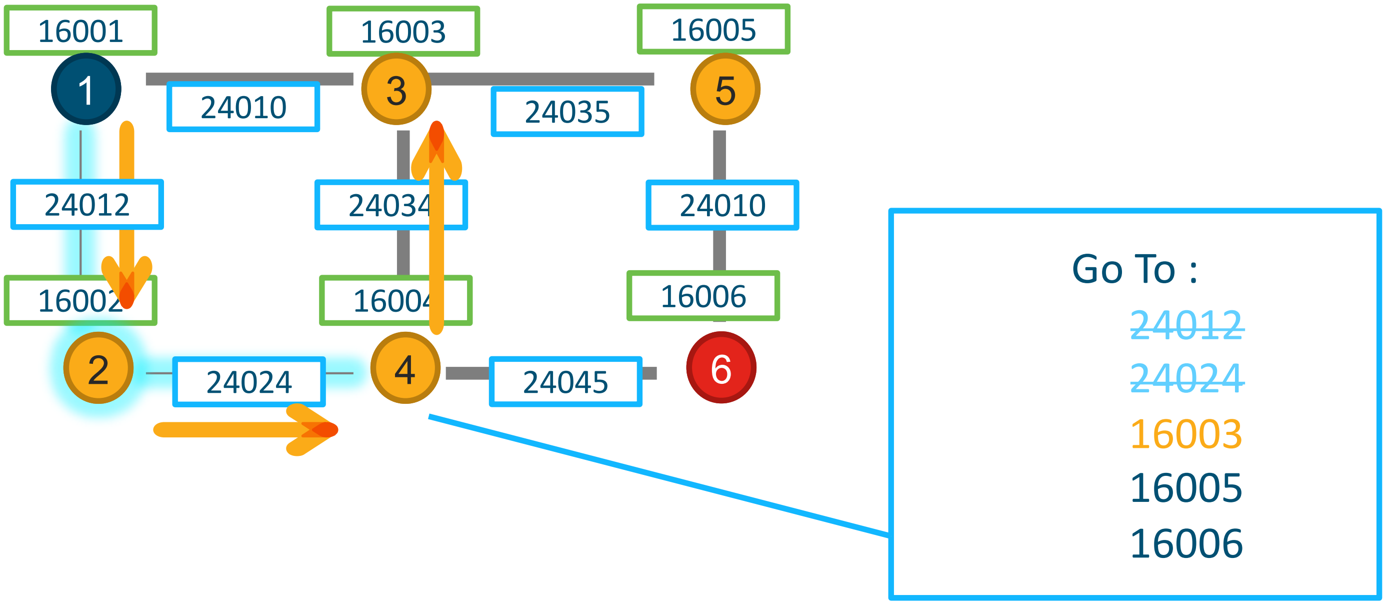
Segment Routing – Programming The Path



Go To :

~~24012~~

~~24024~~

16003

16005

16006

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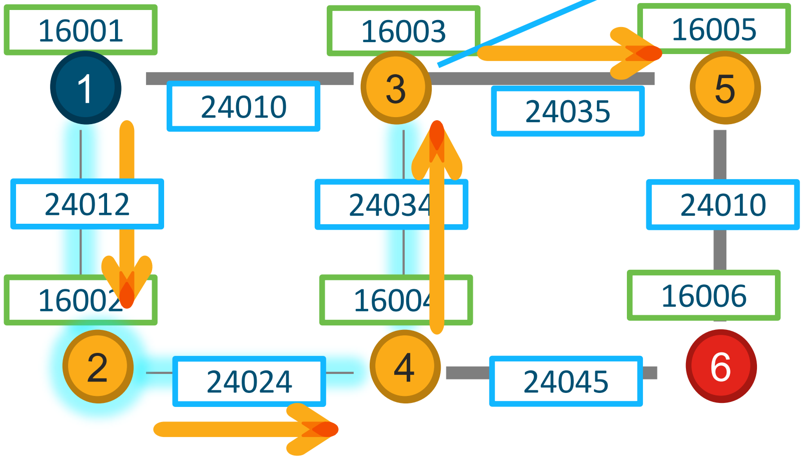
Segment Routing – Programming The Path



Go To :

~~24012~~

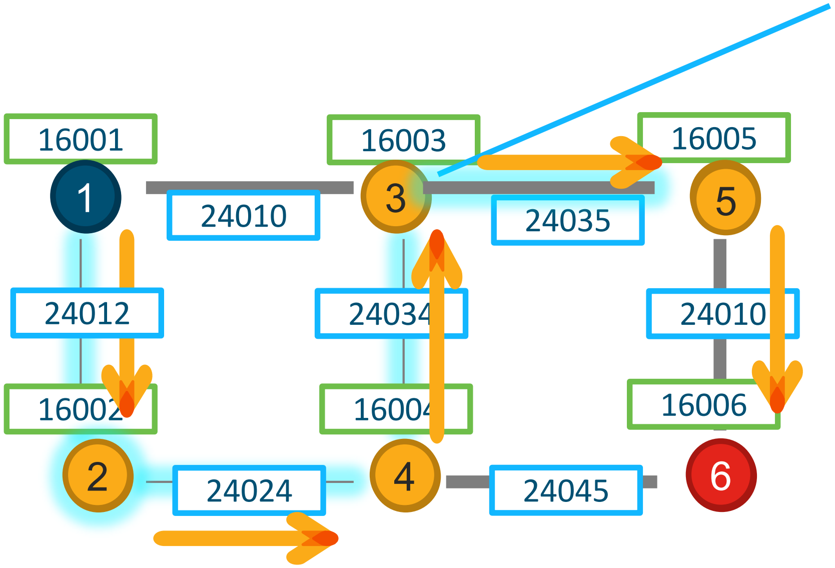
~~24024~~

~~16003~~

16005

16006

Segment Routing – Programming The Path



Go To :

~~24012~~

~~24024~~

~~16003~~

~~16005~~

16006

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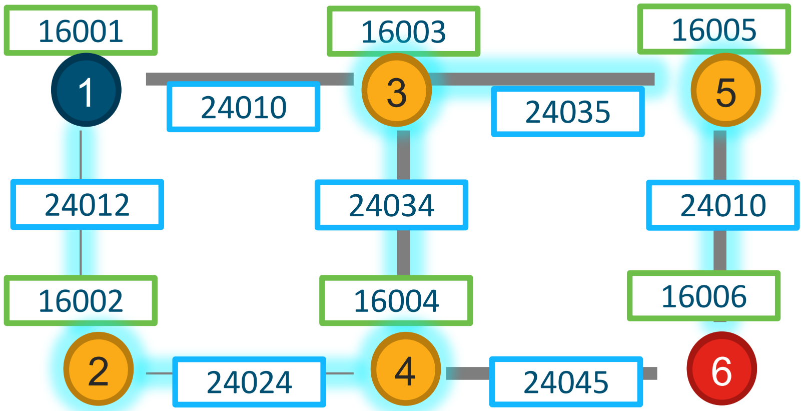
Segment Routing – Programming The Path

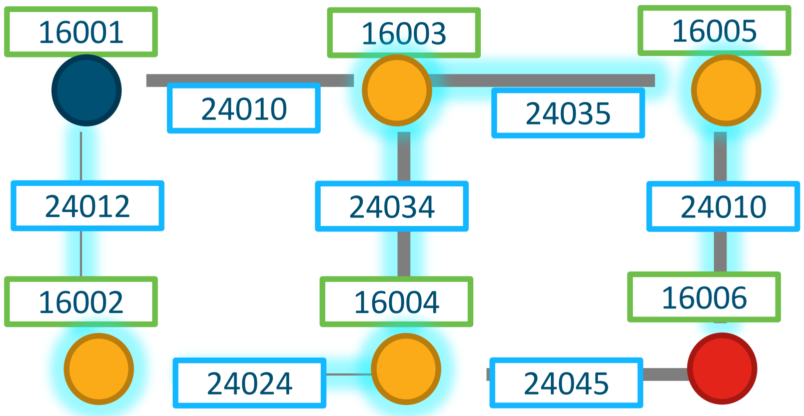
SRTE



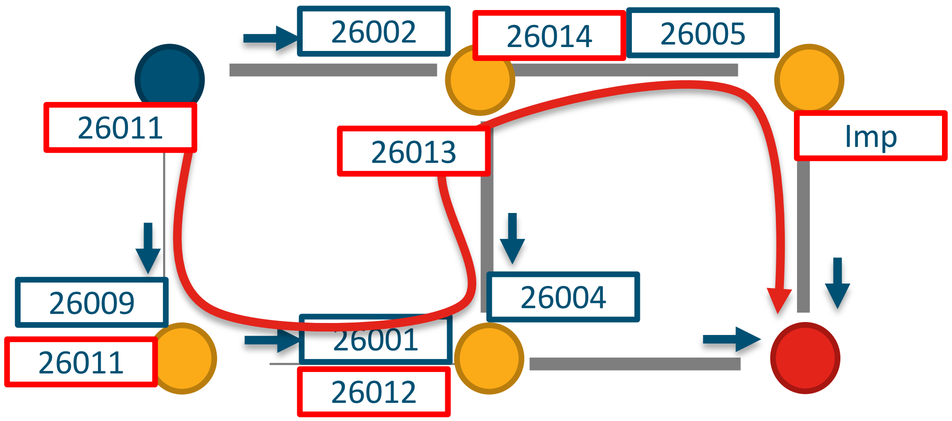
Reached ”RED”

Programming The Path – SRTE vs RSVP-TE

SRTE



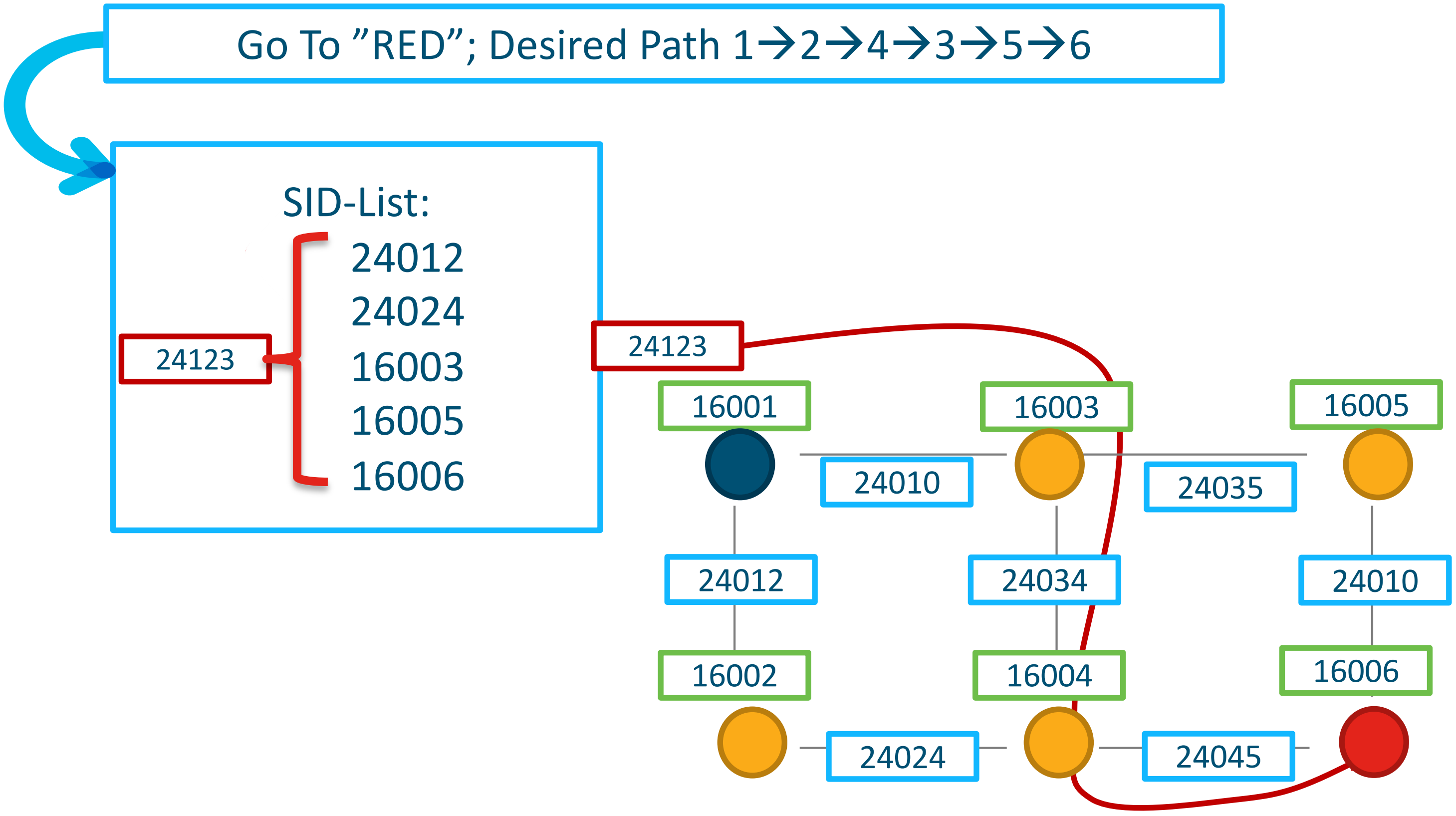
RSVP-TE



	SR-TE	RSVP-TE
TE state only at head-end	✓	✗
Engineered for SDN	✓	✓ / ✗
ECMP-capability for TE	✓	✗

SRTE – Binding SID

Go To ”RED”; Desired Path 1→2→4→3→5→6



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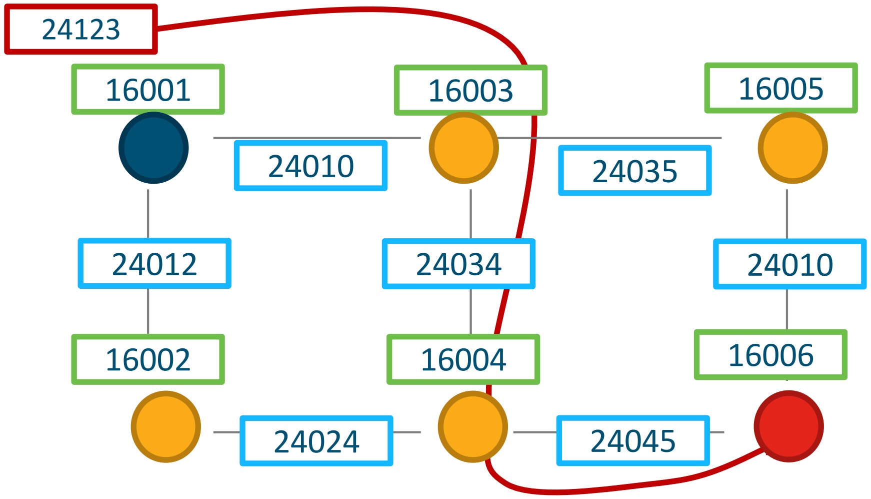
Segment Routing – Technology Overview

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



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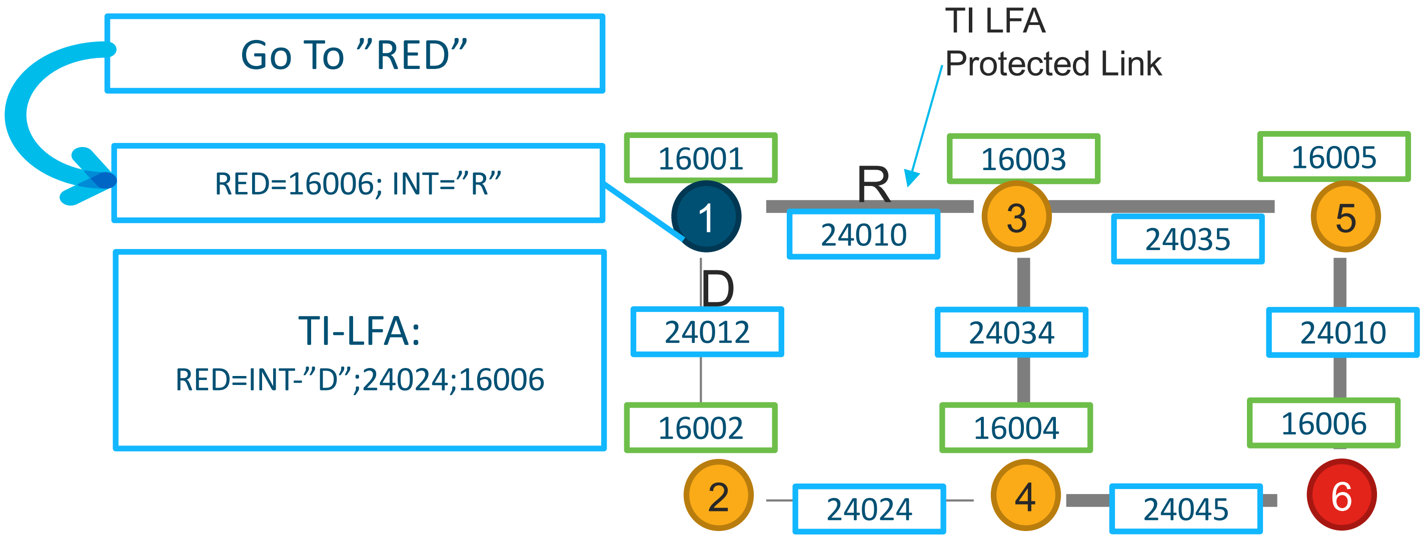
Fundamentals of Next Gen Network Architectures:

- Intent Based programmable Transport
  - Fast Re-Route
  - SRTE – Constructs & Configuration
  - On Demand Next Hop (ODN)
  - Flex Algo
- Application Based Forwarding Architecture
- BGP Based VPNs

You make security **possible**

Fast Re-route with Segment Routing : TI-LFA

Topology Independent Loop Free Alternate Fast Re-route



Go To "RED"

RED=16006; INT="R"

TI-LFA:

RED=INT-"D";24024;16006

TI LFA
Protected Link

https://www.ietf.org/id/draft-ietf-rtgwg-segment-routing-ti-lfa-01.txt

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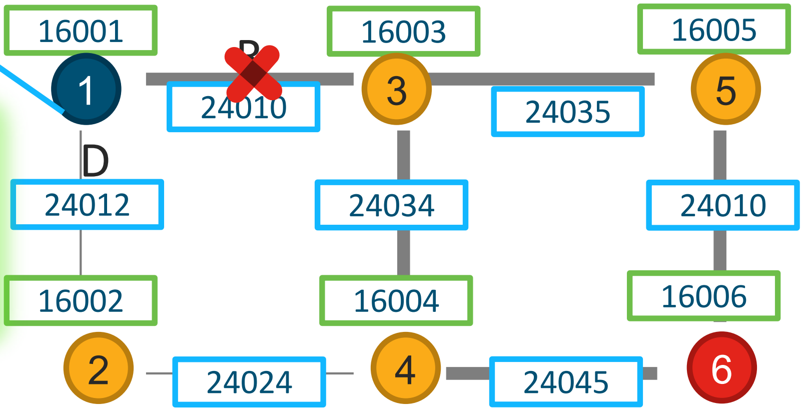
Fast Re-route with Segment Routing : TI-LFA

Topology Independent Loop Free Alternate Fast Re-route

Go To ”RED”

RED=16006; INT=”R”

TI-LFA:
RED=INT=”D”;24024;16006



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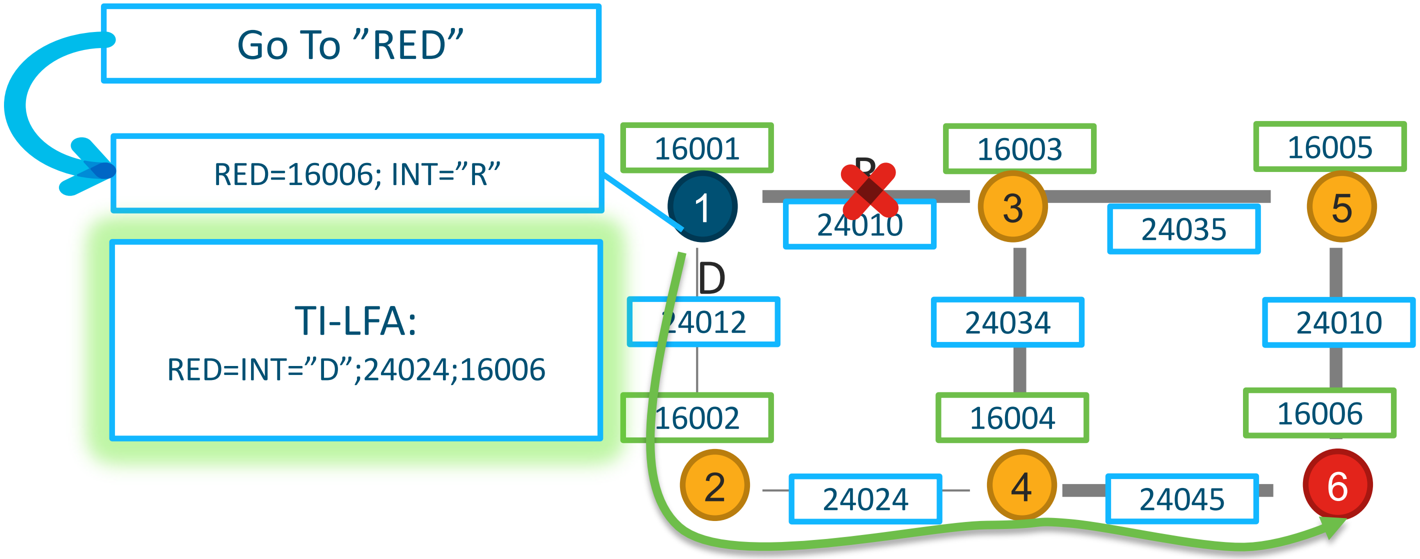

Go To "RED"

RED=16006; INT="R"

TI-LFA:
RED=INT="D";24024;16006

https://www.ietf.org/id/draft-ietf-rtgwg-segment-routing-ti-lfa-01.txt

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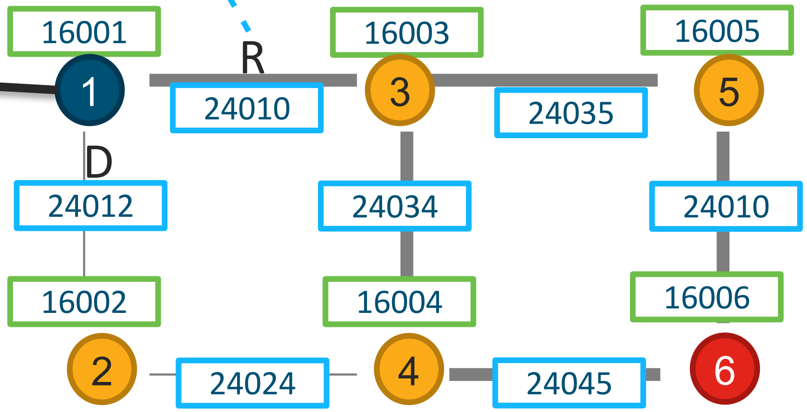
SRTE Protection using TI-LFA

```
router isis 100
 interface GigabitEthernet0/0/0/0
  address-family ipv4 unicast
   fast-reroute per-prefix
   fast-reroute per-prefix ti-lfa
  !
 !
```



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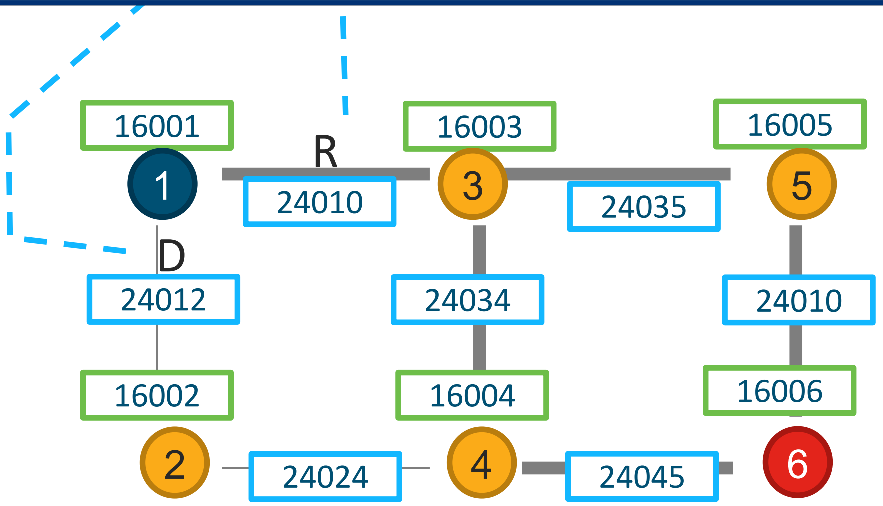
SRTE Protection using TI-LFA

```
RP/0/RP0/CPU0:R1#show mpls forwarding labels 16003
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
16003  16003       SR Pfx (idx 5)     Gi0/0/0/0    192.1.3.3       640
       16003       SR Pfx (idx 5)     Gi0/0/0/1    192.1.2.2       0            (!)
```



SRTE Protection using TI-LFA

```
RP/0/RP0/CPU0:R1#show mpls forwarding labels 16003 detail
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
16003  16003       SR Pfx (idx 5)     Gi0/0/0/0    192.1.3.3       2720
     Updated: Jun  6 21:12:49.488
     Path Flags: 0x400 [  BKUP-IDX:1 (0xee64350) ]
     Version: 88, Priority: 1
     Label Stack (Top -> Bottom): { 16003 }
     NHID: 0x0, Encap-ID: N/A, Path idx: 0, Backup path idx: 1, Weight: 0
     MAC/Encaps: 4/8, MTU: 1500
     Outgoing Interface: GigabitEthernet0/0/0/0 (ifhandle 0x01000018)
     Packets Switched: 68


       16003       SR Pfx (idx 5)     Gi0/0/0/1    192.1.2.2       0             (!)
     Updated: Jun  6 21:12:49.488
     Path Flags: 0x300 [  IDX:1 BKUP, NoFwd ]
     Version: 88, Priority: 1
     Label Stack (Top -> Bottom): { Imp-Null 24024 16003 }
     NHID: 0x0, Encap-ID: N/A, Path idx: 1, Backup path idx: 0, Weight: 0
     MAC/Encaps: 4/8, MTU: 1500
     Outgoing Interface: GigabitEthernet0/0/0/1 (ifhandle 0x01000020)
     Packets Switched: 0
     (!): FRR pure backup

  Traffic-Matrix Packets/Bytes Switched: 0/0
```

Notice that FRR backup path that is calculated and ready in case of failure

Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
  - Fast Re-Route
  - SRTE – Constructs & Configuration
  - On Demand Next Hop (ODN)
  - Flex Algo
- Application Based Forwarding Architecture
- BGP Based VPNs

You make security **possible**

SRTE Policy

SRTE policy : defines a routing intent based on constraints

Policy is uniquely identified by a 3-tuple

Head End	Where the SR Policy is instantiated (*implemented*)	H
Color	Numeric value to differentiate multiple SRTE Policies between the same pair of nodes	C
Endpoint	Destination of the SR Policy	E

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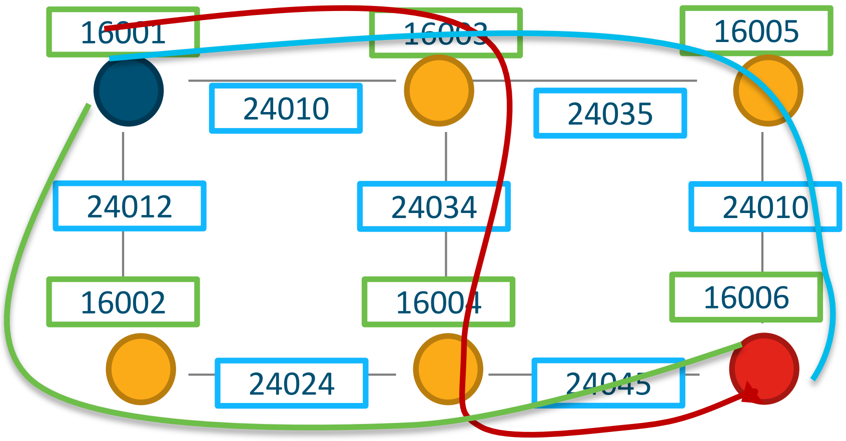
SRTE Policy Identification

	H	C	E
Policy-1	🔵	Red	🔴
Policy-2	🔵	Green	🔴
Policy-3	🔵	Blue	🔴



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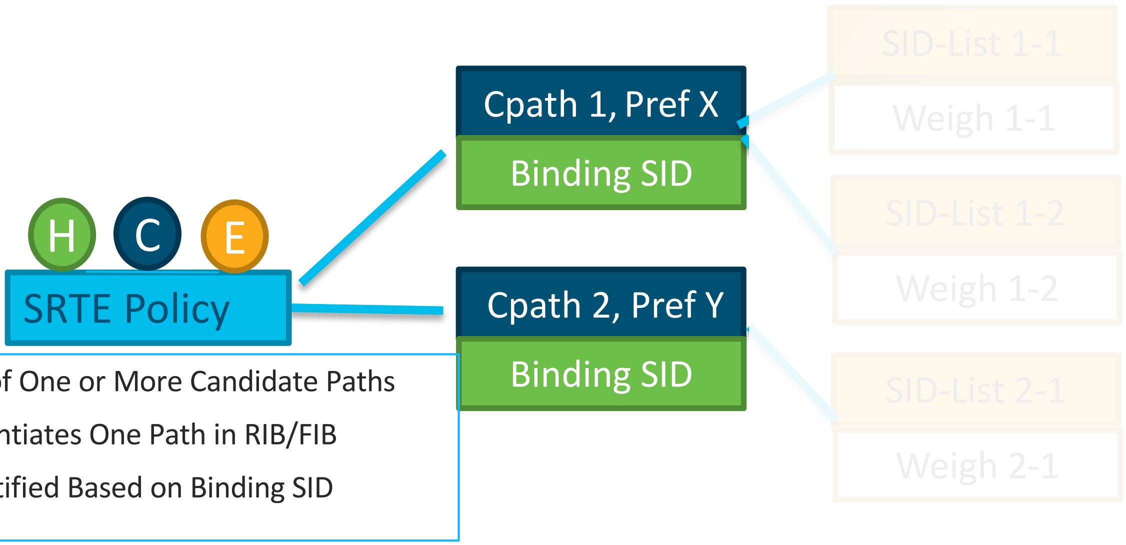
SRTE Policy – Candidate Paths

Explicit

Dynamic - Local

Dynamic - Remote



Consists of One or More Candidate Paths

Instantiates One Path in RIB/FIB

Identified Based on Binding SID

SRTE Policy – Candidate Paths

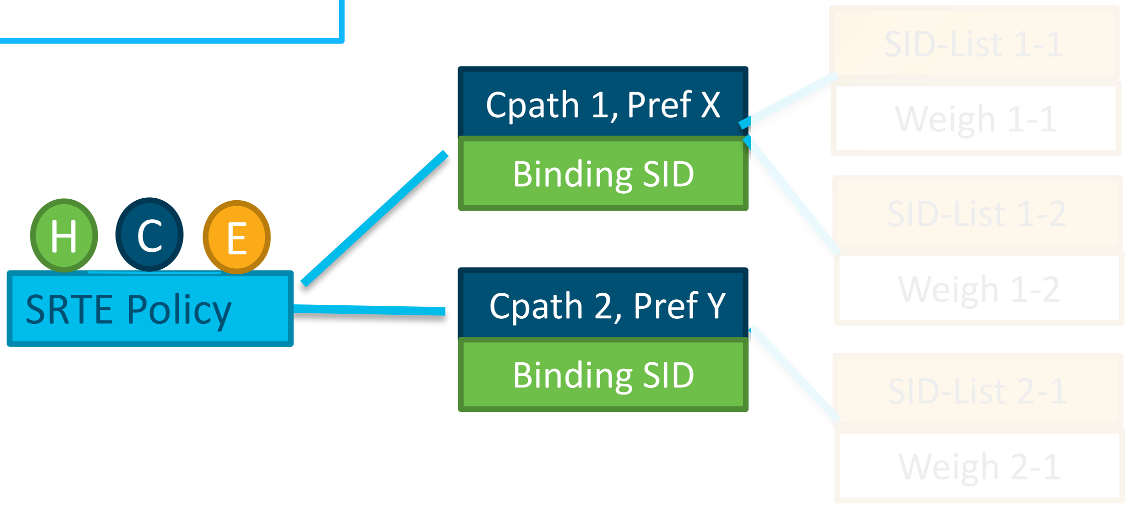
Explicit

Dynamic - Local

Dynamic - Remote

Explicitity Defined using:

- SID
- Prefix



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SRTE Policy – Candidate Paths

Explicit

Explicitity Defined using:
- SID
- Prefix

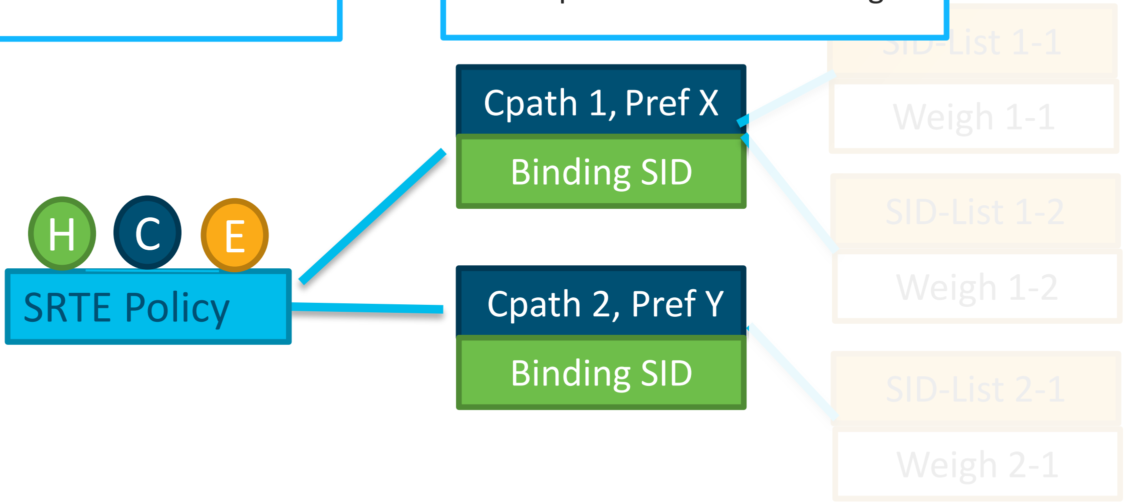
Dynamic - Local

Dynamically Computed by Headed

Based on Constraints

Recomputed if Network changes

Dynamic - Remote



SRTE Policy – Candidate Paths

Explicit

Explicitity Defined using:

- SID
- Prefix

Dynamic - Local

Dynamically Computed by Headed

Based on Constraints

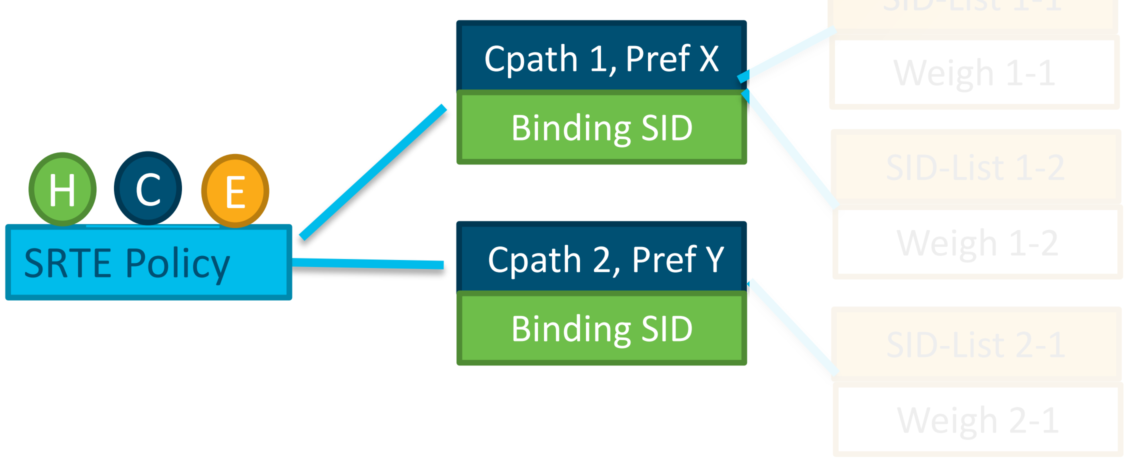
Recomputed if Network changes

Dynamic - Remote

Dynamically Computed by Controller

Based on Constraints

Recomputed if Network changes



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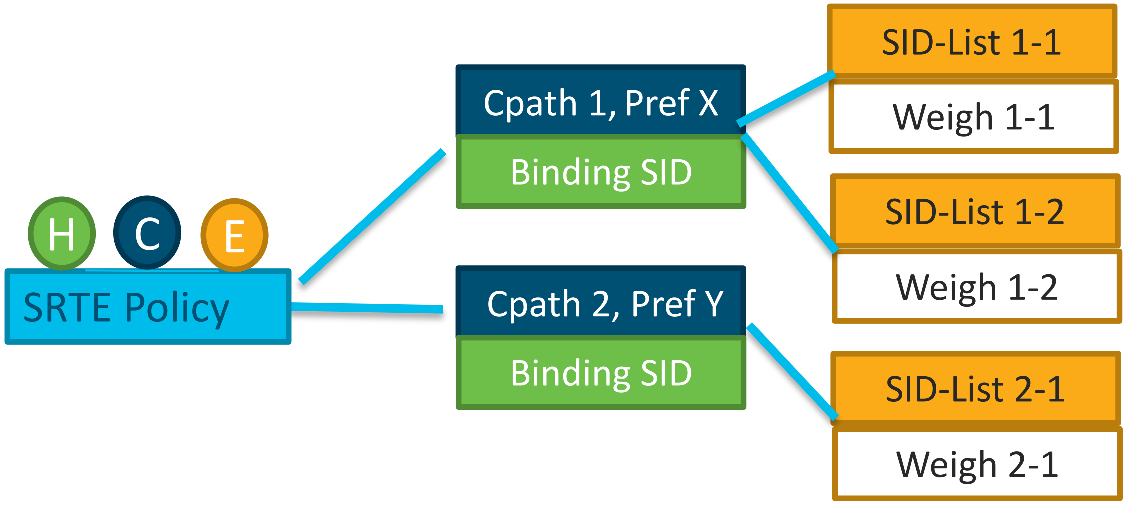
SRTE Policy – SID-Lists

- Each SRTE Candidate Path…
  - Single SID Lists, or Weighed SID-Lists
  - Traffic on Candidate Path is Load Balanced
  - Weight defines Load-Balance Ratio



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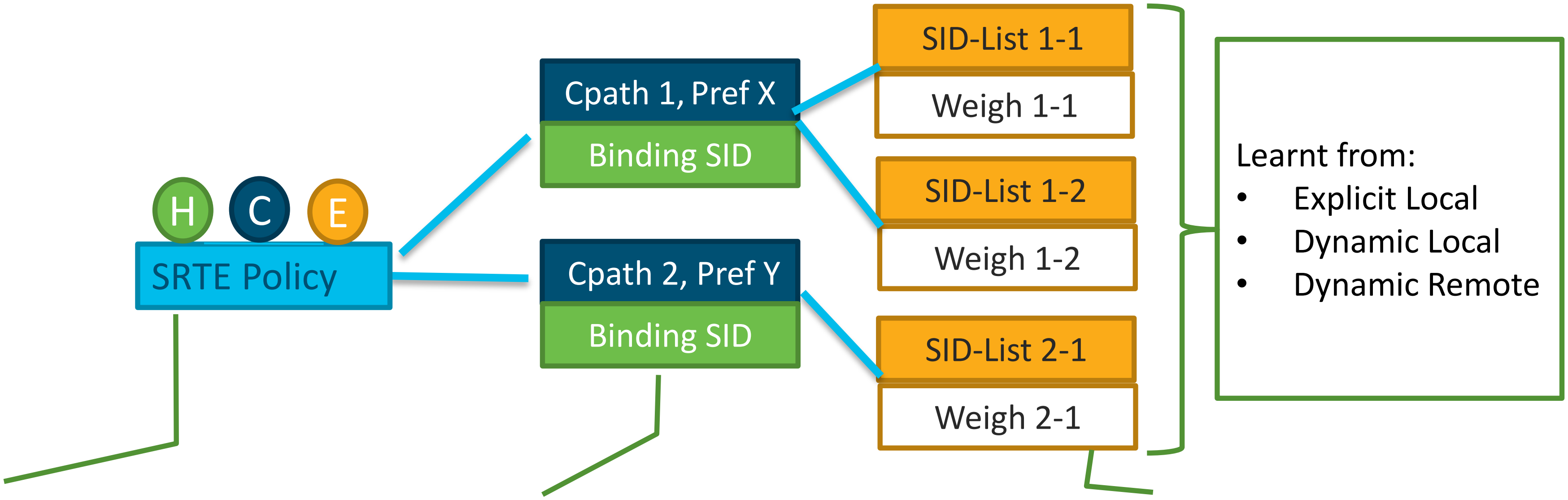
SRTE Policy - Summary



H C E

SRTE Policy

Cpath 1, Pref X

Binding SID

Cpath 2, Pref Y

Binding SID

SID-List 1-1

Weigh 1-1

SID-List 1-2

Weigh 1-2

SID-List 2-1

Weigh 2-1

Learnt from:

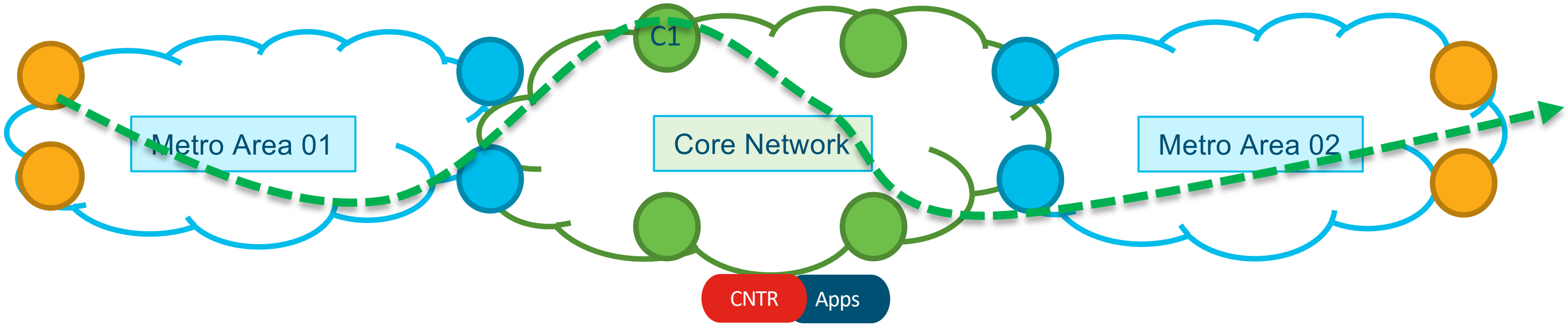
- Explicit Local
- Dynamic Local
- Dynamic Remote

- Identified by Unique: (Head-End + Color + End-Point)

- Chosen based on Preference
- Valid if: Any of the SID-list is valid
- Identified by: Binding SID (Auto)

- Programmed in FIB simultaneously
- Load-balanced based on
- Weight

SRTE – Path Compute & Configuration



Computed : Locally
Configured : Locally

- Explicit Path
- Dynamic Path
- Based on constraints
  IGP, BW, Delay, SRLG, Affinity …

Computed : Controller
Configured : Locally

- Requested by Headend
  - Configured
  - On-Demand
- Computed by Controller using Network View

Computed : Controller
Configured : Controller

- Application Triggered
- Configured on Controller
- Pushed down to Headend

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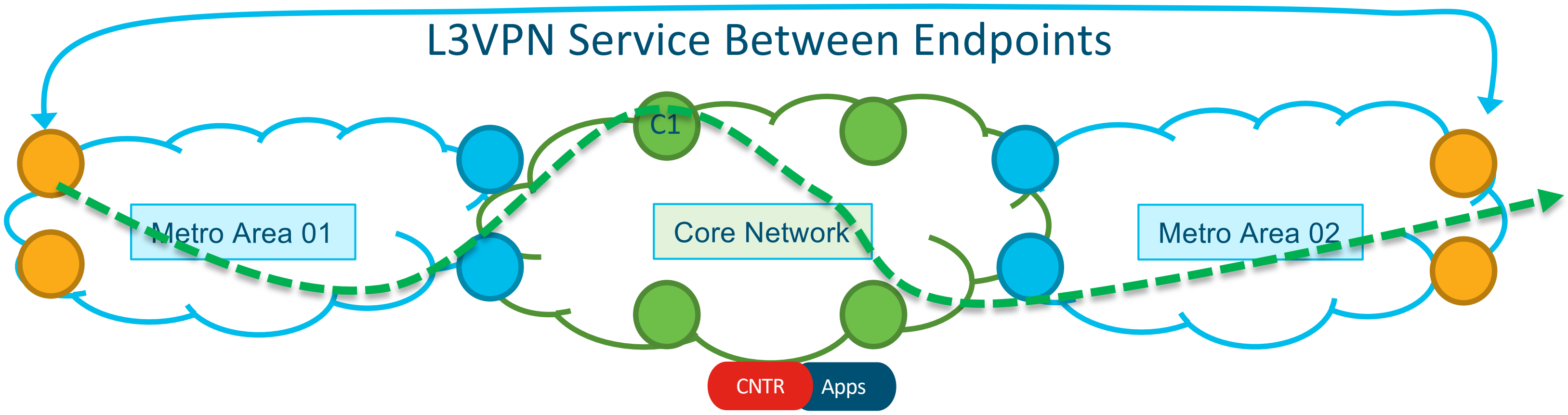
SRTE – Configuration Example



Setting Color using Ext Community

```
extcommunity-set opaque BLUE
  25
end-set

route-policy SET_COLOR_BLUE
 if destination in (10.100.1.1/32) then
    set extcommunity color BLUE
  endif
end-policy
```

Coloring a Route in BGP

```
router bgp 65000
 neighbor 192.168.0.15
  remote-as 65000
  update-source Loopback0

  address-family vpnv4 unicast
   route-policy SET_COLOR_BLUE in
      !could be outbound policy as well
```

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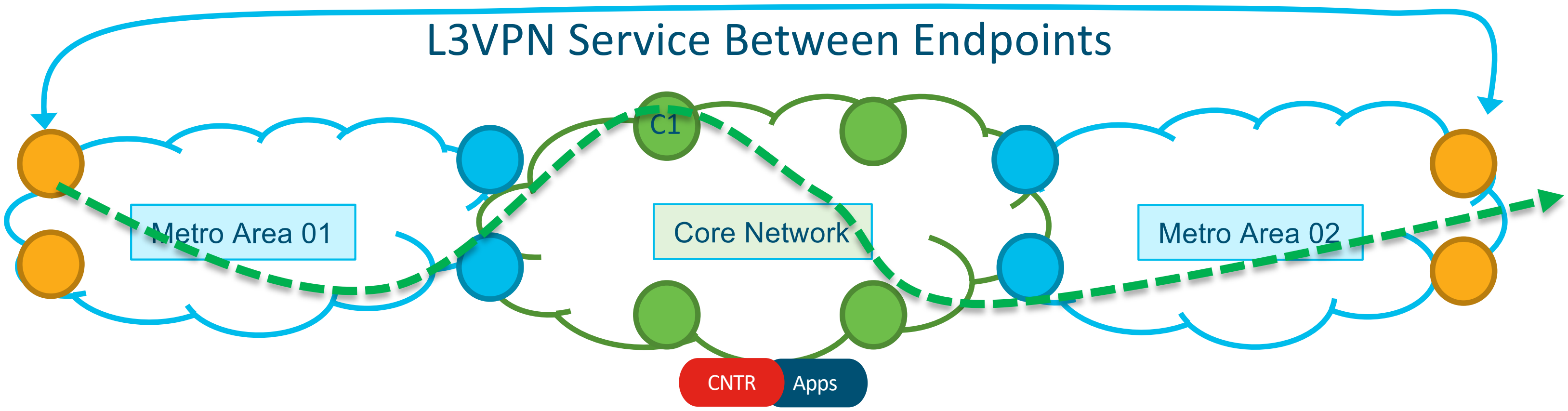
SRTE – Configuration Example



Verify Route Coloring

```
RP/0/0/CPU0:PE25#sh bgp vpnv4 unicast vrf L3VPN-1  10.100.1.0
BGP routing table entry for 10.100.1.0/24, Route Distinguisher: 65000:1
<snip>
Extended community: Color:25 RT:65000:1
      Originator: 192.168.0.15, Cluster list: 192.168.0.5
      Source AFI: VPNv4 Unicast, Source VRF: L3VPN-1, Source Route Distinguisher: 65000:1
<snip>
```

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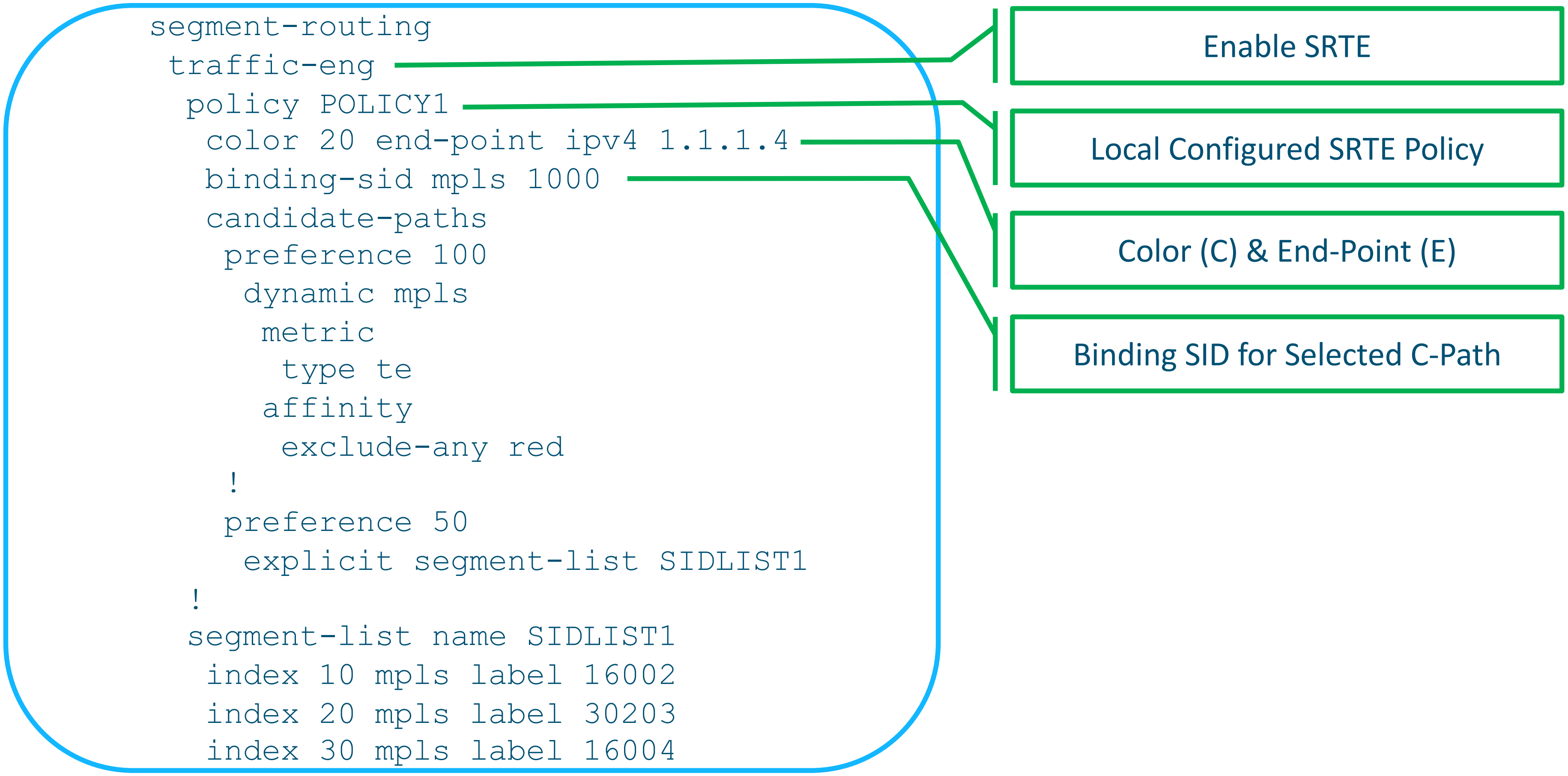
SRTE - Configuration Example [Local Policy]

```
segment-routing
 traffic-eng
  policy POLICY1
   color 20 end-point ipv4 1.1.1.4
   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
      affinity
       exclude-any red
    !
    preference 50
     explicit segment-list SIDLIST1
  !
  segment-list name SIDLIST1
   index 10 mpls label 16002
   index 20 mpls label 30203
   index 30 mpls label 16004
```

Enable SRTE

Local Configured SRTE Policy

SRTE - Configuration Example [Local Policy]



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  policy POLICY1
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   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
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    !
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  !
  segment-list name SIDLIST1
   index 10 mpls label 16002
   index 20 mpls label 30203
   index 30 mpls label 16004
```

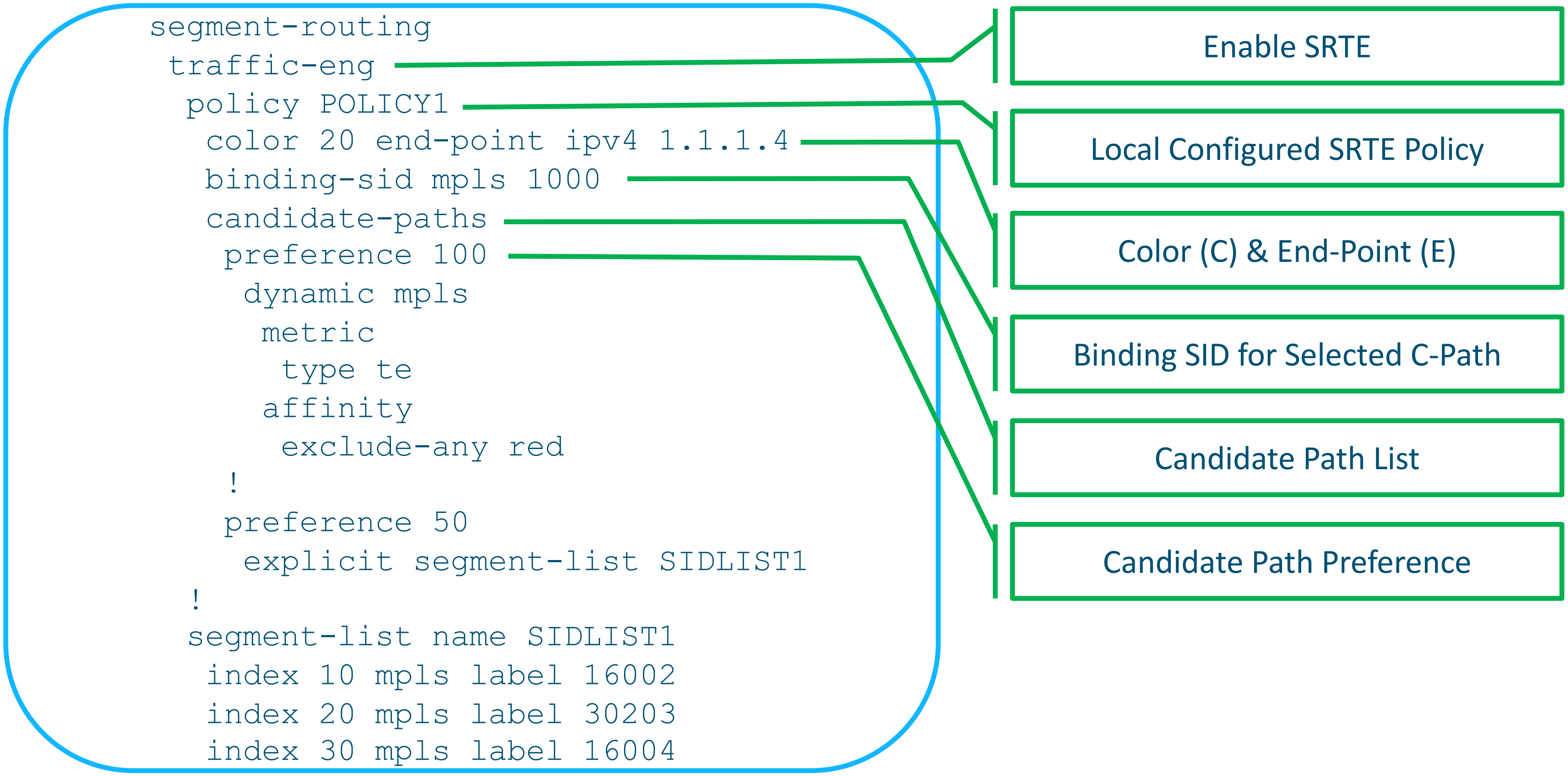
Enable SRTE

Local Configured SRTE Policy

Color (C) & End-Point (E)

Binding SID for Selected C-Path

SRTE - Configuration Example [Local Policy]



```
segment-routing
 traffic-eng
  policy POLICY1
   color 20 end-point ipv4 1.1.1.4
   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
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```

Enable SRTE

Local Configured SRTE Policy

Color (C) & End-Point (E)

Binding SID for Selected C-Path

Candidate Path List

Candidate Path Preference

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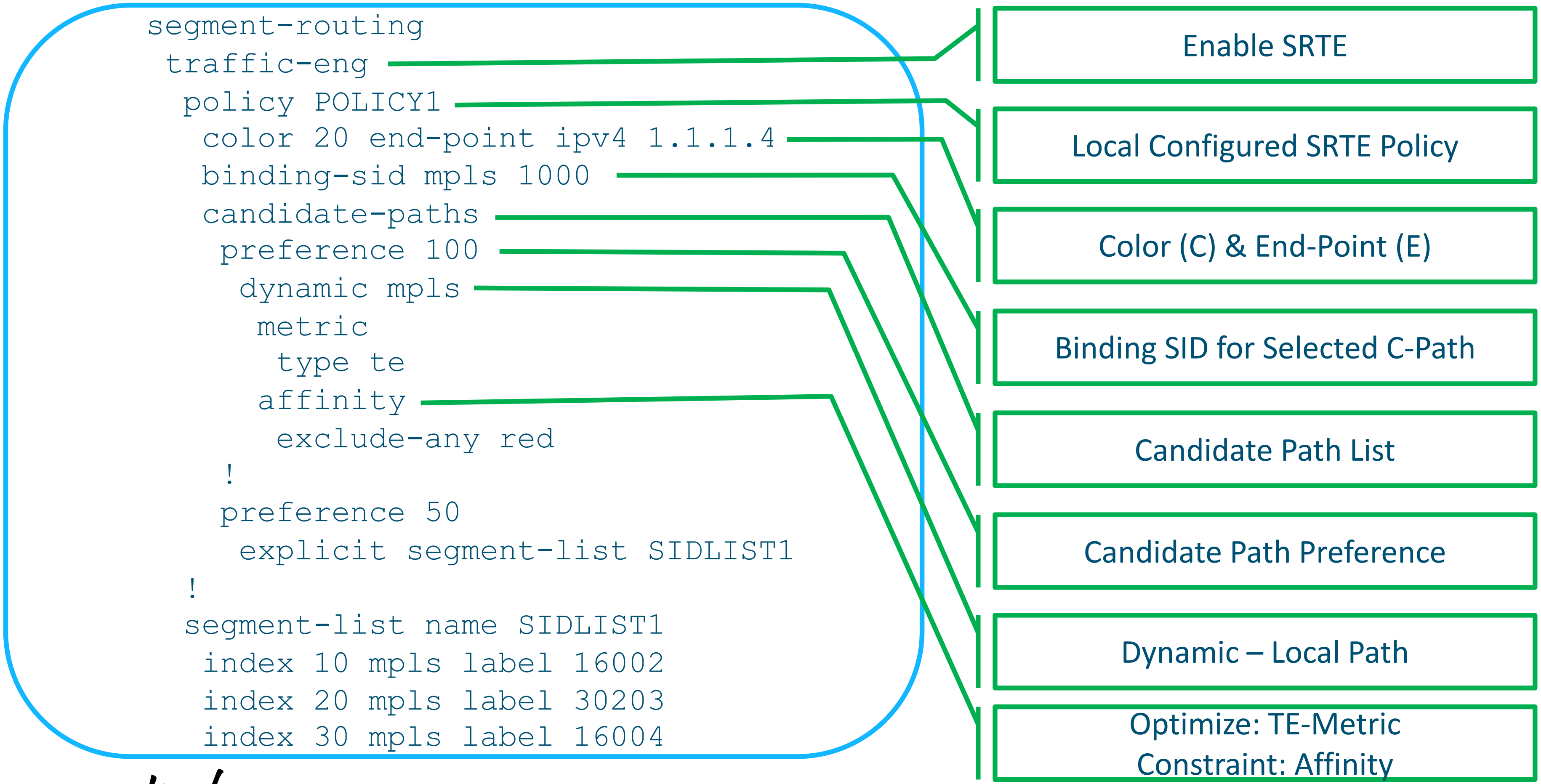
SRTE - Configuration Example [Local Policy]



```
segment-routing
 traffic-eng
  policy POLICY1
   color 20 end-point ipv4 1.1.1.4
   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
      affinity
       exclude-any red
    !
    preference 50
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   index 30 mpls label 16004
```

Enable SRTE

Local Configured SRTE Policy

Color (C) & End-Point (E)

Binding SID for Selected C-Path

Candidate Path List

Candidate Path Preference

Dynamic – Local Path

Optimize: TE-Metric
Constraint: Affinity

SRTE - Configuration Example [Local Policy]

```
segment-routing
 traffic-eng
  policy POLICY1
   color 20 end-point ipv4 1.1.1.4
   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
      affinity
       exclude-any red
    !
    preference 50
     explicit segment-list SIDLIST1
  !
  segment-list name SIDLIST1
   index 10 mpls label 16002
   index 20 mpls label 30203
   index 30 mpls label 16004
```

Enable SRTE

Local Configured SRTE Policy

Color (C) & End-Point (E)

Second Candidate Path;
Lower Preference

Using Explicit SID-List

SID-List

Dynamic – Local Path

Optimize: TE-Metric
Constraint: Affinity

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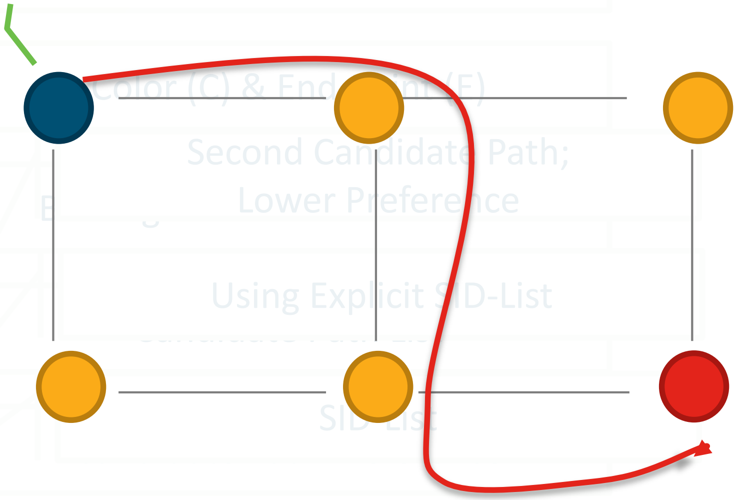
SRTE - Configuration Example [Local Policy]

```
segment-routing
 traffic-eng
  policy POLICY1
   color 20 end-point ipv4 1.1.1.4
   binding-sid mpls 1000
   candidate-paths
    preference 100
     dynamic mpls
      metric
       type te
      affinity
       exclude-any red
     !
    preference 50
     explicit segment-list SIDLIST1
  !
  segment-list name SIDLIST1
   index 10 mpls label 16002
   index 20 mpls label 30203
   index 30 mpls label 16004
```

Selected

FIB Programmed:
POLICY1 → Dynamic Computed
Incoming Label 1000 → POLICY1
Color=20, End-Point=1.1.1.4 → POLICY1



Color (C) & End-Point (E)

Second Candidate Path;
Lower Preference

Using Explicit SID-List

SID-List

Dynamic – Local Path

Optimize: TE-Metric
Constraint: Affinity

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Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
  - Fast Re-Route
  - SRTE – Constructs & Configuration
  - On Demand Next Hop (ODN)
  - Flex Algo
- Application Based Forwarding Architecture
- BGP Based VPNs

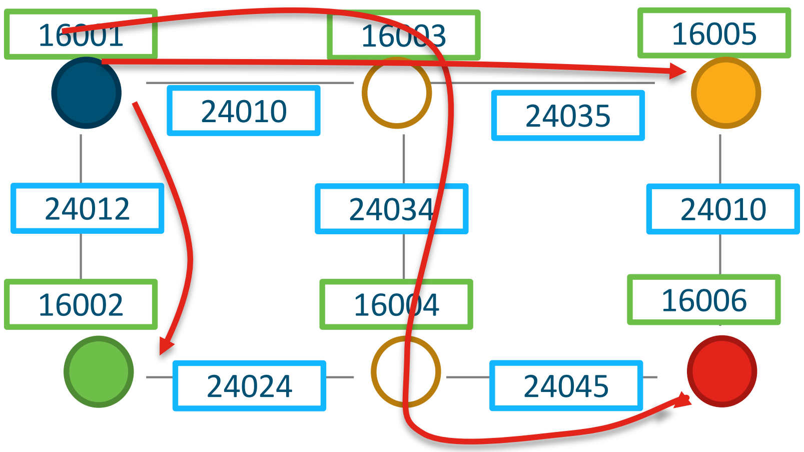
You make security **possible**

Cisco live!

SRTE - On Demand NextHop (ODN) Policy

	H	C	E
Policy-1	🔵	Red	🔴
Policy-2	🔵	Red	🟠
Policy-3	🔵	Red	🟢

Policy-1, Policy-2 & Policy-3
Have same constraints but
different end points
(e.g. L3VPN with multiple endpoints)



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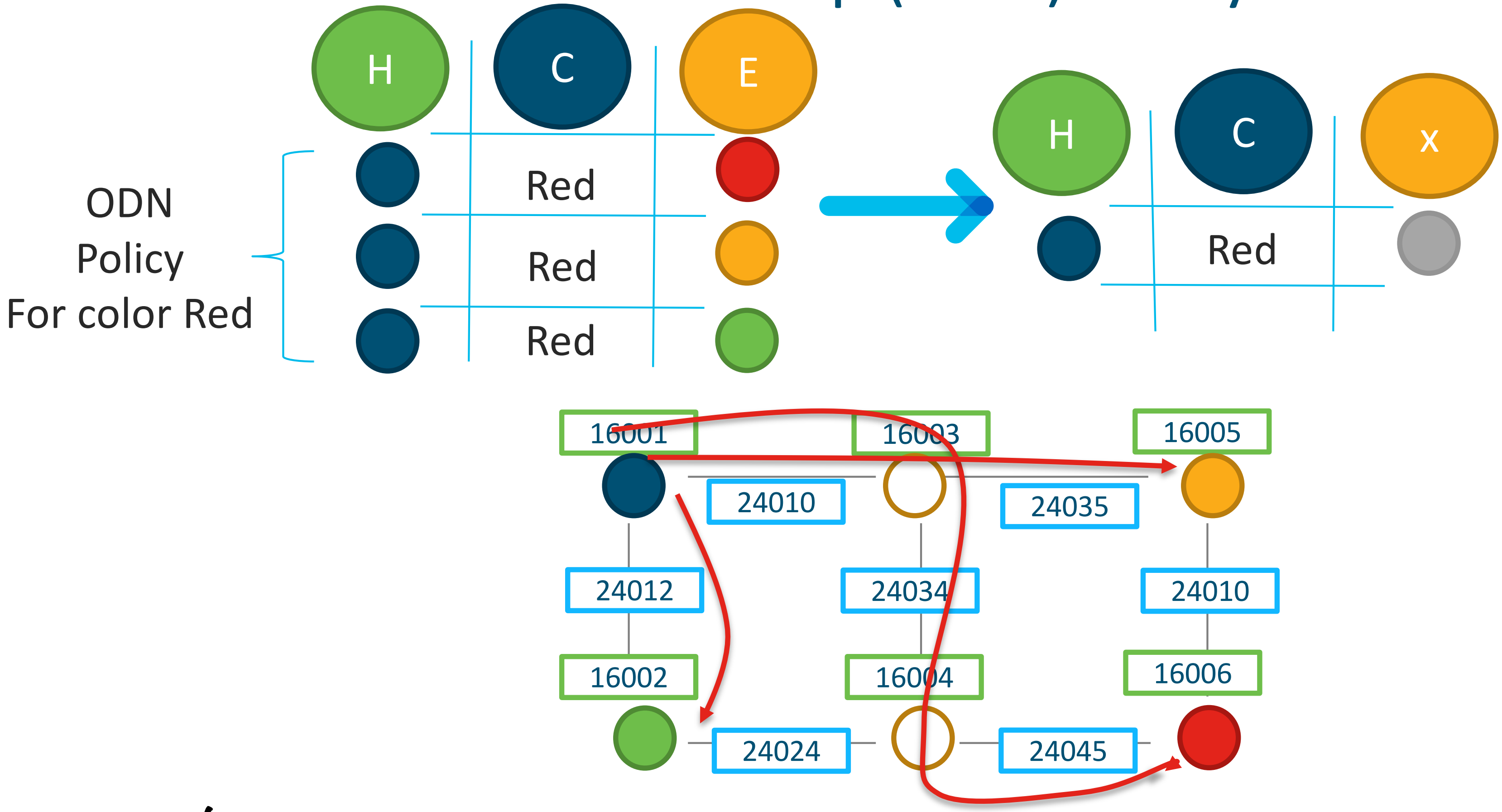
SRTE - On Demand NextHop (ODN) Policy



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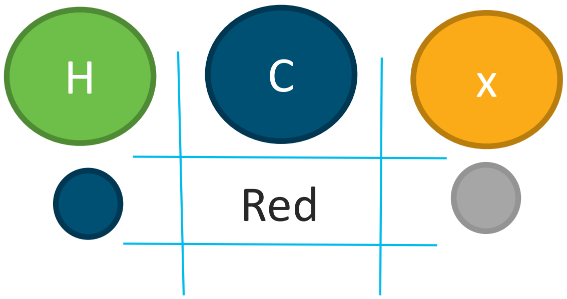
SRTE - Configuration Example [ODN]



```
segment-routing
   traffic-eng
    on-demand color 2
      dynamic
        metric
          type latency
```

Enable SRTE

Define Color for ODN

Dynamic policy using latency as metric

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Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
  - Fast Re-Route
  - SRTE – Constructs & Configuration
  - On Demand Next Hop (ODN)
  - Flex Algo
- Application Based Forwarding Architecture
- BGP Based VPNs

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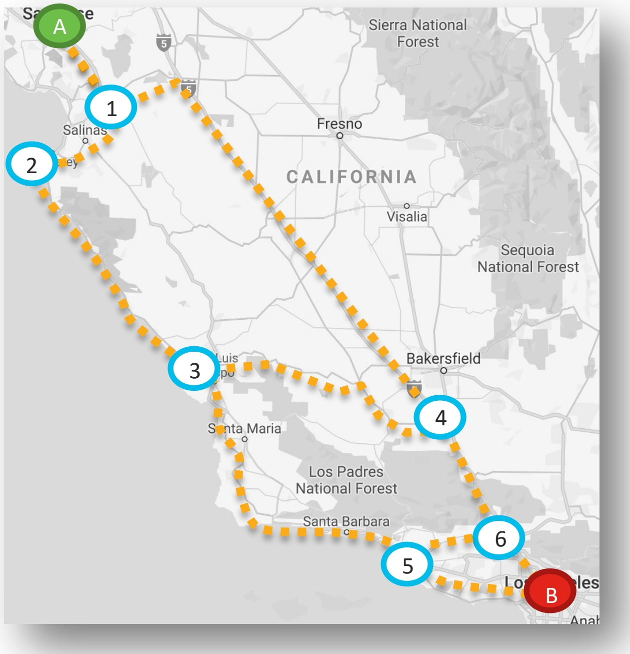
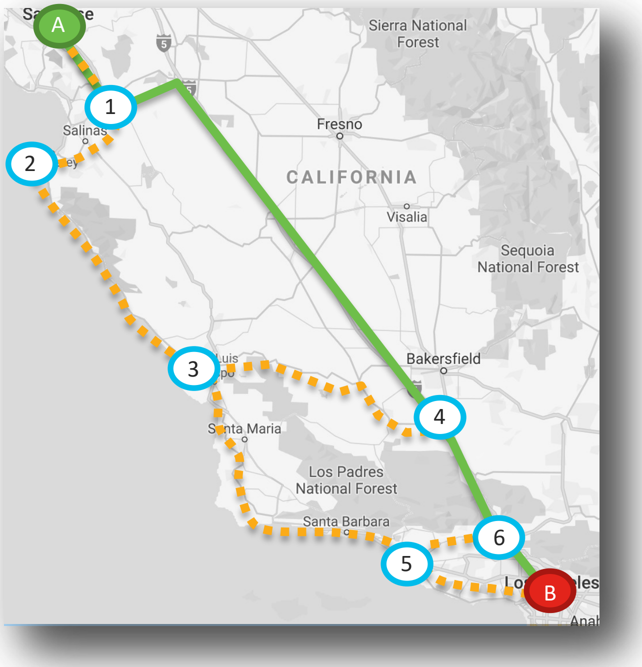
Flex Algo - Introduction



- Many Possible Routes from SJC to SFO
- Interior Routing Protocols will use Metrics
  - Metric:
    - OSPF Based on Bandwidth
    - ISIS Based on Hop

Flex Algo - Introduction

Intent == Shortest Path



- Many Possible Routes from SJC to SFO
- Interior Routing Protocols will use Metrics
    - Metric:
        - OSPF Based on Bandwidth
        - ISIS Based on Hop

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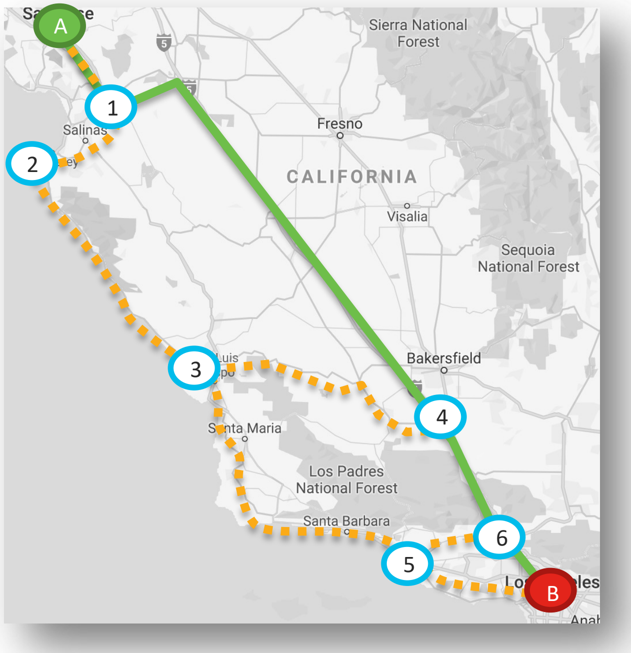
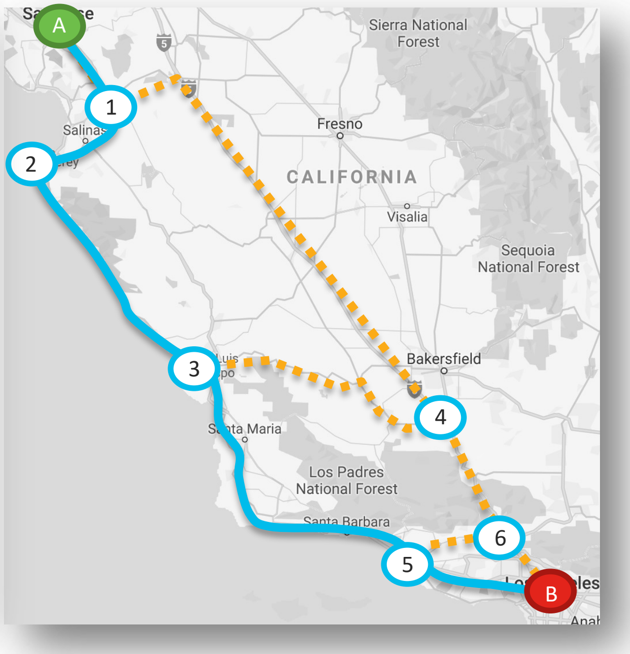
Flex Algo –Different Intent, Different Paths

Intent == Shortest Path



A→1→4→5→B

Intent == Scenic



A→1→2→3→5→B

Different Intent may end up calculating different best paths, based upon constraints

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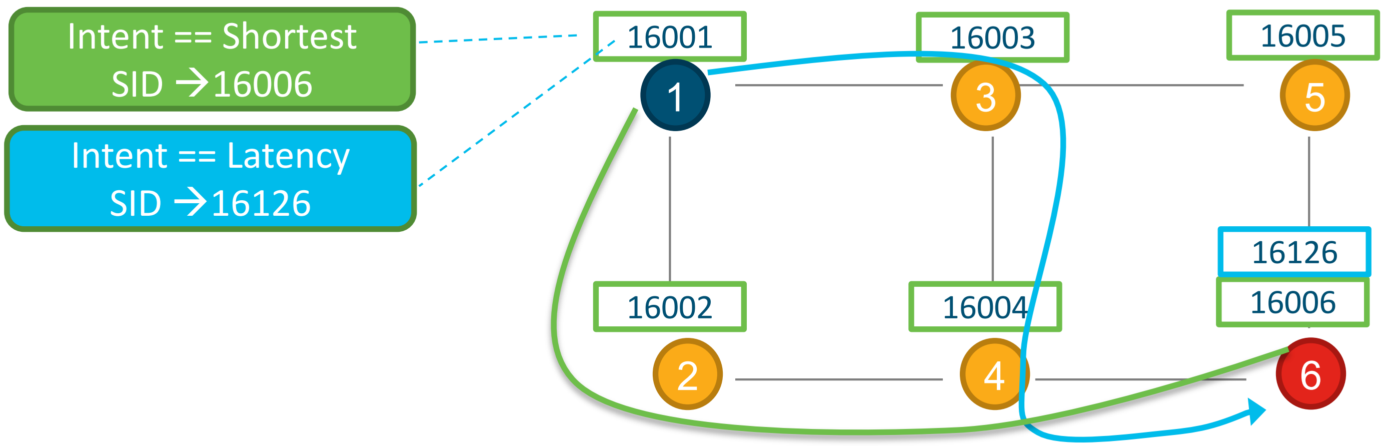
Flex Algo –Segment Routing TE

- A new Algo is defined in IGP , with new constraints (Latency etc)
- A node may or may not participate in non default Algo(s)
- Each participating node must advertise Flex-Algo(s) that it is participating in
- Nodes participating in a Flex-Algo, also advertise a prefix SID for that Flex-Algo



Node 6 advertises

Prefix SID 16006 for ALGO 0

Prefix SID 16126 for ALGO 128

Every node participating in

Algo 0, 128

https://tools.ietf.org/html/draft-ietf-lsr-flex-algo-02

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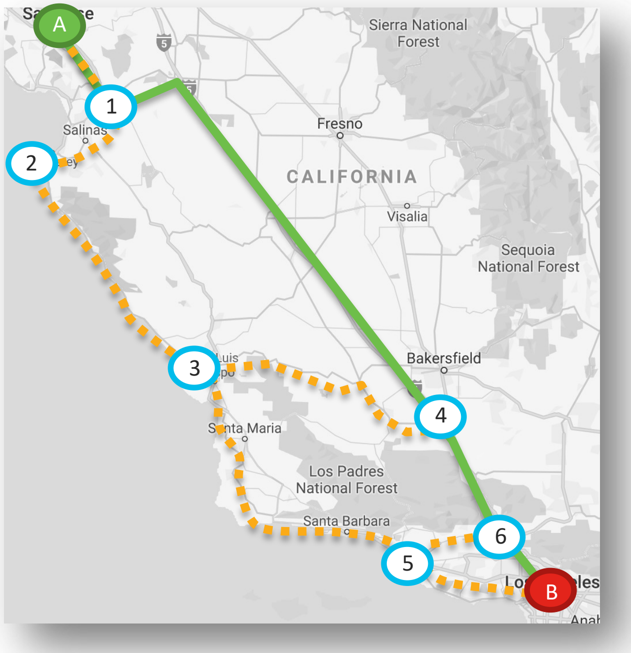
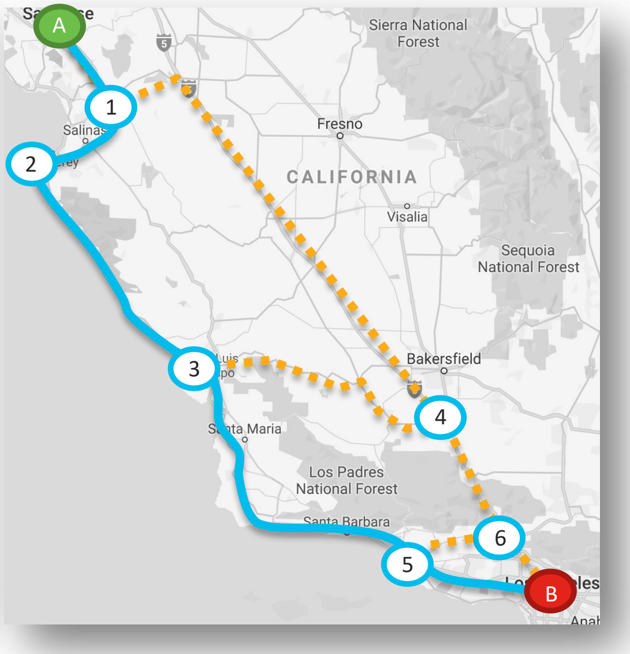
Flex Algo

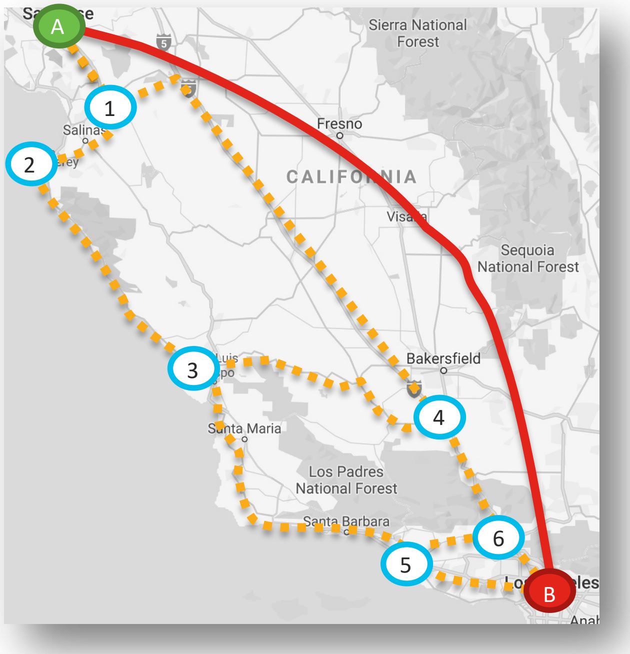
Intent == Shortest



Intent == Scenic



Intent == Avoid Driving



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Flex Algo –Segment Routing TE

Intent == Shortest
SID →16006

Intent == Low Latency
SID →16126

Intent == Secure/Encrypted
SID →16136

Node 6 advertises

Prefix SID 16006 for ALGO 0

Prefix SID 16126 for ALGO 128

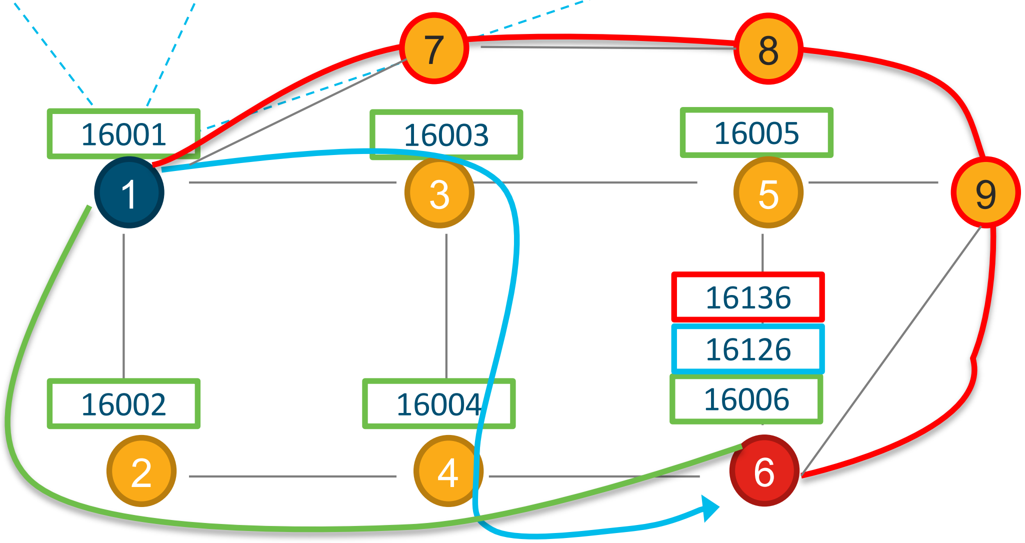
Prefix SID 16146 for ALGO 129

Node 1-6 :

participating in Algo 0, 128

Node 1,7,8.9.6 :

participating in Algo 129



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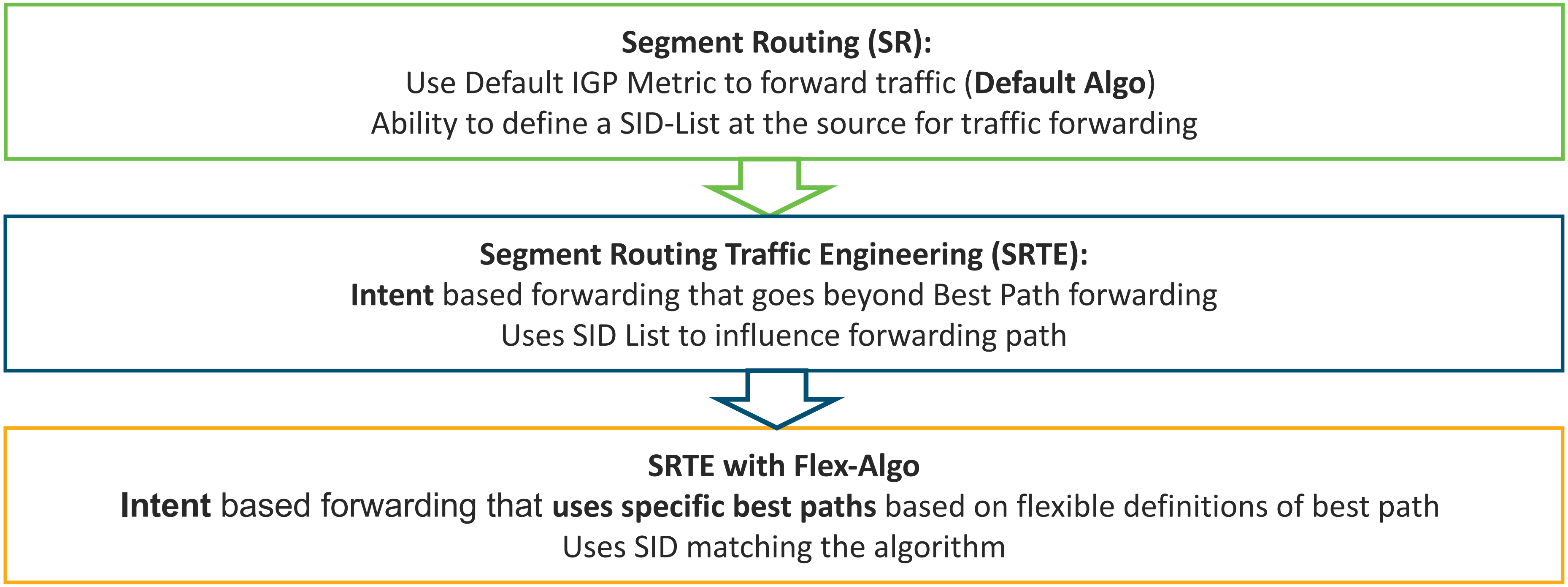
Flex Algo & Segment Routing TE



Segment Routing (SR):
Use Default IGP Metric to forward traffic (**Default Algo**)
Ability to define a SID-List at the source for traffic forwarding

Segment Routing Traffic Engineering (SRTE):
Intent based forwarding that goes beyond Best Path forwarding
Uses SID List to influence forwarding path

SRTE with Flex-Algo
Intent based forwarding that **uses specific best paths** based on flexible definitions of best path
Uses SID matching the algorithm

Flex-Algo Leverages all SRTE benefits and simplicity – TI-LFA, ODN, Auto Steering, Coloring, etc.

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Flex-Algo Configuration Example

```
router isis 1
net 49.0001.0000.0000.0002.00
 flex-algo 128
   metric-type latency
 !
 address-family ipv4 unicast
   router-id 6.1.1.9
   segment-routing mpls
 !
 interface Loopback0
  address-family ipv4 unicast
   prefix-sid index 2
   prefix-sid algorithm 128 absolute 16802

segment-routing
  traffic-eng
    on-demand color 100
       dynamic
          sid-algo 128
```

Flex Algo Definition. Multiple Flex-Algo's (128-255) could be defined

Defining Intent for Flex Algo. Default is IGP. Constraints could be defined here as well.

Prefix SID for Default Algo (IGP)

Additional Per-Algo Prefix SID is defined.
Same rules as default Prefix SID (uses SRGB, can be defined as index or absolute, etc)

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Flex-Algo Configuration Example

```
router isis 1
net 49.0001.0000.0000.0002.00
 flex-algo 128
   metric-type latency
 !
 address-family ipv4 unicast
   router-id 6.1.1.9
   segment-routing mpls
 !
 interface Loopback0
  address-family ipv4 unicast
   prefix-sid index 2
   prefix-sid algorithm 128 absolute 16802

segment-routing
  traffic-eng
    on-demand color 100
        dynamic
           sid-algo 128
```

Flex Algo Definition. Multiple Flex-Algo's (128-255) could be defined

Defining Intent for Flex Algo. Default is IGP. Constraints could be defined here as well.

Prefix SID for Default Algo (IGP)

Additional Per-Algo Prefix SID is defined. Same rules as default Prefix SID (uses SRGB, can be defined as index or absolute, etc)

Uses Automated Steering using colors for Traffic Forwarding (Same as SRTE)

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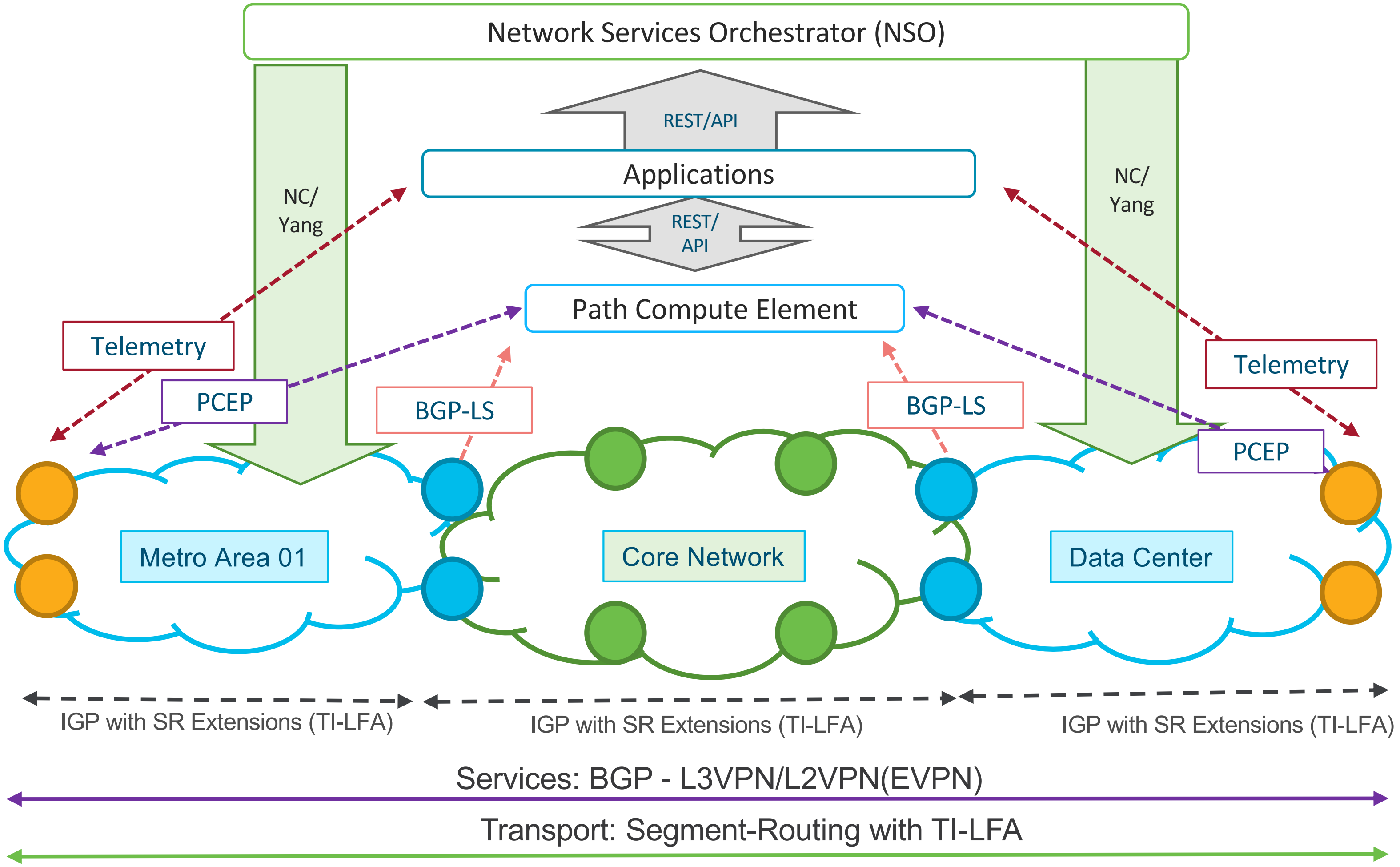
Recap: Intent Based Programmable Network Infrastructure



Network Services Orchestrator (NSO)

REST/API

Applications

REST/ API

Path Compute Element

NC/ Yang

NC/ Yang

Telemetry

PCEP

BGP-LS

BGP-LS

Telemetry

PCEP

Metro Area 01

Core Network

Data Center

IGP with SR Extensions (TI-LFA)

IGP with SR Extensions (TI-LFA)

IGP with SR Extensions (TI-LFA)

Services: BGP - L3VPN/L2VPN(EVPN)

Transport: Segment-Routing with TI-LFA

- □ App. Driven N/W and Usecases
- □ Automation
- □ Data Collection & Analytics
- □ Device and Services Onboarding
- □ EVPN Based Services
- □ Controller Based Forwarding
- ☑ Segment Routing Transport

Fundamentals of Next Gen Network Architectures:

Intent Based Programmable Transport

Application Based Forwarding Architecture

BGP Based VPNs

You make security **possible**

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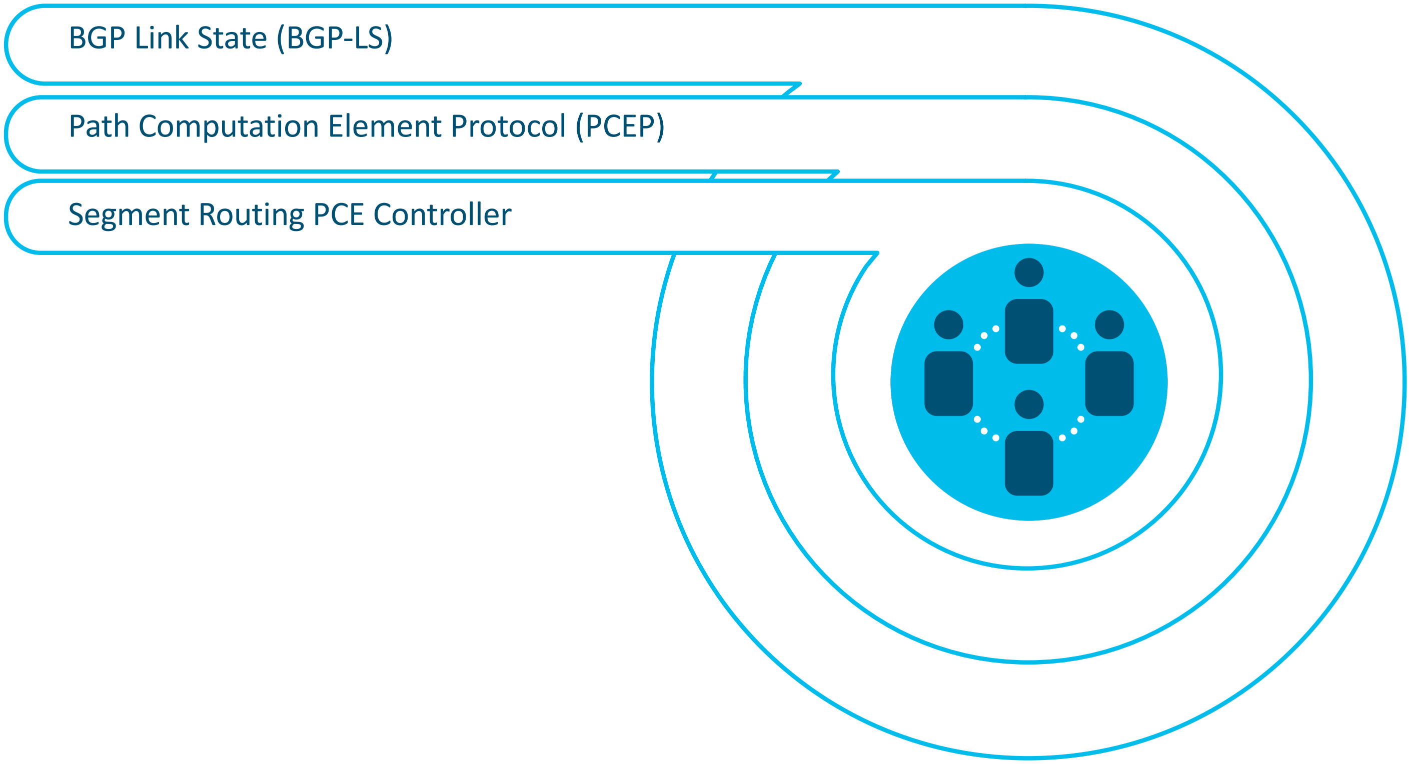
Centralized Control for SRTE – Building Blocks



BGP Link State (BGP-LS)

Path Computation Element Protocol (PCEP)

Segment Routing PCE Controller

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Centralized Control for SRTE – Building Blocks

BGP Link State (BGP-LS)

Path Computation Element Protocol (PCEP)

Segment Routing PCE Controller

Centralized Knowledge of IGP Database

- IGP Database knowledge contained in IGP domains
- IGP DB is Distributed into new BGP NLRI
- BGP Carries the information to Central Controller

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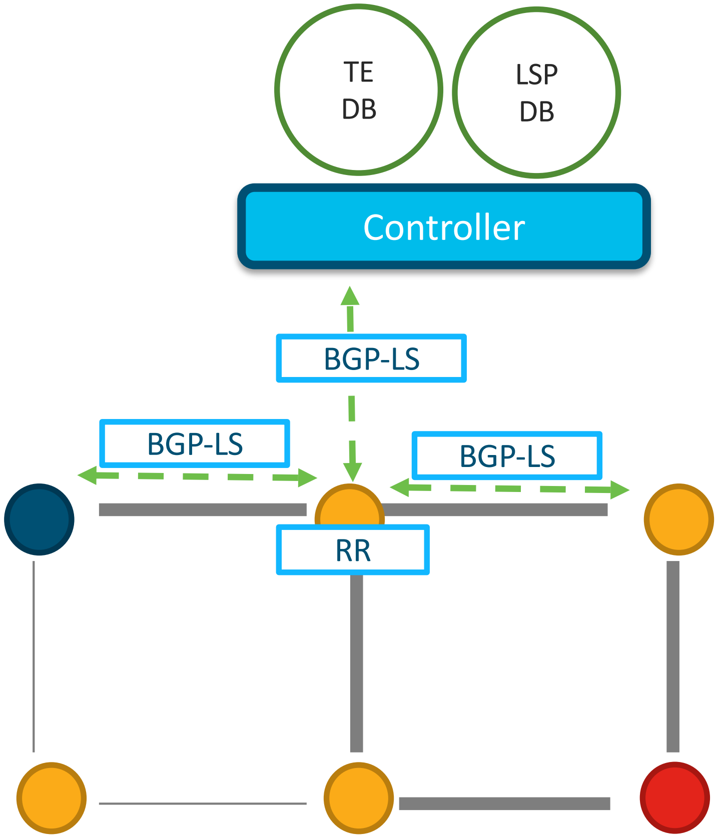
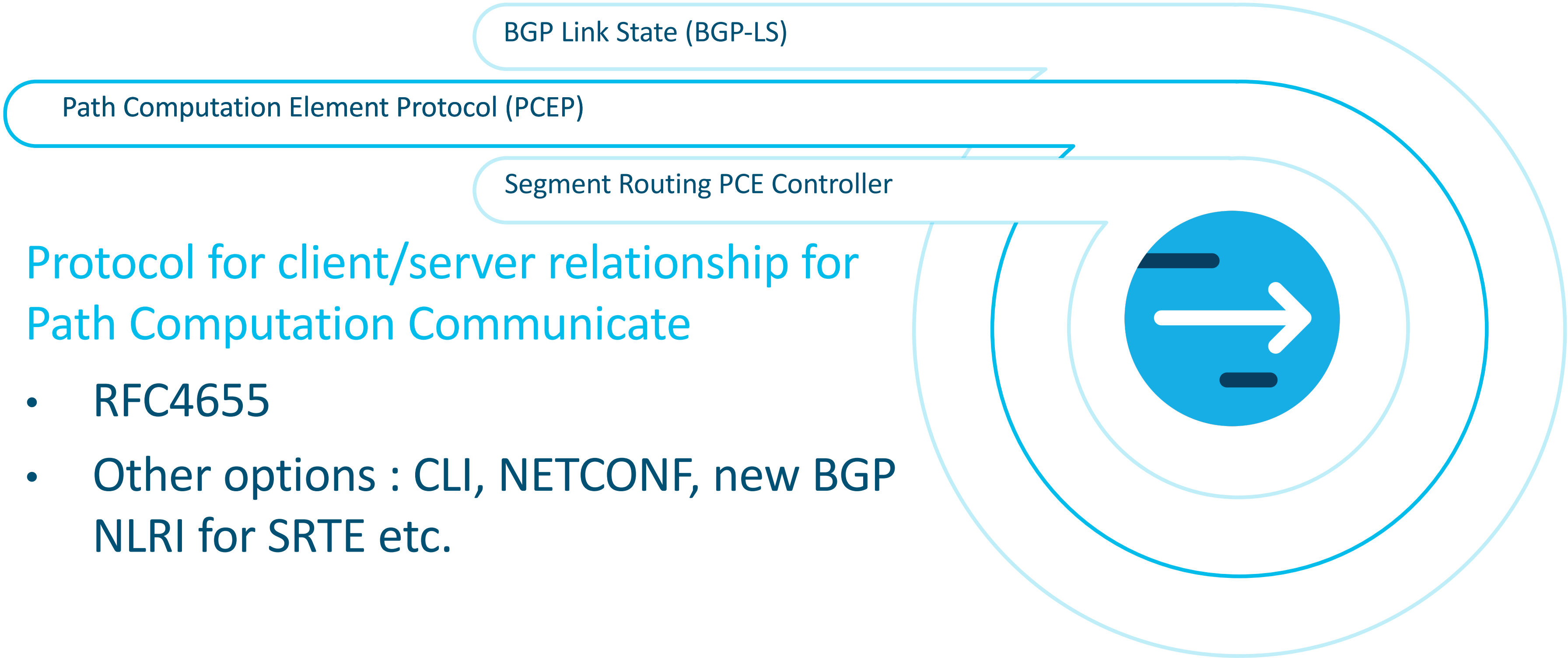
BGP Link State - Overview

- Build TE-DB for Multi-area Optimal Path Computation
- Scalable Solution is BGP, not IGP.
- BGP is less chatty
- Can carry multiple IGP domains
- BGP-LS is an address-family
  - afi=16388, safi=71
- Defined to carry IGP link-state database via BGP
  - Supports both IS-IS and OSPF
  - Delivers topology information to outside agents



Centralized Control for SRTE – Building Blocks



BGP Link State (BGP-LS)

Path Computation Element Protocol (PCEP)

Segment Routing PCE Controller

Protocol for client/server relationship for Path Computation Communicate

- RFC4655
- Other options : CLI, NETCONF, new BGP NLRI for SRTE etc.

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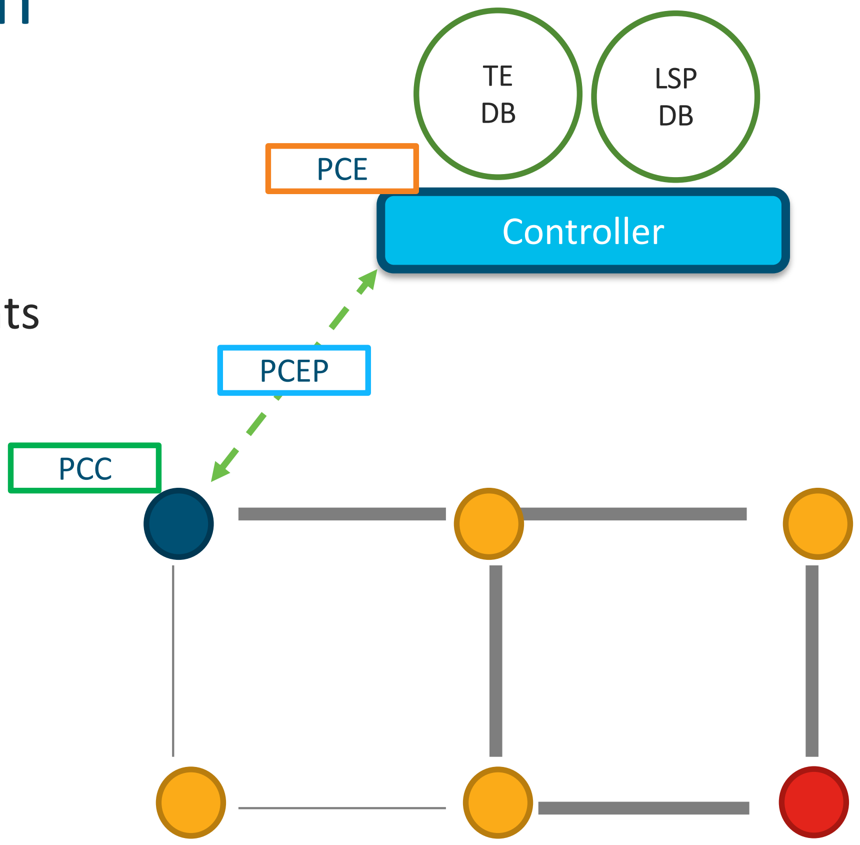
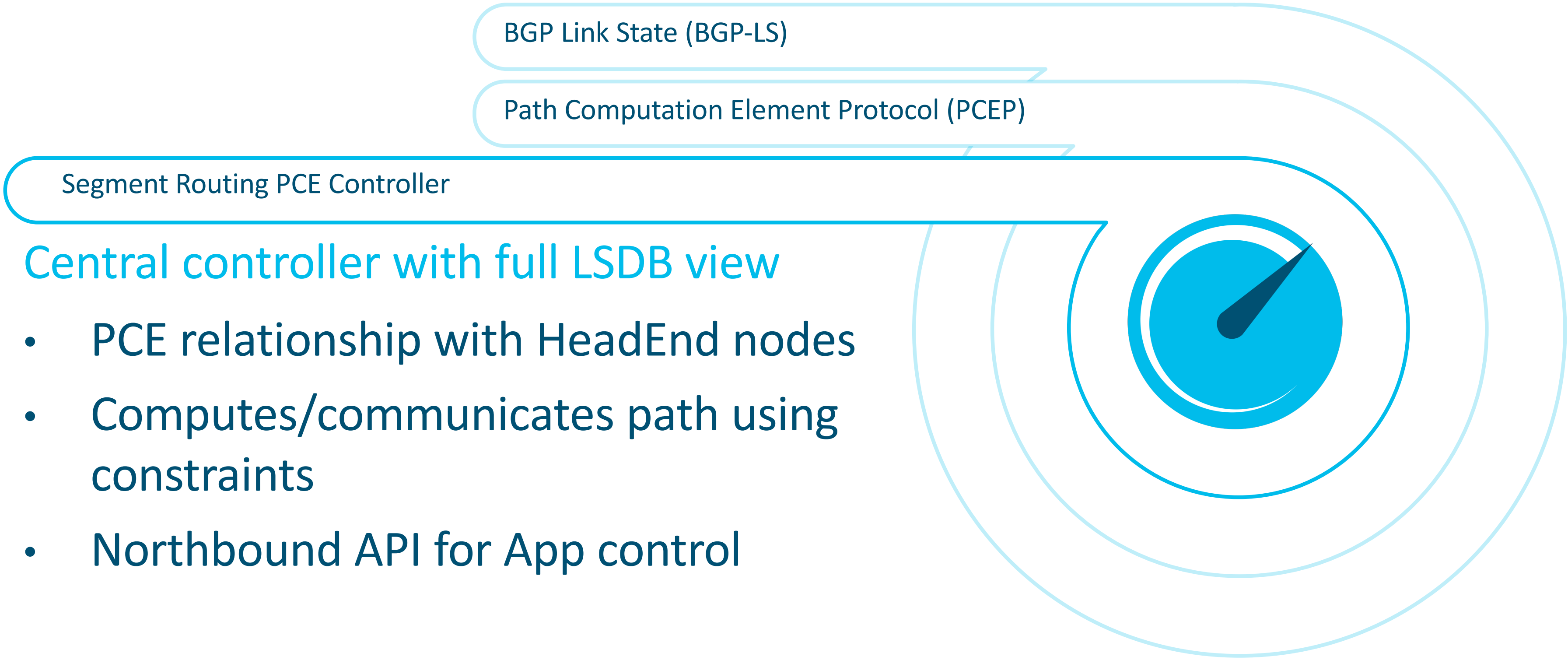
PCEP Architectural Introduction

- Path Compute Element (PCE):
  - Stores TE Topology Database
  - Computes Network Path based on constraints
  - May initiate Path Creation
- Path Compute Client (PCC):
  - Requests path computation by PCE
  - Send Path updates to PCE
- Path Compute Element Protocol (PCEP):
  - Protocol for PCE-PCC Communication



Centralized Control for SRTE – Building Blocks



BGP Link State (BGP-LS)

Path Computation Element Protocol (PCEP)

Segment Routing PCE Controller

Central controller with full LSDB view

- PCE relationship with HeadEnd nodes
- Computes/communicates path using constraints
- Northbound API for App control

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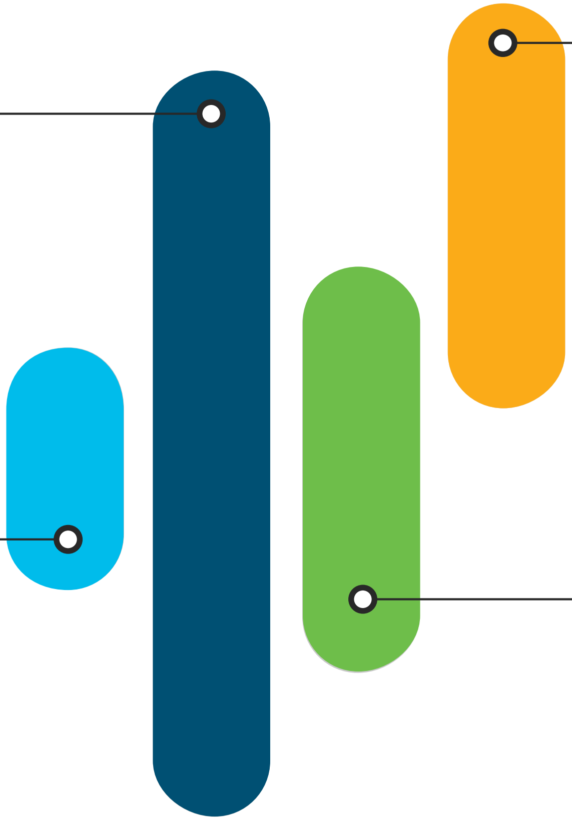
SR PCE Functions & Building Blocks



Topology Collection

Learn Network Topology across domains

Maintain Multi-domain Network Topology

Uses: BGP-LS or IGP

Application Interface

REST API Based communication

with External Applications

Path Computation

Compute TE path based on policy constraints

Uses PCEP for accepting path computation requests

Deploy TE Policy

Program & Instantiate TE policy on the Headend

Uses PCEP or BGP-SR

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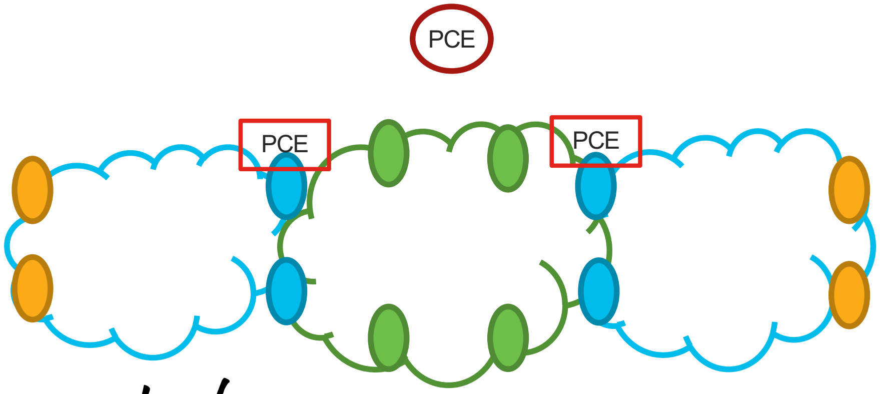
SR PCE Implementation

SR PCE runs as IOS XR feature

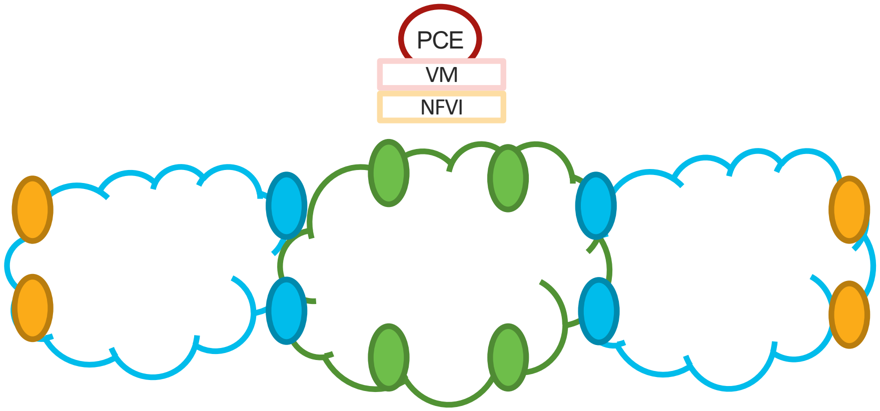
Deployed on Physical IOS XR Device

Inline or Centralized



Deployed as Virtual IOS XR

XRV9000
NFV Infrastructure
VRR License + SR-PCE License



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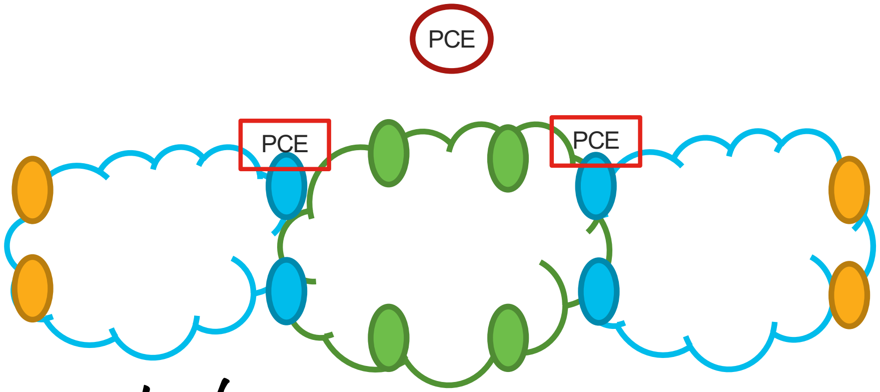
SR PCE Implementation

NFV Scalability

SR PCE runs as IOS XR feature

Deployed on Physical IOS XR Device

Inline or Centralized

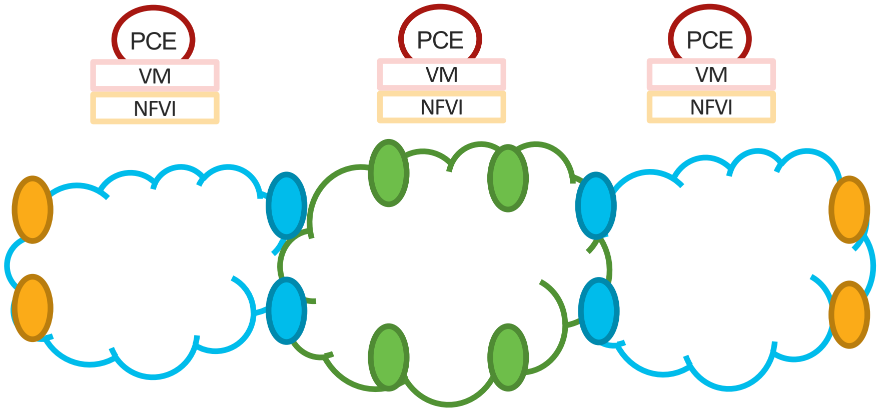


Deployed as Virtual IOS XR

XRV9000

NFV Infrastructure

VRR License + SR-PCE License



Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
- Application Based Forwarding Architecture
  - SR-PCE Configuration Samples
- BGP Based VPNs

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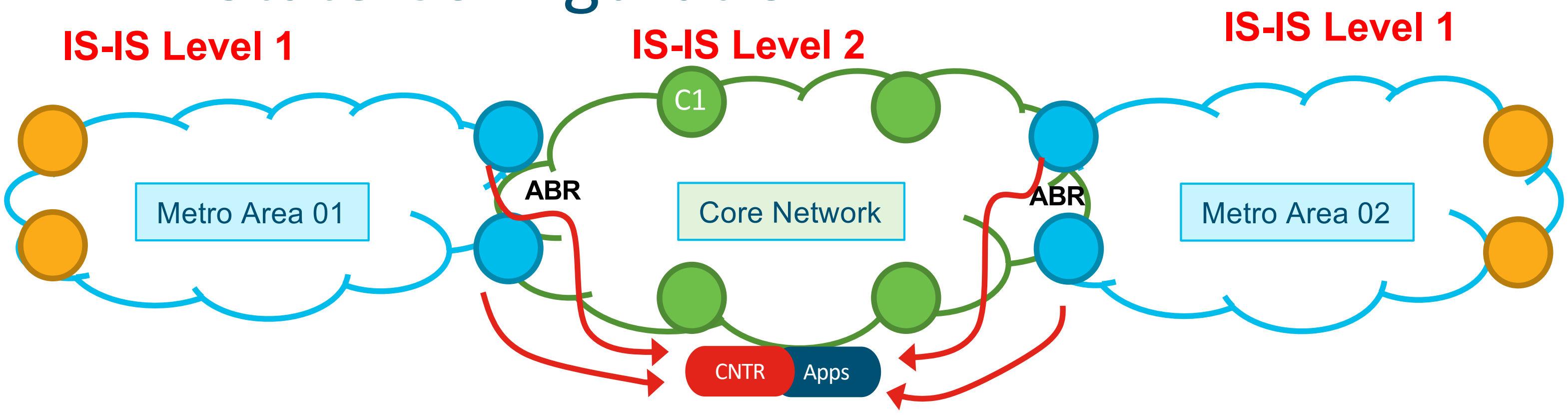
BGP Link State Configuration



- BGP–RR could be used to scale BGP-LS feed
- Need to have at least 1 BGP-LS Speaker in each IGP domain, 2 recommended for redundancy
- IGP Link State is redistributed into BGP, then advertised via BGP-LS

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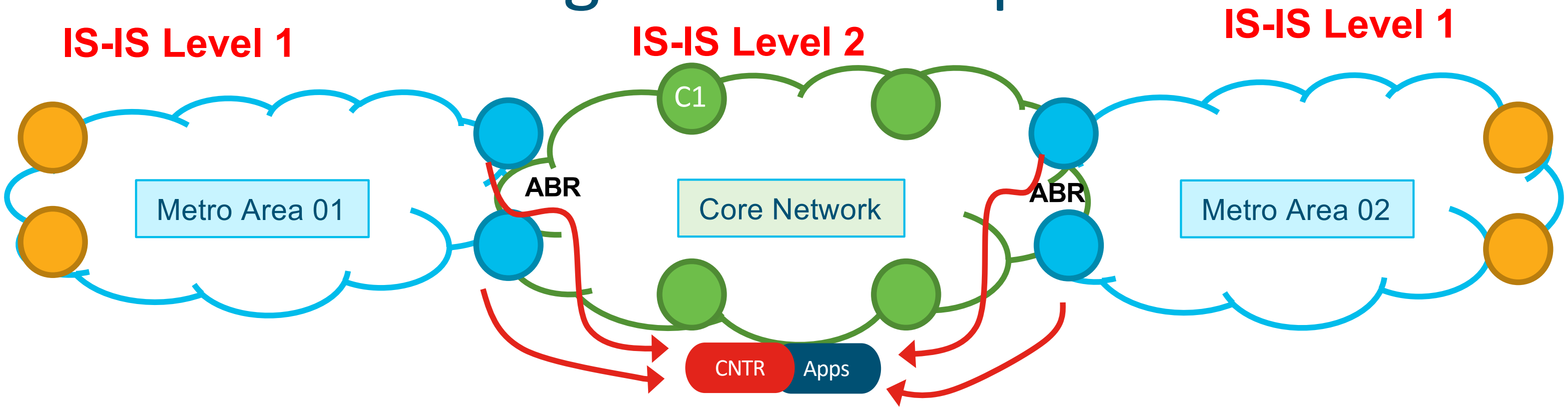
BGP Link State Configuration Sample



Redistribute IGP Link State

```
router isis 100
 net 49.1921.5500.0004.00
 distribute link-state
```

Advertise via BGP-LS

```
router bgp 65000
 address-family link-state link-state
 neighbor 192.168.0.15
  remote-as 65000
  update-source Loopback0
  address-family ipv4 unicast
  !
  address-family link-state link-state
   route-reflector-client
```

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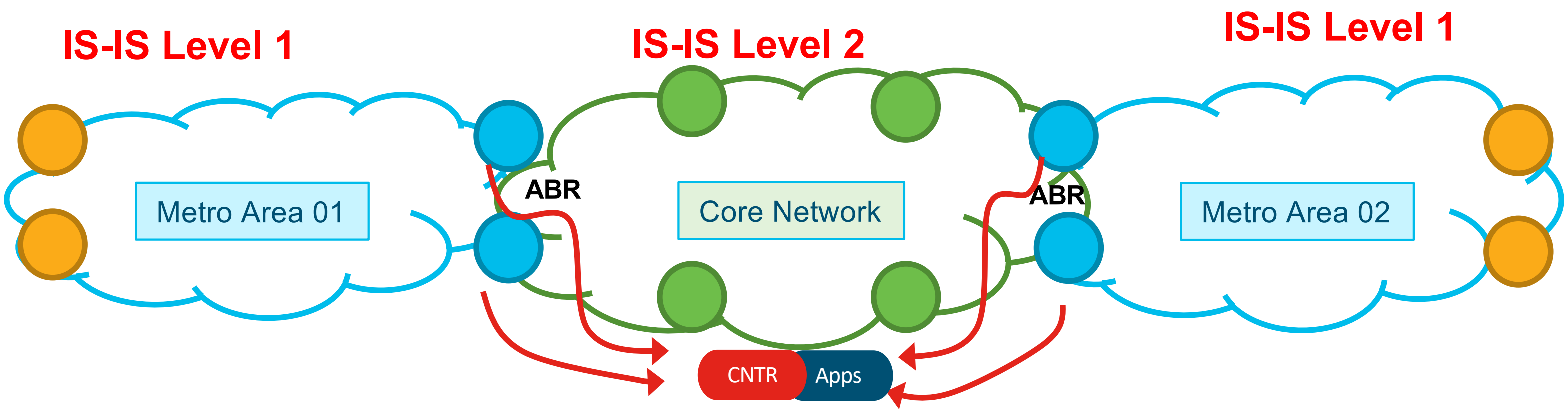
PCEP Client and Server Configuration



PCE Client Configuration

```
segment-routing
traffic-eng
 pcc
   source-address ipv4 6.1.1.1
   pce address ipv4 6.1.1.100 precedence 100
   pce address ipv4 6.1.1.102 precedence 102
           ! Higher precedence server preferred
```

PCE Server Configuration

```
pce
 address ipv4 6.1.1.100  → Enable PCE Server
 rest  → Option, Enable Application Access

 peer ipv4 6.1.1.1 → Optional, required for
                      Remote SR Policy
                     Instantiation
```

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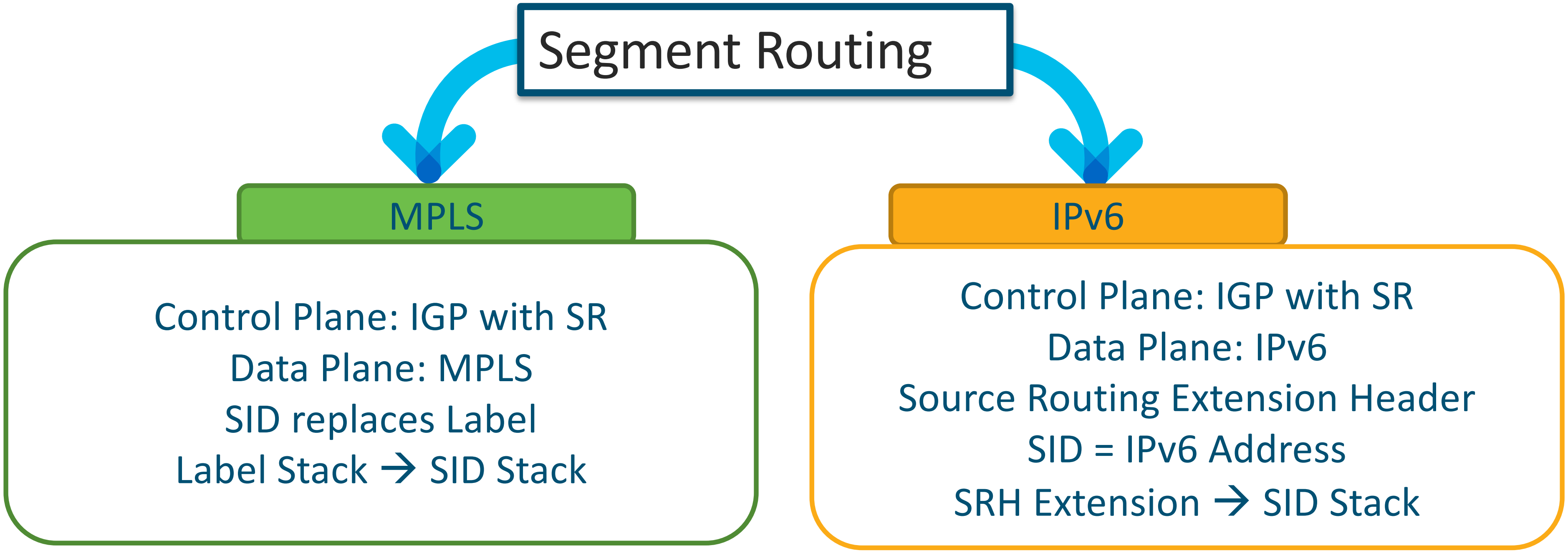
Introducing SRv6 Pathway to the Future

You make security **possible**

Cisco live!

Segment Routing Data Plane with IPv6



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"

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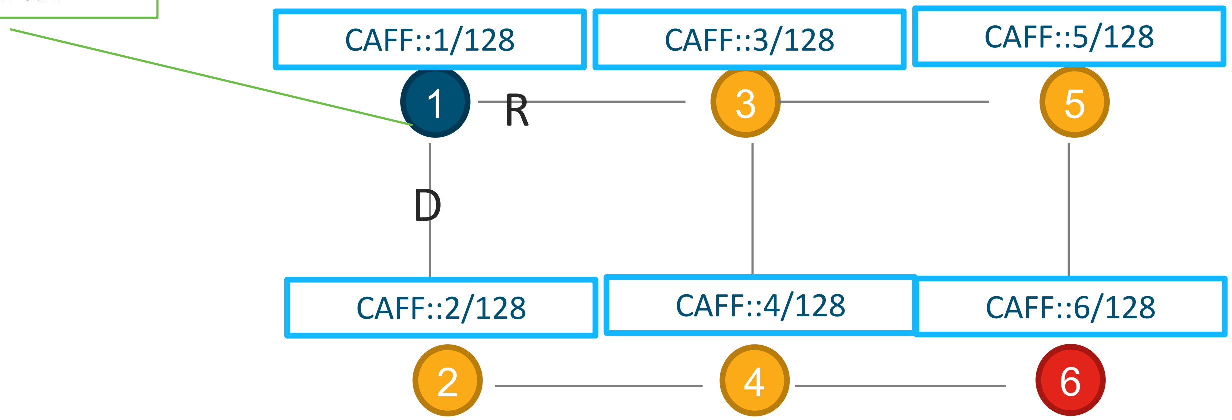
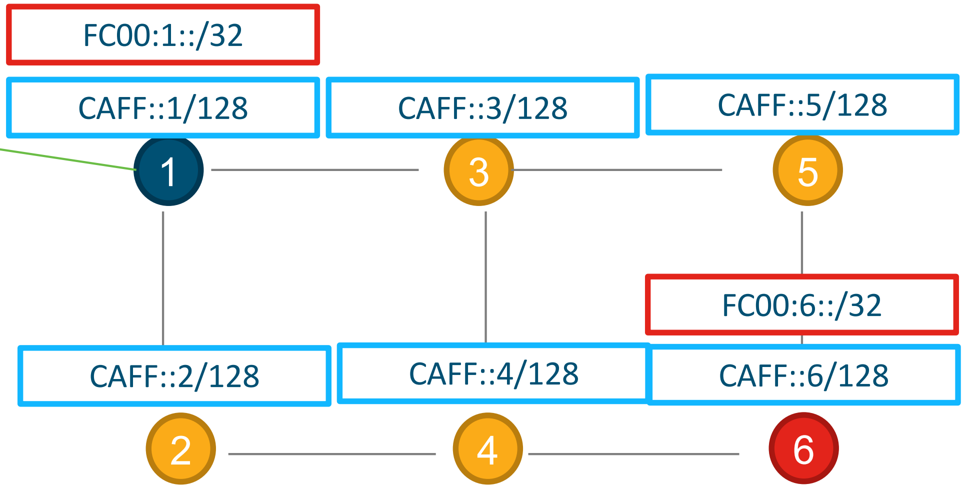
SRv6 Locator

CAFF::1/128 → Lo0
CAFF::2/128 → Int D
CAFF::3/128 → Int R
CAFF::4/128 → Int D&R
CAFF::5/128 → Int R
CAFF::6/128 → Int D&R



SRv6 Locator

CAFF::1/128 → Lo0
CAFF::2/128 → Int D
CAFF::3/128 → Int R
CAFF::4/128 → Int D&R
CAFF::5/128 → Int R
CAFF::6/128 → Int D&R
FC00:1::/32 → Lo10
FC00:6::/32 → Int D&R



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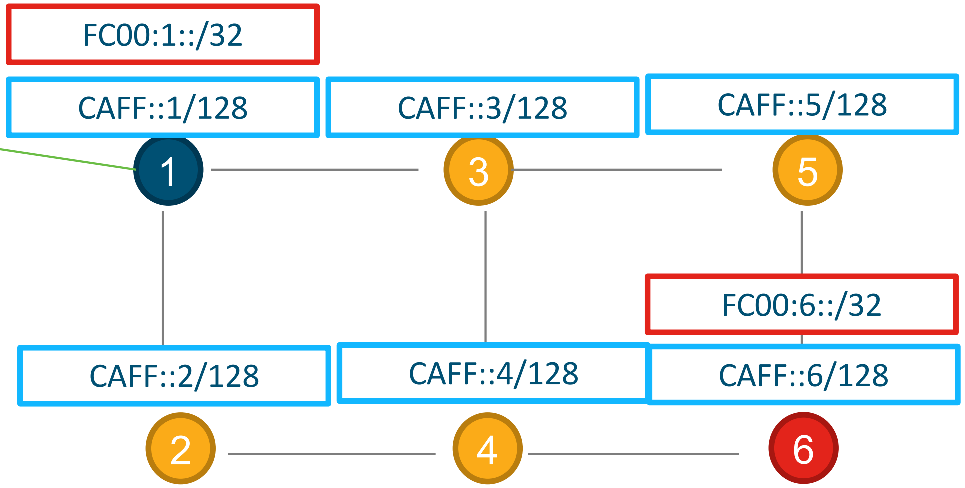
SRv6 Locator

CAFF::1/128 → Lo0
CAFF::2/128 → Int D
CAFF::3/128 → Int R
CAFF::4/128 → Int D&R
CAFF::5/128 → Int R
CAFF::6/128 → Int D&R
FC00:1::/32 → ~~Lo10~~ SRv6
FC00:6::/32 → Int D&R



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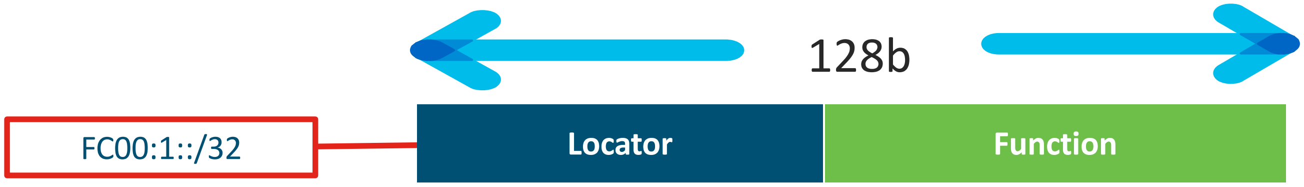
SRv6 SID



- 128b SRv6 SID
- Locator: Node Reachability to Destination
- Function: Packet Processing Instructions at Destination

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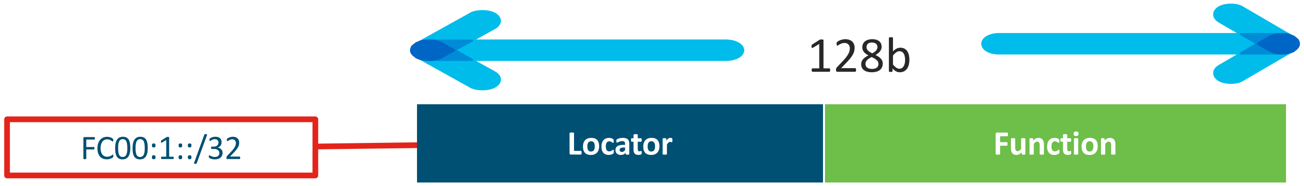
SRv6 SID – Locator & Function



128b

FC00:1::/32

Locator

Function

- Locator is routable
  - ensures reachability to a node
- Function is locally defined on the node (where it is executed)
  - may range from simply moving forward in the segment list to any complex user-defined behavior.
  - The definition of the function is locally defined on the device & then advertised to peers
  - May require additional arguments

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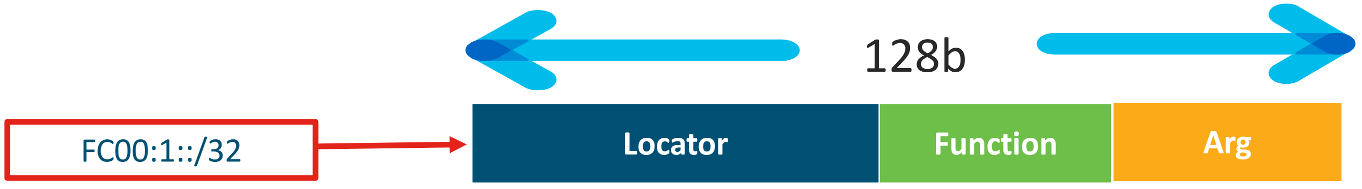
SRv6 SID



- 128b SRv6 Segment ID
  - Locator: Reachability identifier to Destination
  - Function: Packet Processing Instructions at Destination
  - Optional Argument bits for the function

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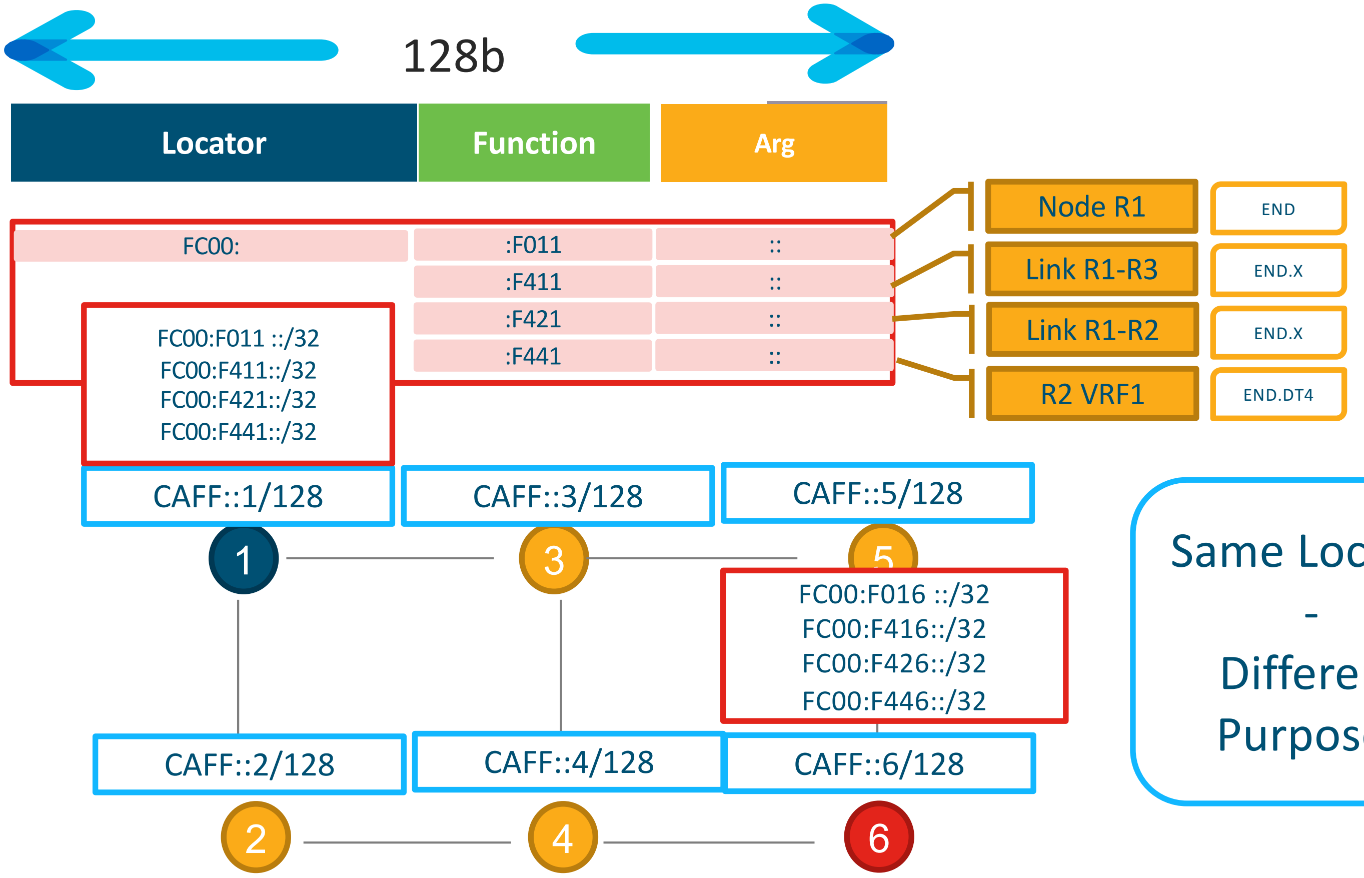
SRv6 SID Functions



128b

Locator	Function	Arg
FC00:	:F011	::
	:F411	::
	:F421	::
	:F441	::

Node R1	END
Link R1-R3	END.X
Link R1-R2	END.X
R2 VRF1	END.DT4

FC00:F011 ::/32
FC00:F411::/32
FC00:F421::/32
FC00:F441::/32

CAFF::1/128

CAFF::3/128

CAFF::5/128

FC00:F016 ::/32
FC00:F416::/32
FC00:F426::/32
FC00:F446::/32

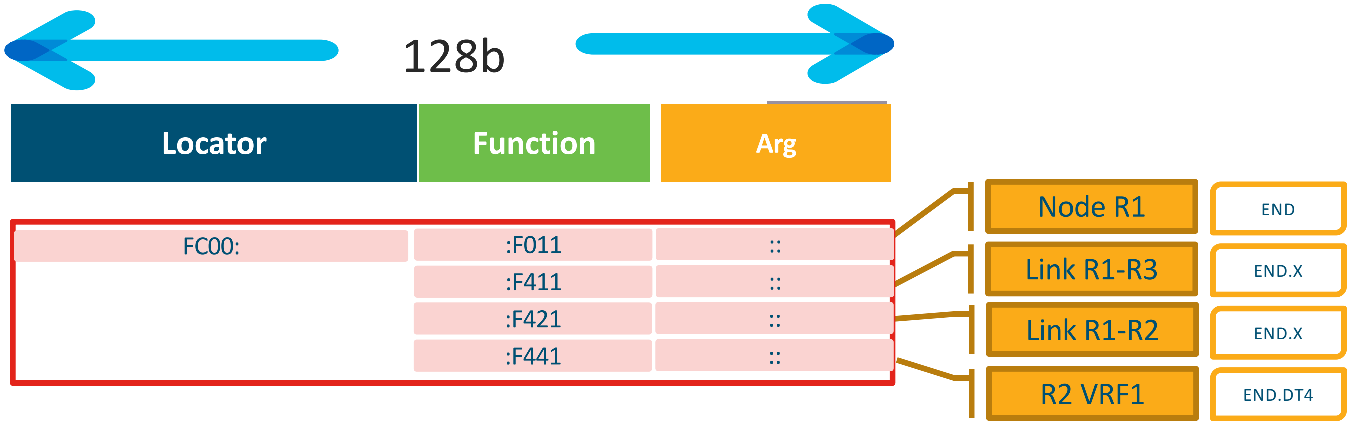
CAFF::2/128

CAFF::4/128

CAFF::6/128

Same Locator
-
Different Purposes

SRv6 SID Functions



Codename	Behavior
End	Segment Ends on this router
End.X	Segment ends at a layer 3 cross connect(interface) on this router
End.DX4	Segment ends at this router after a decapsulation and layer 3 cross connect lookup in a specific VRF Table
End.DT4	Segment ends at this router after a decapsulation and IPv4 table lookup in a specific VRF table

SR-MPLS Equivalent

Node SID

Adj SID

Per CE VPN4 +
Node SID

Per VRFVPN4 +
Node SID

Additional Segment Routing Resources

Stay up-to-date:

SR Segment Routing segment-routing.net

Segment Routing – Part 1& 2
http://amzn.com/B07PHN48GS

linkedin.com/groups/8266623

@SegmentRouting

@SegmentRouting

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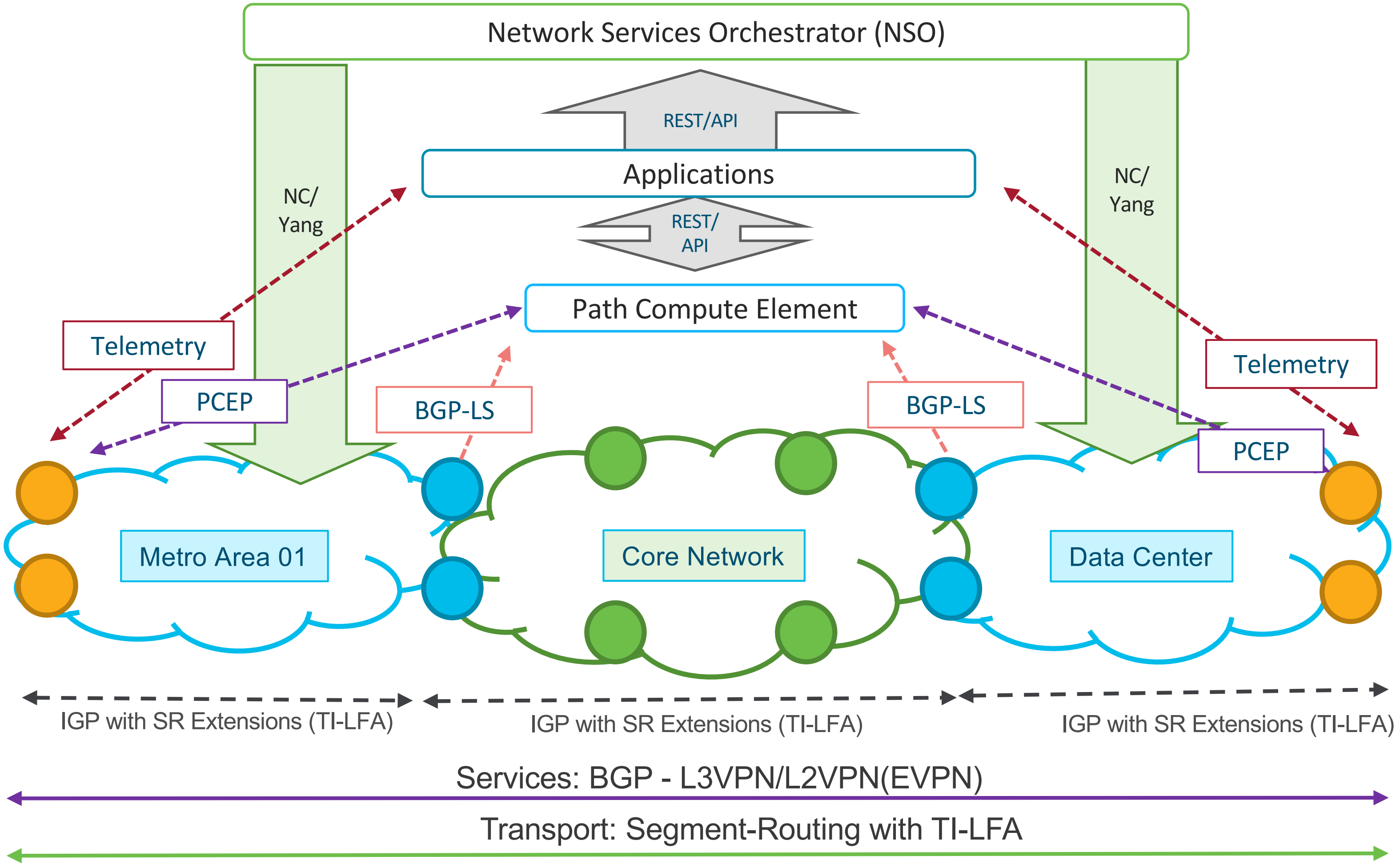
Recap: Intent based Programmable Network Infrastructure


Network Services Orchestrator (NSO)
REST/API
Applications
REST/
API
Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Metro Area 01
Core Network
Data Center
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

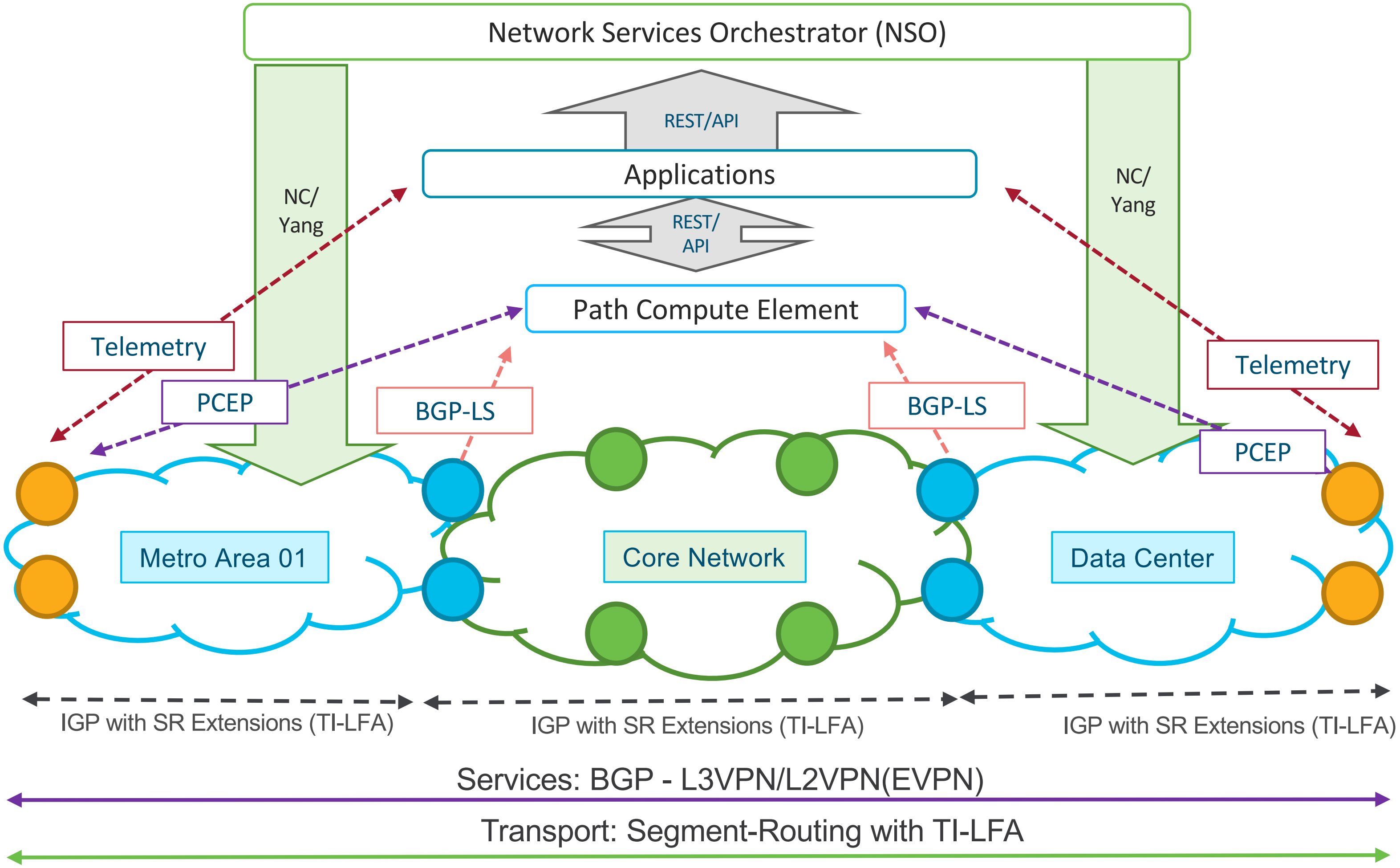
- □ App. Driven N/W and Usecases
- □ Automation
- □ Data Collection & Analytics
- □ Device and Services Onboarding
- □ EVPN Based Services
- ✓ Controller Based Forwarding
- ✓ Segment Routing Transport

Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
- Application Based Forwarding Architecture
- BGP Based VPNs
  - Why Ethernet VPN?
  - EVPN Fundamentals
  - EVPN Operations and Examples

You make networking **possible**

Recap: Intent based Programmable Network Infrastructure


Network Services Orchestrator (NSO)
REST/API
Applications
REST/
API
Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Metro Area 01
Core Network
Data Center
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
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- □ App. Driven N/W and Usecases
- □ Automation
- □ Data Collection & Analytics
- □ Device and Services Onboarding
- □ EVPN Based Services
- ☑ Controller Based Forwarding
- ☑ Segment Routing Transport

EVPN+SR Enabling Unified Fabric & Control Plane

Overlay	Unified EVPN Control Plane based on BGP: EVPN, EVPN-VPWS, EVPN-VXLAN
Underlay	Unified Data Plane: Segment Routing w/ IGP

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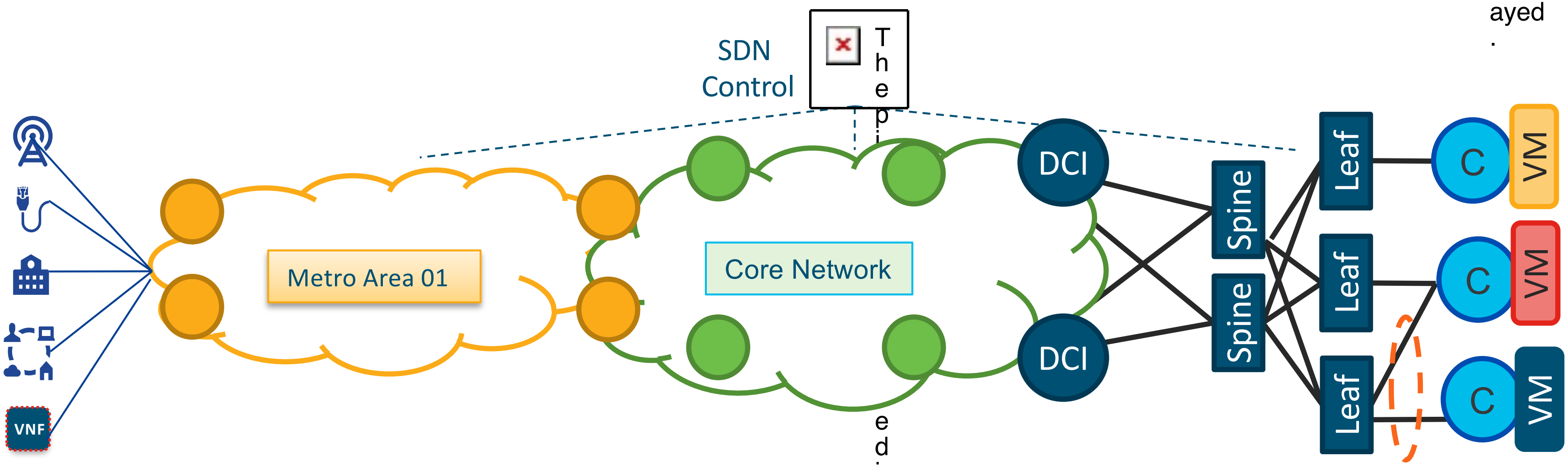
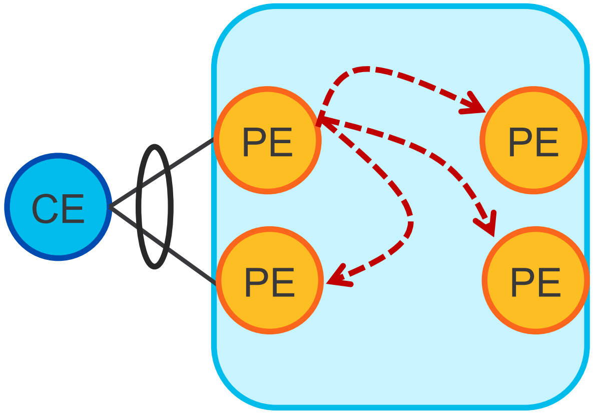


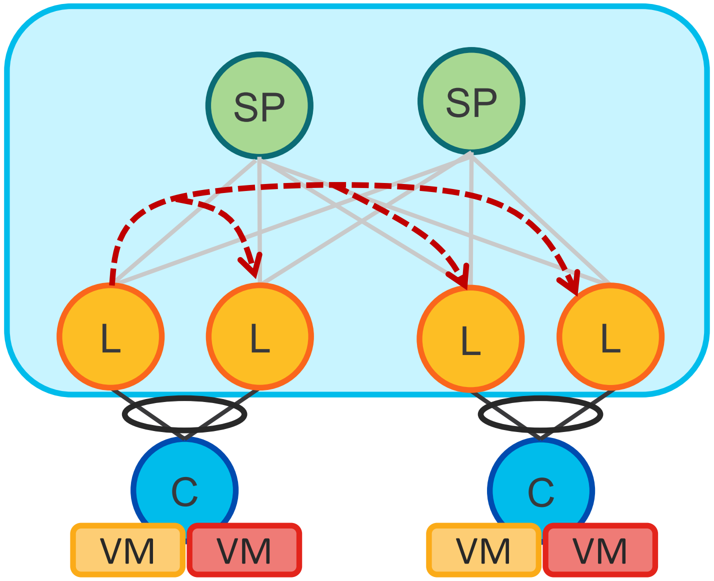
Overlay	L2/L3VPN (BGP,T-LDP) - VPLS, EoMPLS	VPLS, OTV	FabricPath, TRILL
Underlay	IP, IGP, MPLS (LDP), RSVP-TE, BGP-LU	IP, MPLS,L2	L2, STP, VLAN

Limited Cross-domain Automation, Cumbersome Service Assurance, Complex E2E QoS

Unified, Consistent Fabric with EVPN

- Originally Developed for Metro networks, applies equally to Data Centers
- Extensible, repeatable design across network boundaries





Should we just use new tech (such as EVPN) because it provides uniformity?

Well, EVPN solves some legacy architectural problems as well.

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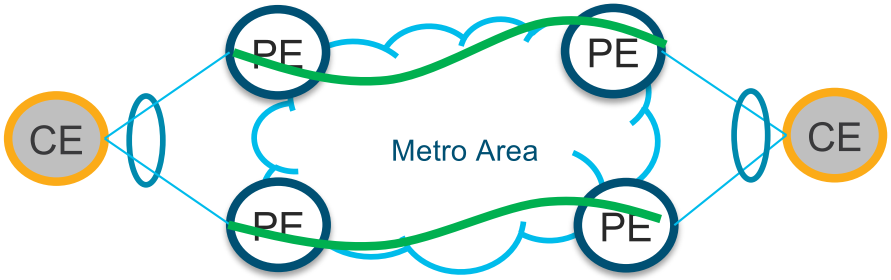
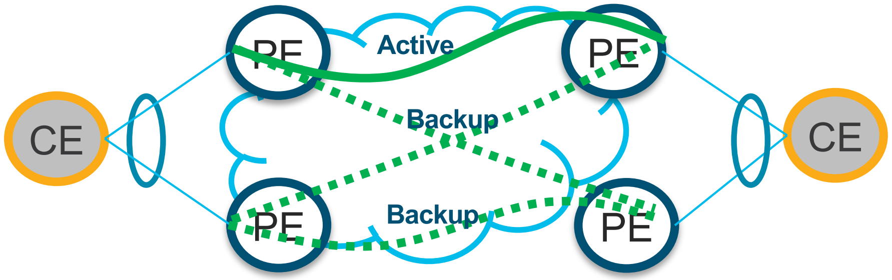
P2P L2VPN With Redundancy

- No MAC Learning = Duplication of traffic to CE
- Requires Access PE Loop prevention
- Requires PW States (Active/Backup) manipulation everywhere
- All active multi-homing not possible
- Lots of overhead, it could be more simpler …



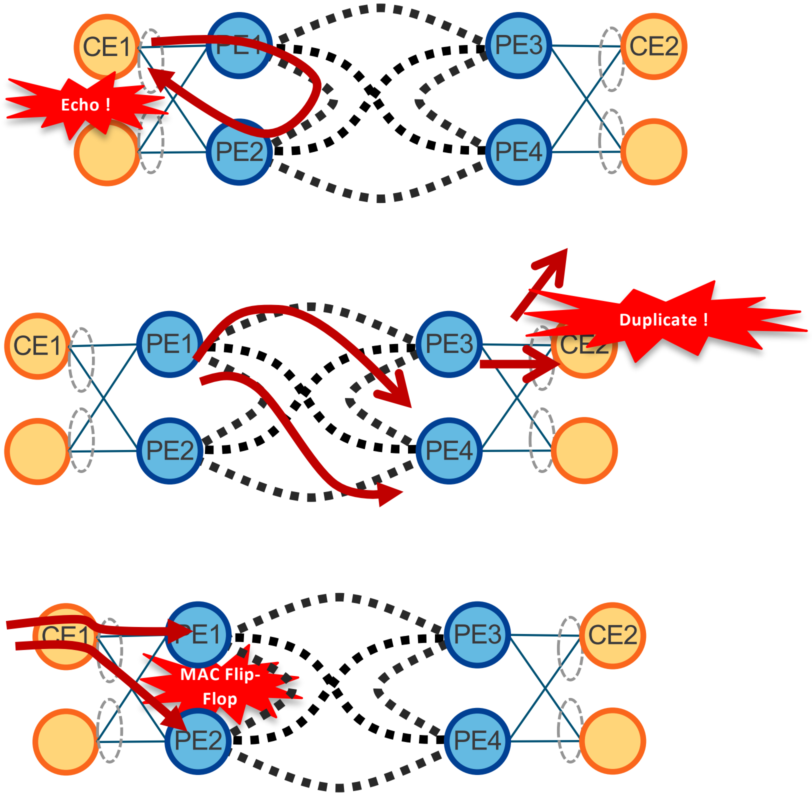
All Active Service Requirement



Typical Active-Standby Implementation

Multi-Point L2VPN (VPLS) Issues

- Possible Looping of Traffic Flooded from PE
- Duplicate Frames from Floods from the Core
- MAC Flip-Flopping over Pseudowire
- Inherent L2 VPN Issues like MAC Scale and traffic flooding on a local fault
  - E.g. customer convergence might introduce flooding throughout the Provider network
- Lots of overhead, it could be more simpler..



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EVPN: Architectural and Operational Arguments

Control Plane exists in most networks (BGP)	Builtin Loop Prevention (BGP)	Allows All-Active MultiHoming	multiple transport protocol integration	Integrated Fast Convergence (BGP PIC)
L2/L3 capabilities - DC, Metro, Ent applications	No Customer network impact into SP	BGP MAC withdrawl instead of flood	Fewer control Protocols (no LDP)	Ultra High Scale though BGP

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Fundamentals of Next Gen Network Architectures:

- Intent Based Programmable Transport
- Application Based Forwarding Architecture
- BGP Based VPNs
    - Why Ethernet VPN?
    - EVPN Fundamentals
    - EVPN Operations and Examples

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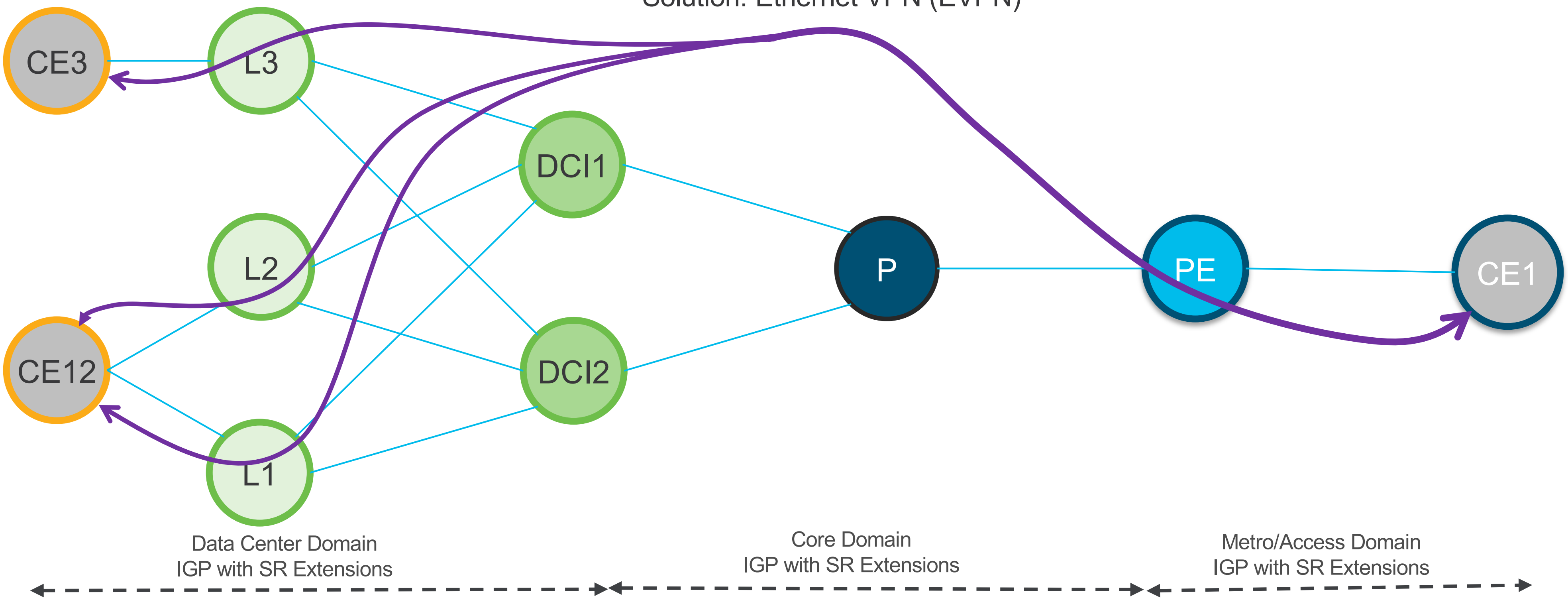
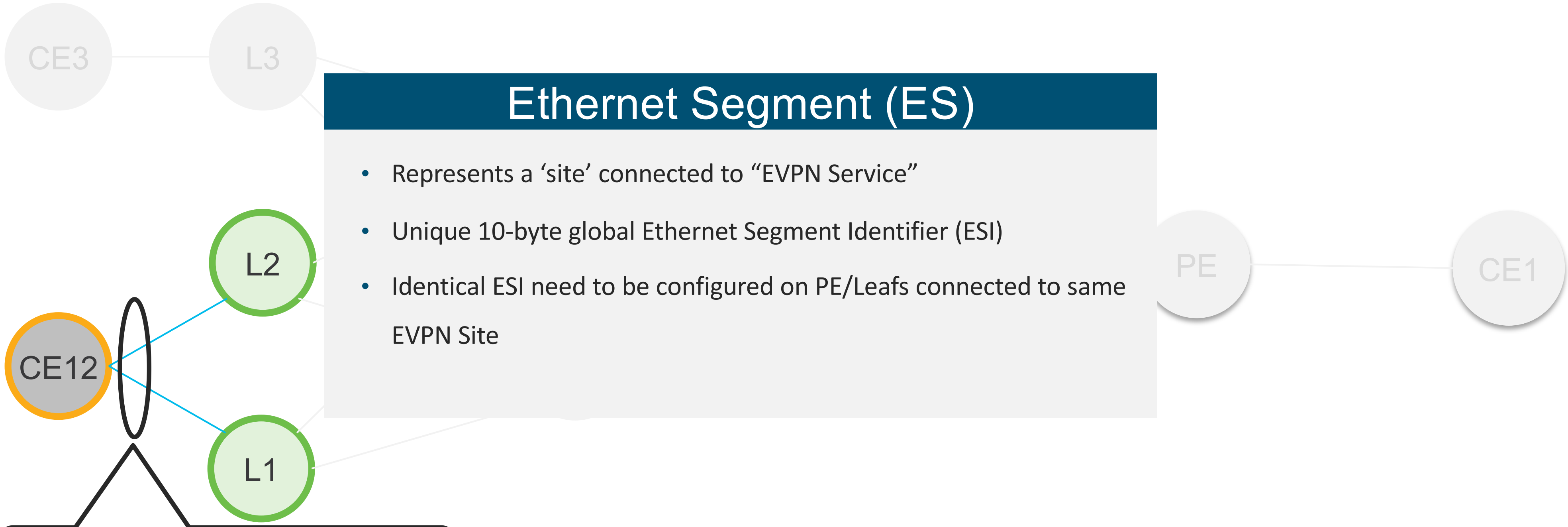
EVPN Fundamentals – Baseline Intent Based Transport

Required: End to End L2/L3 Services
Solution: Ethernet VPN (EVPN)



Transport: Segment-Routing with TI-LFA

EVPN Fundamentals – Ethernet Segment



Ethernet Segment (ES)

- Represents a ‘site’ connected to “EVPN Service”
- Unique 10-byte global Ethernet Segment Identifier (ESI)
- Identical ESI need to be configured on PE/Leafs connected to same EVPN Site

VM12 “site” Represented by the same ESI on Leaf1 and Leaf2

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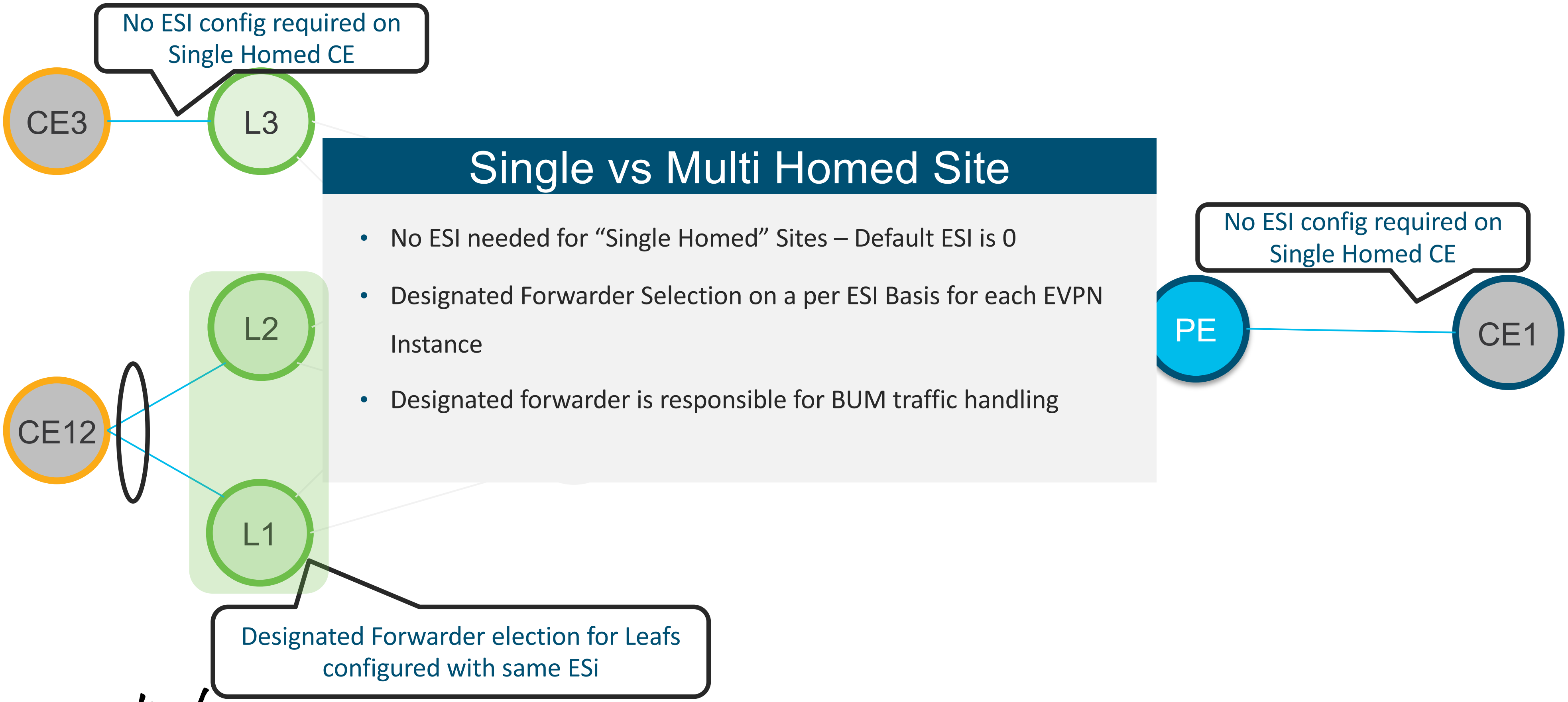
EVPN Fundamentals – Single-Homing vs Multi-Homing



No ESI config required on Single Homed CE

No ESI config required on Single Homed CE

Designated Forwarder election for Leafs configured with same ESi

Single vs Multi Homed Site

- No ESI needed for “Single Homed” Sites – Default ESI is 0
- Designated Forwarder Selection on a per ESI Basis for each EVPN Instance
- Designated forwarder is responsible for BUM traffic handling

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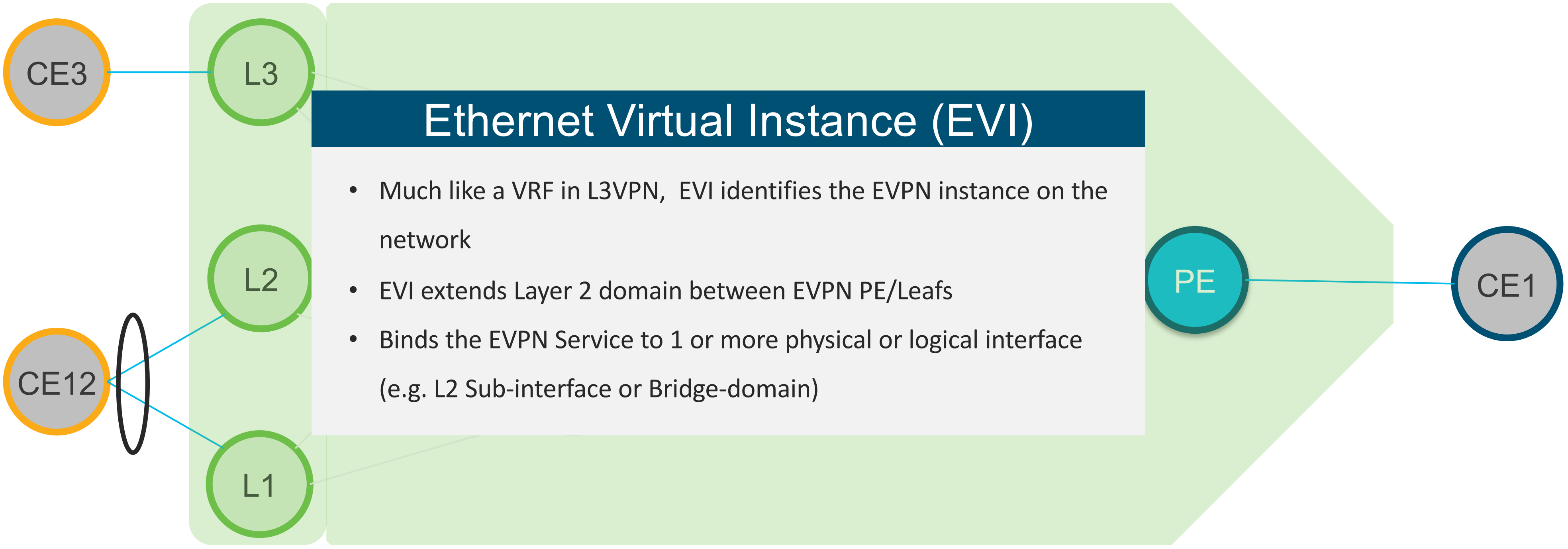
EVPN Fundamentals – Ethernet Virtual Instance



Ethernet Virtual Instance (EVI)

- Much like a VRF in L3VPN, EVI identifies the EVPN instance on the network
- EVI extends Layer 2 domain between EVPN PE/Leafs
- Binds the EVPN Service to 1 or more physical or logical interface (e.g. L2 Sub-interface or Bridge-domain)

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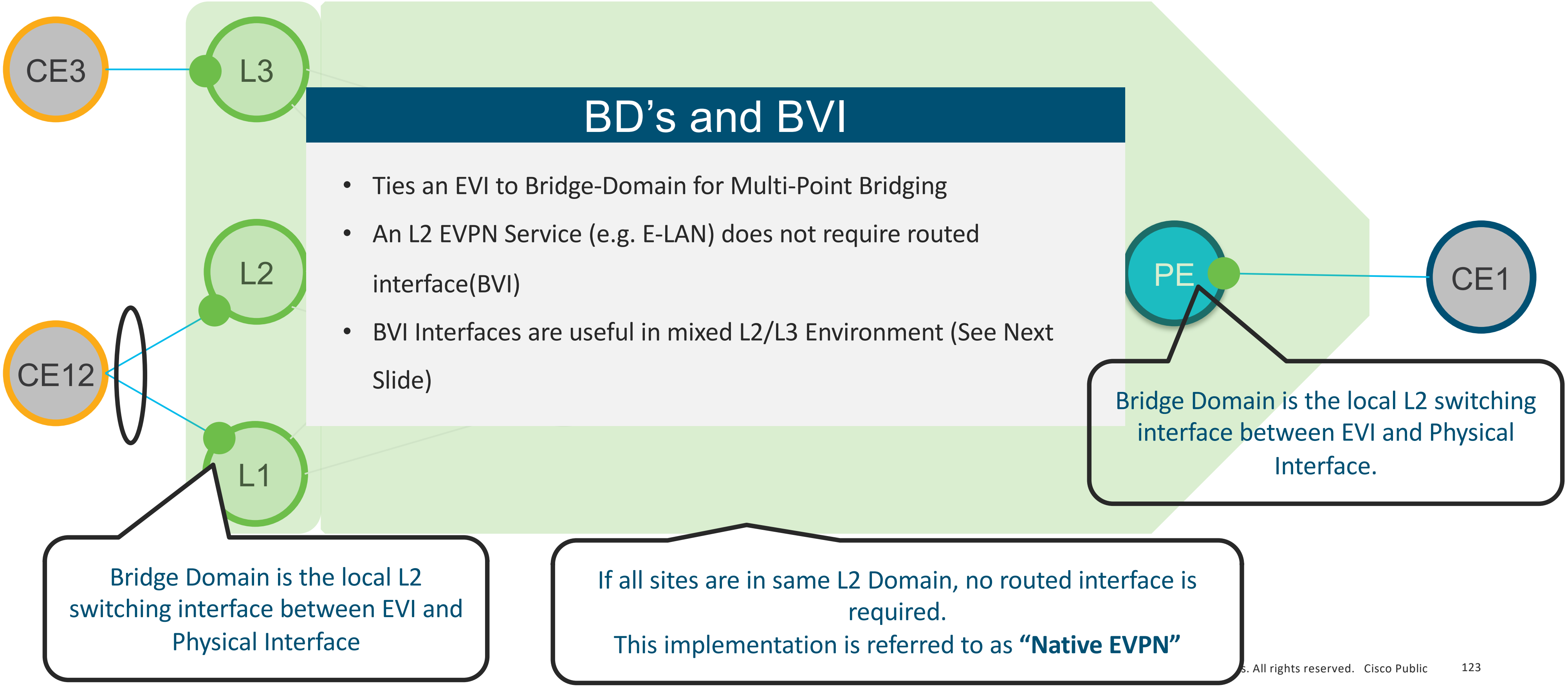
EVPN Fundamentals – Bridge Domain (BD) and Bridged Virtual Interface(BVI)



BD’s and BVI

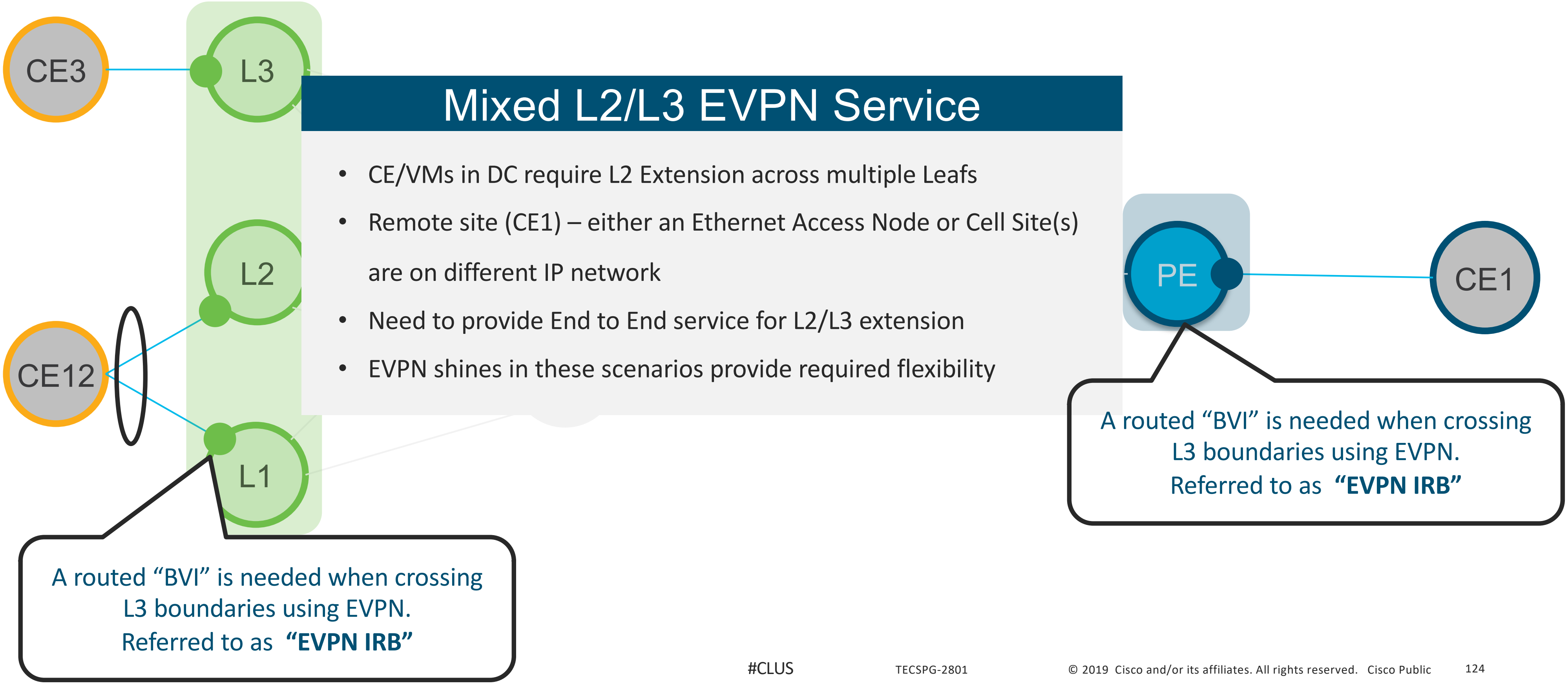
- Ties an EVI to Bridge-Domain for Multi-Point Bridging
- An L2 EVPN Service (e.g. E-LAN) does not require routed interface(BVI)
- BVI Interfaces are useful in mixed L2/L3 Environment (See Next Slide)

Bridge Domain is the local L2 switching interface between EVI and Physical Interface.

Bridge Domain is the local L2 switching interface between EVI and Physical Interface

If all sites are in same L2 Domain, no routed interface is required.
This implementation is referred to as **“Native EVPN”**

EVPN Fundamentals – Bridge Domain (BD) and Bridged Virtual Interface(BVI)



Mixed L2/L3 EVPN Service

- CE/VMs in DC require L2 Extension across multiple Leafs
- Remote site (CE1) – either an Ethernet Access Node or Cell Site(s) are on different IP network
- Need to provide End to End service for L2/L3 extension
- EVPN shines in these scenarios provide required flexibility

A routed "BVI" is needed when crossing L3 boundaries using EVPN. Referred to as **"EVPN IRB"**

A routed "BVI" is needed when crossing L3 boundaries using EVPN. Referred to as **"EVPN IRB"**

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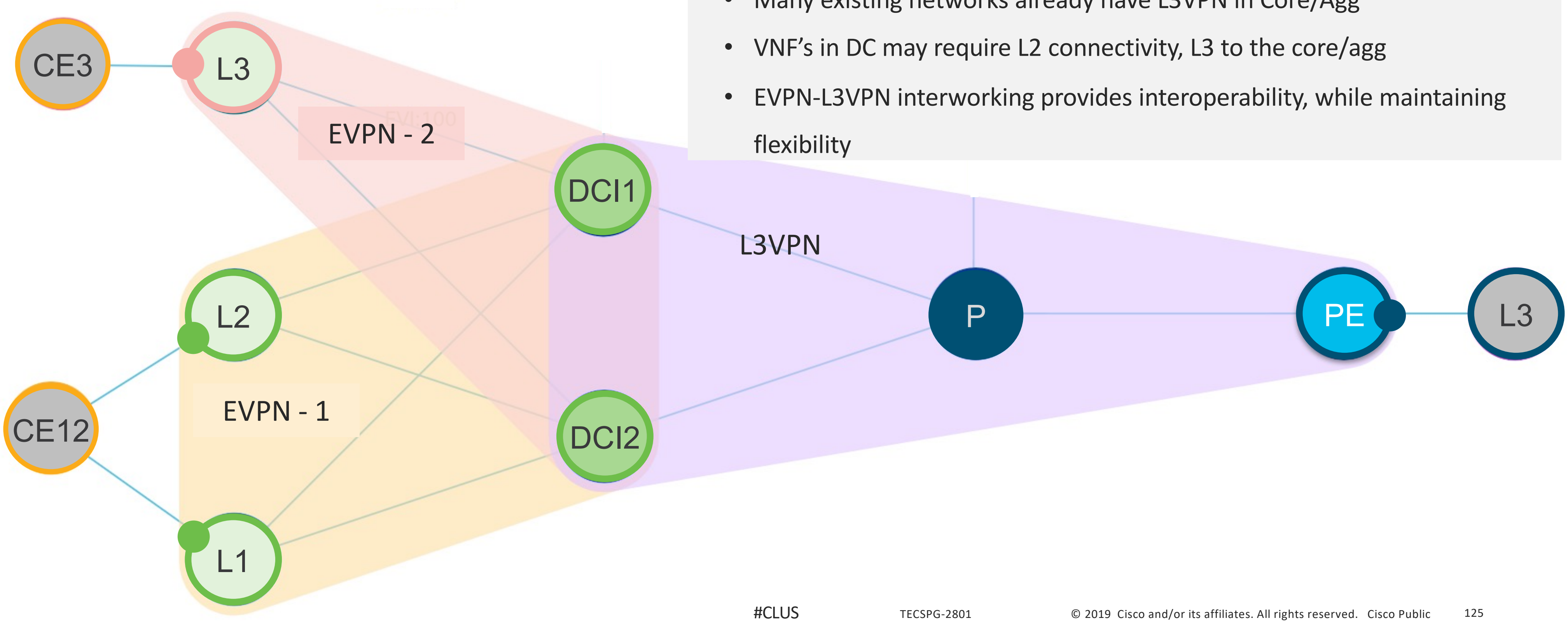
EVPN Fundamentals – EVPN and L3VPN Interworking

Interoperability with existing VPNs

- Many existing networks already have L3VPN in Core/Agg
- VNF's in DC may require L2 connectivity, L3 to the core/agg
- EVPN-L3VPN interworking provides interoperability, while maintaining flexibility



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BGP EVPN Route Type

Reference Slide

Route type	Usage
0x1 Ethernet Auto-Discovery (A-D) Route	• MAC Mass-Withdraw • Aliasing (load balancing) • Split-Horizon
0x2 MAC Advertisement Route	• Advertises MAC addresses /IP for VM reachability • Provides MAC/IP address bindings for ARP broadcast suppression
0x3 Inclusive Multicast Route	• Indicates interest of BUM traffic for attached L2 segments • Multicast tunnels used to BUM frame
0x4 Ethernet Segment Route	• Auto discovery of Multi-homed Ethernet Segments, i.e. redundancy group discovery • Designated Forwarder (DF) Election
0x5 IP Prefix Route	• Advertises IP prefix for a subnet for L3 NLRI only inter-subnet routing via EVPN address family

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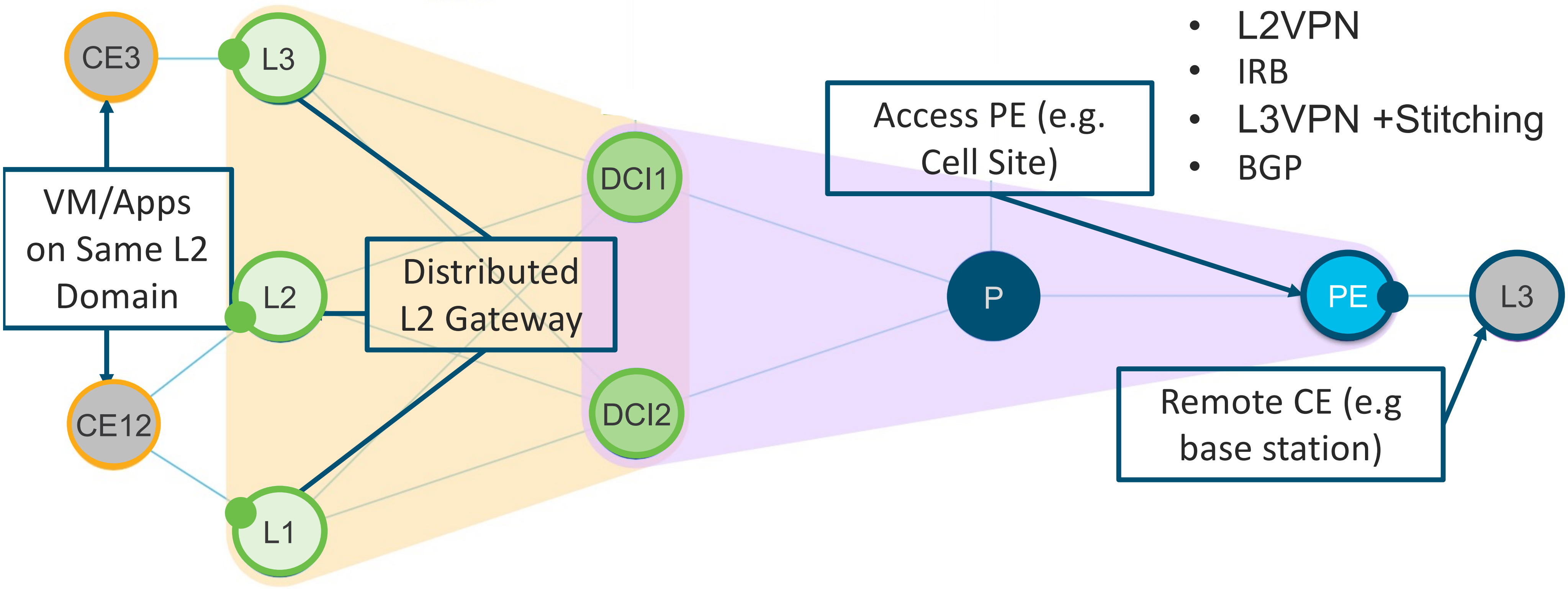
You make networking **possible**

Service Example over Intent Based Transport: EVPN In DC, L3VPN in Access

Configs Required:

- EVPN
- L2VPN
- IRB
- L3VPN +Stitching
- BGP


CE3
L3
VM/Apps on Same L2 Domain
L2
Distributed L2 Gateway
DCI1
DCI2
CE12
L1
Access PE (e.g. Cell Site)
P
PE
L3
Remote CE (e.g base station)

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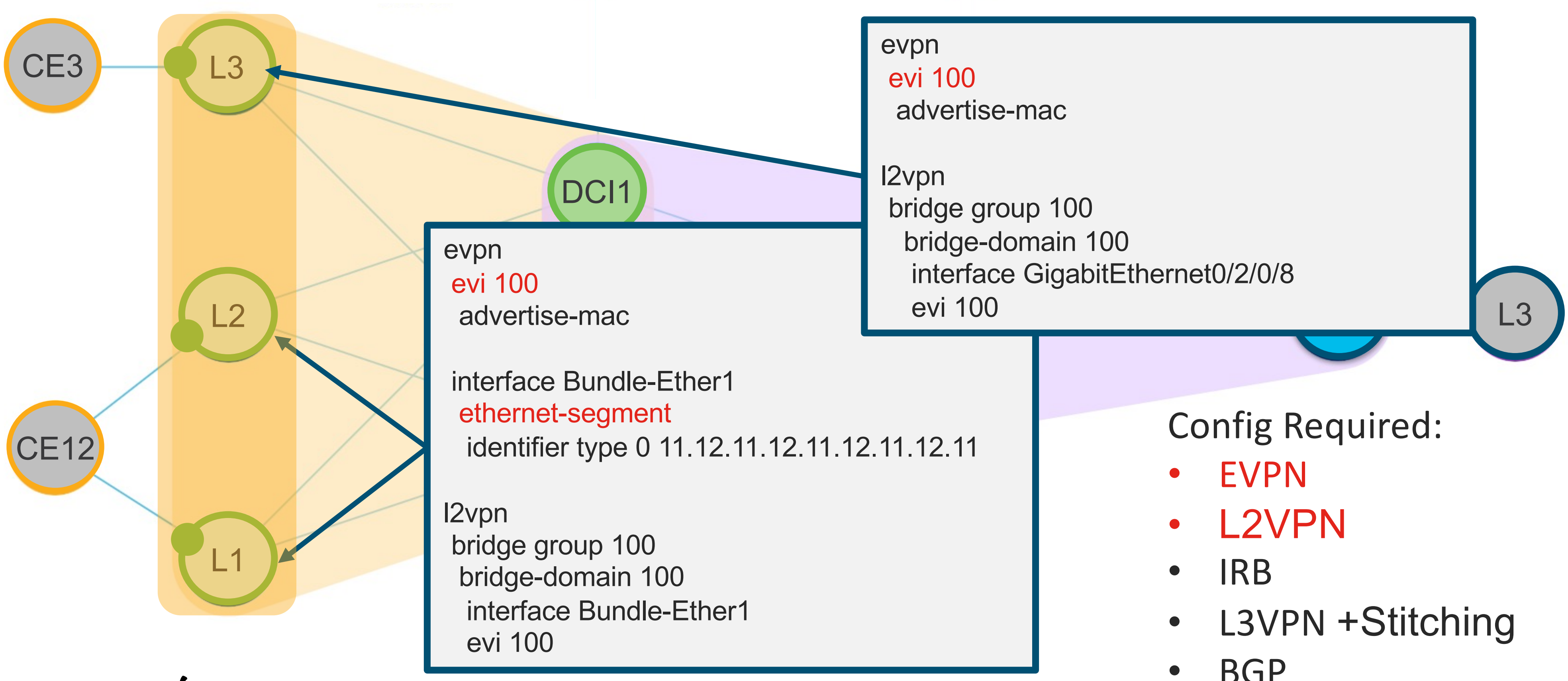
Step 1: Create a Layer 2 Extension For DC CE’s



```
evpn
 evi 100
  advertise-mac

l2vpn
 bridge group 100
  bridge-domain 100
   interface GigabitEthernet0/2/0/8
   evi 100
```

```
evpn
 evi 100
  advertise-mac

 interface Bundle-Ether1
  ethernet-segment
   identifier type 0 11.12.11.12.11.12.11.12.11

l2vpn
 bridge group 100
  bridge-domain 100
   interface Bundle-Ether1
   evi 100
```

Config Required:

- EVPN
- L2VPN
- IRB
- L3VPN +Stitching
- BGP

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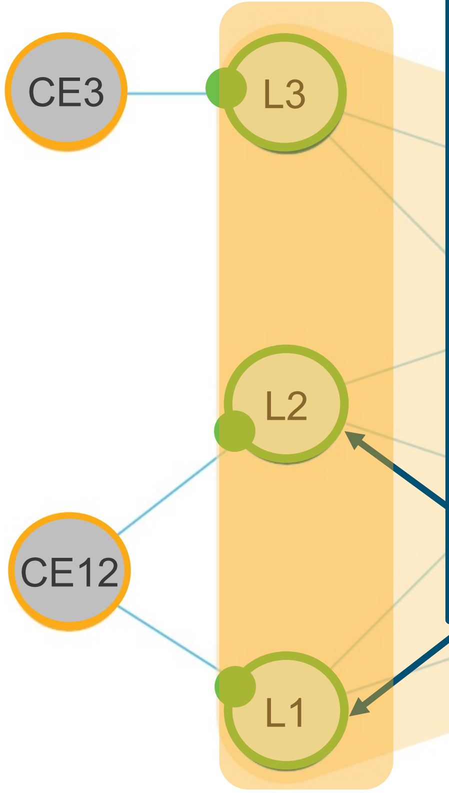
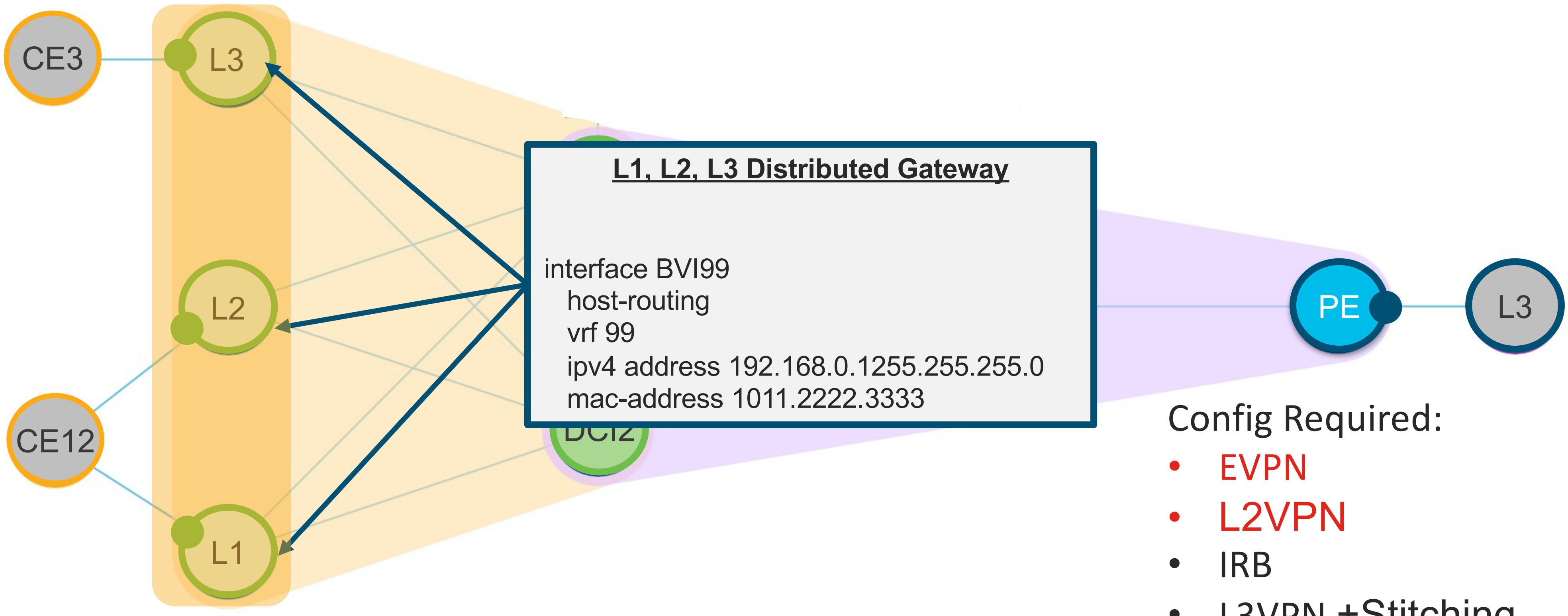
Step 1: Verify DF for Dual Homing of Layer 2 CE



```
RP/0/0/CPU0:L2#show evpn ethernet-segment carving detail
<snip>
  Topology          :
     Operational    : MH, All-active
     Configured     : All-active (AApF) (default)
  Service Carving   : Auto-selection
  Peering Details   : 1.1.1.1[MOD:P:00] 1.1.1.2[MOD:P:00]
  Service Carving Results:
     Forwarders     : 1
     Permanent      : 0
     Elected        : 0
     Not Elected    : 1
     EVI E   :      100
  MAC Flushing mode : STP-TCN
<snip>
```

```
RP/0/0/CPU0:L1#show evpn ethernet-segment carving detail
<snip>
  Topology          :
     Operational    : MH, All-active
     Configured     : All-active (AApF) (default)
  Service Carving   : Auto-selection
  Peering Details   : 1.1.1.1[MOD:P:00] 1.1.1.2[MOD:P:00]
  Service Carving Results:
     Forwarders     : 1
     Permanent      : 0
     Elected        : 1
            EVI E   :      100
     Not Elected    : 0
  MAC Flushing mode : STP-TCN
<snip>
```

Step 1a: Distributed L2 Gateway for Mobility



L1, L2, L3 Distributed Gateway

```
interface BVI99
  host-routing
  vrf 99
  ipv4 address 192.168.0.1255.255.255.0
  mac-address 1011.2222.3333
```

Config Required:

- EVPN
- L2VPN
- IRB
- L3VPN +Stitching
- BGP

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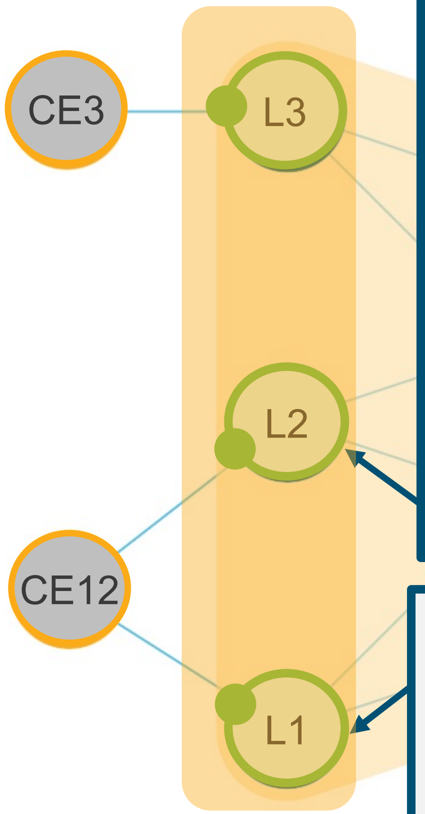
Step 2: Adding IRB



L1, L2, L3 VRF/BVI Config

```
vrf 99
 address-family ipv4 unicast
  import route-target
   60000:99
  export route-target
   60000:99

interface BVI99
 host-routing
 vrf 99
 ipv4 address 192.168.0.1/24
 mac-address 1011.2222.3333
```

L1, L2, L3 BGP Config

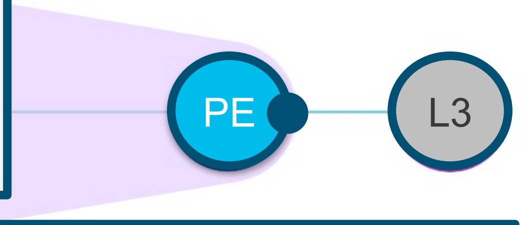
```
router bgp 1
 address-family ipv4 unicast
 address-family vpnv4 unicast
 address-family l2vpn evpn

 neighbor 1.1.1.8
  address-family l2vpn evpn
   advertise vpnv4 unicast

 vrf 99
  rd auto
  address-family ipv4 unicast
   maximum-paths ibgp 2
   redistribute connected
```

Config Required:

- EVPN
- L2VPN
- IRB
- L3VPN+Stitching
- BGP



L1, L2, L3 L2VPN Config

```
l2vpn
 bridge group 100
  bridge-domain 100
   interface Bundle-Ether1 (Gig 0/2/0/8 for L3)
   routed interface BVI99
   evi 100
```

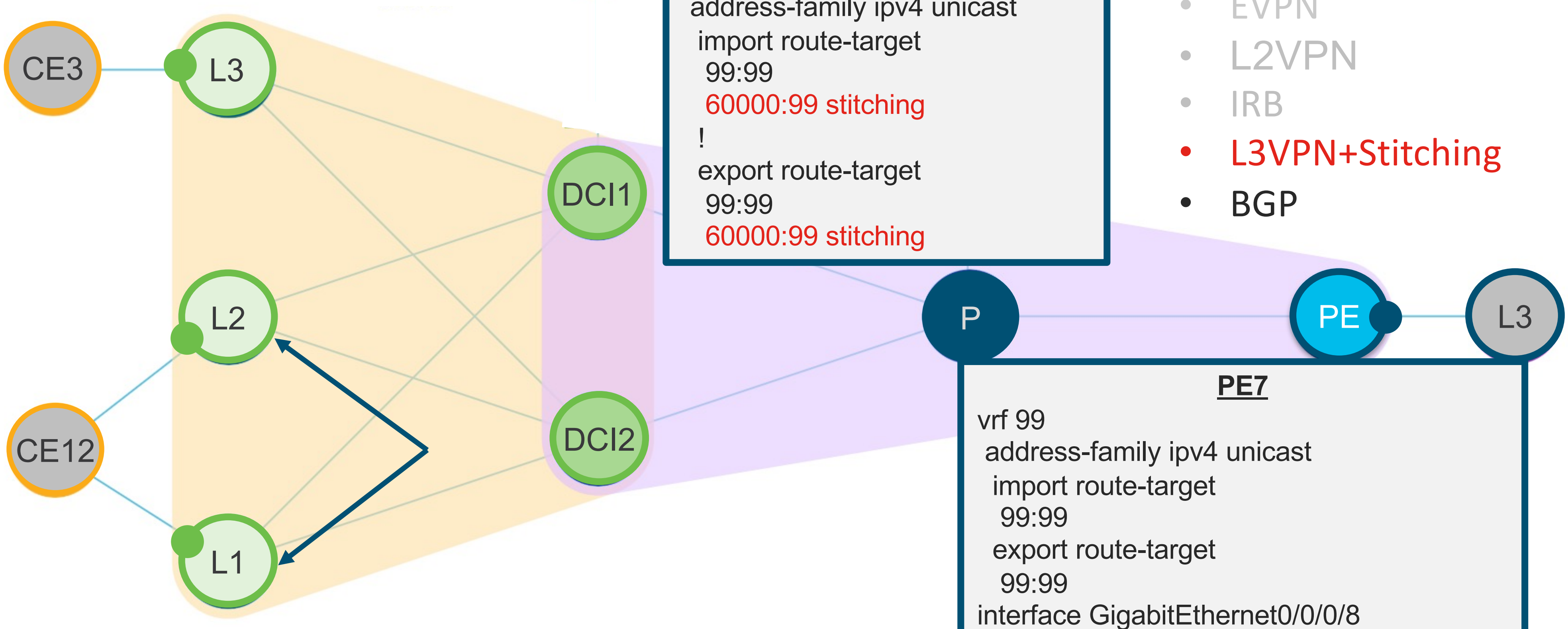
L1, L2, L3 EVPN. Config (No Change)

```
evpn
 evi 100
  advertise-mac

(Below Configs for L1/L2 only)
 interface Bundle-Ether1
  ethernet-segment
   identifier type 0 11.12.11.12.11.12.11.12.11
```

Cisco*live!*

Step 3: EVPN-L3VPN Stitching Configs



DCI1 and DCI2

```
vrf 99
 address-family ipv4 unicast
  import route-target
   99:99
   60000:99 stitching
  !
  export route-target
   99:99
   60000:99 stitching
```

Config Required:

- EVPN
- L2VPN
- IRB
- L3VPN+Stitching
- BGP

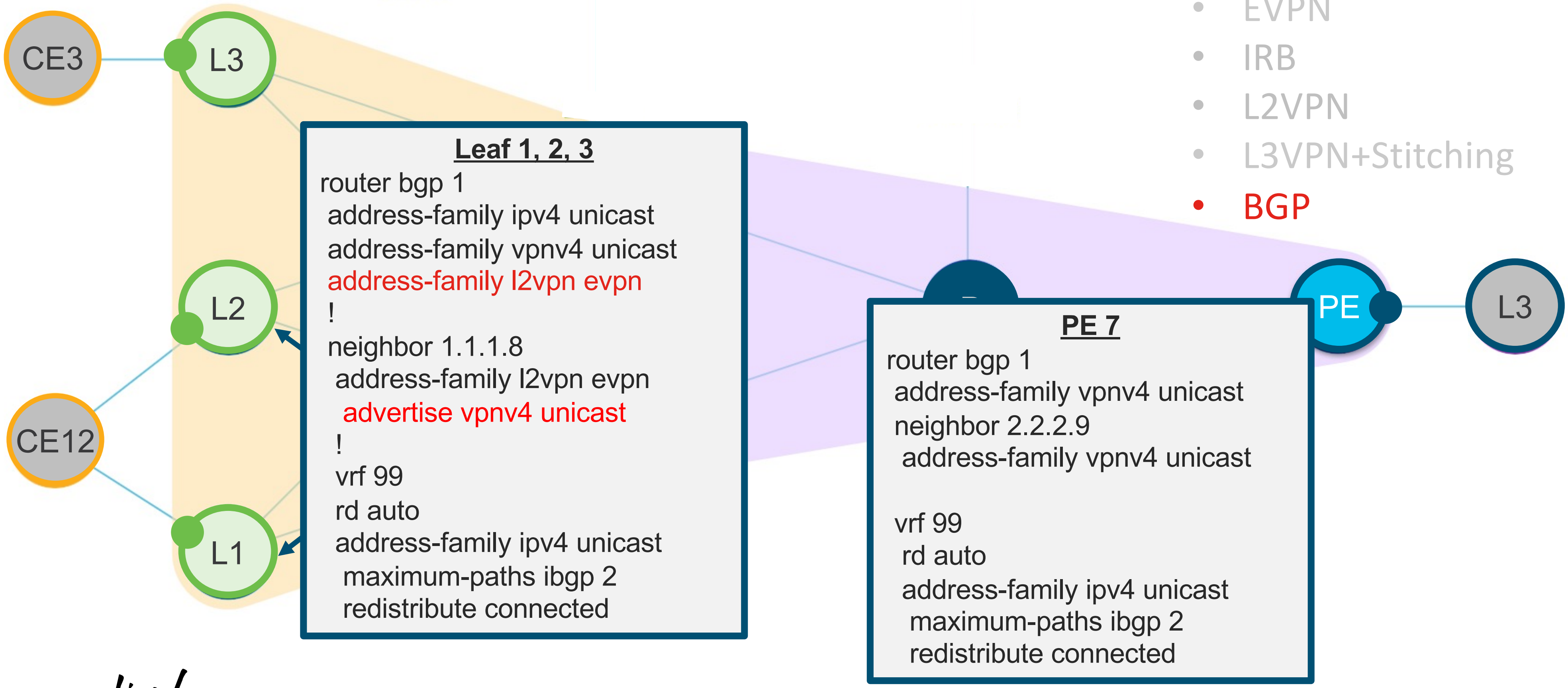
PE7

```
vrf 99
 address-family ipv4 unicast
  import route-target
   99:99
  export route-target
   99:99
interface GigabitEthernet0/0/0/8
   vrf 99
    ipv4 address 7.7.7.7 255.255.255.0
```

Step 3: EVPN-L3VPN stitching – BGP Configs (PE and Leaf)

Config Required:

- EVPN
- IRB
- L2VPN
- L3VPN+Stitching
- BGP



Leaf 1, 2, 3

```
router bgp 1
 address-family ipv4 unicast
 address-family vpnv4 unicast
 address-family l2vpn evpn
 !
 neighbor 1.1.1.8
  address-family l2vpn evpn
   advertise vpnv4 unicast
  !
  vrf 99
  rd auto
  address-family ipv4 unicast
   maximum-paths ibgp 2
   redistribute connected
```

PE 7

```
router bgp 1
 address-family vpnv4 unicast
 neighbor 2.2.2.9
  address-family vpnv4 unicast

 vrf 99
  rd auto
  address-family ipv4 unicast
   maximum-paths ibgp 2
   redistribute connected
```

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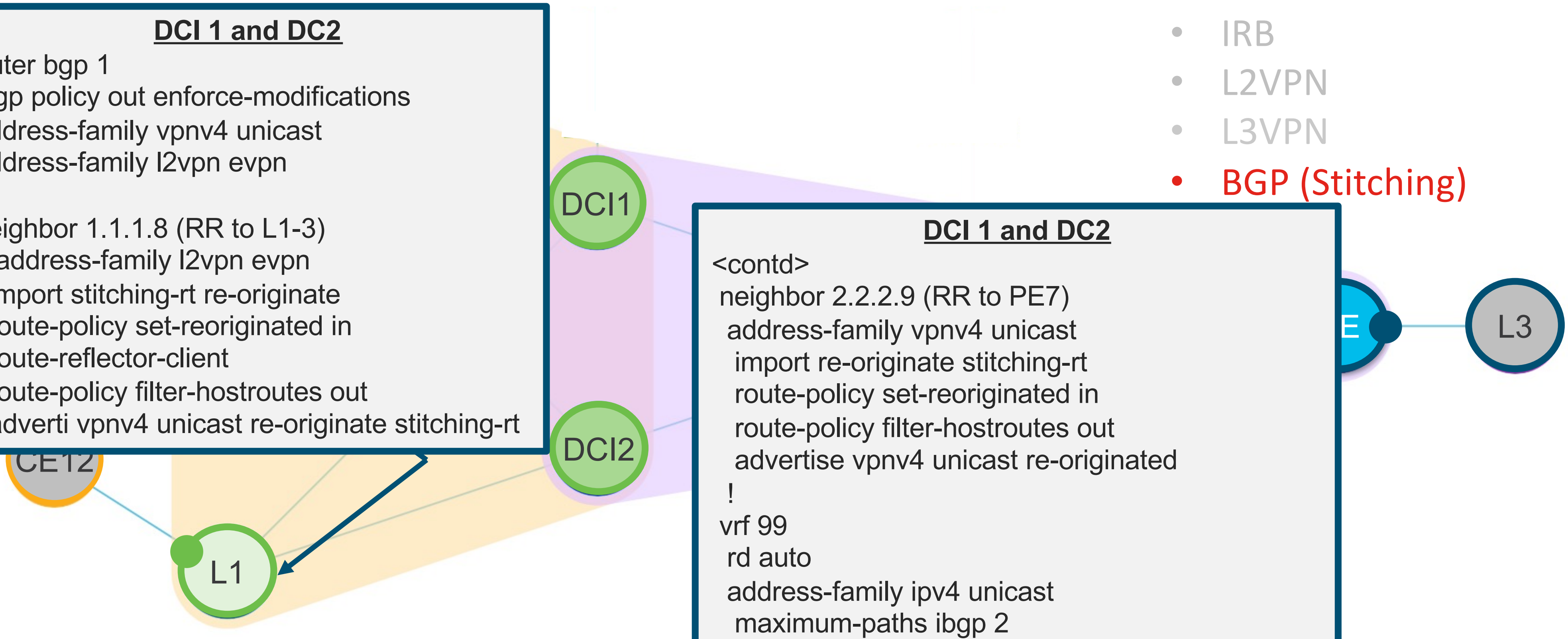
Step 3: EVPN-L3VPN stitching – BGP Configs (Border Leafs)

Config Required:

- EVPN
- IRB
- L2VPN
- L3VPN
- BGP (Stitching)



DCI 1 and DC2

```
router bgp 1
 ibgp policy out enforce-modifications
 address-family vpnv4 unicast
 address-family l2vpn evpn

 neighbor 1.1.1.8 (RR to L1-3)
    address-family l2vpn evpn
   import stitching-rt re-originate
   route-policy set-reoriginated in
   route-reflector-client
   route-policy filter-hostroutes out
   adverti vpnv4 unicast re-originate stitching-rt
```

DCI 1 and DC2

```
<contd>
 neighbor 2.2.2.9 (RR to PE7)
  address-family vpnv4 unicast
   import re-originate stitching-rt
   route-policy set-reoriginated in
   route-policy filter-hostroutes out
   advertise vpnv4 unicast re-originated
 !
 vrf 99
  rd auto
  address-family ipv4 unicast
   maximum-paths ibgp 2
   redistribute connected
```

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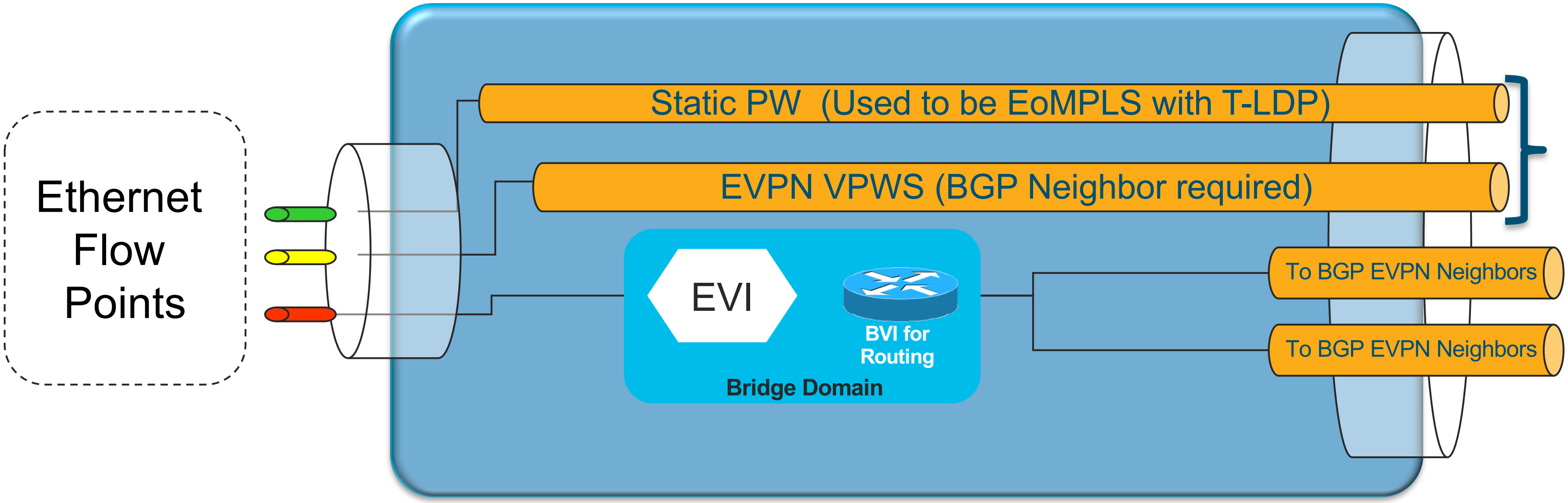
EVPN Summary

You make the power of data **possible**

EVPN Service Flow Summary



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Which EVPN Flavor Require What Configuration and provide what services

	Configuration Parameters						Service Type			
	LACP to CE	ESI	EVI	P2P XC	BD	BVI	P2P	P2MP	L2 VPN	L2+L3 VPN
EVPN VPWS Single Home				✓			✓		✓	
EVPN VPWS Multi Home	✓	✓		✓			✓		✓	
EVPN Multipoint	✓*	✓*	✓		✓			✓	✓	
EVPN IRB	✓*	✓*	✓		✓	✓		✓		✓

* Required for Multihomed CE's only

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EVPN Summary*

- L2 + L3 Functionality in same technology/configuration construct
- More scalable than traditional L2VPN solutions like VPLS
- Seamless integration with traditional L3 VPN deployments
- Applicable in DC and Metro equally!!
- Simplifies network by eliminating protocols (no LDP required)
- Recommended attending EVPN Deep Dive Session for more details

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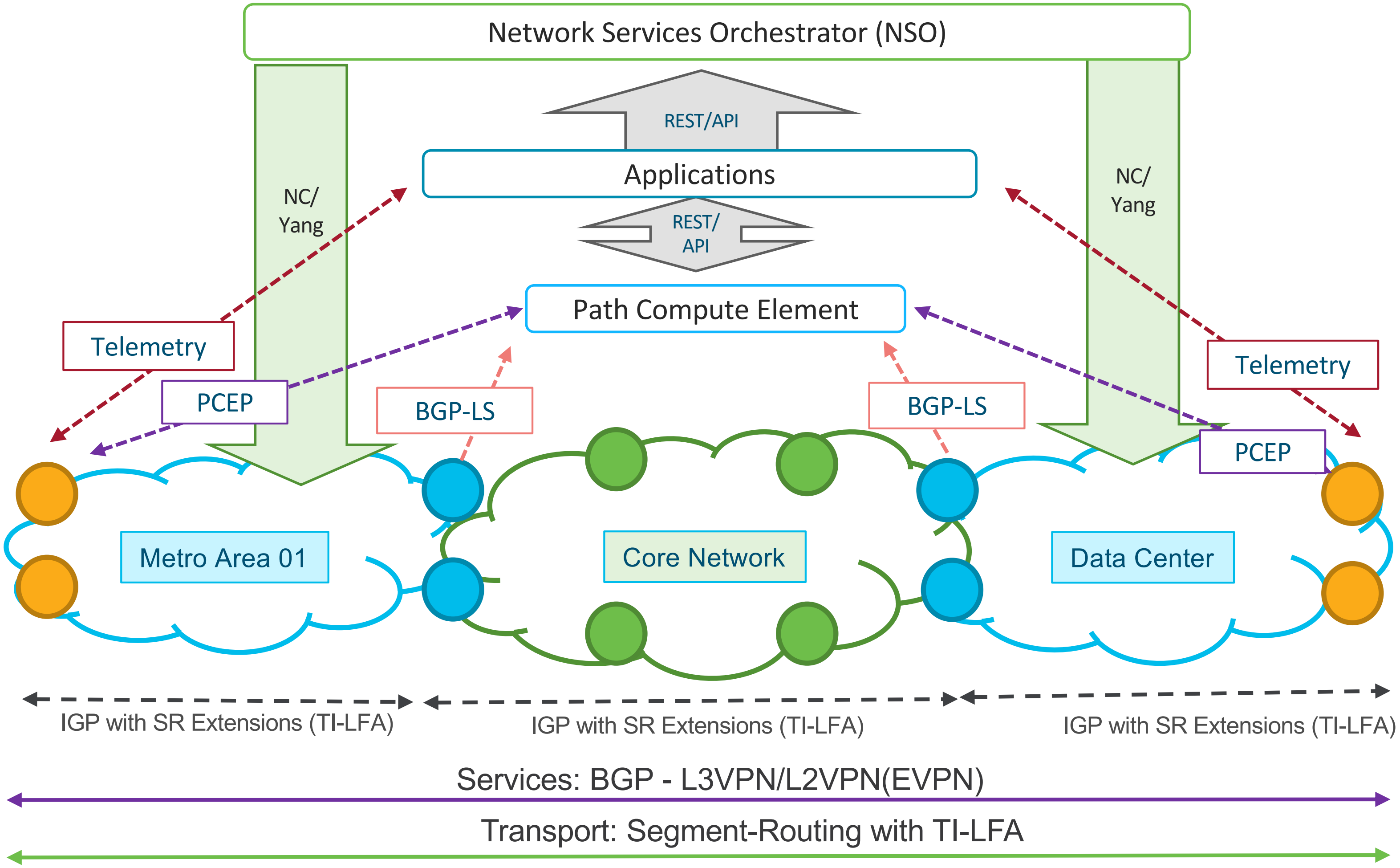
Recap: Intent based Programmable Network Infrastructure


Network Services Orchestrator (NSO)
REST/API
Applications
REST/
API
Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Metro Area 01
Core Network
Data Center
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

- □ App. Driven N/W and Usecases
- □ Automation
- □ Data Collection & Analytics
- □ Device and Services Onboarding
- ✓ EVPN Based Services
- ✓ Controller Based Forwarding
- ✓ Segment Routing Transport

Agenda

- Architectural Transformation Landscape
- Fundamentals of Next Generation Architecture
- Deployment and Configuration Samples
- Achieving Operational Efficiency
- Summary

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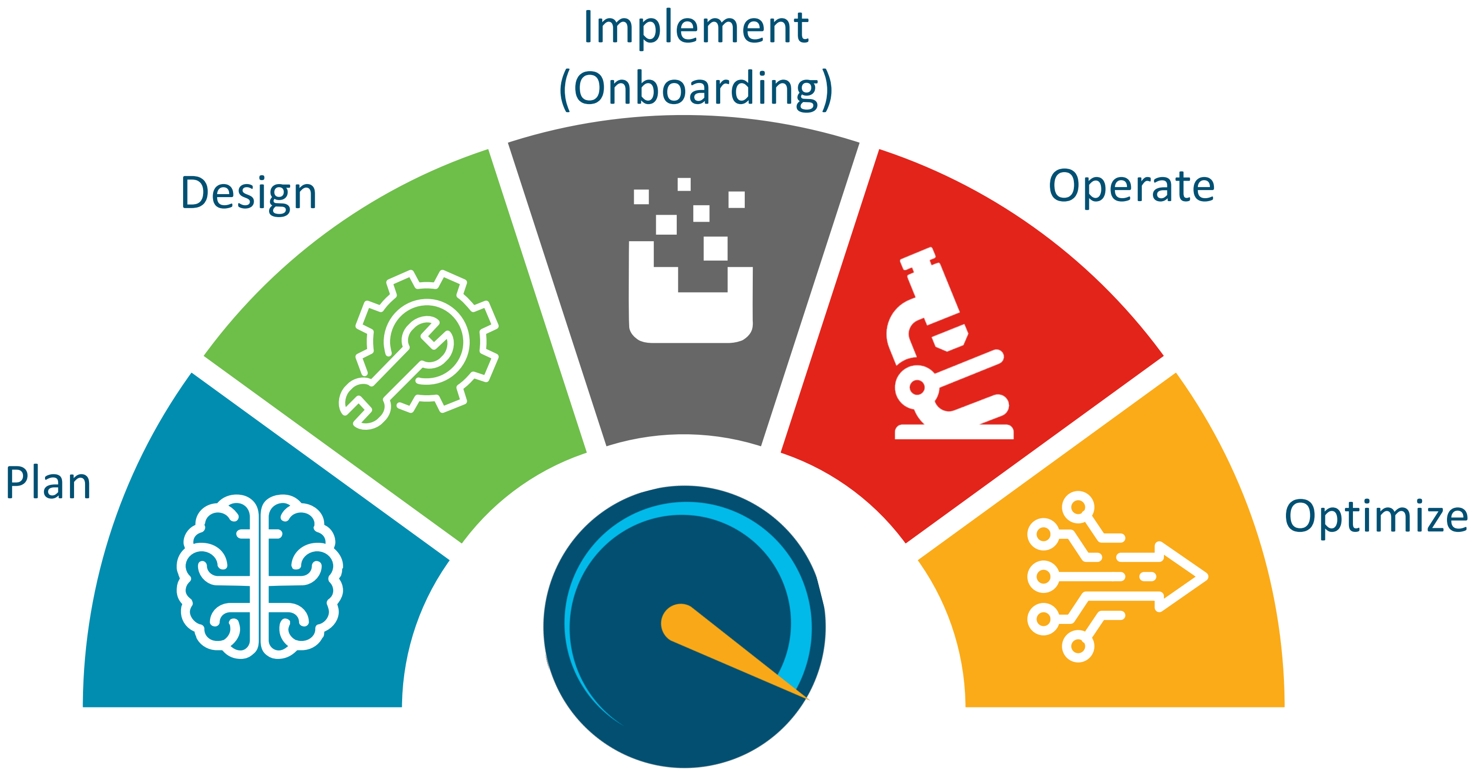
Architectural and Service Lifecycle



Modernizing Device Lifecycle

	Device Onboarding (Day 0)	Service Orchestration (Day 1)	Monitoring, Analytics, Operations (Day 2)
Yesterday	• Costly device Bring up • Skilled labor required on site • Manual, lengthy config process	• Scripts for service bring-up • High Maintenance, inflexible	• Non Scalable pull mechanism • Unstructured and periodic data bursts
Today	• Zero touch Deployment • Orders of Magnitude faster	• Automation friendly, flexible • Vendor neutral Model Driven Service bring up	• Near real time push mechanism • Consistent, scalable and machine readable

Orchestration, Data Analytics, Closed Loop Automation drive next generation SP Ops

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Achieving Operational Efficiency

Automated Onboarding

Services Orchestration

Monitoring and Analytics

Closed Loop Automation

You make multi-cloud **possible**

Why Zero Touch Deployment

Agility and Speed of Deployment

Automation for Repetitive Tasks

OpEx Savings by Minimizing Human Errors

TTM for growing number of Devices

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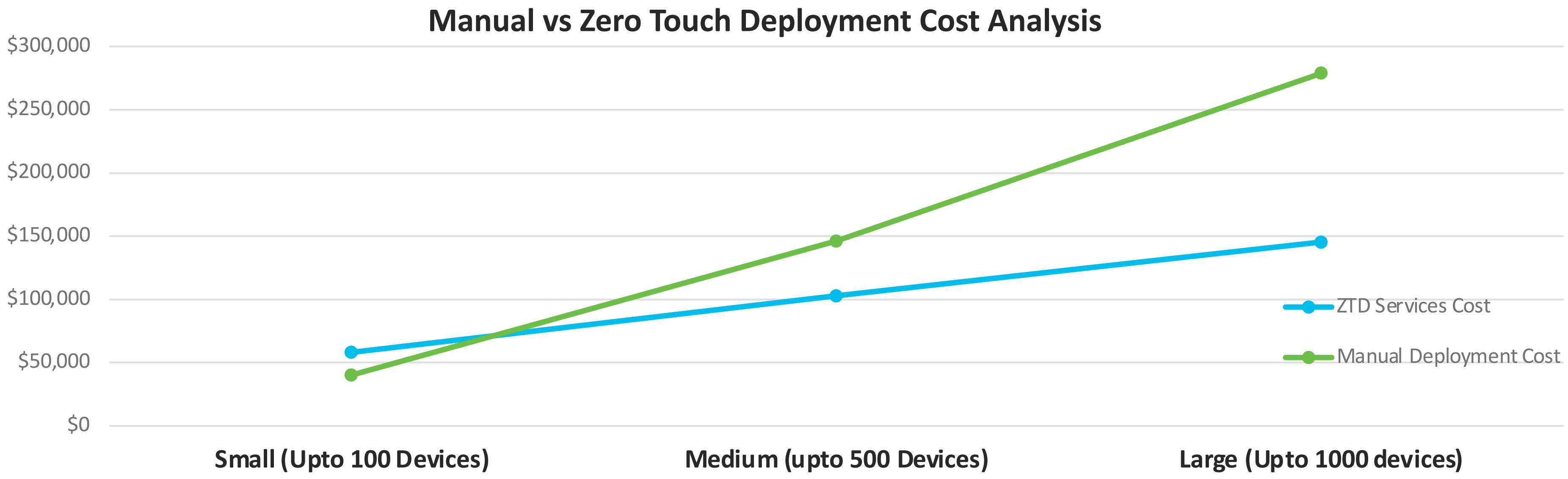
Cost Analysis*: Manual vs Z

- Higher startup cost for smaller deployments
- Cost savings beyond ~200 devices using ZTD

Deployment Type	ZTD Cost	Manual Deployment Cost
Small (Upto 100 Devices)	$58,186.85	$40,267.22
Medium (upto 500 Devices)	$102,760.00	$146,289.44
Large (Upto 1000 devices)	$145,437.78	$278,817.22


Manual vs Zero Touch Deployment Cost Analysis

* Analysis based on a specific usecase. Other costs may vary

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Case Study – ZTD at Tier 1

Solution Requirements and Components

ZTD Solution Requirements

- Use Cisco ASR-920 as Cell Site Router
- Automatic Configuration of Cell Site Router during Maintenance Window
- No Dedicated Management i.e ZTP over Data Ports
- Use pre-determined VLANs for connectivity

Solution Components

Orchestrator (Cisco NSO)

Cell Site Router

DHCP/TFTP Server

Lease Client and Import Scripts

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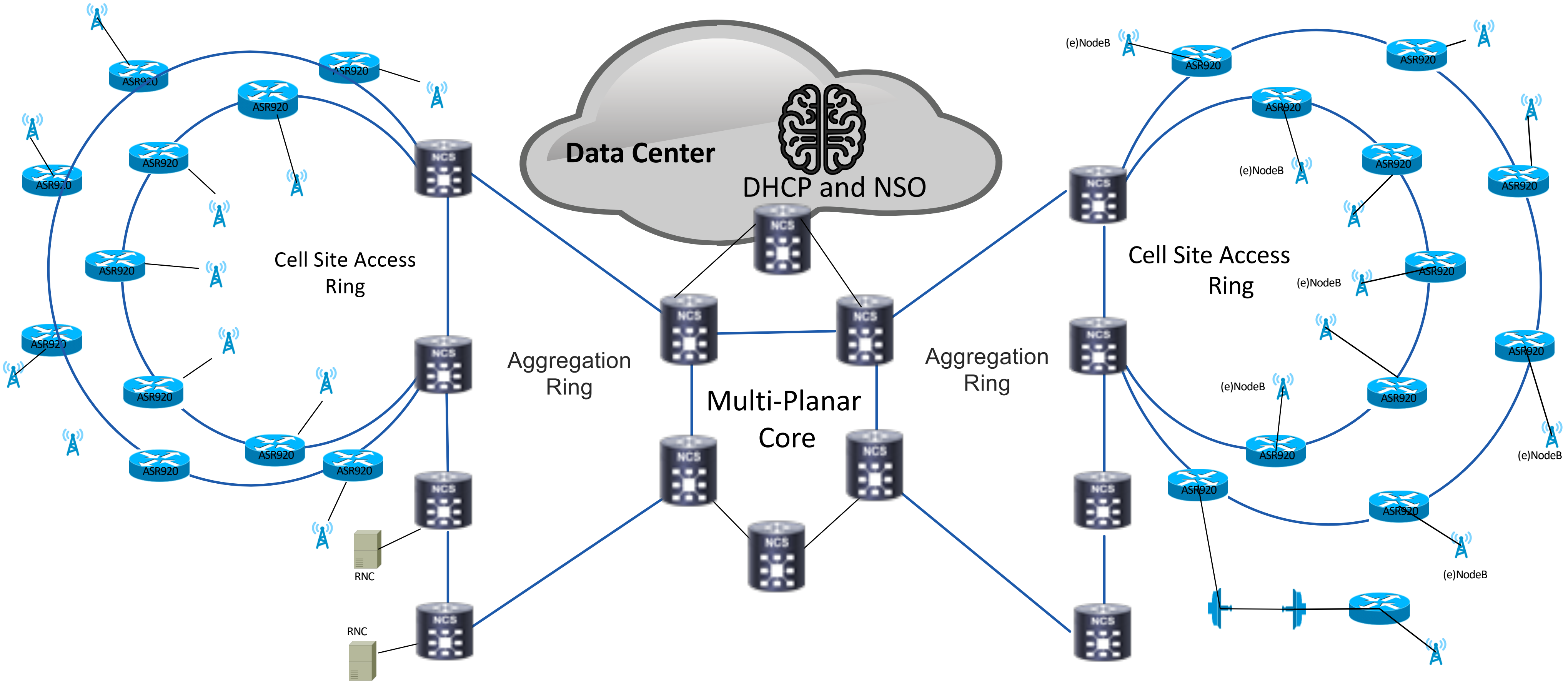
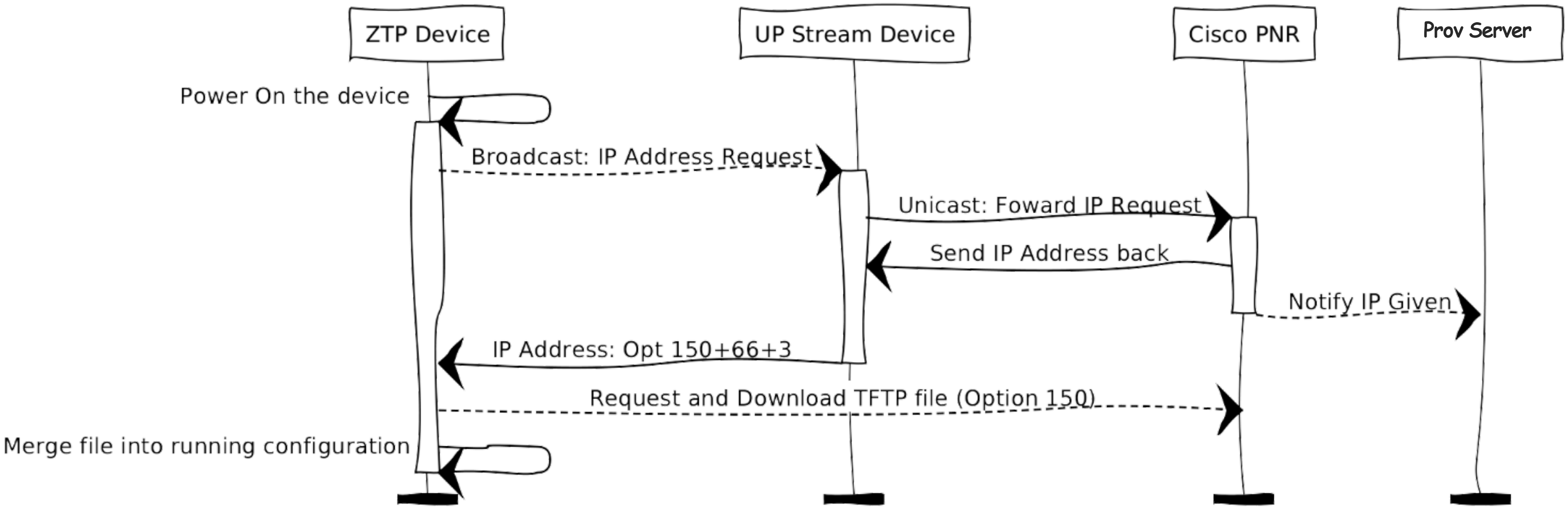
Case Study – ZTD at Tier 1 SP



ZTD Design and Workflow – Device Startup


ZTP Device
UP Stream Device
Cisco PNR
Prov Server
Power On the device
Broadcast: IP Address Request
Unicast: Foward IP Request
Send IP Address back
Notify IP Given
IP Address: Opt 150+66+3
Request and Download TFTP file (Option 150)
Merge file into running configuration

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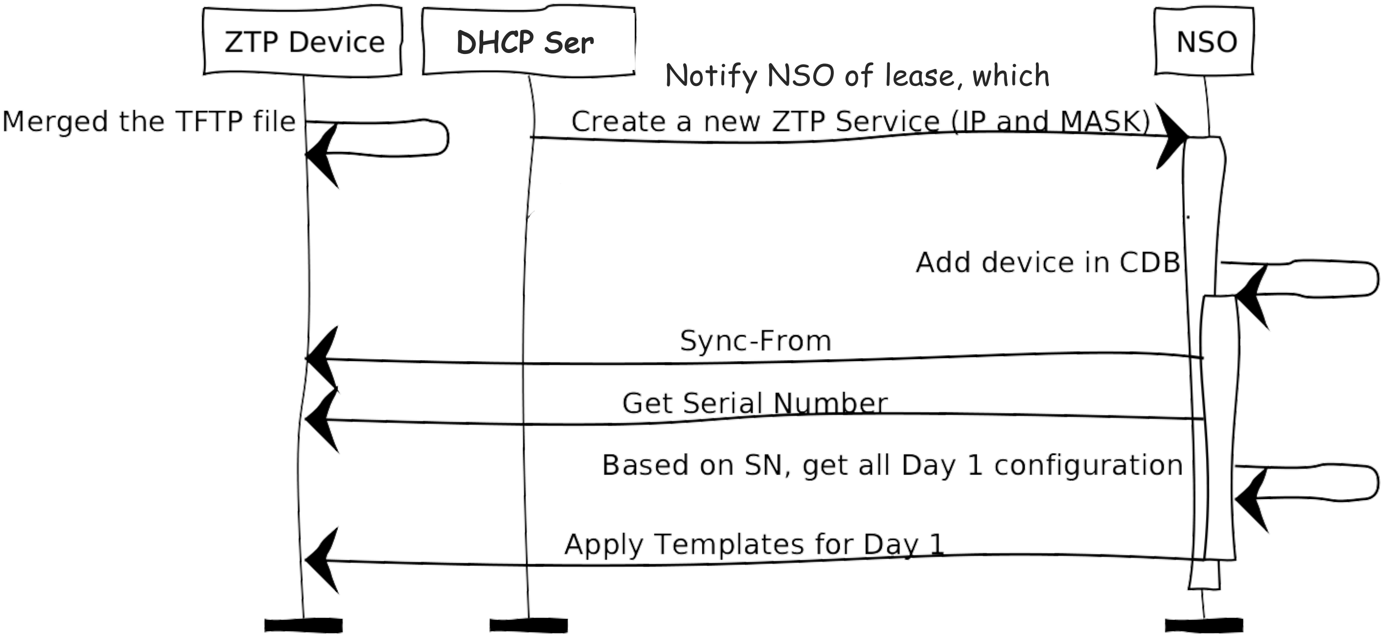
ZTD Design and Workflow – Config Application


ZTP Device
DHCP Ser
NSO
Notify NSO of lease, which
Merged the TFTP file
Create a new ZTP Service (IP and MASK)
Add device in CDB
Sync-From
Get Serial Number
Based on SN, get all Day 1 configuration
Apply Templates for Day 1

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Zero Touch Deployment Challenges & Solutions

Username/Password Required for Telnet	Challenge: Require Authentication config before NSO could connect. Solution: Use TFTP with a common config file for all devices
Device to Site Correlation	Challenge: Serial Number to installation site mapping Solution: Do not pre-assign devices to sites, ask installation team to provide serial number to site mapping via Excel
Preparing Backend	Challenge: NSO to be pre-configured with devices' config templates Solution: Standardized port usage, XLS sheet w/ all Devices baseline parameters, Custom script to import XLS into NSO DB
Process Enhancements	Process enhancement and alignment between Deployment and Ops team

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Achieving Operational Efficiency

Automated Onboarding

Services Orchestration

Monitoring and Analytics

Closed Loop Automation

You make multi-cloud **possible**

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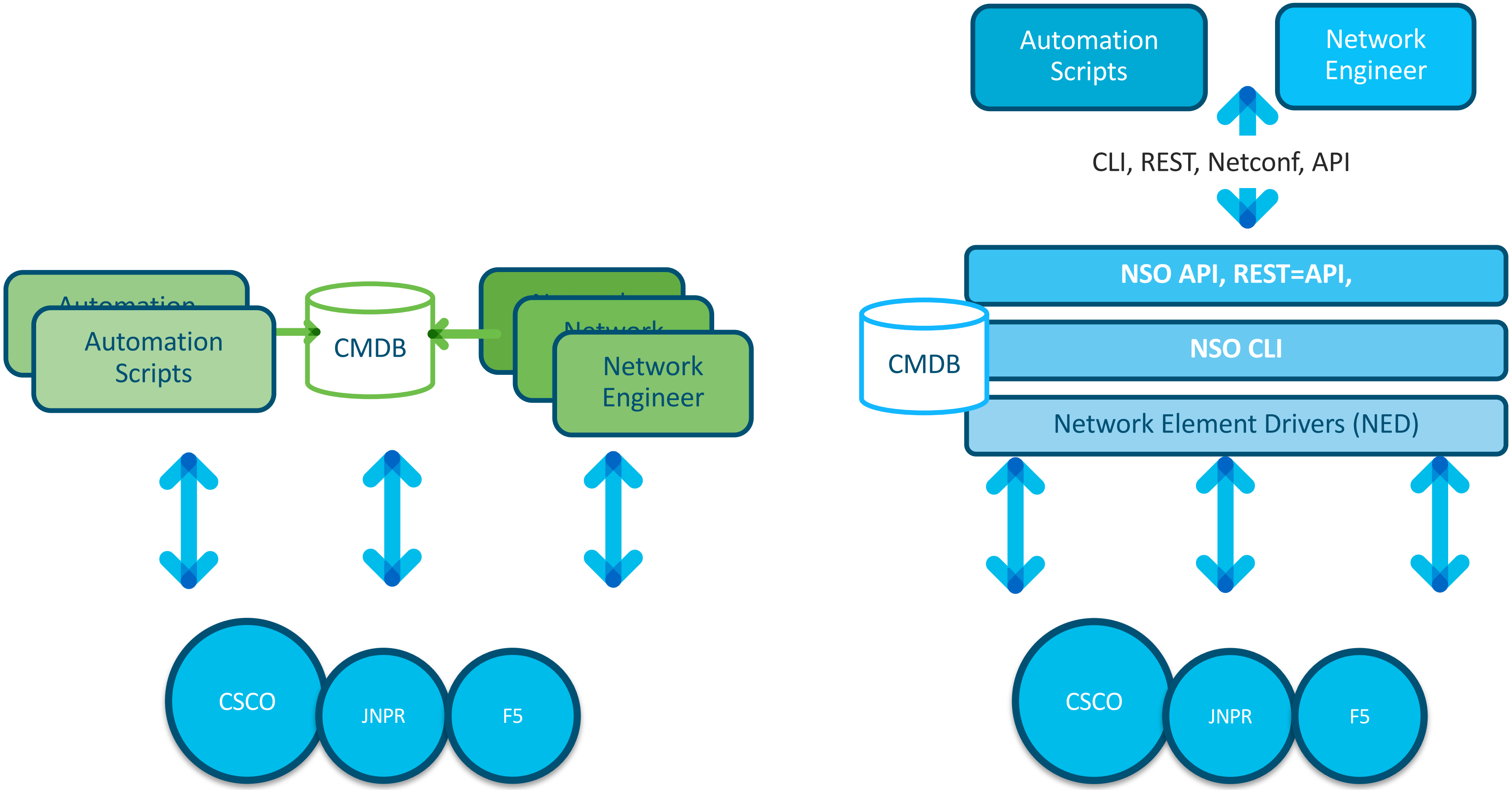
Cisco Network Services Orchestrator (NSO)



Automation Scripts

CMDB

Network Engineer

CSCO

JNPR

F5

Automation Scripts

Network Engineer

CLI, REST, Netconf, API

NSO API, REST=API,

NSO CLI

CMDB

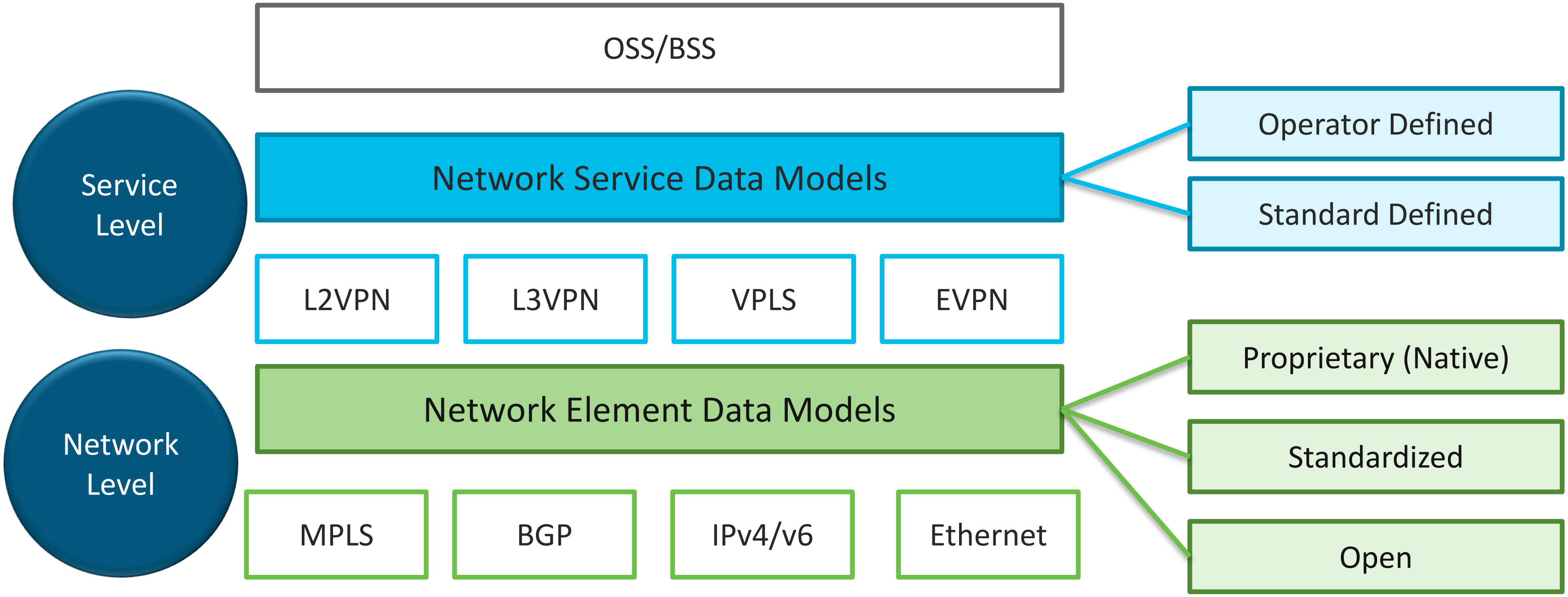
Network Element Drivers (NED)

CSCO

JNPR

F5

Network and Services Orchestration



Refer to "BRKSPG-2303: Model-Driven Programmability for Cisco IOS XR" for more details

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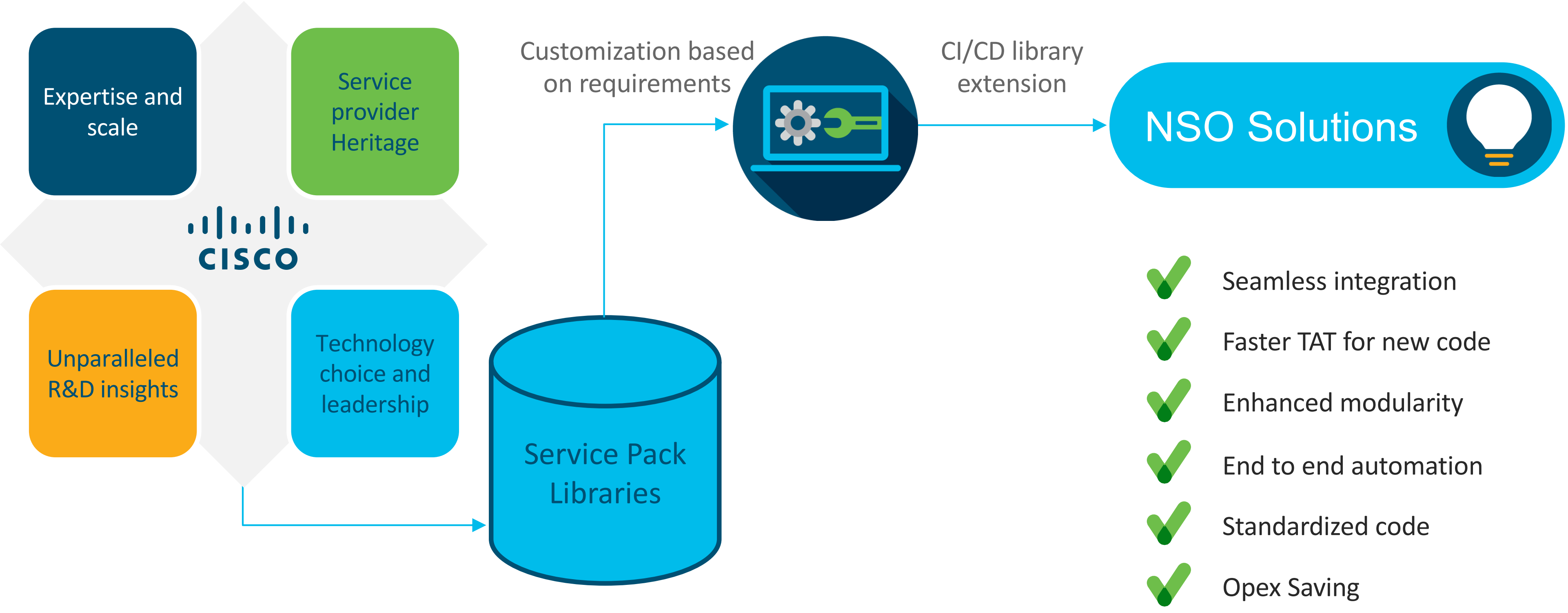
Automation Service Packs



Expertise and scale

Service provider Heritage

cisco

Unparalleled R&D insights

Technology choice and leadership

Service Pack Libraries

Customization based on requirements

CI/CD library extension

NSO Solutions

- ✓ Seamless integration
- ✓ Faster TAT for new code
- ✓ Enhanced modularity
- ✓ End to end automation
- ✓ Standardized code
- ✓ Opex Saving

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Automation Services Packages
Code libraries for easier insertion and expansion

Reference

Zero Touch Provisioning	Onboard new network devices with no human interaction.
Device OS Upgrade	Upgrade from source OS version to target OS version with pre and post checks
Device Port Turn up	Configure physical ports using configures attributes e.g. VLAN, MTU & Speed
Service Discovery Framework	User can define transformation logic for a particular service and SDF will discover and populate the service model.
Device Migration	Migrate configuration from device A to device B with pre and post checks
Metro E Services	(1) Ethernet Private Line (2) Ethernet Virtual Private Line (3) Ethernet Network Service
ACL Management	Manage firewall ACL in multi-firewall environment

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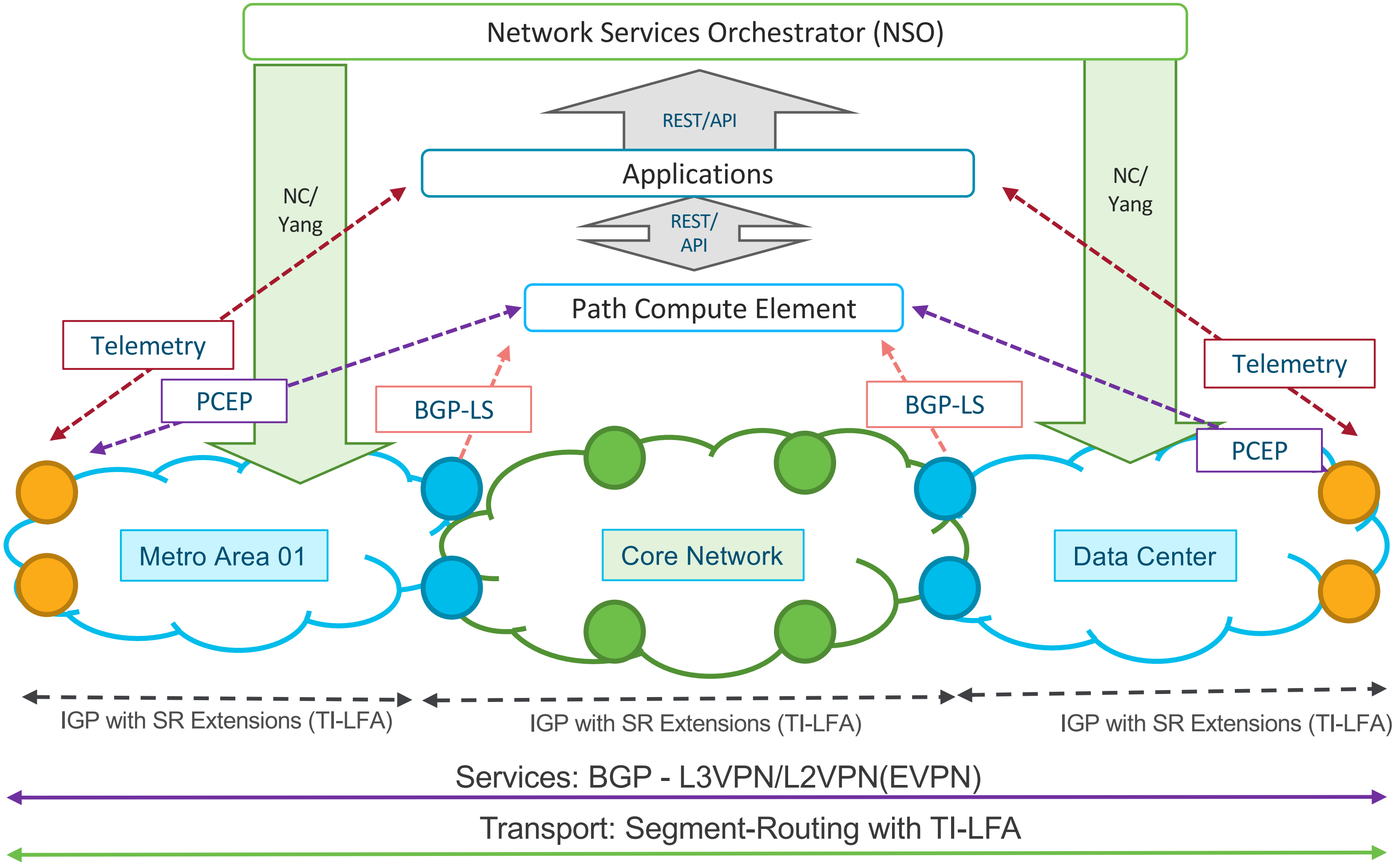
Recap: Intent Based Programmable Network Infrastructure


Network Services Orchestrator (NSO)
REST/API
Applications
REST/
API
Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Metro Area 01
Core Network
Data Center
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

☐ App. Driven N/W and Usecases

☐ Automation

☐ Data Collection & Analytics

✓ Device and Services Onboarding

✓ EVPN Based Services

✓ Controller Based Forwarding

✓ Segment Routing Transport

Achieving Operational Efficiency

Automated Onboarding

Services Orchestration

Monitoring and Analytics

Closed Loop Automation

You make multi-cloud **possible**

Pull vs Push Data Collection

Too slow

Not Adequate

For necessities only

SNMP

Syslogs

CLI Based Data Collection

Always available

Fast and convenient

Potential of flooding !!

Telemetry

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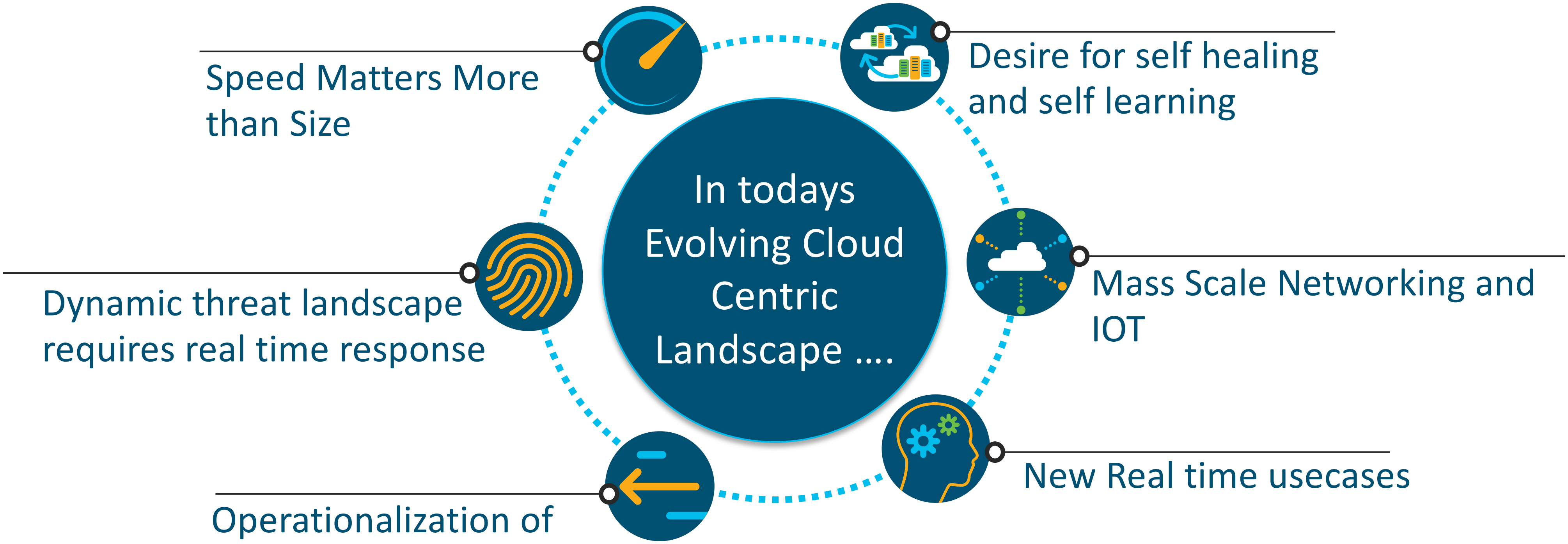
Why Network Visibility Matter Today?



In todays Evolving Cloud Centric Landscape ….

Speed Matters More than Size

Desire for self healing and self learning

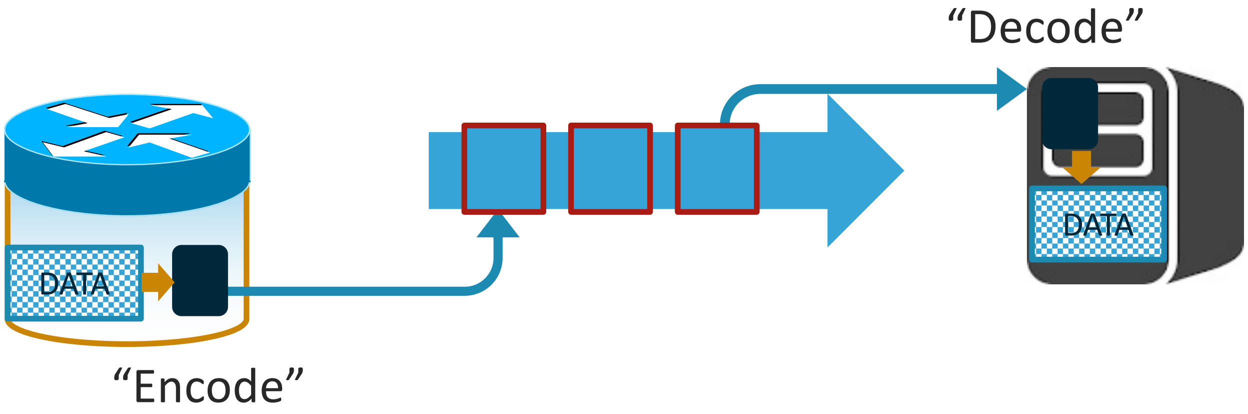
Dynamic threat landscape requires real time response

Mass Scale Networking and IOT

New Real time usecases

Operationalization of Steaming Data

Telemetry Basic Concept: Encoding



Common Text-Based Encodings

- JSON
- XML

Encoding: XML vs Telemetry

Traditional Networking Approach: XML

```
<interface-name>GigabitEthernet0/0/0/0</interface-name>
 <packets-received>13560392</packets-received>
 <bytes-received>1903082966</bytes-received>
 <packets-sent>2887148</packets-sent>
 <bytes-sent>2482103559</bytes-sent>
 <multicast-packets-received>0</multicast-packets-received>
 <broadcast-packets-received>63445</broadcast-packets-received>
 …
```

Telemetry: GPB

```
 1: GigabitEthernet0/0/0/0
50: 13560392
51: 1903082966
52: 2887148
53: 0
54: 63445
    …
```

Other options: self-describing GPB, JSON

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Telemetry Basic Concept: Encoding

GPB – Compact Encoding

```
1: GigabitEthernet0/0/0/0
50: 449825
51: 41624083
52: 360333
53: 29699362
54: 91299
   <snip>
```

GPB – Self Describing Encoding

```
{InterfaceName: GigabitEthernet0/0/0/0
     GenericCounters {
       PacketsSent: 449825
       BytesSent: 41624083
       PacketsReceived: 360333
       BytesReceived: 29699362
       MulticastPacketsReceived: 91299
       <snip>
```

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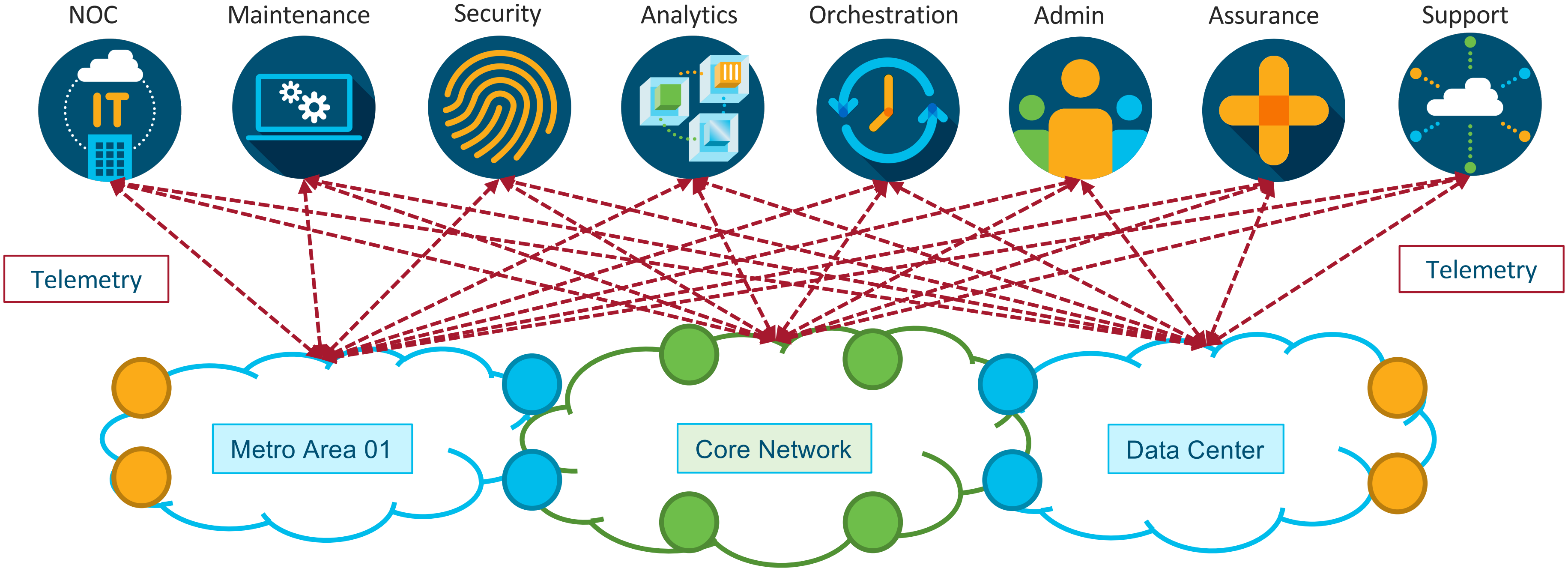
With Power comes Responsibility !!!!



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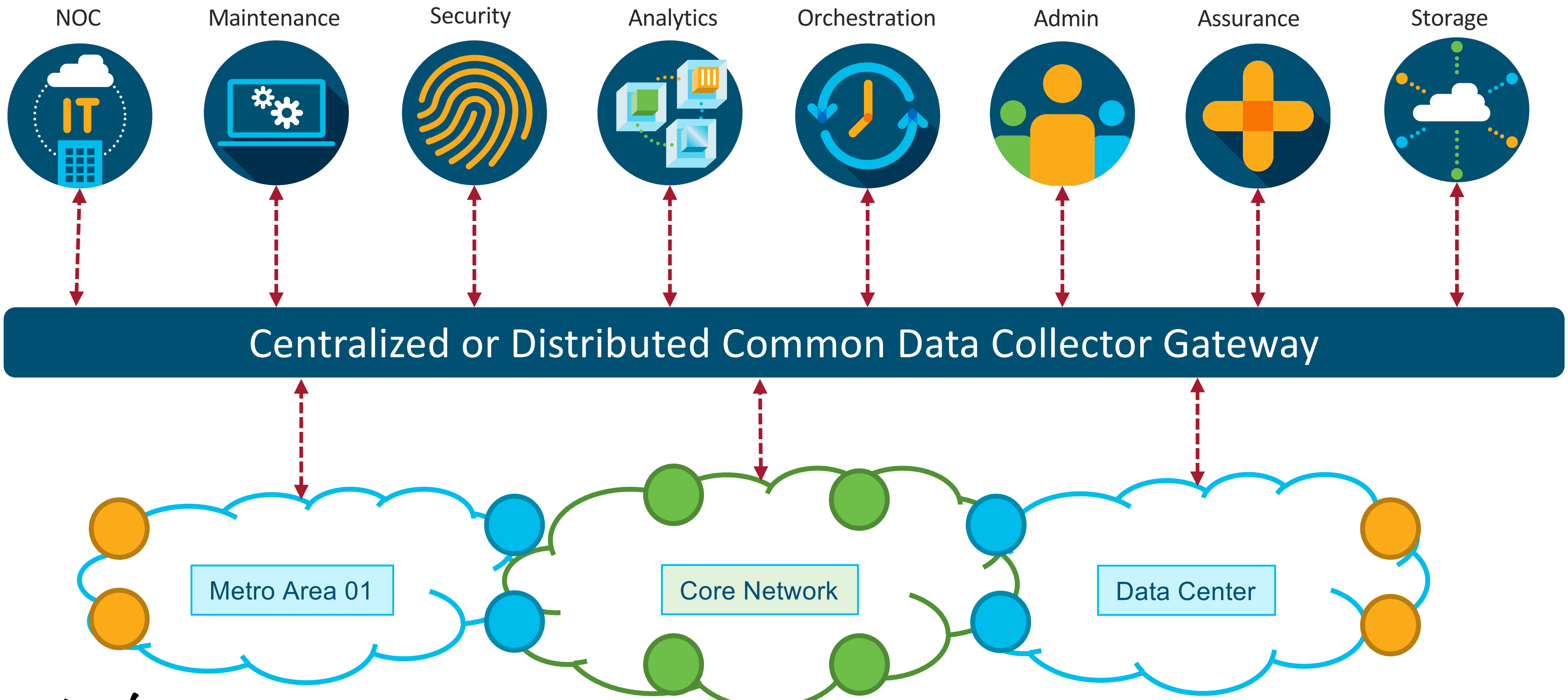
Data Collection Architecture for Efficiency!!!



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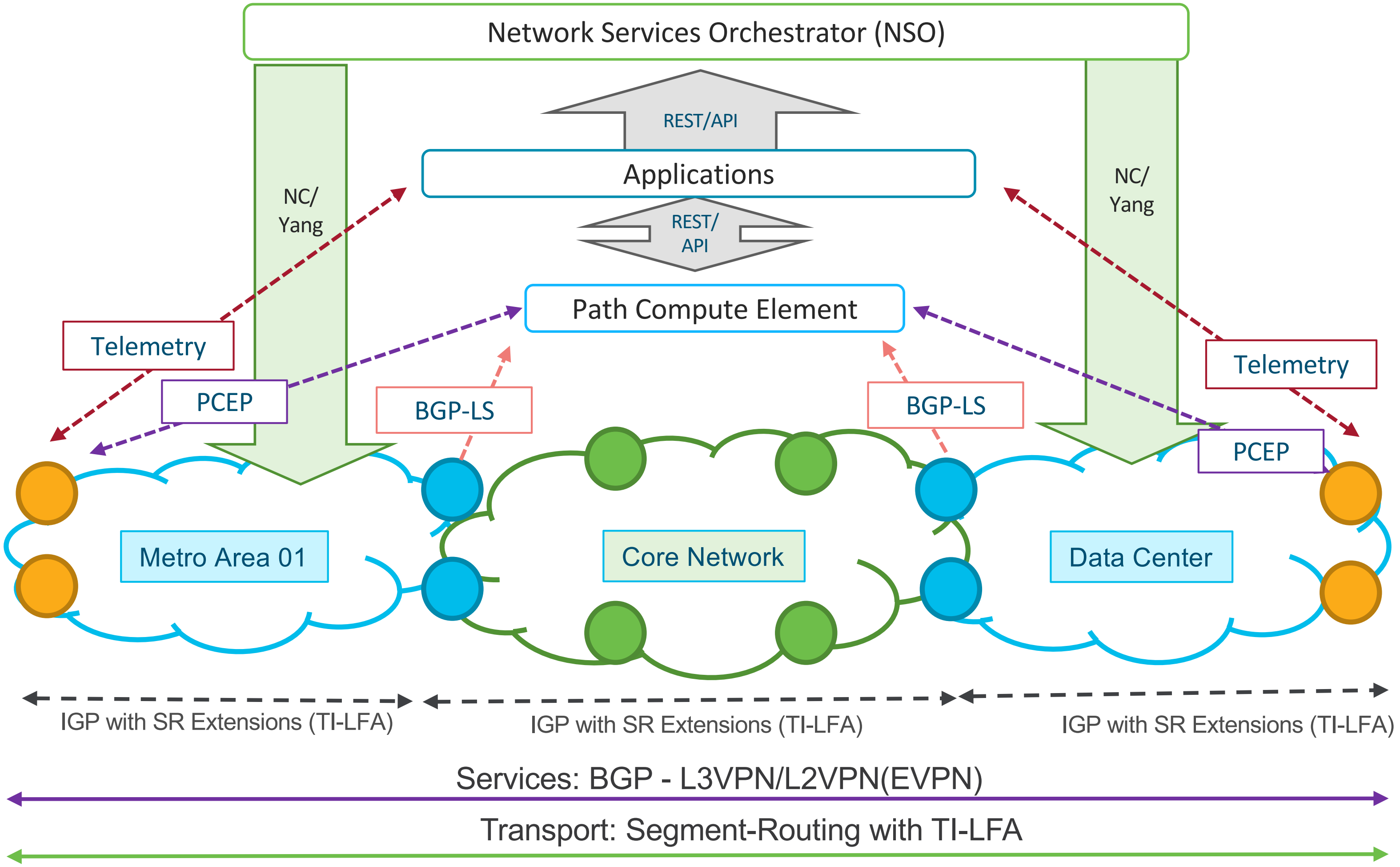
Recap: Programmable Network Infrastructure


Network Services Orchestrator (NSO)
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Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
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IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
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Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

- ☐ App. Driven N/W and Usecases
- ☐ Automation
- ☑ Data Collection & Analytics
- ☑ Device and Services Onboarding
- ☑ EVPN Based Services
- ☑ Controller Based Forwarding
- ☑ Segment Routing Transport

Achieving Operational Efficiency

Automated Onboarding

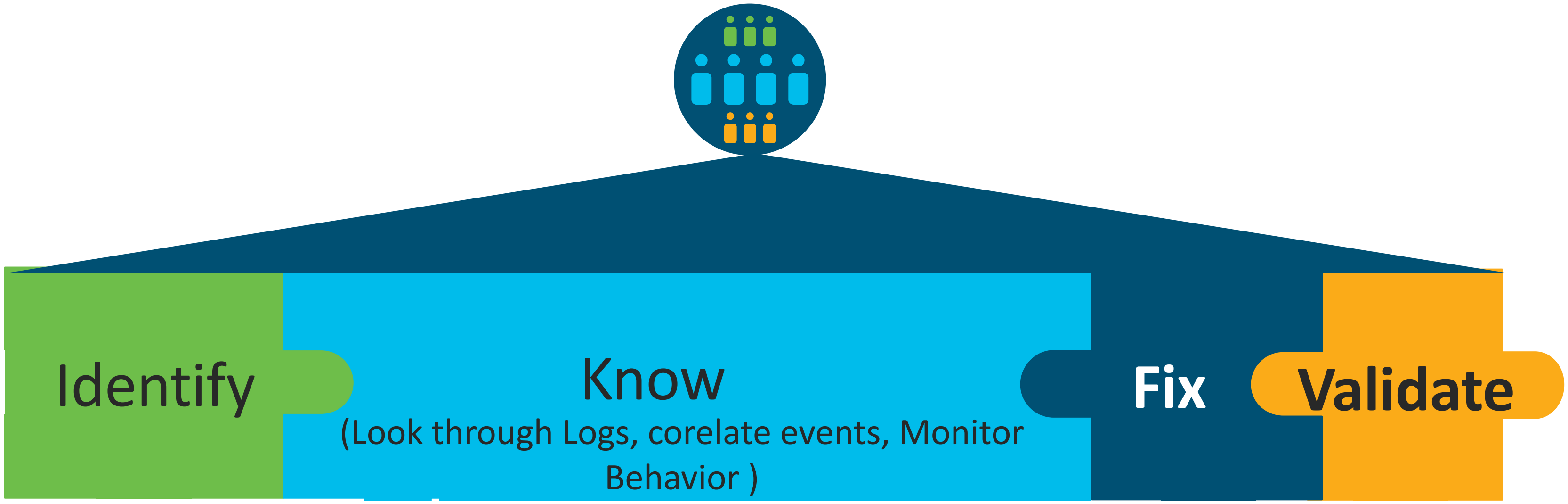
Services Orchestration

Monitoring and Analytics

Closed Loop Automation

You make multi-cloud **possible**

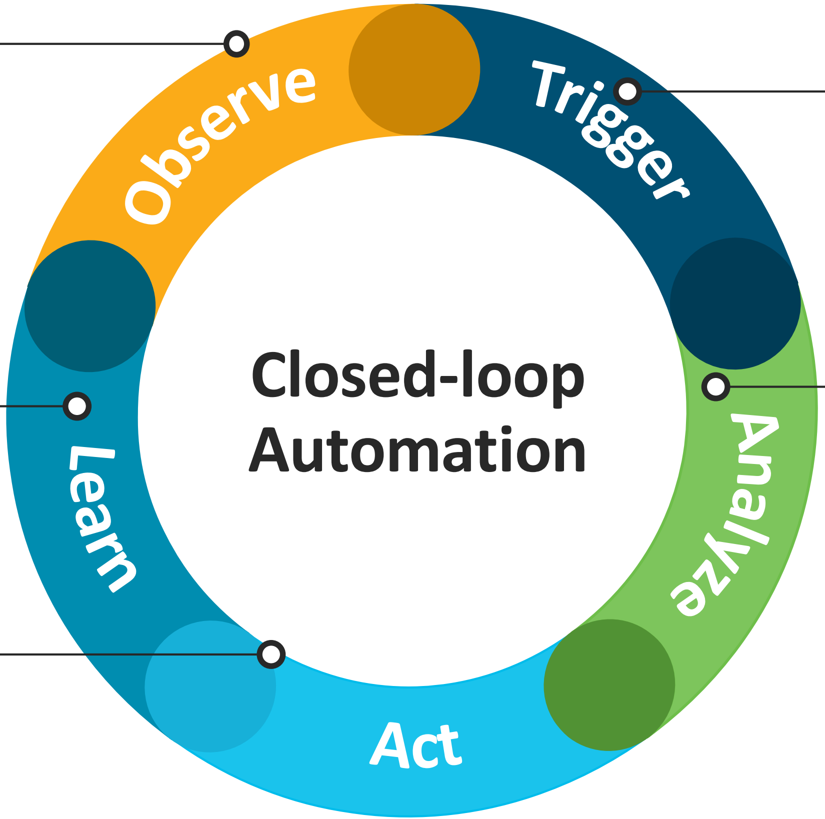
Problem Resolution Life Cycle



Do you know upto 100% of this could be Automated? *

http://cs.co/BRKSPG-2810

Closed Loop Automation Basics



Observe

Anomaly Observed e.g.

- E2E Latency Change
- Excessive Interface flaps
- High resource utilization

Trigger and Notify

BGL-LS update

Streaming telemetry

Analyze

Corrective action need analysis

Path Precomputation

Interface Isolation

Add new resources

Learn

Update KPI’s

Human or Machine Learning

Take Action

Auto Remediation

- Push New SR Policy /Recompute path
- Shutdown interface or Spin up new VM

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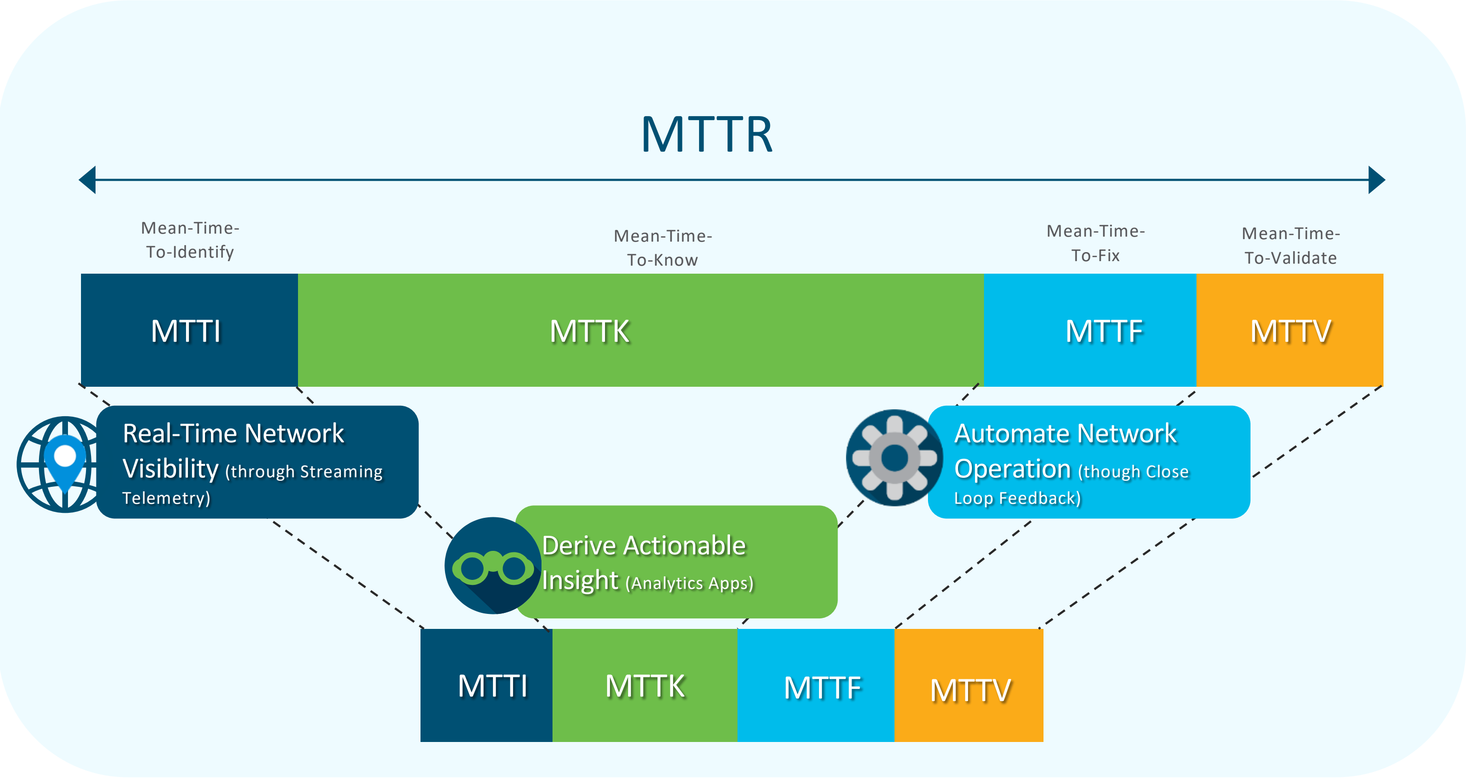
Analytics and Automation enable MTTR Reduction


MTTR
Mean-Time-To-Identify
Mean-Time-To-Know
Mean-Time-To-Fix
Mean-Time-To-Validate
MTTI
MTTK
MTTF
MTTV
Real-Time Network Visibility (through Streaming Telemetry)
Derive Actionable Insight (Analytics Apps)
Automate Network Operation (though Close Loop Feedback)
MTTI
MTTK
MTTF
MTTV

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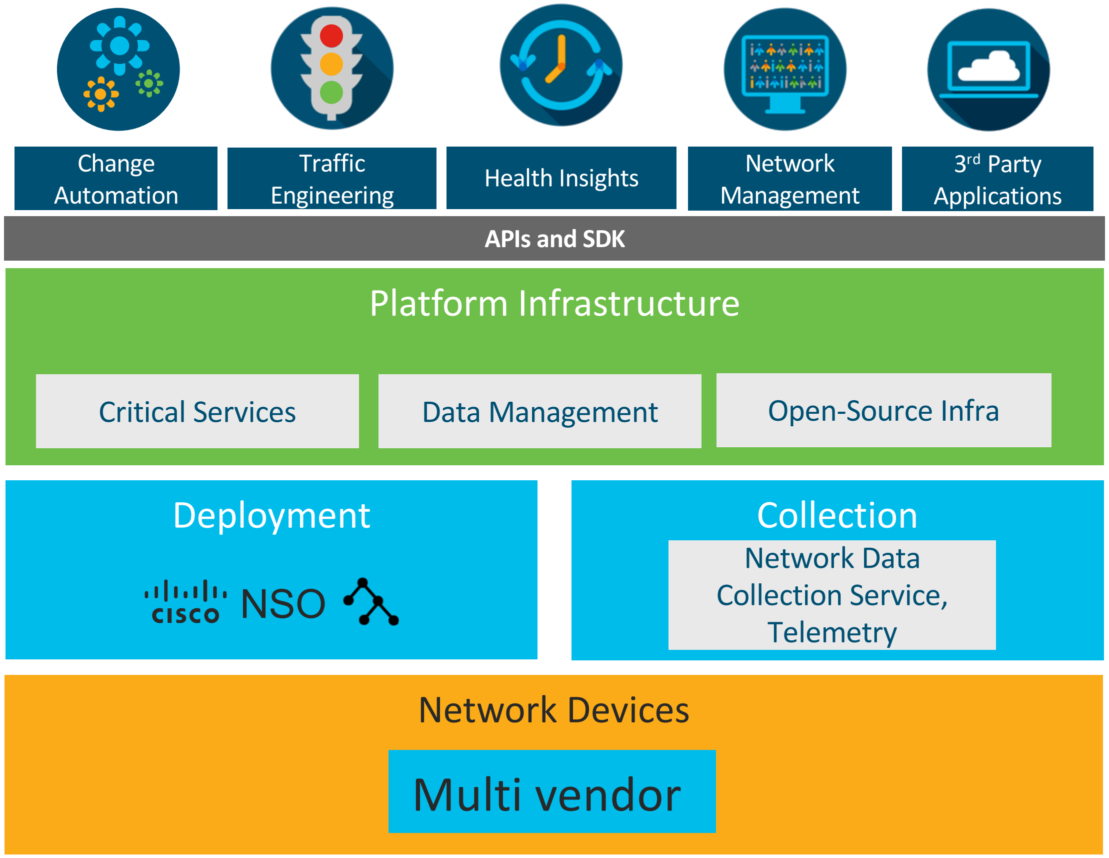
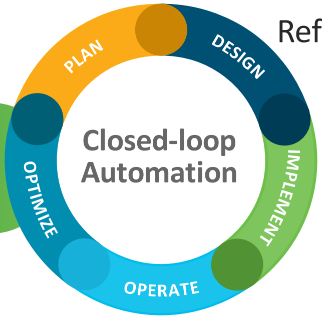
Building Blocks to Operational Automation



Cisco brings network expertise to provide solution integration and support

Cisco SP Network Automation
Exploring the Solutions

Reference



Crosswork Network Automation

The first closed-loop, mass scale automation solution that embraces multi-vendor networks

Change Automation Application that creates extensible device workflows to reduce human error

Health Insights Uses smart monitors to capture device health and change network behavior

Network Insights SaaS Cloud based analytics platform focused on network insights

Situation Manager Event correlation tool that leverages social troubleshooting to reduce MTTR

Common Collector Unified data collection and secured distribution

Cisco NSO **Cisco WAE** **Cisco EPN-M**

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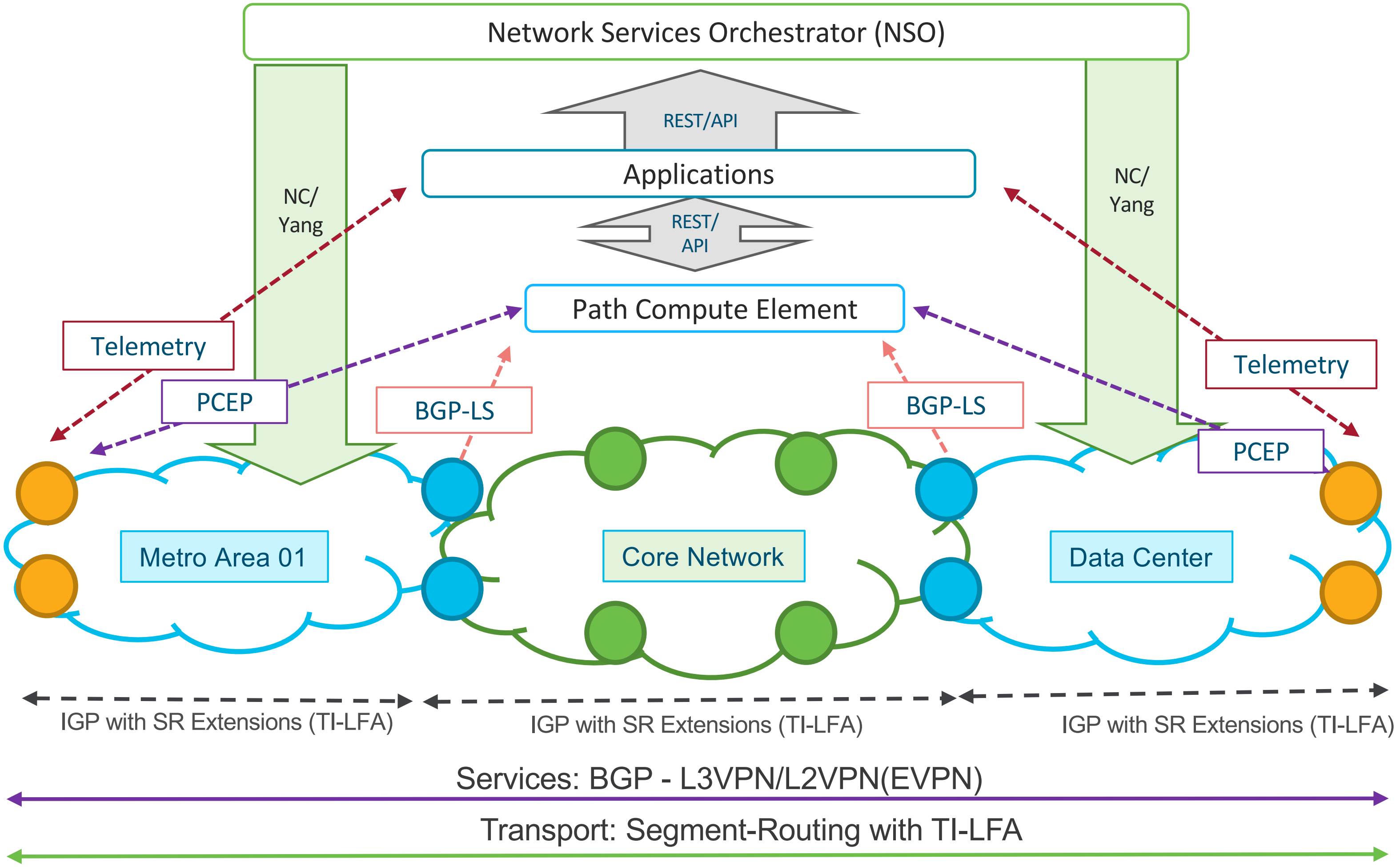
Application Driven Networks and Operational Usecases

You make customer experience **possible**

Intent based Programmable Networks

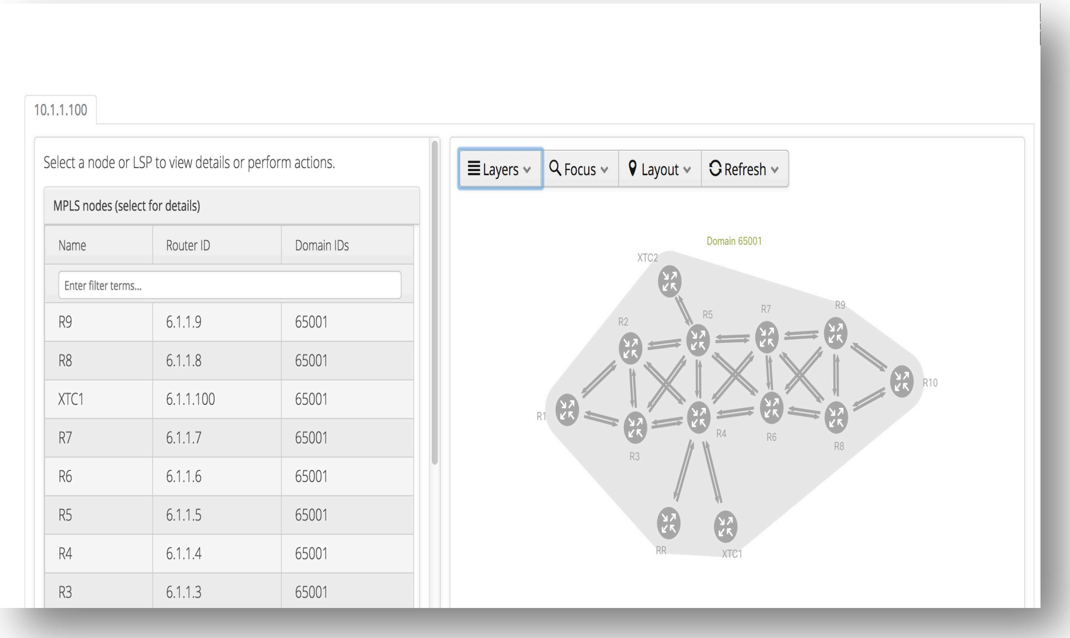

Network Services Orchestrator (NSO)
REST/API
Applications
REST/
API
Path Compute Element
NC/
Yang
NC/
Yang
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Metro Area 01
Core Network
Data Center
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

- ☐ App. Driven N/W and Usecases
- ✓ Automation
- ✓ Data Collection & Analytics
- ✓ Device and Services Onboarding
- ✓ EVPN Based Services
- ✓ Controller Based Forwarding
- ✓ Segment Routing Transport

Intent Based Network Use Cases –

Example1: Centralized Control and Visualization for End-to-End Path

- SR-PCE has full topology and LSP information
- SR-PCE enables REST on its NBI
- External Application gather topology and LSP data from SR-PCE



Select a node or LSP to view details or perform actions.

MPLS nodes (select for details)

Name	Router ID	Domain IDs
Enter filter terms...		
R9	6.1.1.9	65001
R8	6.1.1.8	65001
XTC1	6.1.1.100	65001
R7	6.1.1.7	65001
R6	6.1.1.6	65001
R5	6.1.1.5	65001
R4	6.1.1.4	65001
R3	6.1.1.3	65001

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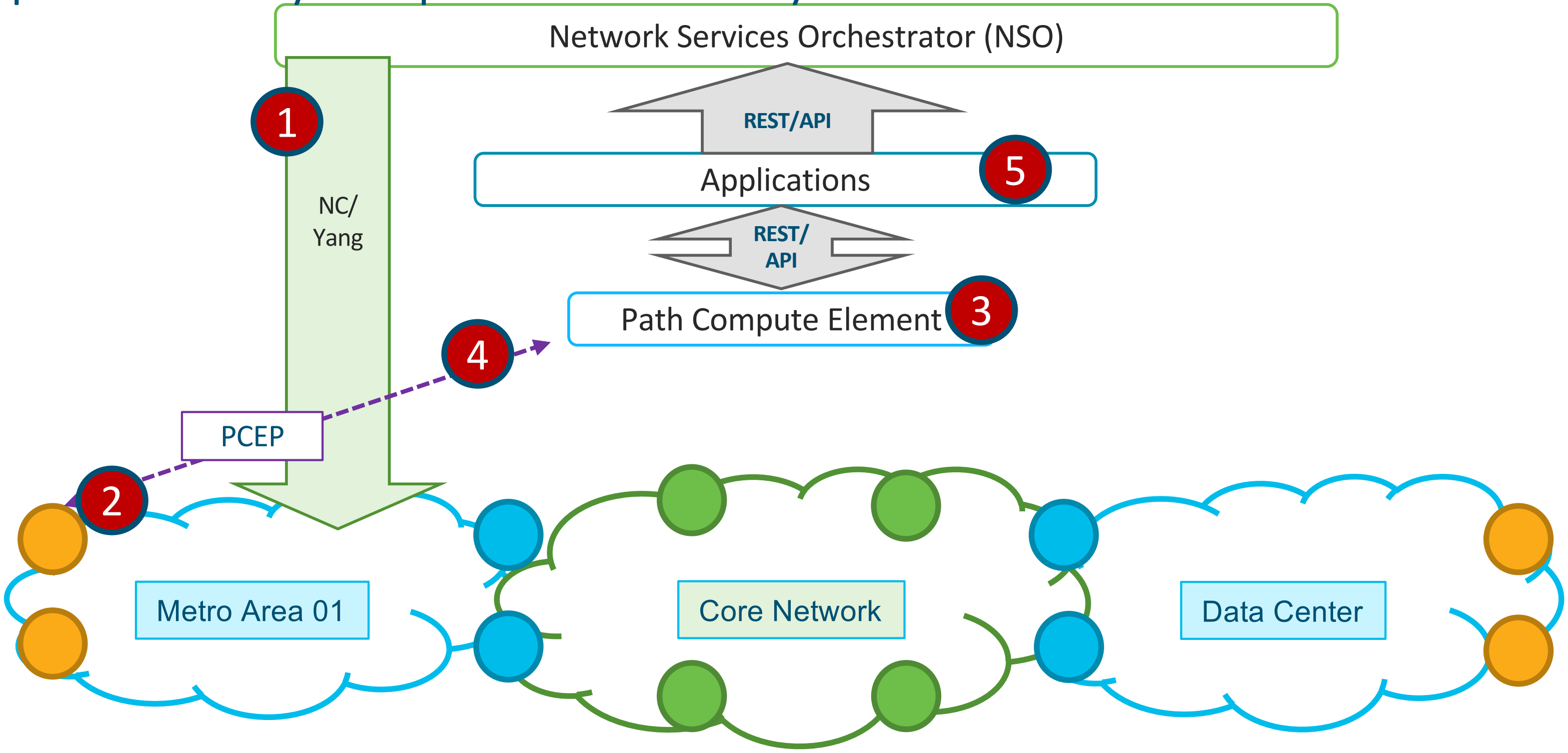
Intent Based Network Use Cases –

Example2: Centrally Computed Low Latency SRTE



1. Provision Low Latency Service

2. Request LSP Computation

3. Perform Computation

4. Send Computed LSP

5. Applications Updated with new LSP

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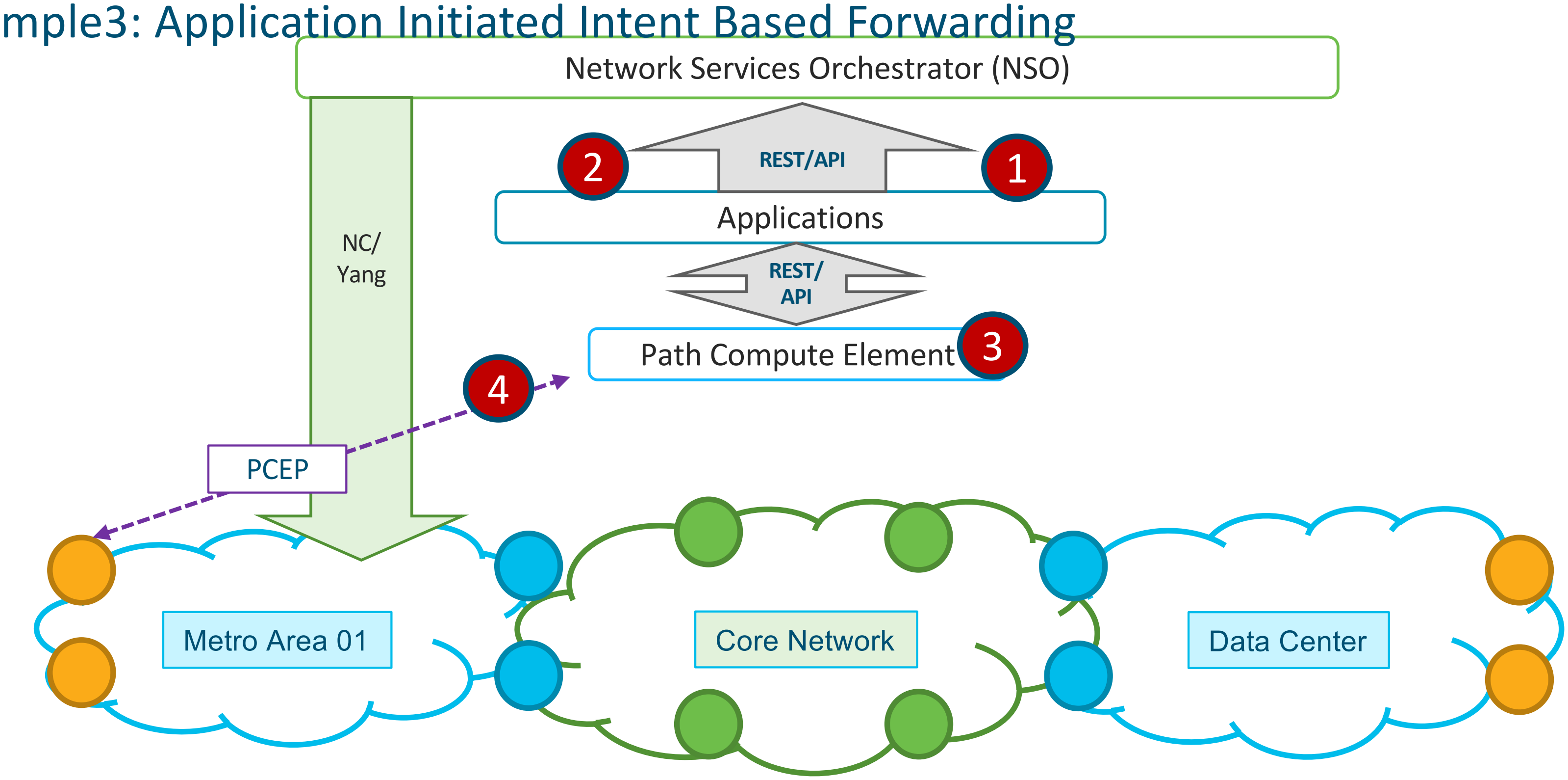
Intent Based Network Use Cases –

Example3: Application Initiated Intent Based Forwarding



1. Application Determines need for an intent based path

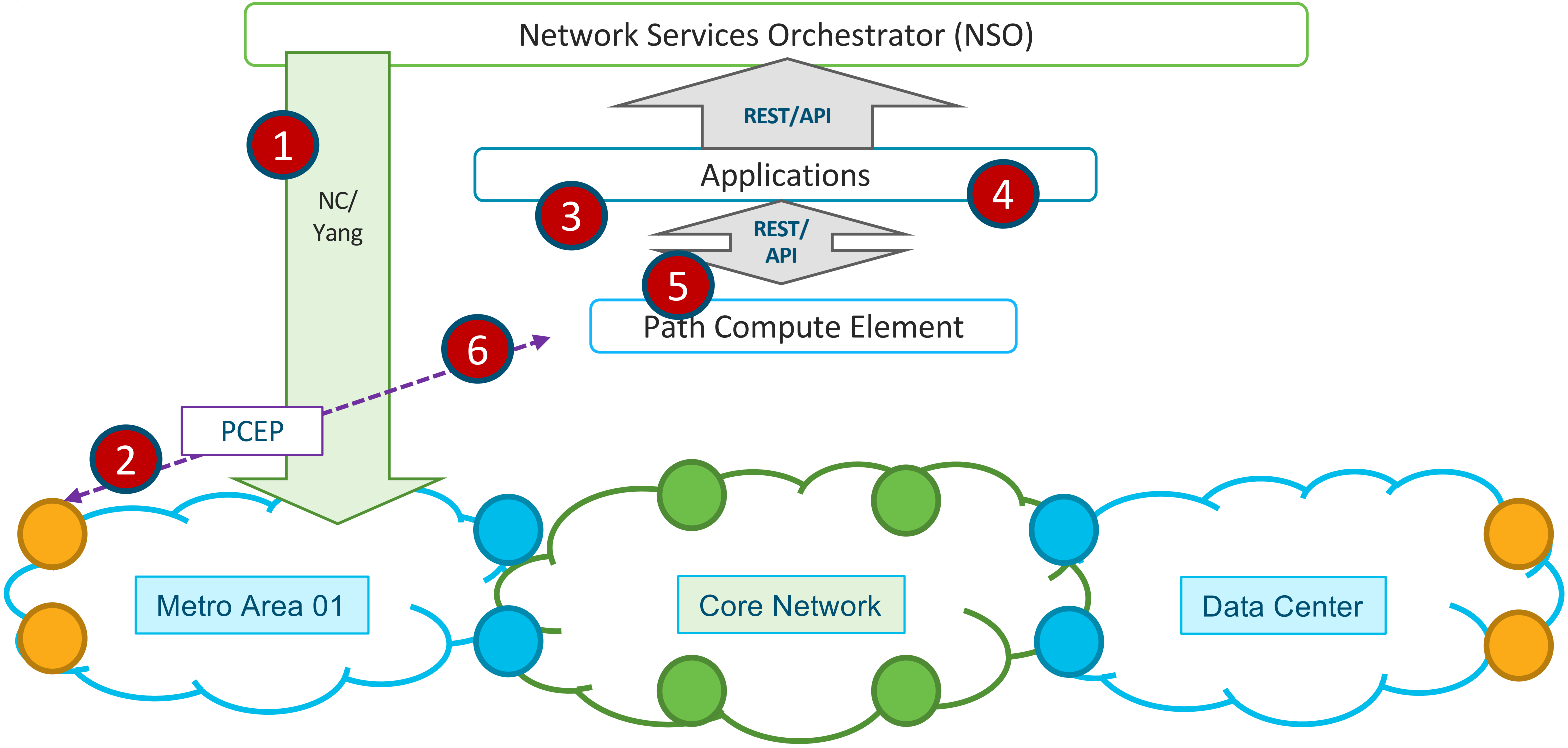
2. Application Computes new LSP

3. Application Instructs SR PCE to initiate an LSP

4. Intent based policy is pushed to Headend

Intent Based Network Use Cases

Example4: Bandwidth Guarantee Intent



1. New Service Requests BW

2. LSP Computation Requested

3. Computation Delegated to Application

4. LSP Path Computed

5. LSP Path pushed to SR PCE

6. LSP Path with BW allocated sent to Headend

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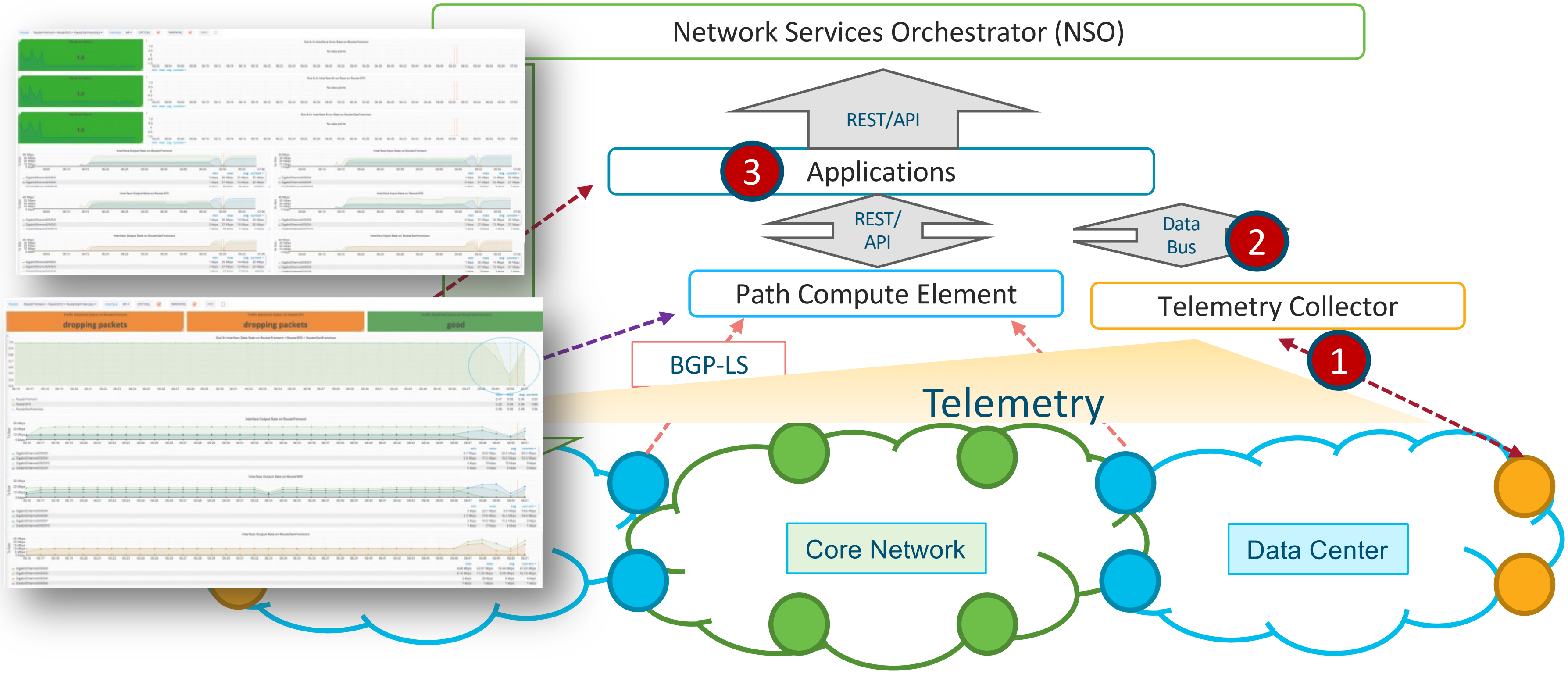
Intent Based Network Use Cases –

Example5: Network Health Monitoring



1. Network Telemetry Data (Model/Event)

2. Published on Data Bus for Subscribers

3. Applications Collect Data and Analyze

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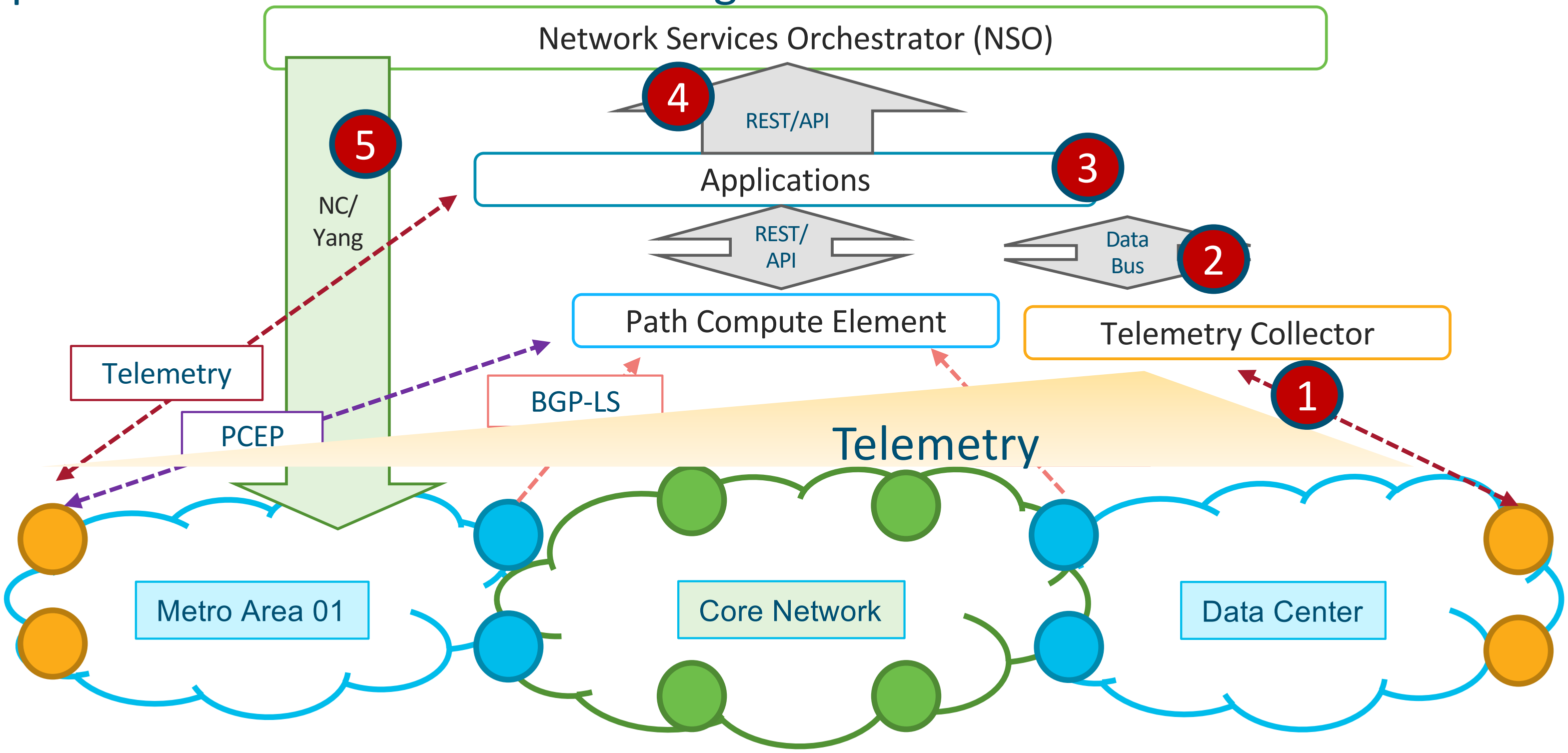
Intent Based Network Use Cases

Example6: Remediation and Self Healing



1. Network Telemetry Data (Model/Event)

2. Published on Data Bus for Subscribers

3. Application Analyze Collect Data, find Congestion

4. Applications Takes Corrective Decision, advices NSO

5. NSO provisions new policy to move priority traffic off congested path

Intent based Network Use Cases - Recap

	Doesn’t require Centralized Control	May Also Be Done on PCE	Require Applications
Shortest Path	✓	✓	
Low Latency Path	✓	✓	
DisJoint Path	✓	✓	
Link/Node Avoidance	✓	✓	
Bandwidth Optimization			✓
Bandwidth On-Demand			✓
Health Insight and Remediation			✓

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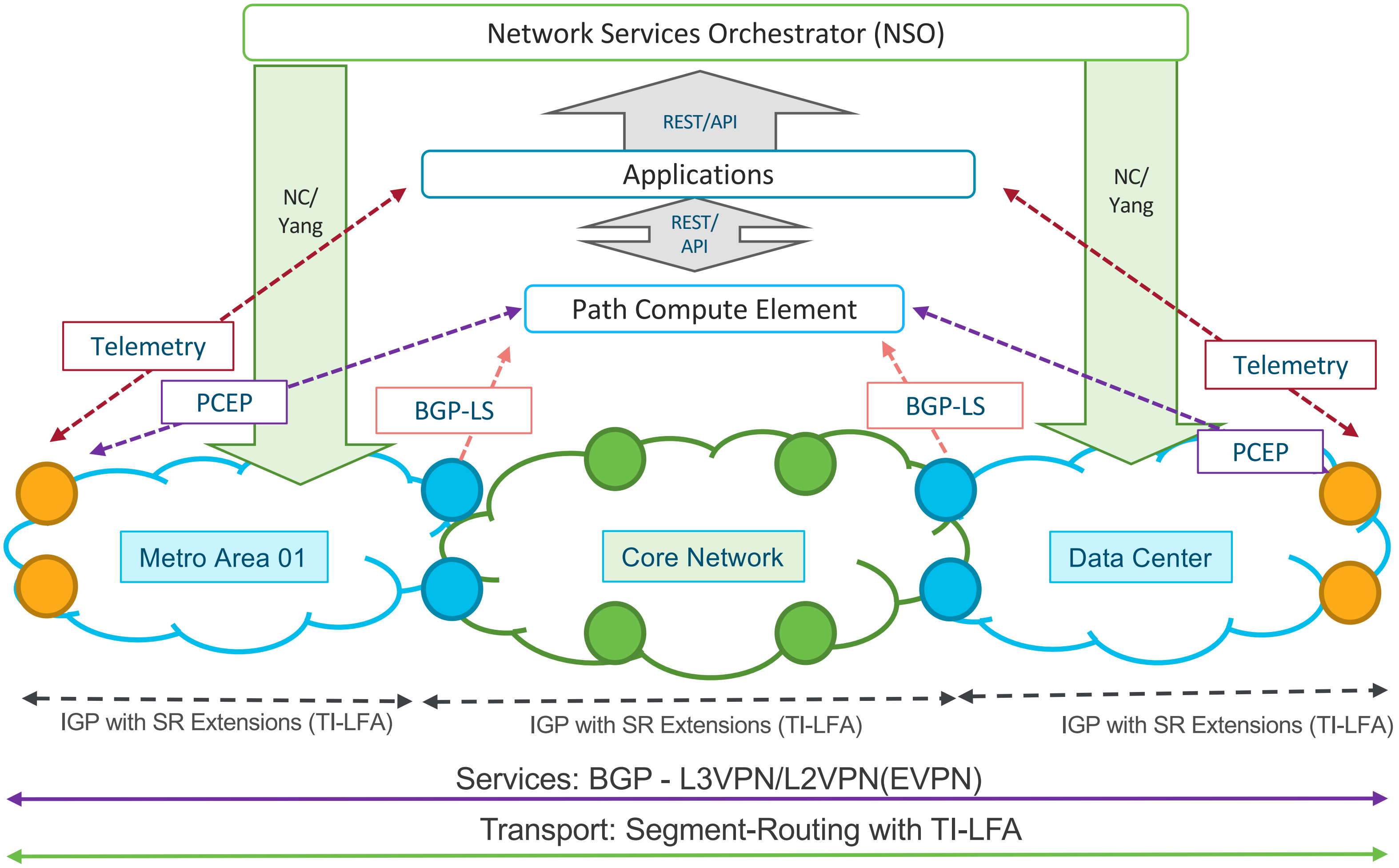
Intent based Programmable Networks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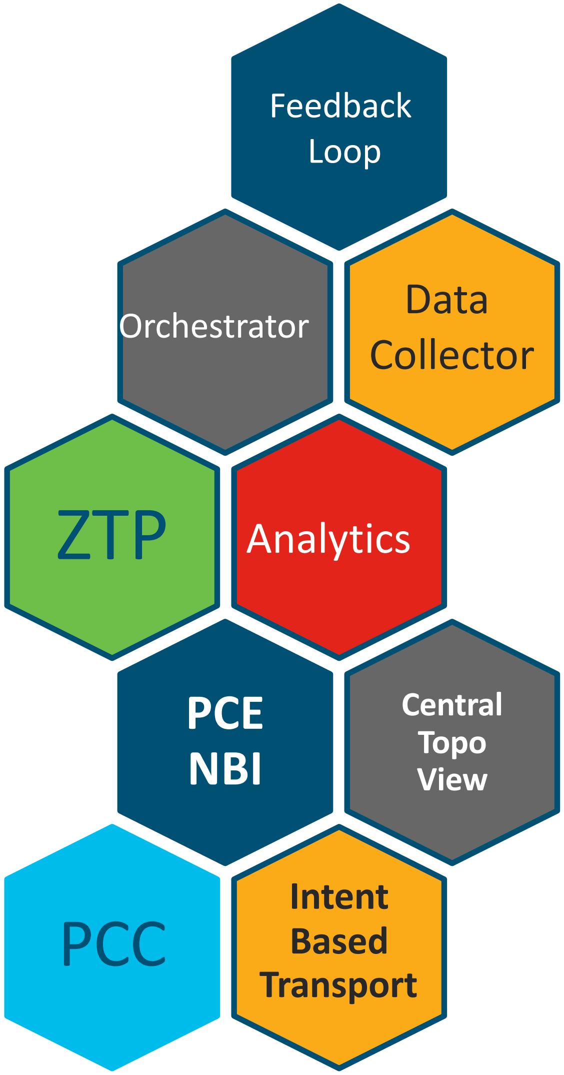
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

A Recipe For Transport SDN

- Network Simplification and intent based transport paves the way
- Individual components for a “Transport SDN” architecture widely available
- Integration between various software components in key
- Applications interact with and actively drive Transport Network



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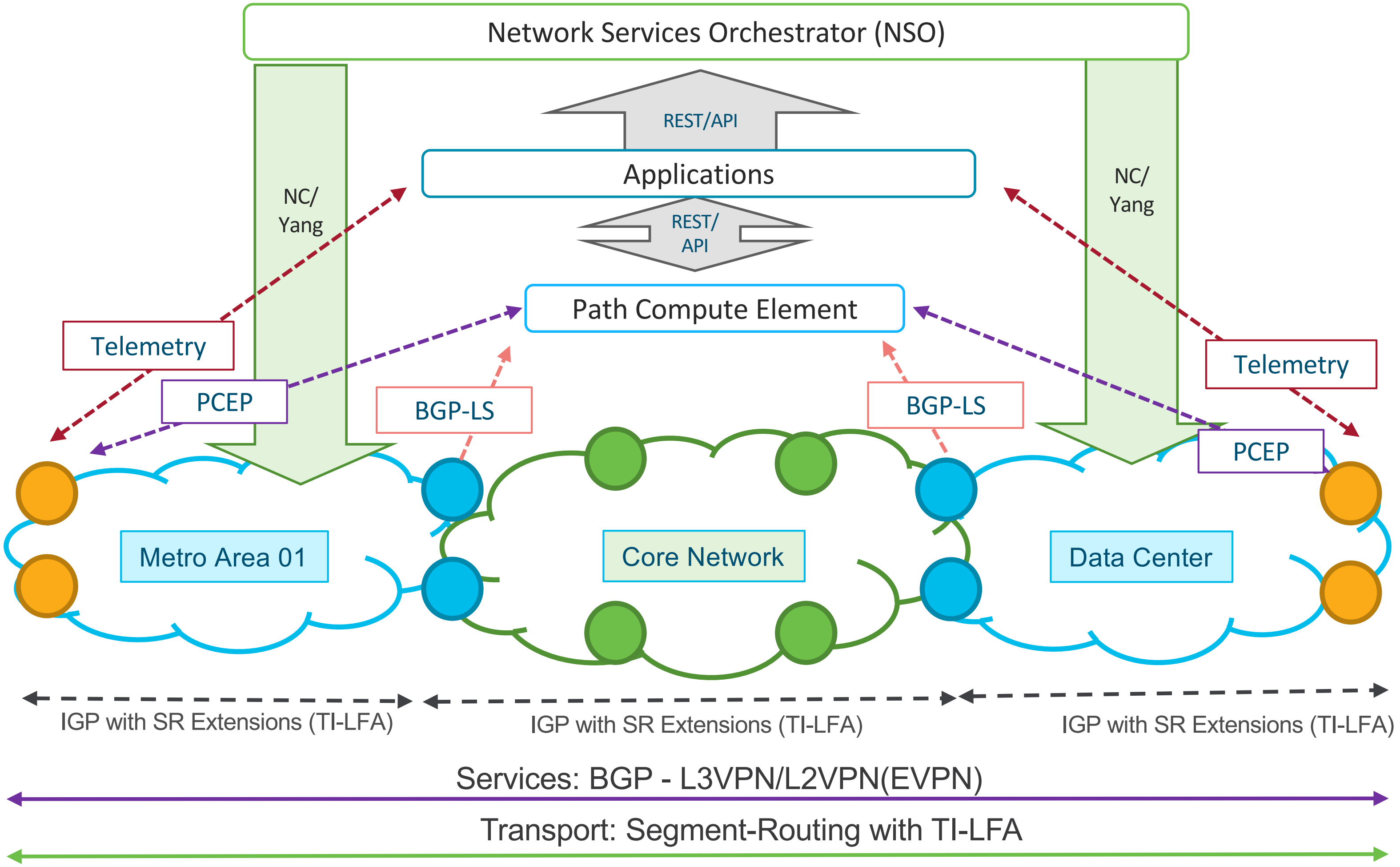
In Conclusion

You make security **possible**

Intent Based Transport SDN Networks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- Complete a minimum of 4 session surveys and the Overall Conference survey (starting on Thursday) to receive your Cisco Live water bottle.
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SPG Sessions Monday, Tuesday

ID	Date	Time	Title	Session type	Catalog Link
			Monday Sessions		
BRKSPG-3001	Monday, June 10, 2019	08:00 AM	Introduction to SRv6 technology	Breakout	http://cs.co/BRKSPG-3001
BRKSPG-2003	Monday, June 10, 2019	08:30 AM	Internet Peering Concepts and Emerging Trends	Breakout	http://cs.co/BRKSPG-2017
BRKSPG-2602	Monday, June 10, 2019	01:00 PM	IPv4 Exhaustion: NAT and Transition to IPv6 for Service Providers	Breakout	http://cs.co/BRKSPG-2602
LTRSPG-2100	Monday, June 10, 2019	01:00 PM	Deploying Intent Based Programmable Network Infrastructure - A Hands-On Lab	Instructor-Led Lab	http://cs.co/LTRSPG-2100
BRKSPG-2017	Monday, June 10, 2019	04:00 PM	SD-WAN in Service Provider networks	Breakout	http://cs.co/BRKSPG-2017
BRKSPG-1000	Monday, June 10, 2019	04:00 PM	Network Transformation and Essential Skills for Next Generation Network Engineers	Breakout	http://cs.co/BRKSPG-1000
			Tuesday Sessions		
LTRSPG-2968	Tuesday, June 11, 2019	08:00 AM	IOS-XR EVPN Hands-On Lab	Instructor-Led Lab	http://cs.co/LTRSPG-2968
BRKSPG-3002	Tuesday, June 11, 2019	08:00 AM	Service Provider Network Fabric: How to bring Access Services using EVPN.	Breakout	http://cs.co/BRKSPG-3002
BRKSPG-2724	Tuesday, June 11, 2019	01:00 PM	Network Function Virtualization (NFV) using IOS-XR	Breakout	http://cs.co/BRKSPG-2724
BRKSPG-2518	Tuesday, June 11, 2019	01:00 PM	Service Provider Programmable Intent-Based Networking, Powered by Segment Routing and EVPN	Breakout	http://cs.co/BRKSPG-2518
LTRSPG-2414	Tuesday, June 11, 2019	01:00 PM	IOS-XR hands-on lab. End-to-end story.	Instructor-Led Lab	http://cs.co/LTRSPG-2414
BRKSPG-2535	Tuesday, June 11, 2019	04:00 PM	Next Generation SP Network Architectures: A Practical Path to Network Transformation	Breakout	http://cs.co/BRKSPG-2535
BRKSPG-2069	Tuesday, June 11, 2019	04:00 PM	Introduction to the Next Generation IOS-XR architecture	Breakout	http://cs.co/BRKSPG-2069

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SPG Sessions Wednesday and Thursday

ID	Date	Time	Title	Session type	Catalog Link
Wednesday Sessions					
BRKSPG-2698	Wednesday, June 12, 2019	08:00 AM	Disaggregating Network Devices and Software : A reality check !	Breakout	http://cs.co/BRKSPG-2698
BRKSPG-2810	Wednesday, June 12, 2019	08:00 AM	Next Generation Large Scale network management using analytics, machine learning and automation	Breakout	http://cs.co/BRKSPG-2810
BRKSPG-3965	Wednesday, June 12, 2019	08:00 AM	EVPN Deep Dive and Troubleshooting with IOS-XR Configuration examples for Service Provider Metro and Data Center	Breakout	http://cs.co/BRKSPG-3965
BRKSPG-2013	Wednesday, June 12, 2019	01:00 PM	Brave New World: Web Scale Network Automation goes Mainstream	Breakout	http://cs.co/BRKSPG-2013
BRKSPG-2014	Wednesday, June 12, 2019	01:00 PM	Path to an SDN Ready Infrastructure: Segment Routing and EVPN Migration Strategies and Usecases	Breakout	http://cs.co/BRKSPG-2014
BRKSPG-2015	Wednesday, June 12, 2019	01:00 PM	Carrier Grade Disaggregation with IOS XR	Breakout	http://cs.co/BRKSPG-2015
Thursday Sessions					
LTRSPG-2601	Thursday, June 13, 2019	08:00 AM	Cisco IOS XR Programmability	Instructor-Led Lab	http://cs.co/LTRSPG-2601
BRKSPG-2011	Thursday, June 13, 2019	08:00 AM	5G Timing & Sychnronization Architecture	Breakout	http://cs.co/BRKSPG-2011
BRKSPG-2159	Thursday, June 13, 2019	10:30 AM	Deploying Next Generation SP Access Networks with the NCS540/NCS560 Platforms	Breakout	http://cs.co/BRKSPG-2159
BRKSPG-2345	Thursday, June 13, 2019	01:00 PM	Automation at scale with Business Process Automation (BPA)	Breakout	http://cs.co/BRKSPG-2345
BRKSPG-2503	Thursday, June 13, 2019	01:00 PM	Advanced Topics in Cisco OS Telemetry	Breakout	http://cs.co/BRKSPG-2503

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Session ID	Title
LABSPG-1020	MPLS Segment Routing Introduction
LABSPG-1327	Introduction to Segment Routing v6 (SRv6) with IOS-XR
LABSPG-2000	Network Slicing with Segment Routing Flex-Algorithm for 5G and other Applications
LABSPG-2001	Intent Based Networking using Segment Routing Traffic Engineering
LABSPG-2068	Configure and Implement BGP-EVPN with Segment Routing using IOS-XR
LabSPG-2109	Ethernet VPN (EVPN) Implementation and Troubleshooting

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