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Next-Gen SD-WAN (Viptela)

Design, Deployment and Best Practices

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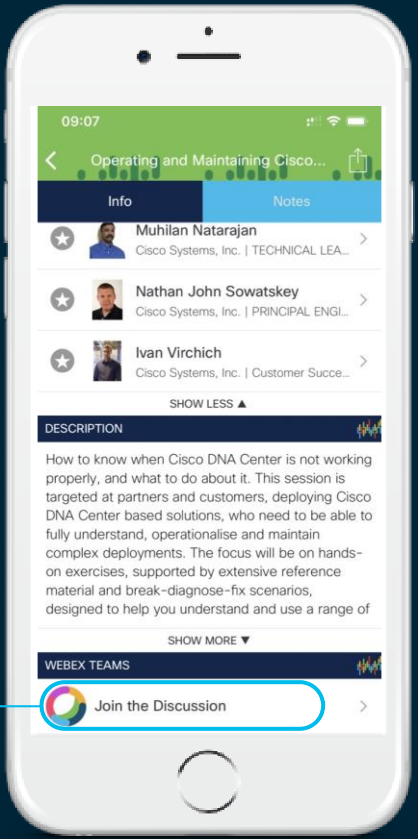

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Operating and Maintaining Cisco...

Info | Notes

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DESCRIPTION

How to know when Cisco DNA Center is not working properly, and what to do about it. This session is targeted at partners and customers, deploying Cisco DNA Center based solutions, who need to be able to fully understand, operationalise and maintain complex deployments. The focus will be on hands-on exercises, supported by extensive reference material and break-diagnose-fix scenarios, designed to help you understand and use a range of

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WEBEX TEAMS

Join the Discussion

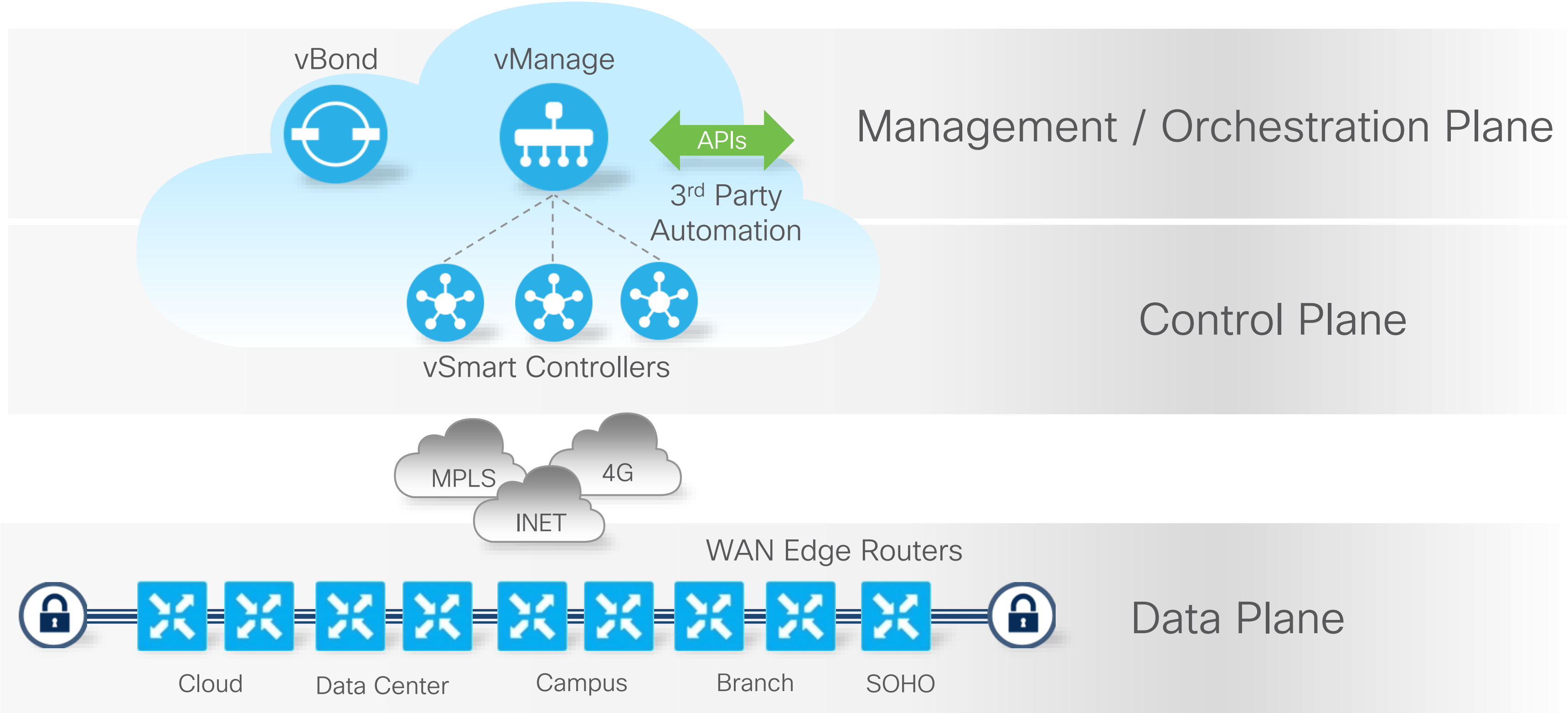
Agenda

- Introduction and Cisco SD-WAN Architecture Review
- SD-WAN Controller Deployment
- SD-WAN Control Plane and Design
- SD-WAN Data Plane and Design
- Policy Framework Introduction
- Overlay Network Design and Services
- Site Design
- Recommended Settings and Operational Best Practices

Cisco SD-WAN – Architecture Review

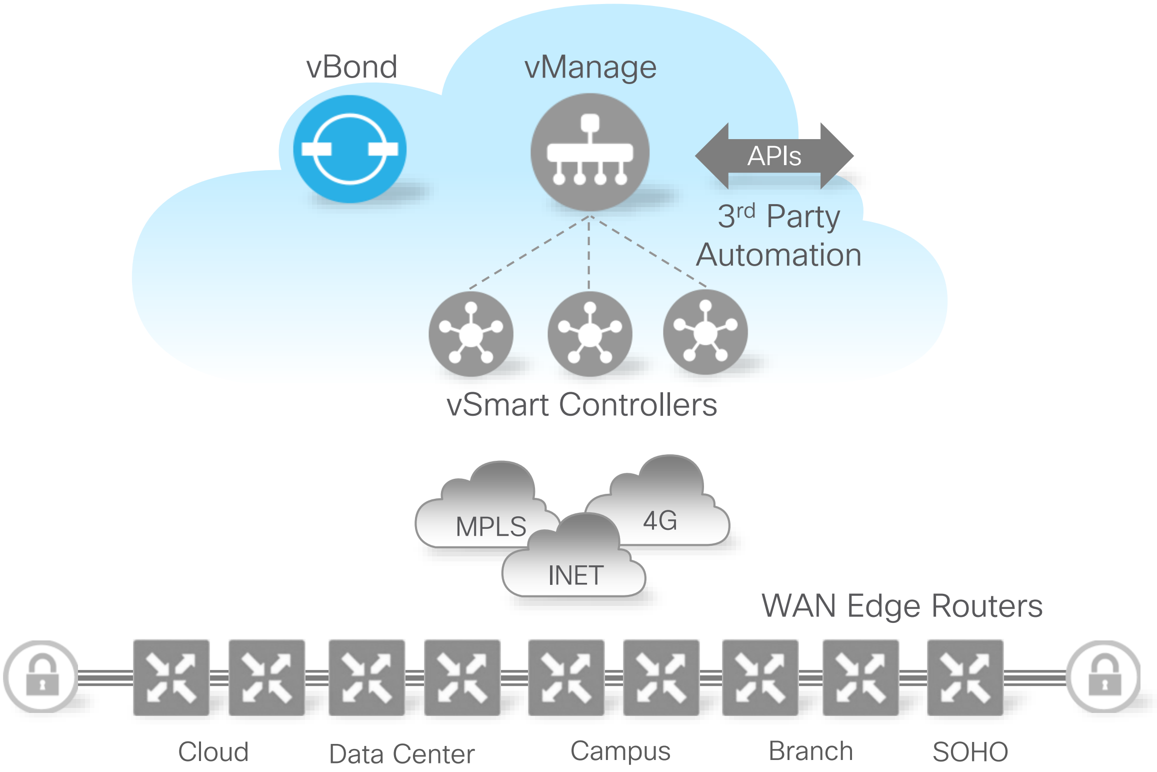
Cisco SD-WAN Architecture Overview

Applying SDN Principles Onto The Wide Area Network



Cisco SD-WAN Architecture Overview

Orchestration Plane - vBond

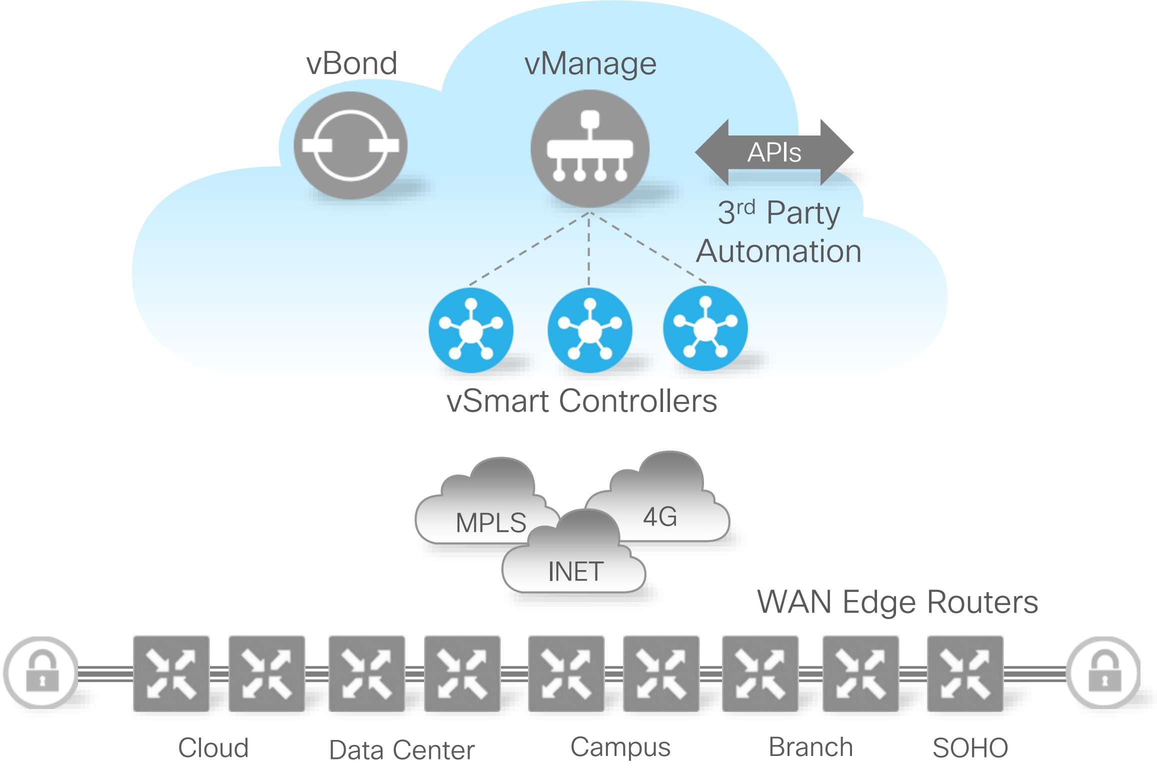


Characteristics

- Orchestrates control and management plane
- First point of authentication
- Distributes list of vSmarts/ vManage to WAN Edge routers
- Facilitates NAT traversal
- Requires universally reachable IP-Address/Port [Can reside behind Port-Forwarding]
- Independent and resilient layer
- Multitenant or single tenant

Cisco SD-WAN Architecture Overview

Control Plane - vSmart

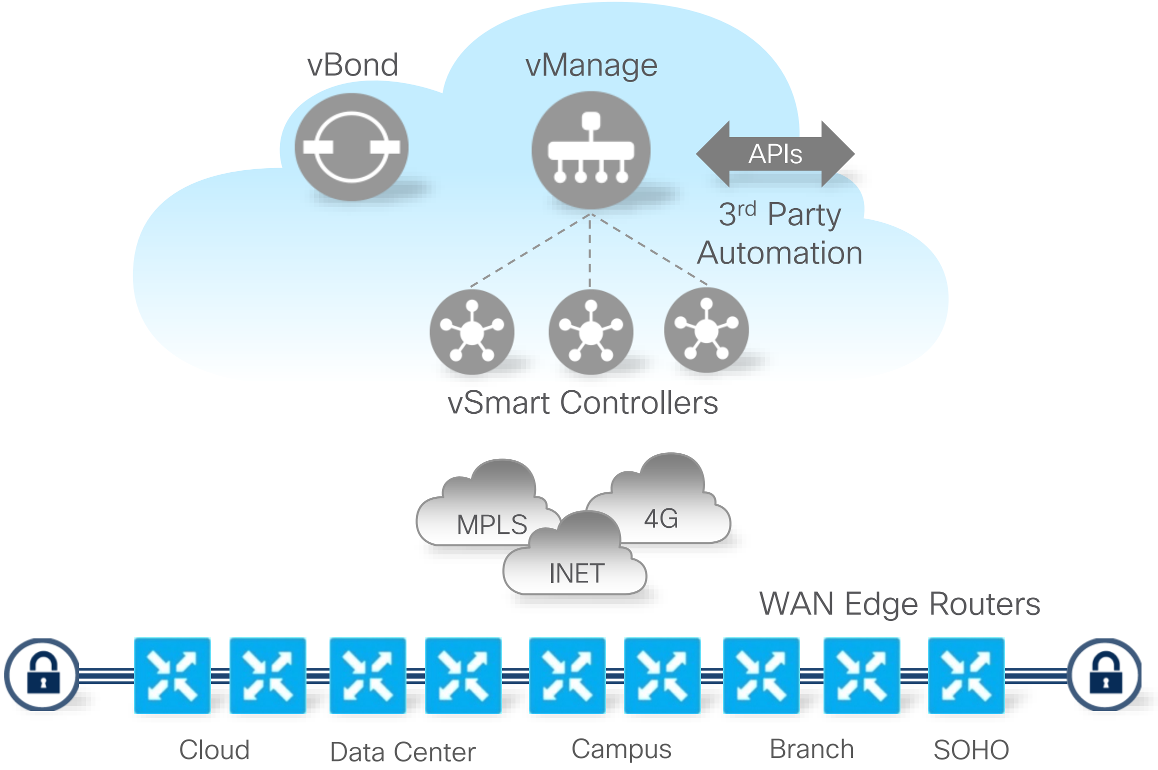


Characteristics

- Runs the Overlay Management Protocol (OMP)
- Facilitates fabric discovery
- Disseminates control plane information between Edges
- Distributes Data and App-Aware Routing policies to WAN Edge routers
- Implements control plane policies
- Enables simple and scalable hub-and-spoke control plane
- Independent and resilient layer

Cisco SD-WAN Architecture Overview

Data Plane - WAN Edge

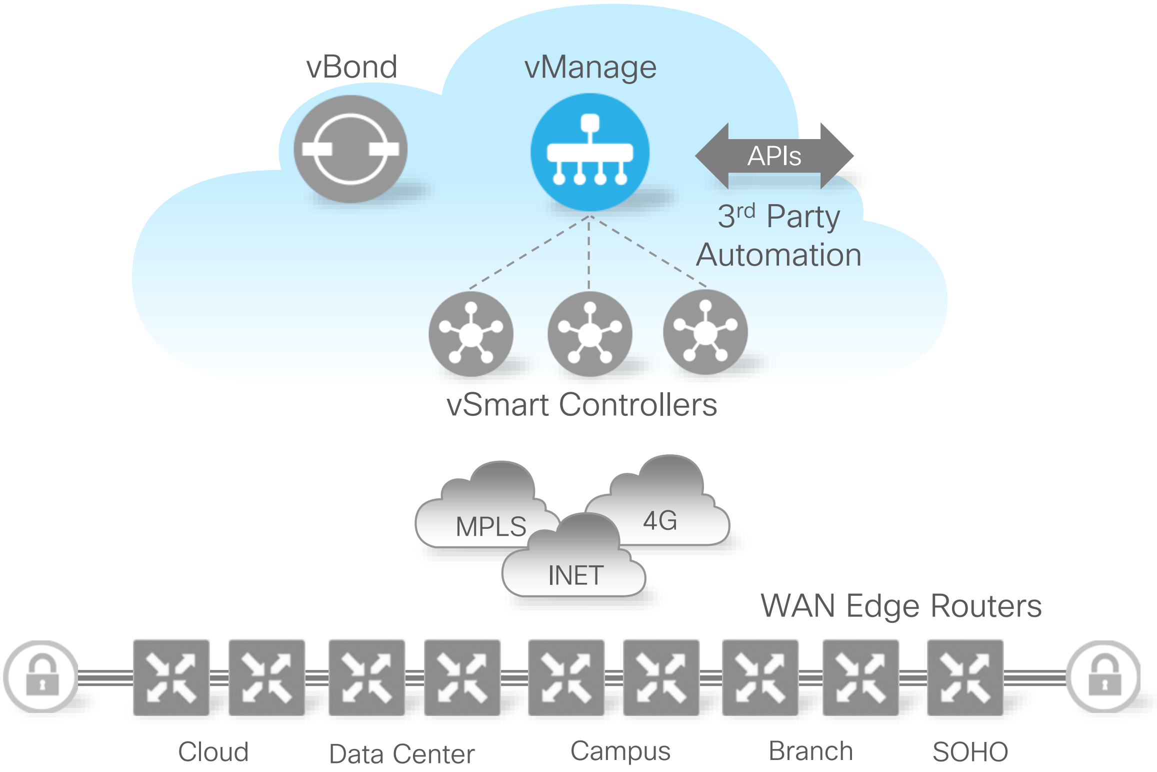


Characteristics

- Full stack WAN Edge router
- Secure data plane with remote WAN Edge routers
- Establishes secure control plane with vSmart controllers (OMP)
- Implements Data and App-Aware routing policies
- Collects and exports SLA and performance statistics
- Supports traditional routing protocols (OSPF, BGP) and First-hop Redundancy (VRRP)
- Supports Zero Touch Deployment
- Physical and Virtual form factor

Cisco SD-WAN Architecture Overview

Management Plane - vManage



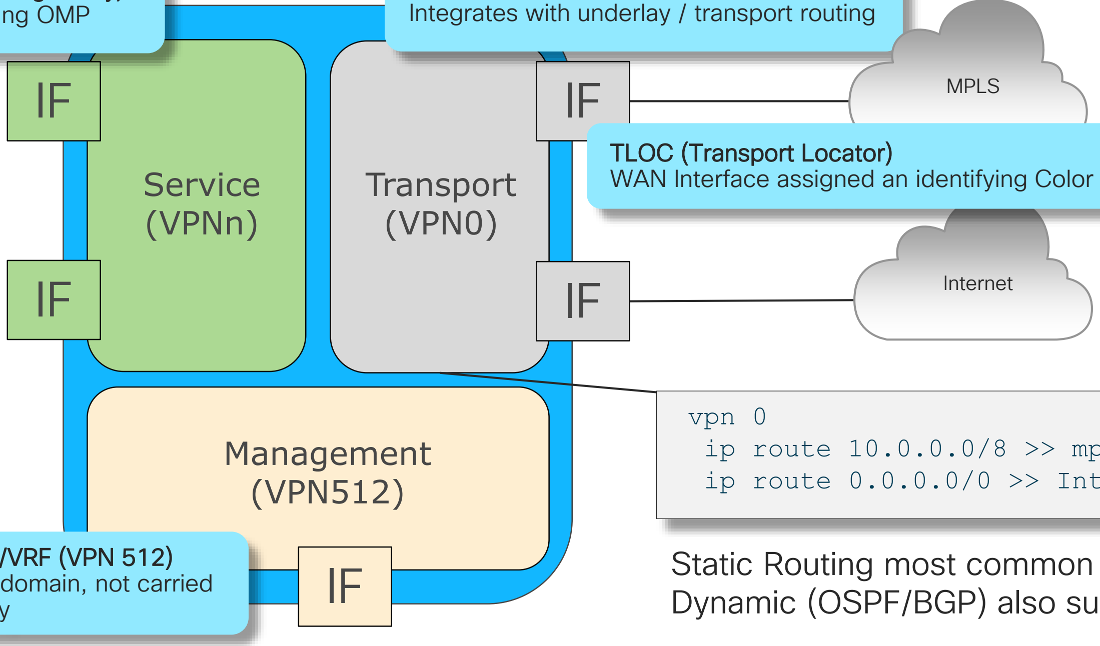
Characteristics

- Single pane of glass for Day0, Day1 and Day2 operations
- Centralized provisioning
- Multitenant or single tenant
- Policies and Templates
- Troubleshooting and Monitoring
- Software upgrades
- GUI with RBAC
- Programmatic interfaces (REST, NETCONF)
- Independent and resilient layer

Cisco SD-WAN - Terminology and key functions

SD-WAN Edge Device Architecture

Connecting the WAN/Transport VRF with the Underlay



Service/LAN VPN/VRF (WAN Edge Only)
Routed across the overlay using OMP

WAN VPN/VRF (VPN 0, Global Table)
Integrates with underlay / transport routing

TLOC (Transport Locator)
WAN Interface assigned an identifying Color

Device Identifying Configuration
Organization-Name: Overlay Identifier
System-IP: Device Identifier
Site-ID: Site Identifier

OOB MGMT VPN/VRF (VPN 512)
Separate routing domain, not carried across the overlay

```
vpn 0
 ip route 10.0.0.0/8 >> mpls
 ip route 0.0.0.0/0 >> Internet
```

Static Routing most common
Dynamic (OSPF/BGP) also supported

Cisco SD-WAN Terminology

- Transport Side – Controller or WAN Edge Interface connected to the underlay/WAN network
  - Always VPN 0 (i.e. Global Table)
  - Traffic typically tunneled/encrypted, unless split-tunneling is used
- Service Side – WAN Edge interface attaching to the LAN
  - VPN 1-511 (512 Reserved for OOB Mgmt)
  - Traffic forwarded as is from original source
- TLOC – Collection of entities making up a transport side connection
  - System-IP: IPv4 Address (non-routed identifier)
  - Color: WAN Interface identifier on local WAN Edge
  - Encryption Key: The encryption key used for traffic destined to the originating TLOC
  - Private TLOC: IP Address on interface sitting on inside of NAT
  - Public TLOC: IP Address on interface sitting on outside of NAT

    Private/Public can be the same if connection is not subject to NAT
- vRoute – Routes Carried in OMP for destinations reachable across the overlay
  - vRoute tagged with attributes as it is picked up by OMP

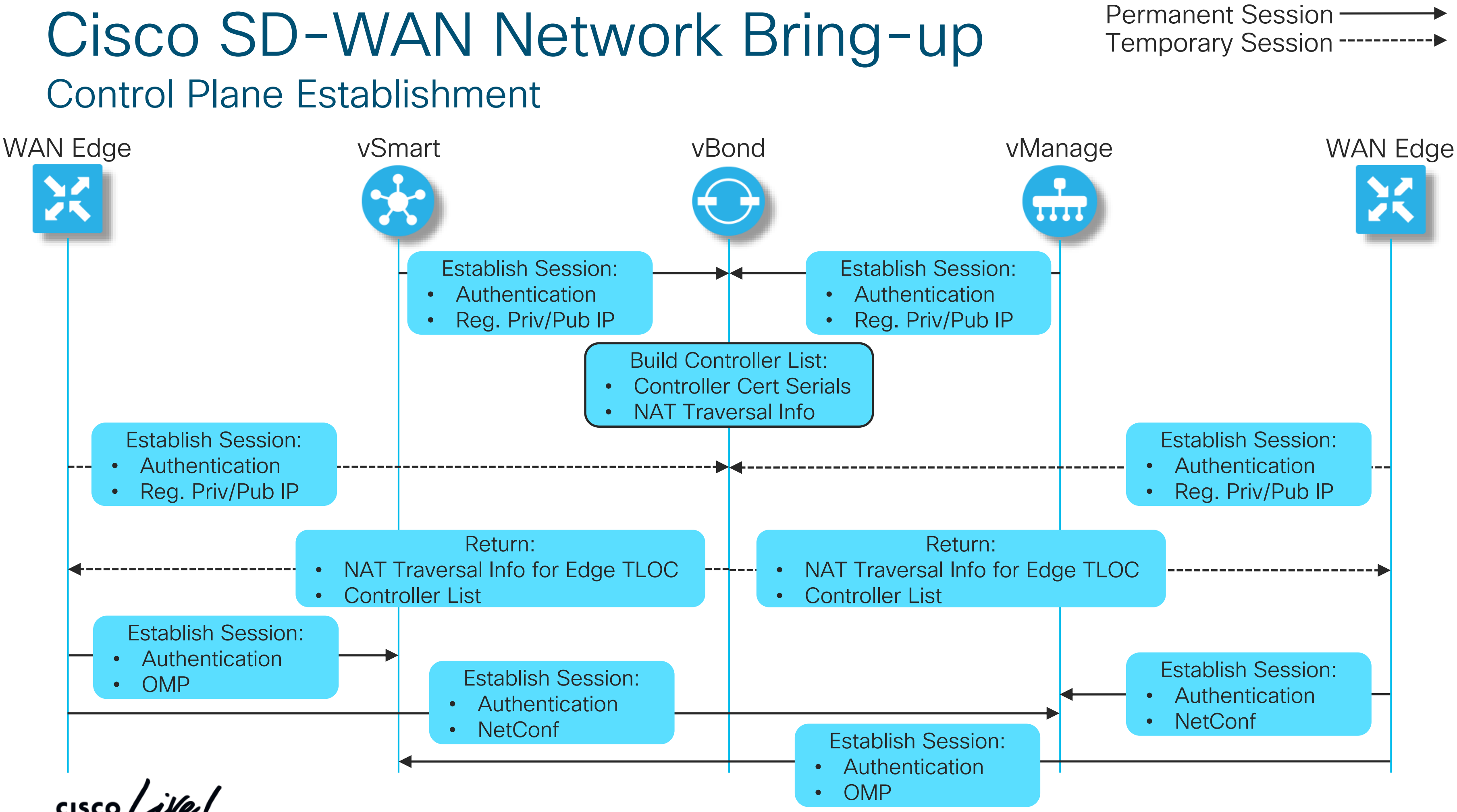
Cisco SD-WAN Terminology

- OMP – Overlay Management Protocol
  - Dynamic Routing Protocol managing the Overlay domain
  - Integrated mechanism for distribution Routing, Encryption and Policies
- Site-ID – Identifies the Source Location of an advertised prefix
  - Configured on every WAN Edge, vSmart and vManage
  - Does not have to be unique, but then assumes same location
  - Required configuration for OMP and TLOC to be brought up
- System-IP – Unique identifier of an OMP Endpoint
  - 32 Bit dot decimal notation (an IPv4 Address)
  - Logically a VPN 0 Loopback Interface, referred to as “system”
  - The system interface is the termination point for OMP
- Organization-Name – Defines the OU to match in the Certificate Auth Process
  - OU carried in both directions for authentication b/t control and WAN Edge nodes
  - Can be set to anything as long as it’s consistent across the Cisco SD-WAN domain

Cisco SD-WAN - Network Bring-up

Cisco SD-WAN Network Bring-up

Control Plane Establishment



Establish Session:
- Authentication
- Reg. Priv/Pub IP

Establish Session:
- Authentication
- Reg. Priv/Pub IP

Build Controller List:
- Controller Cert Serials
- NAT Traversal Info

Establish Session:
- Authentication
- Reg. Priv/Pub IP

Establish Session:
- Authentication
- Reg. Priv/Pub IP

Return:
- NAT Traversal Info for Edge TLOC
- Controller List

Return:
- NAT Traversal Info for Edge TLOC
- Controller List

Establish Session:
- Authentication
- OMP

Establish Session:
- Authentication
- NetConf

Establish Session:
- Authentication
- NetConf

Establish Session:
- Authentication
- OMP

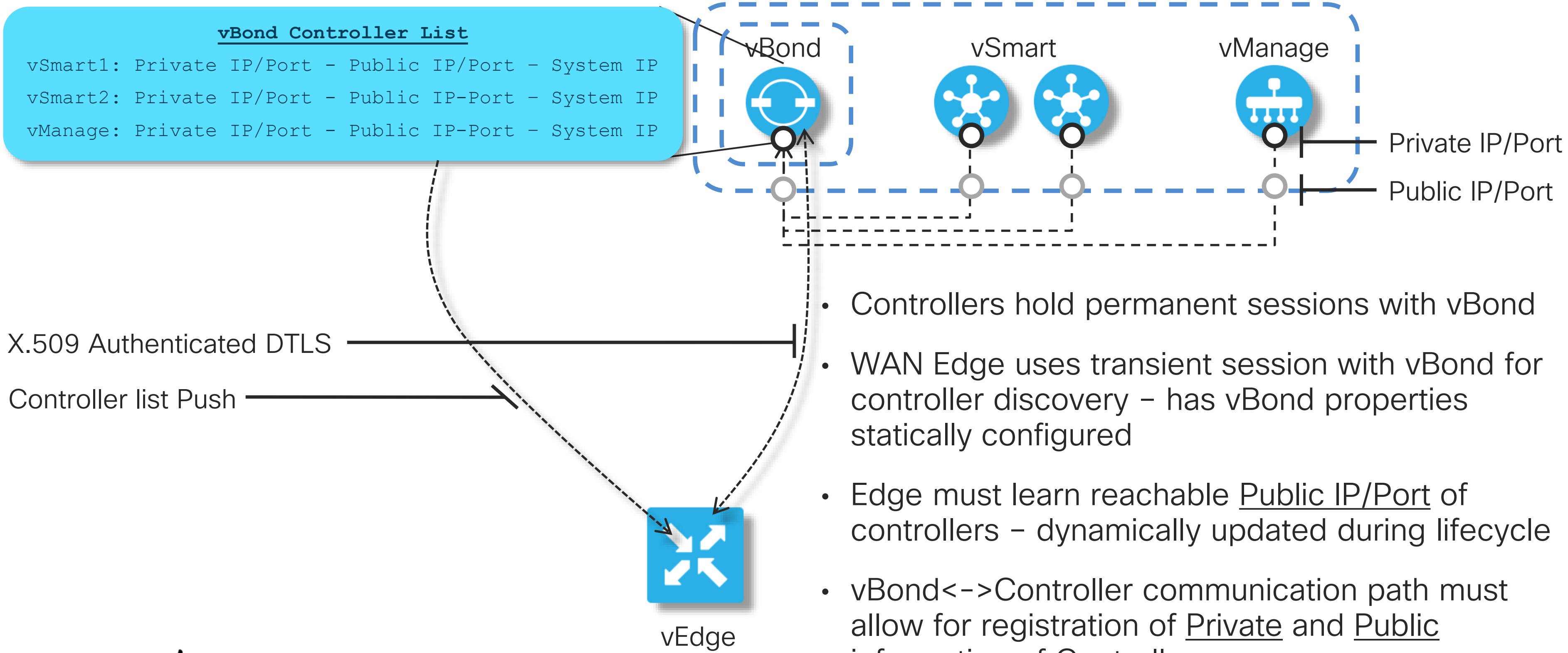
WAN Edge Controller Discovery

Finding vBond

- Controllers and WAN Edges must know about vBond upfront
  - Via Configuration or Zero Touch Provisioning
- Controllers will attach to every known vBond
  - Ensures that every vBond knows of every controller
- WAN Edge will try vBonds one-by-one on every TLOC
  - Controller connections are establish on every TLOC by default
- Both Controllers and WAN Edges find vBonds in the same way:
  - Locally configured IP-address (for a single vBond) or FQDN (for multiple vBonds)
  - FQDN can be resolved via DNS or locally (host statements)
  - In case of ZTP and need for local resolution, an IP-address can be pushed initially and host statements put in place when template configuration is applied

WAN Edge Controller Discovery

Using vBond



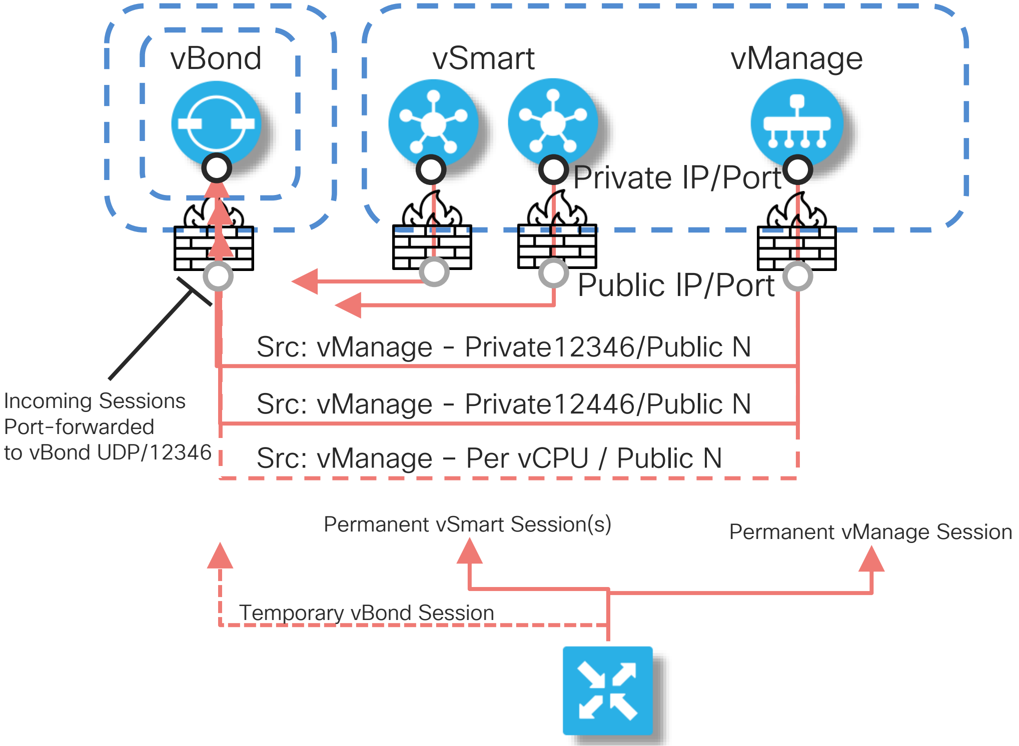
vBond Controller List

```
vSmart1: Private IP/Port - Public IP/Port – System IP
vSmart2: Private IP/Port - Public IP-Port – System IP
vManage: Private IP/Port - Public IP-Port – System IP
```

- Controllers hold permanent sessions with vBond
- WAN Edge uses transient session with vBond for controller discovery – has vBond properties statically configured
- Edge must learn reachable Public IP/Port of controllers – dynamically updated during lifecycle
- vBond<->Controller communication path must allow for registration of Private and Public information of Controllers

Controller Firewall Traversal

Port Numbers and Session Establishment Direction



vBond
vSmart
vManage
Private IP/Port
Public IP/Port
Src: vManage - Private12346/Public N
Src: vManage - Private12446/Public N
Src: vManage – Per vCPU / Public N
Incoming Sessions Port-forwarded to vBond UDP/12346
Permanent vSmart Session(s)
Permanent vManage Session
Temporary vBond Session

- vBond Service: UDP/12346

  Not tied to a local IP-address

- vSmart/vManage behavior is identical

  Will establish permanent sessions with every vBond

  One session established per vCPU for load-sharing

- vSmart: UDP/12346 + 100 per vCPU

  12346, 12446, 12546, etc

- vManage: UDP/12346 + 100 per vCPU

  12346, 12446, 12546, etc

- WAN Edge: UDP/12346 + 20 up to 12426

  12346, 12366, 12386, 12406, 12426*

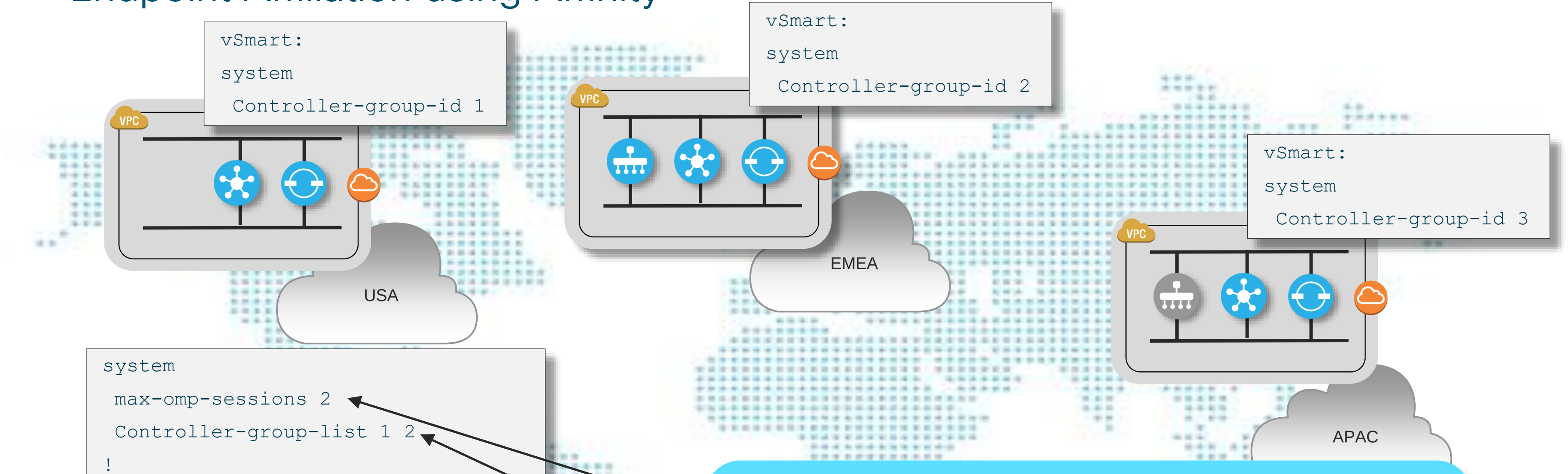
  Source-Port will periodically change if port-hop is enabled* – 12346 is default

  Base port can move +1-19 using port offset**

*https://sdwan-docs.cisco.com/Product_Documentation/Command_Reference/Configuration_Commands/port-hop
**https://sdwan-docs.cisco.com/Product_Documentation/Command_Reference/Configuration_Commands/port-offset

SD-WAN Controller Large Scale Deployment

Endpoint Affiliation using Affinity



```
vSmart:
system
 Controller-group-id 1
```

```
vSmart:
system
 Controller-group-id 2
```

```
vSmart:
system
 Controller-group-id 3
```

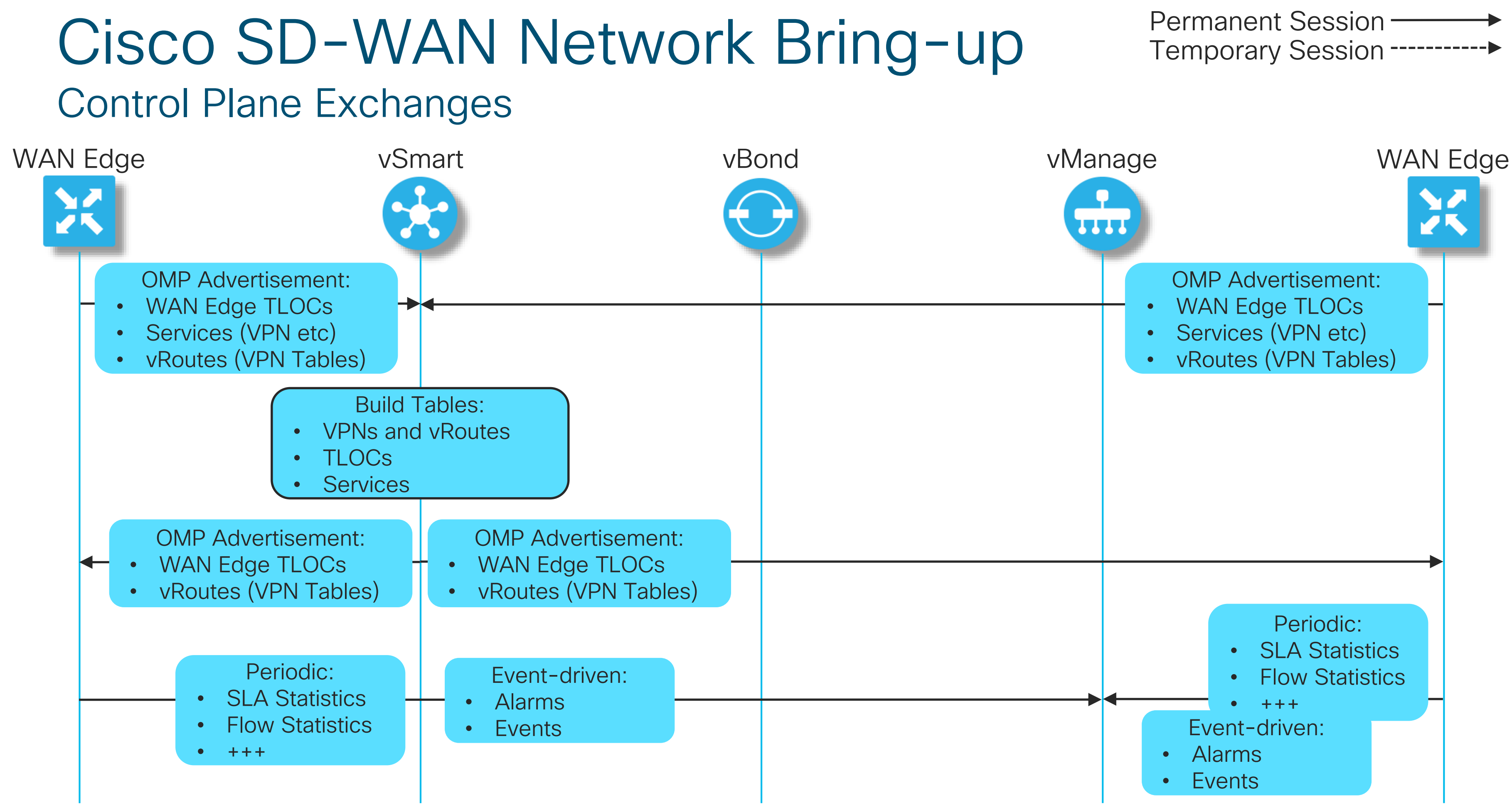
```
system
 max-omp-sessions 2
 Controller-group-list 1 2
!
vpn 0
 Interface ge0/0
  tunnel-interface
  max-control-connections 2
  exclude-controller-group-list 3
  !
!
```

Affinity Logic

1) Attach to # of vSmarts up to max-omp-sessions
2) Attach to # of vSmarts up to max-control-connections per TLOC
3) Prefer Group 1 and continue with Group 2 as allowed by session budget
4) Never attach to Group 3
5) If Group 1 and 2 are unavailable try any other available group except for 3

Cisco SD-WAN Network Bring-up

Control Plane Exchanges



OMP Advertisement:
- WAN Edge TLOCs
- Services (VPN etc)
- vRoutes (VPN Tables)

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- WAN Edge TLOCs
- Services (VPN etc)
- vRoutes (VPN Tables)

Build Tables:
- VPNs and vRoutes
- TLOCs
- Services

OMP Advertisement:
- WAN Edge TLOCs
- vRoutes (VPN Tables)

OMP Advertisement:
- WAN Edge TLOCs
- vRoutes (VPN Tables)

Periodic:
- SLA Statistics
- Flow Statistics
- +++

Periodic:
- SLA Statistics
- Flow Statistics
- +++

Event-driven:
- Alarms
- Events

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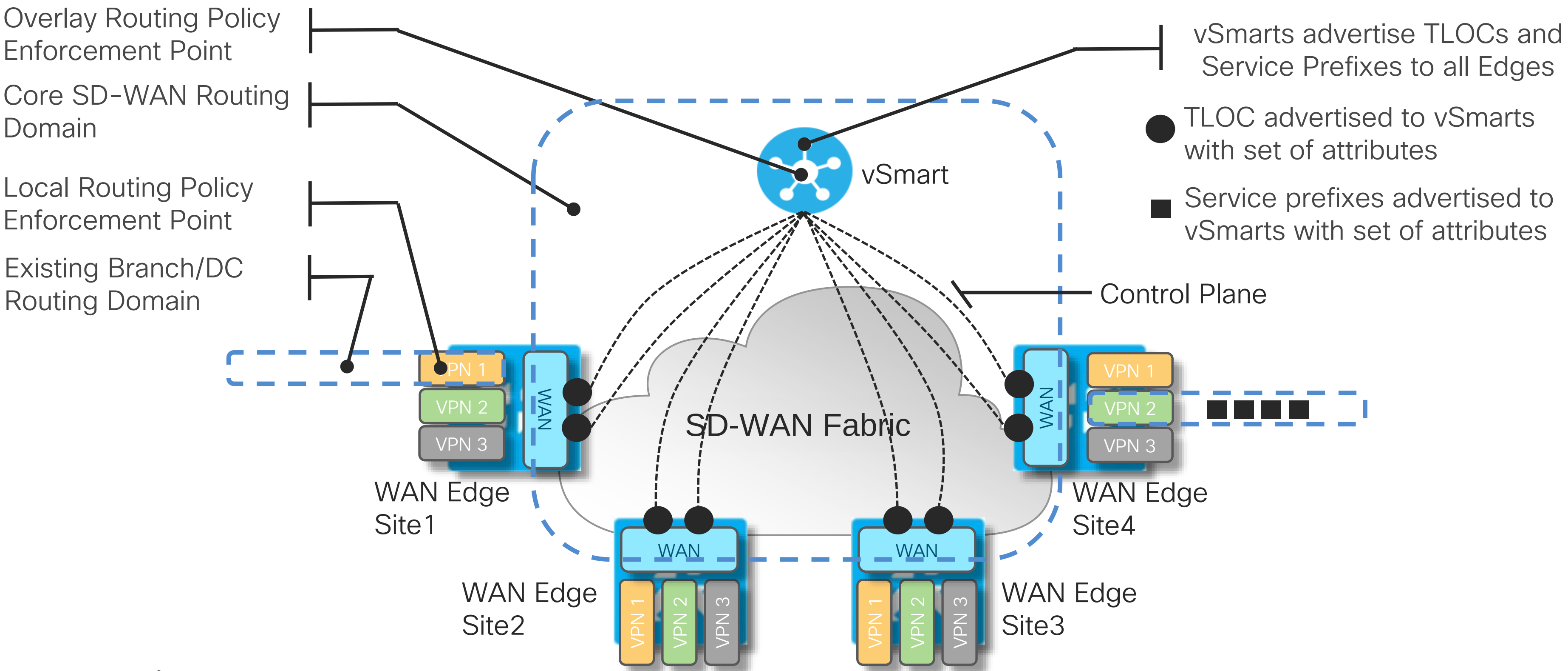
- Alarms
- Events

Cisco SD-WAN Overlay Routing

Multi-domain Routing Fabric



Overlay Routing Policy Enforcement Point
Core SD-WAN Routing Domain
Local Routing Policy Enforcement Point
Existing Branch/DC Routing Domain
vSmarts advertise TLOCs and Service Prefixes to all Edges
● TLOC advertised to vSmarts with set of attributes
■ Service prefixes advertised to vSmarts with set of attributes
vSmart
Control Plane
SD-WAN Fabric
WAN
VPN 1
VPN 2
VPN 3
WAN Edge Site1
WAN Edge Site2
WAN Edge Site3
WAN Edge Site4

Cisco SD-WAN Policy Architecture

Policy Categories

Centralized Policies

Topology and VPN Membership:

Control Policy

VPN Membership Policy

Traffic Rules:

App-Aware Routing Policy

Data Policy (Traffic Data)

cFlowd

Localized Policies

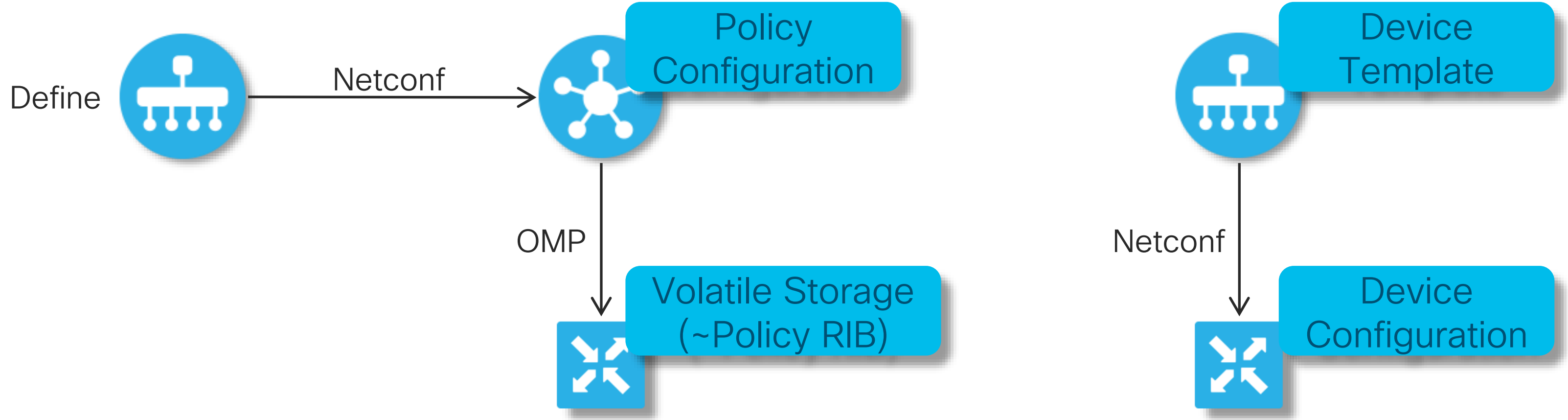
Local Policy:

Local Control Policy

(Routing Policies – OSPF/BGP)

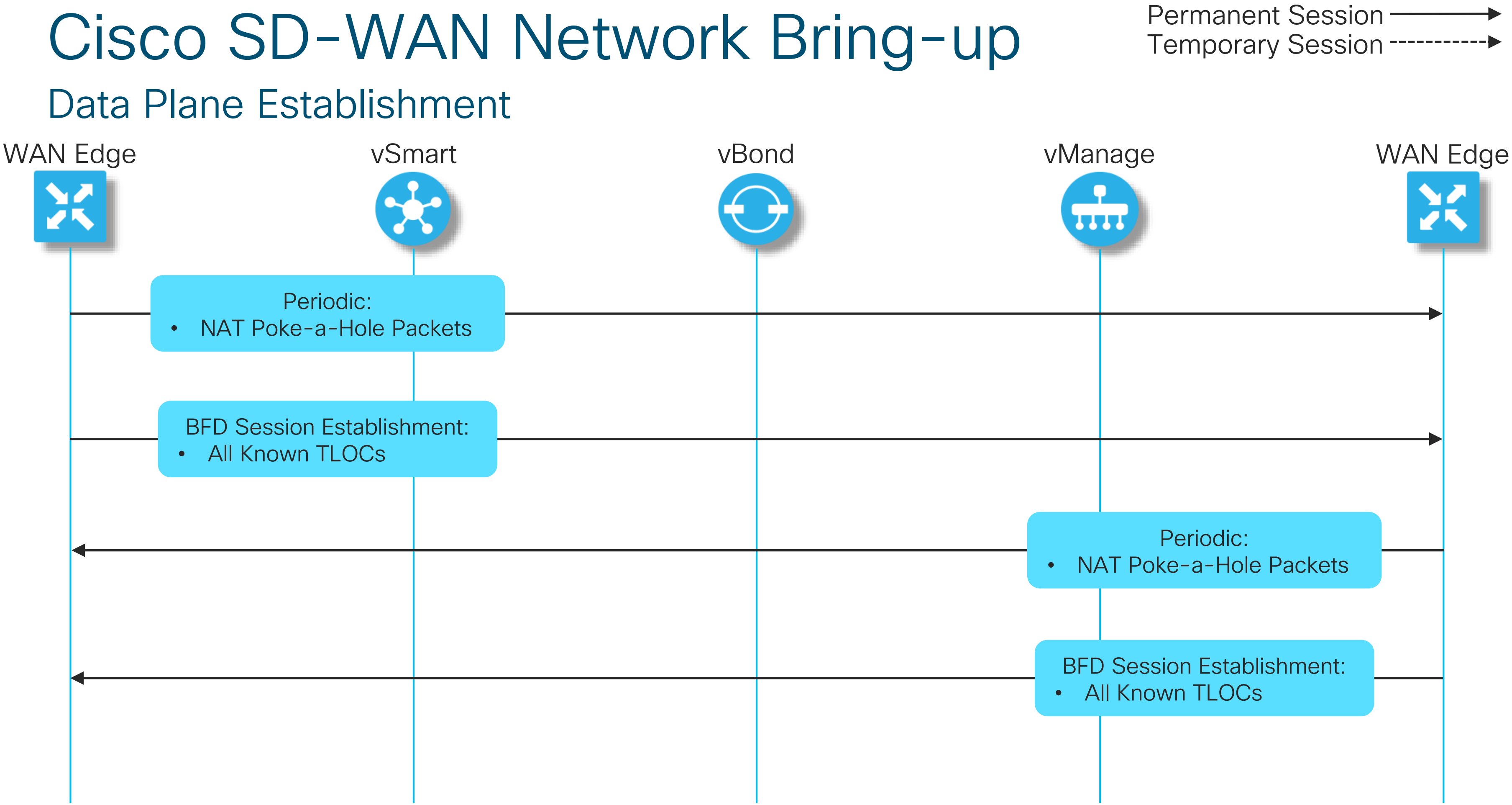
Local Data Policy

(QoS, ACL etc)



Cisco SD-WAN Network Bring-up

Data Plane Establishment



Periodic:
- NAT Poke-a-Hole Packets

BFD Session Establishment:
- All Known TLOCs

Periodic:
- NAT Poke-a-Hole Packets

BFD Session Establishment:
- All Known TLOCs

TLOCs, Colors, Site-IDs and Carriers

Definitions

- TLOC Color used as static identifier for:
  - TLOC Interface on WAN Edge device
  - Underlay network attachment
- The specific color used is categorized as Private or Public
  - Private Colors [mpls, private1-6, metro-ethernet]
  - All other colors are public [red, blue,..., public-ethernet,...]
- Private vs Public color is highly significant
- Color setting applies to:
  - WAN Edge to WAN Edge Communication
  - WAN Edge to Controller Communication

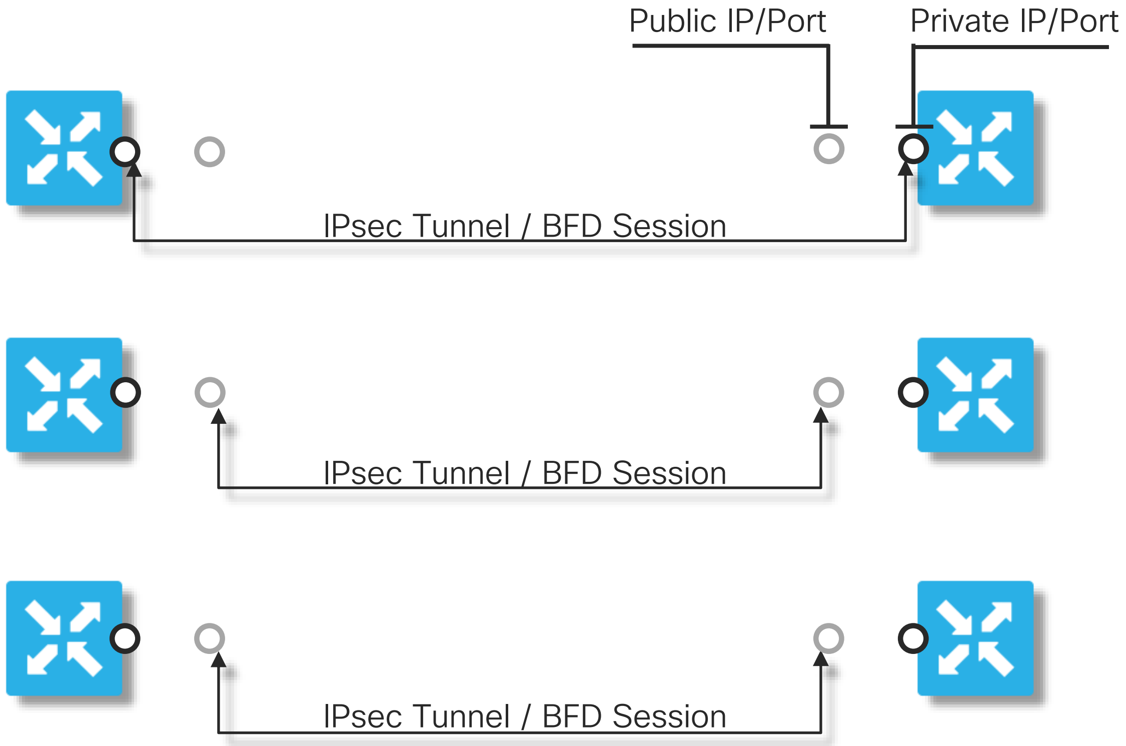
TLOCs, Colors, Site-IDs and Carriers

Private and Public Color Significance

1 Private Color to Private Color

2 Private Color to Public Color

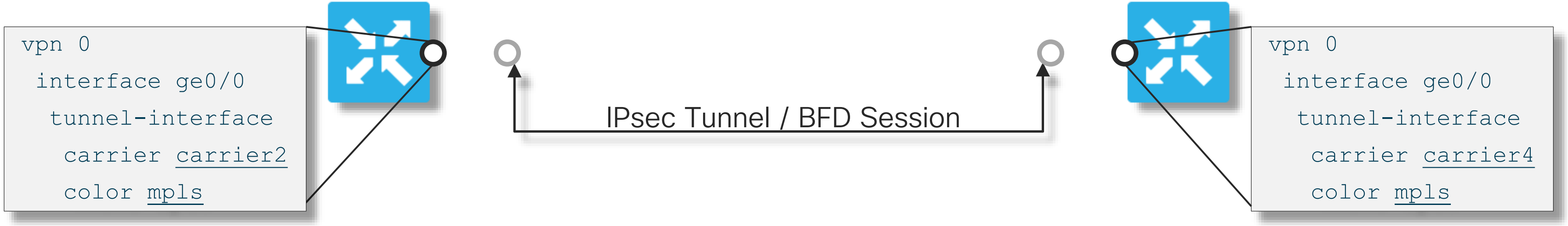
3 Public Color to Public Color


Public IP/Port
Private IP/Port
IPsec Tunnel / BFD Session
IPsec Tunnel / BFD Session
IPsec Tunnel / BFD Session

TLOCs, Colors, Site-IDs and Carriers

Color Contention Resolution

- If Site-IDs are identical and colors public:
  - Use Private information
- Carrier setting is final influencer to decide on Private/Public IP/Port
  - Use if two endpoints are using private colors and you need session between them to be established between their Public IP/Port

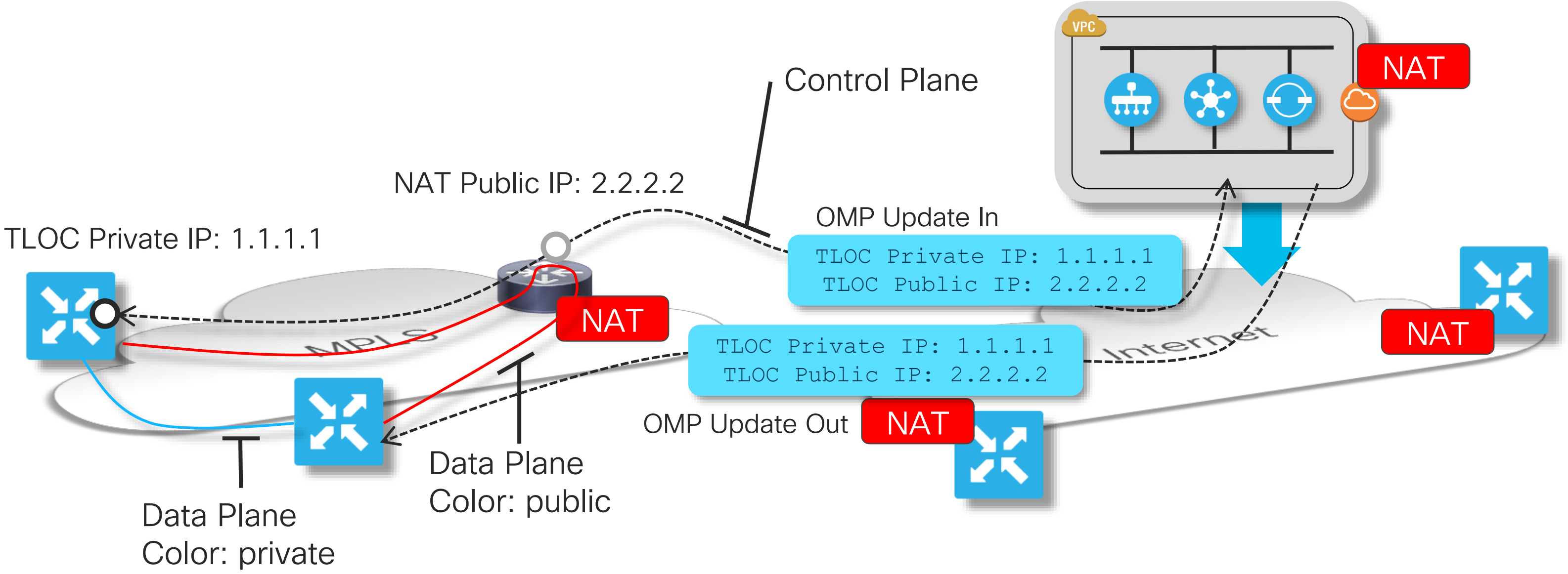


```
vpn 0
 interface ge0/0
  tunnel-interface
   carrier carrier2
   color mpls
```

```
vpn 0
 interface ge0/0
  tunnel-interface
   carrier carrier4
   color mpls
```

Control and Data Plane Establishment

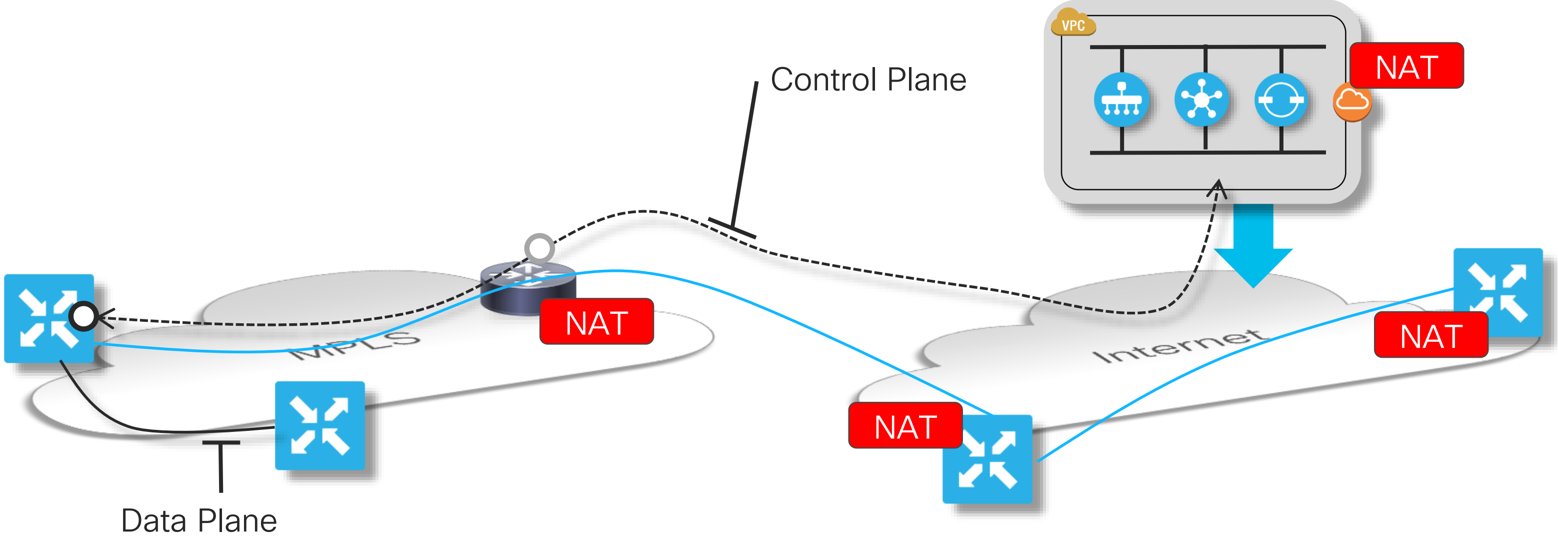
Significance of TLOC Color



- Data plane path formation dependent on presence of NAT and Color Selection
- Domain w/o NAT should use Private Color endpoints, with NAT; use Public Color Endpoints

Control and Data Plane Establishment

Significance of TLOC Color



- MPLS uses Private Color, Internet uses Public Color
- Connectivity optimized within and across domains

Cisco SD-WAN - Controller Deployment

Cisco SD-WAN Controllers

Deployment Options and Designs

- Design is highly influenced by:
  - On or Off-prem hosting
  - Security Requirements
  - Need to manage Data Plane attachment to the overlay in combination with NAT
- Controller Design must handle any combination of data plane and choice of hosting model
- Key concepts, such as TLOC, Colors and Carrier settings are crucial for a fully functional overlay

Cisco SD-WAN – Controller Deployment Models

Controller Deployment Models

- Cloud hosted
- AWS or Azure
- Single or Multiple Availability Zones
- <u>Recommended Model</u>

Microsoft Azure

amazon webservices

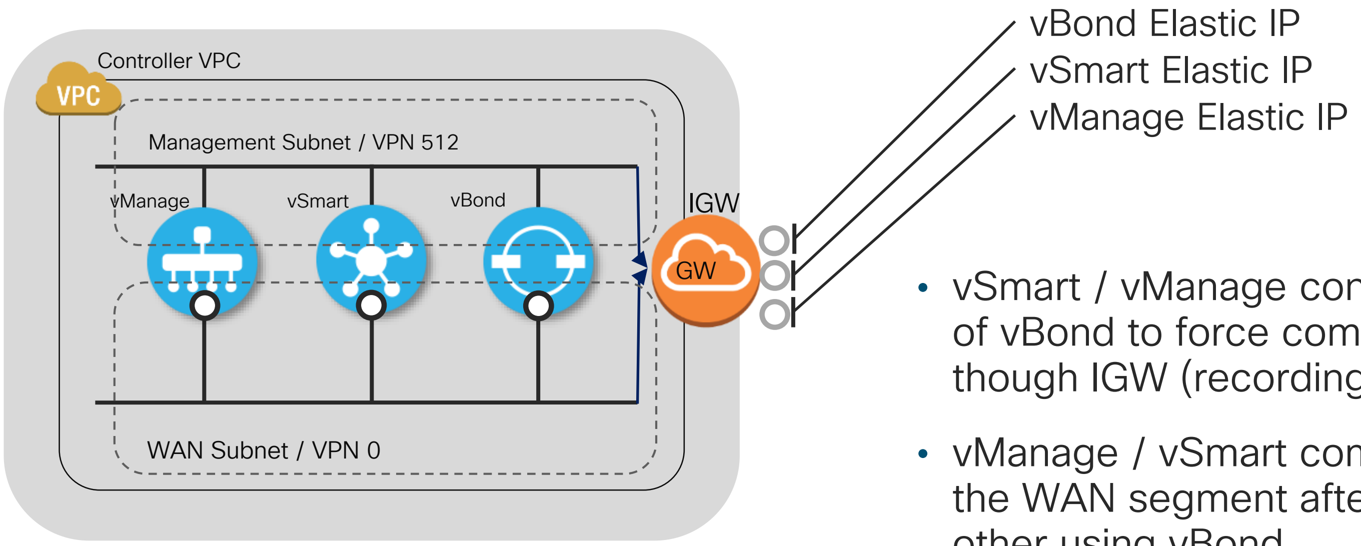
- Cloud hosted + On prem
- Public Cloud, Private Cloud and/or DC
- IP connectivity between domains required
- Not Supported

Microsoft Azure

amazon webservices +

- On prem only
- Private Cloud or DC
- Public and Private transport still supported
- Specific design considerations required

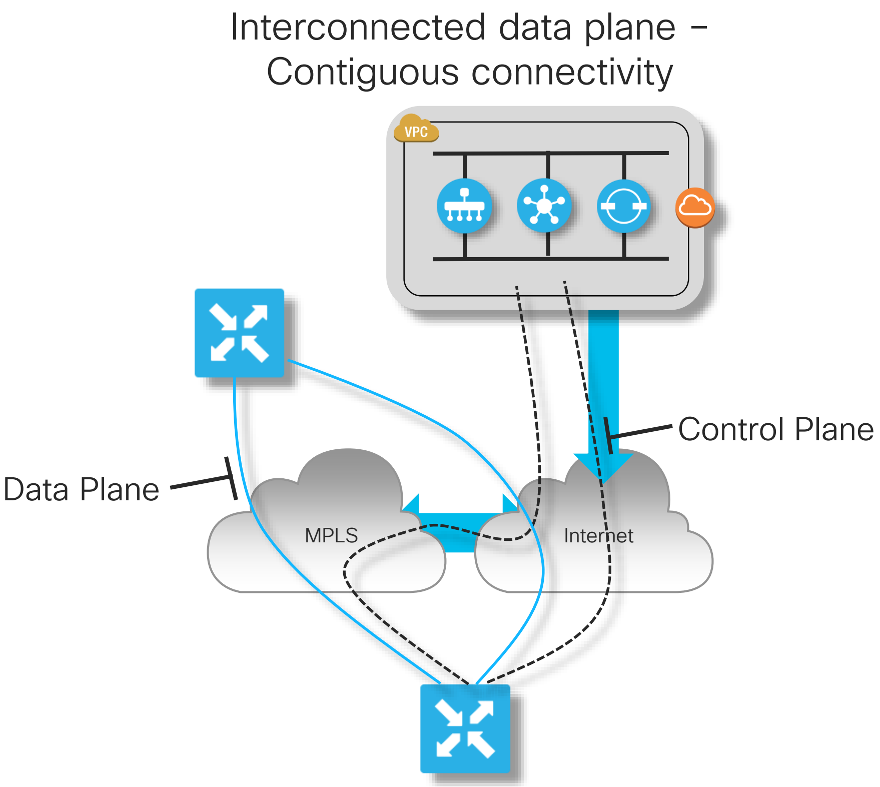
Cloud hosted Deployment - <u>Recommended</u>

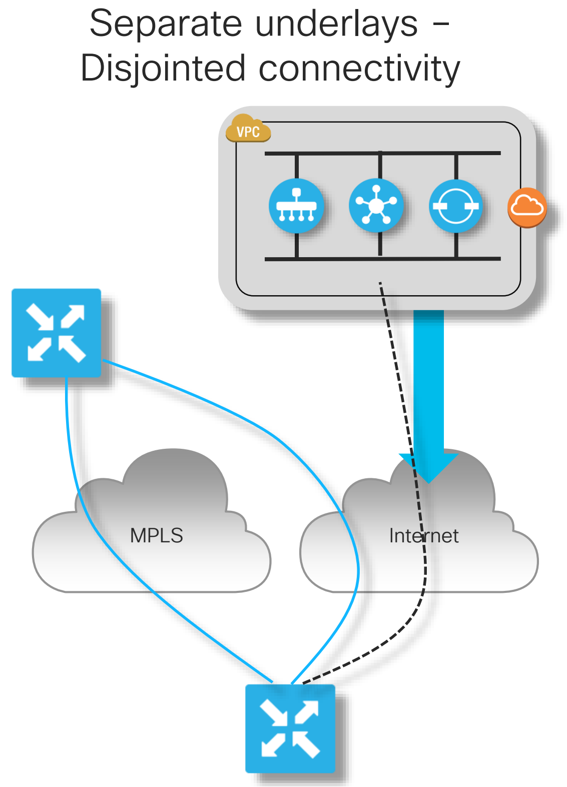


- vSmart / vManage configured with elastic IP of vBond to force communication to pass though IGW (recording Private/Public)
- vManage / vSmart communicate locally on the WAN segment after discovering each other using vBond
- vManage / vSmart having different site-ids, communication via IGW
- Controllers in other zones register with vBond and are dynamically discovered

Cloud hosted Deployment - Recommended

Control and Data Plane Establishment





Cloud-hosted Deployment

Summary

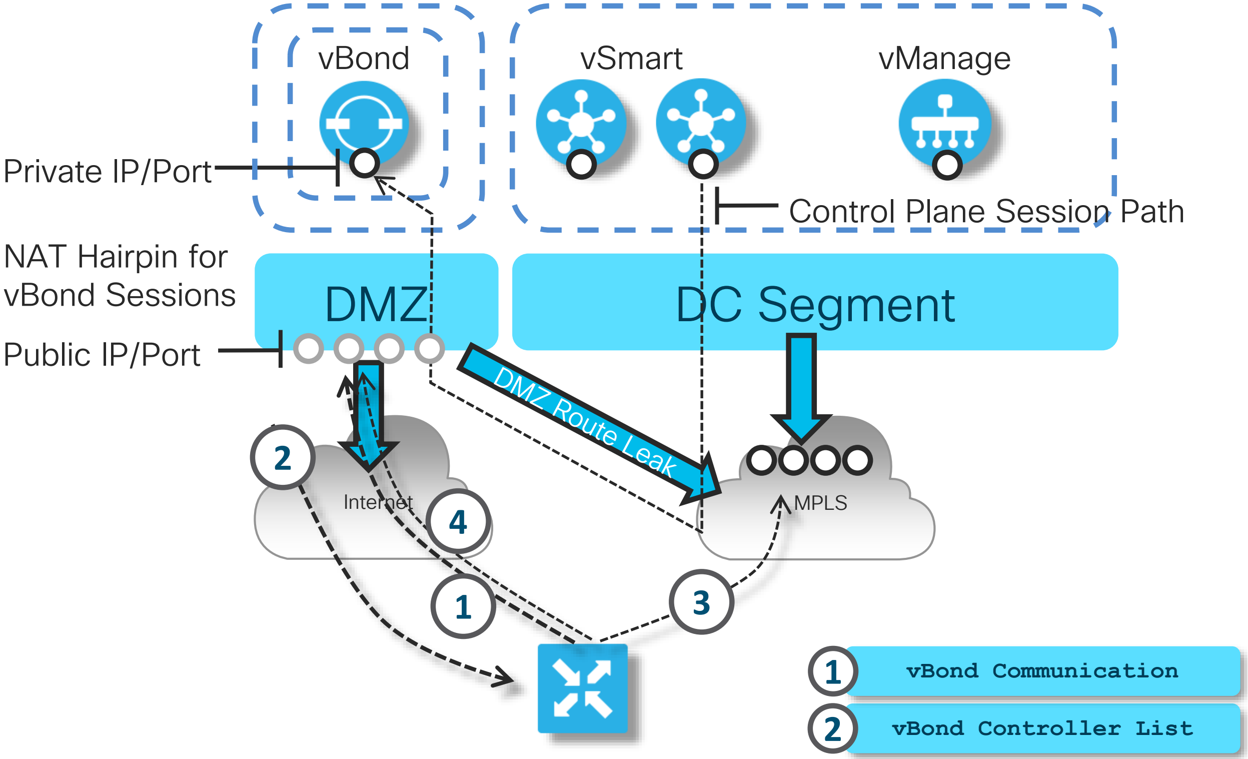
- Recommended mode of deployment
  - Ease of deployment – Cisco orchestrated
  - No On-Prem design considerations
  - Easy to scale and to deliver redundancy / HA
- Requirements
  - Internet connectivity from every site (unless using DirectConnect)
  - If using MPLS Transport, Internet breakout required for Control Plane
- Challenge
  - With a single Internet connection, no DirectConnect or Internet Breakout from MPLS – No Controller Redundancy

On-prem Deployment Considerations

- Supporting NAT Traversal
  - vBond supporting Private + Public Discovery
- Supporting Hybrid Environments
  - Interconnected MPLS and Internet Domains
  - Separate MPLS and Internet Domains
- Redundancy
- Firewall Traversal

On-Prem Deployment – vBond / NAT Traversal

Controllers accessible via Private and Public Transport



- Controllers can support hybrid Private / Public transport connections
- Private transport using private IPs for communication. Prefix advertised in private domain
- Public transport using public IPs, generally assigned by provider
- Multi-homed WAN Edge capable of supporting both models concurrently

1 vBond Communication

2 vBond Controller List

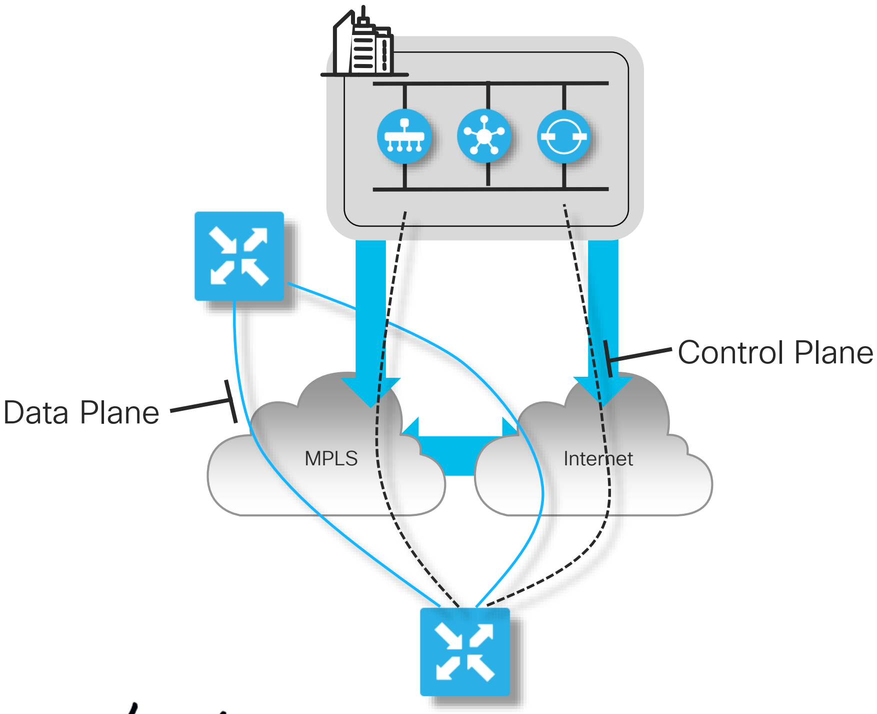
3 MPLS Edge -> Controller Session

4 Internet Edge -> Controller Session

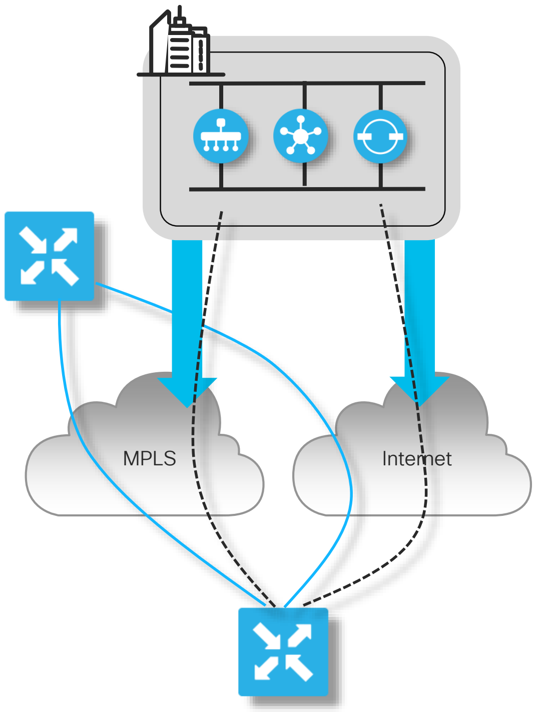
On-Prem Deployment

Control and Data Plane Establishment

Interconnected data plane –
Contiguous connectivity

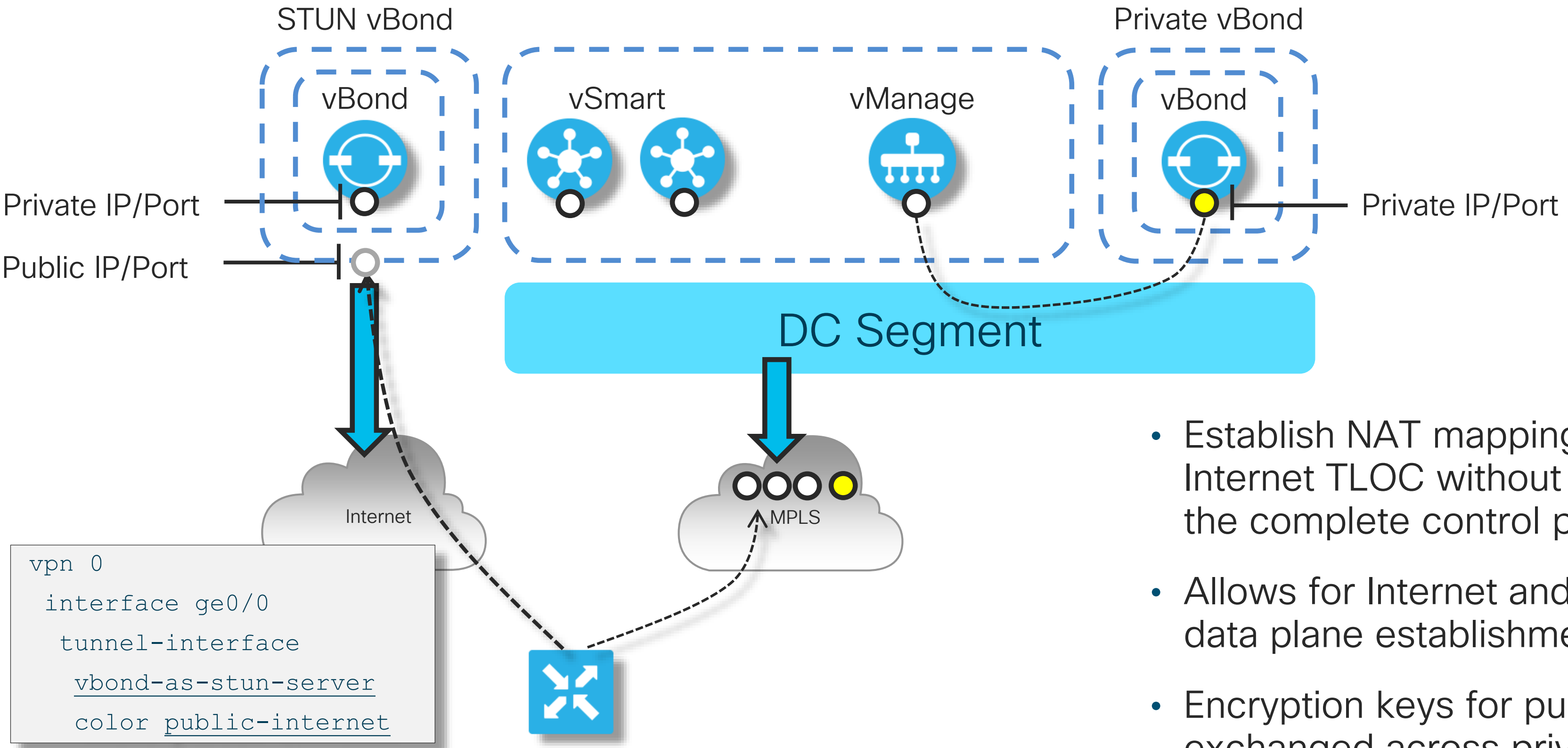


Separate underlays –
Disjointed connectivity



vBond-as-Stun-Server (vEdge Only)

Controllers accessible via Private Transport Only

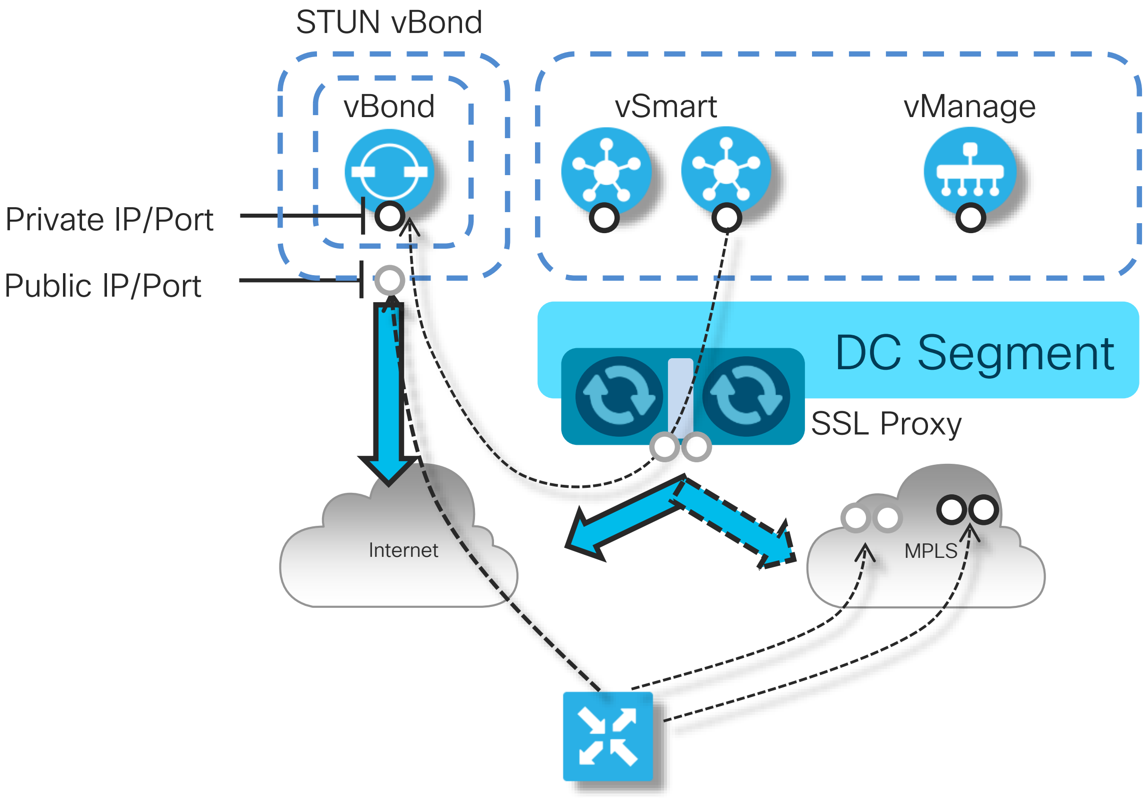


```
vpn 0
 interface ge0/0
  tunnel-interface
   vbond-as-stun-server
   color public-internet
```

- Establish NAT mappings for Internet TLOC without operating the complete control plane
- Allows for Internet and MPLS data plane establishment
- Encryption keys for public exchanged across private only

Controller Proxy Access

Use SSL Proxy to maintain secure isolation of controllers



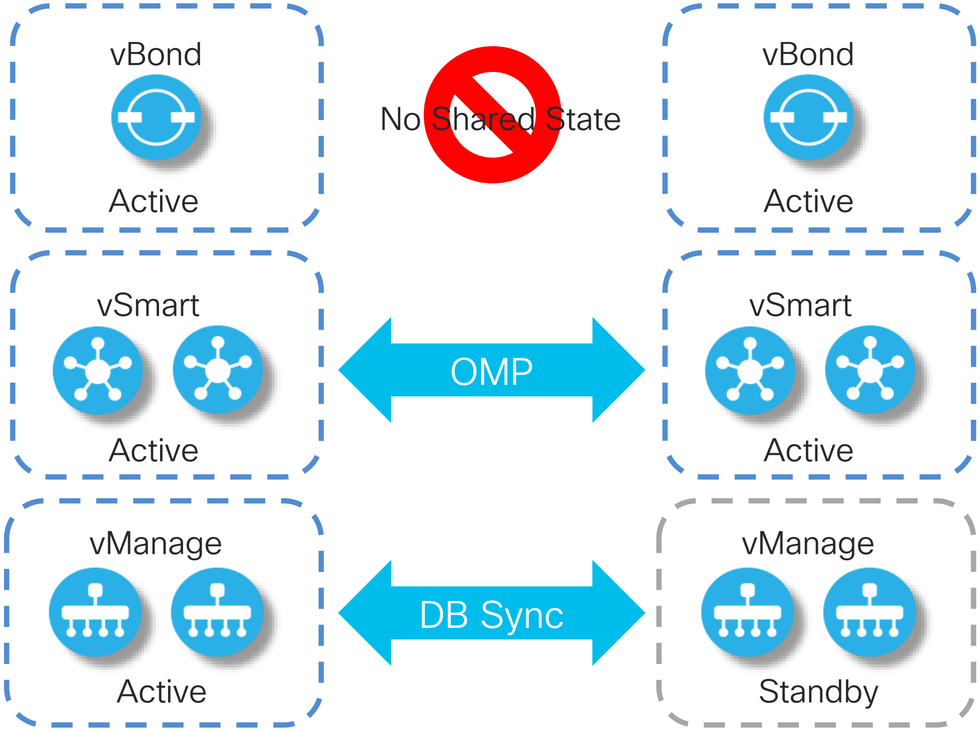
- Private IP/Port information never exposed outside of DC
- Ports assigned on Proxy are configured on vManage/vSmart
- Proxy needs signed cert to allow for controller/edge authentication
- Ports maps are established with vBond using standard mechanism

Cisco SD-WAN – Controller Redundancy

SD-WAN Controller Redundancy

High Level Description

Same Principles Apply for Cloud and On-Prem



No Shared State
DNS FQDN to cover multiple vBonds
(e.g. vbond.enterprise.com)

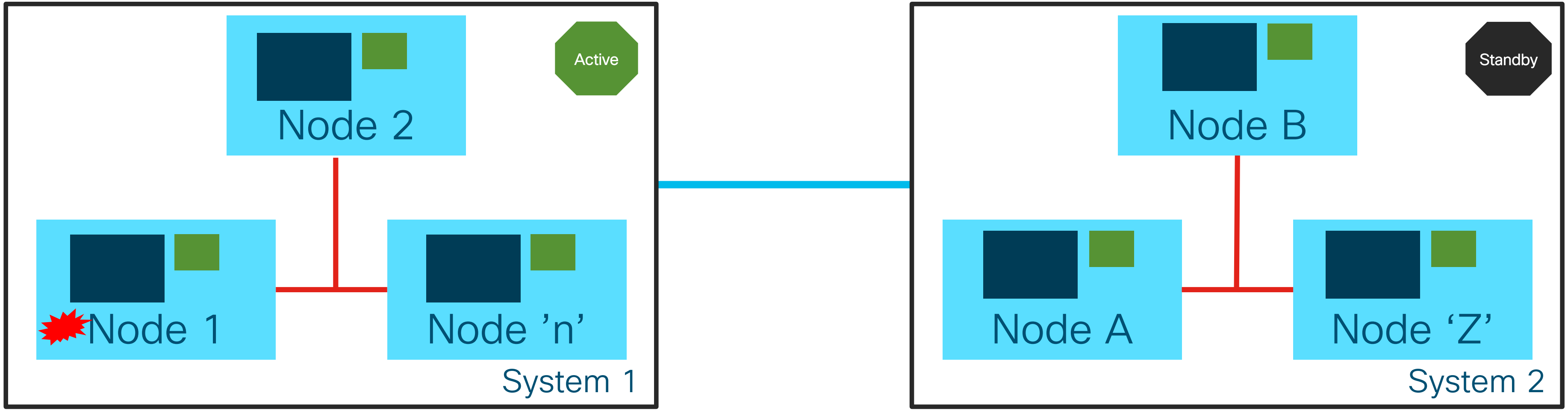
OMP Mesh amongst all active vSmarts
vSmart dynamic discovery via vBond
No configuration Required

Active / Standby Cluster Architecture (Improved in 19.2)
Clusters are maintained from within vManage
Database synchronization required b/t Active/Standby

vManage Controller Redundancy

Passive Redundancy (=>R19.2)

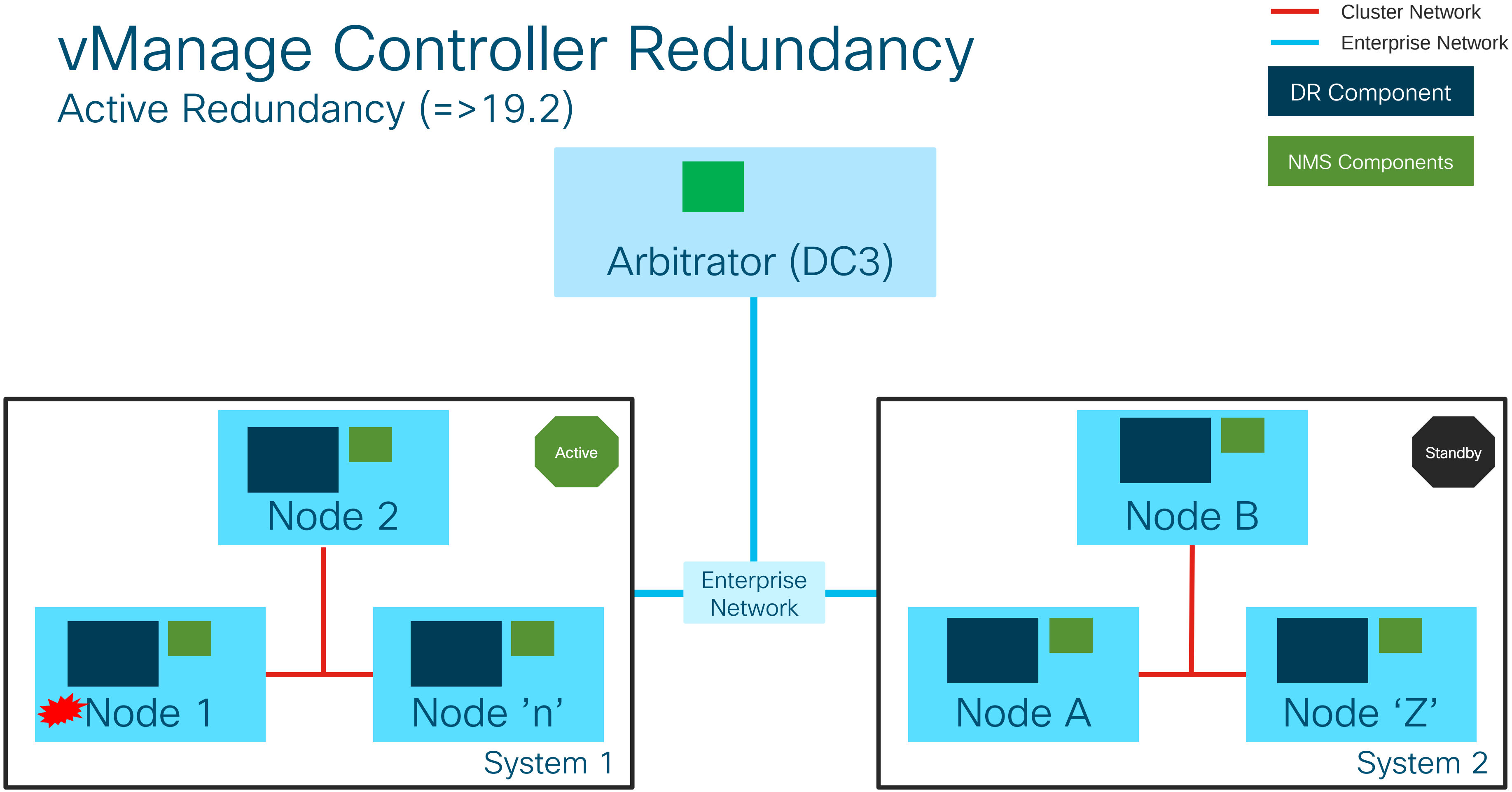
- 🟥 Cluster Network
- 🟦 Enterprise Network
- DR Component
- NMS Components



- vManage scales horizontally using Clustering
- Add more vManage nodes to cluster in DC for Scale and local HA
- Inter-Cluster Redundancy with DC local Clusters
  - Additional vManage interface used for cluster connectivity

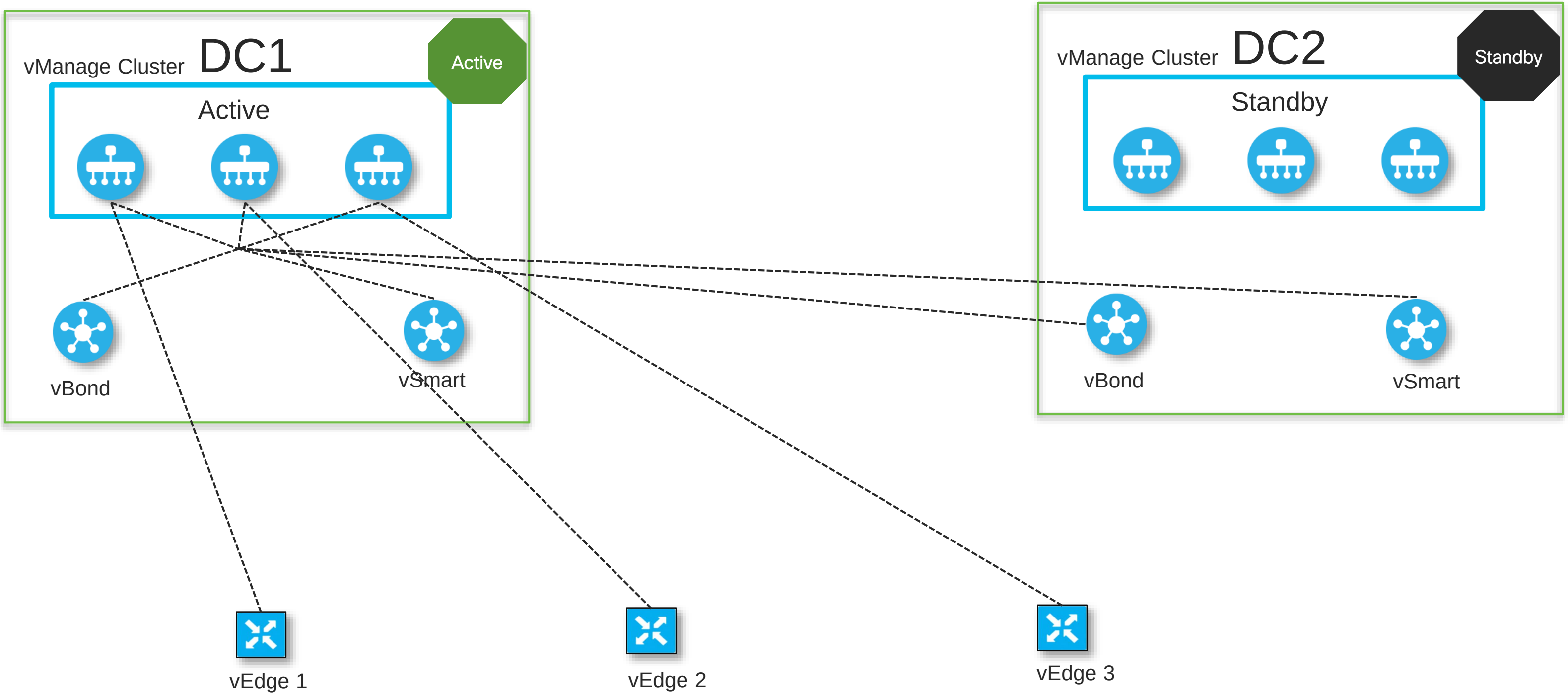
vManage Controller Redundancy

Active Redundancy (=>19.2)



vManage Cluster – Failover

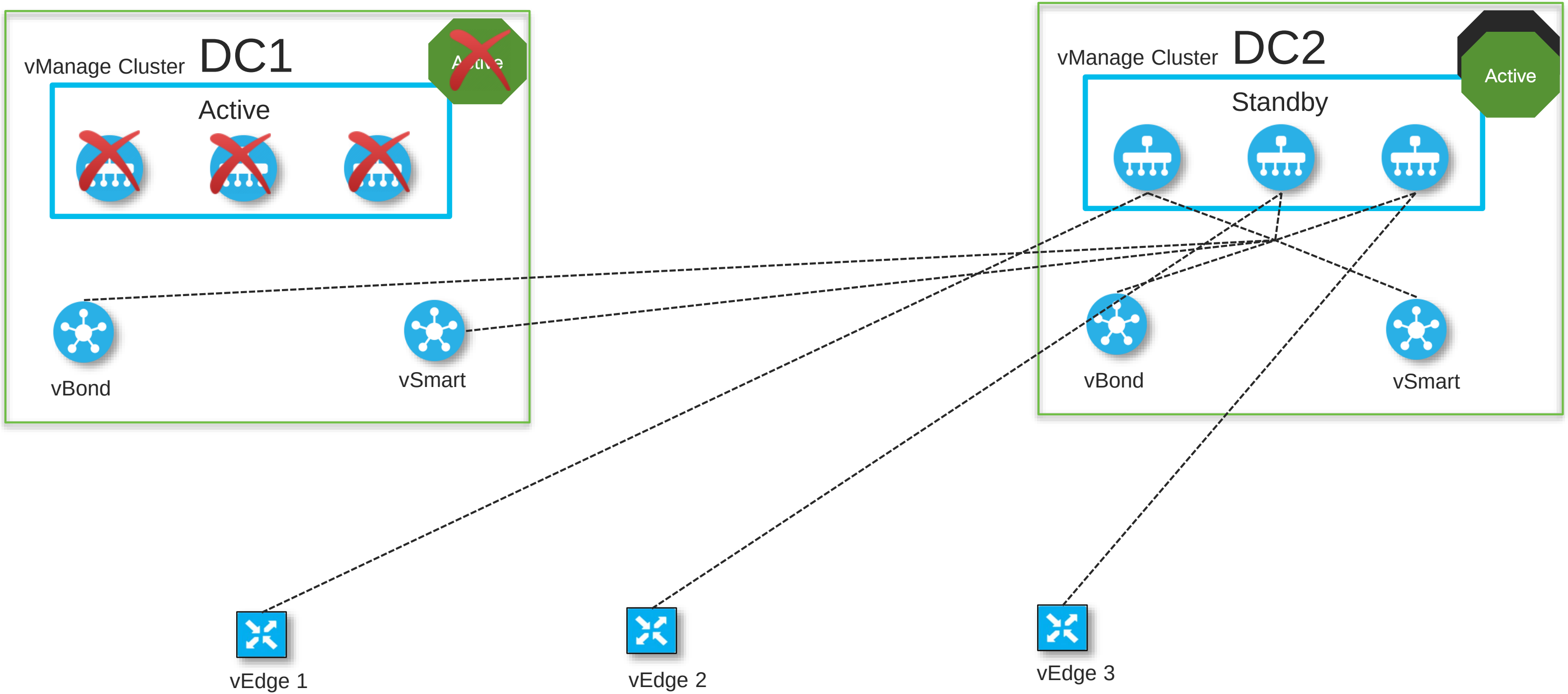
Steady State – Primary Cluster Operational



All WAN Edge to vSmart/vBond control connections not shown for clarity purposes

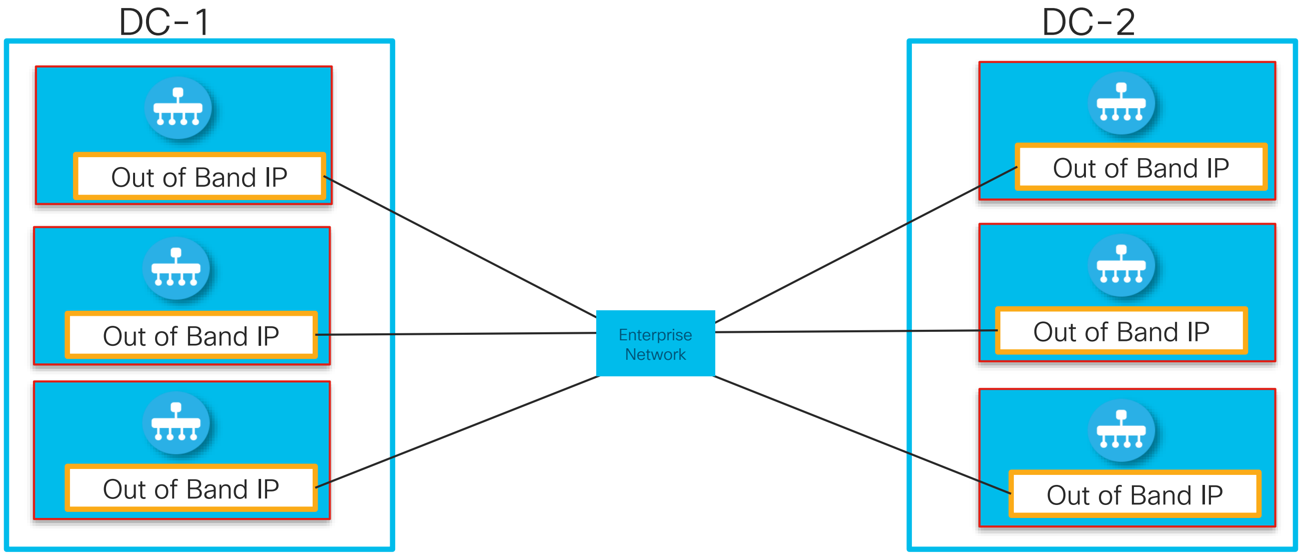
vManage Cluster – Failover

Post Failover State– Standby Cluster Operational



All WAN Edge to vSmart/vBond control connections not shown for clarity purposes

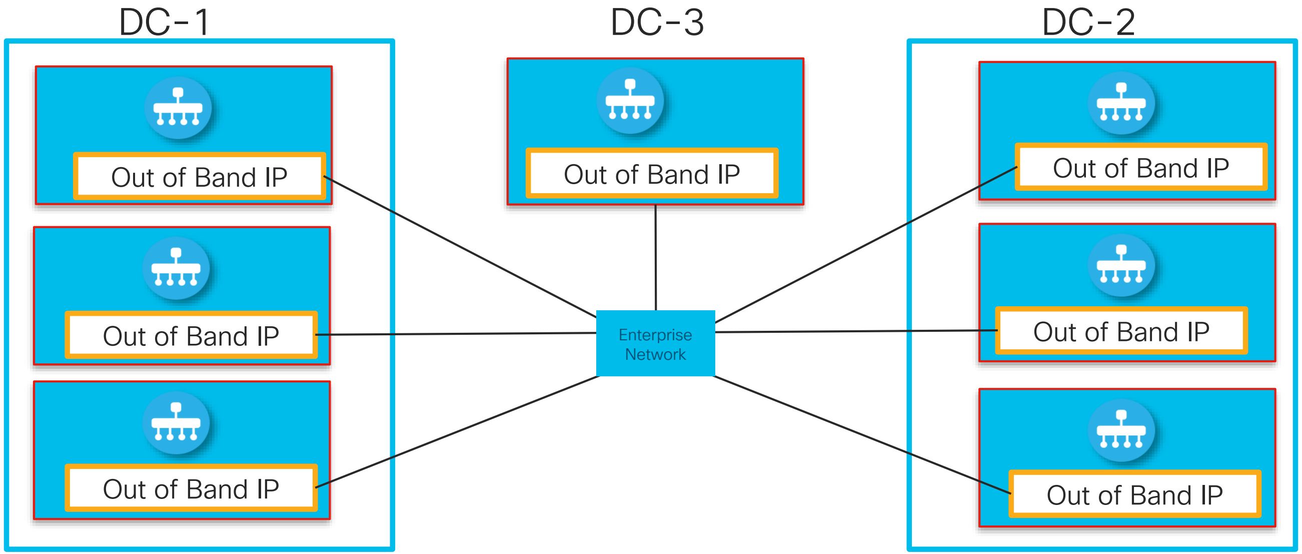
Passive vManage Cluster Redundancy
Database Synchronization



vManage Service	Traffic Direction	Protocol	Port
Application Server	Bidirectional	TCP	443
Netconf	Bidirectional	TCP	830

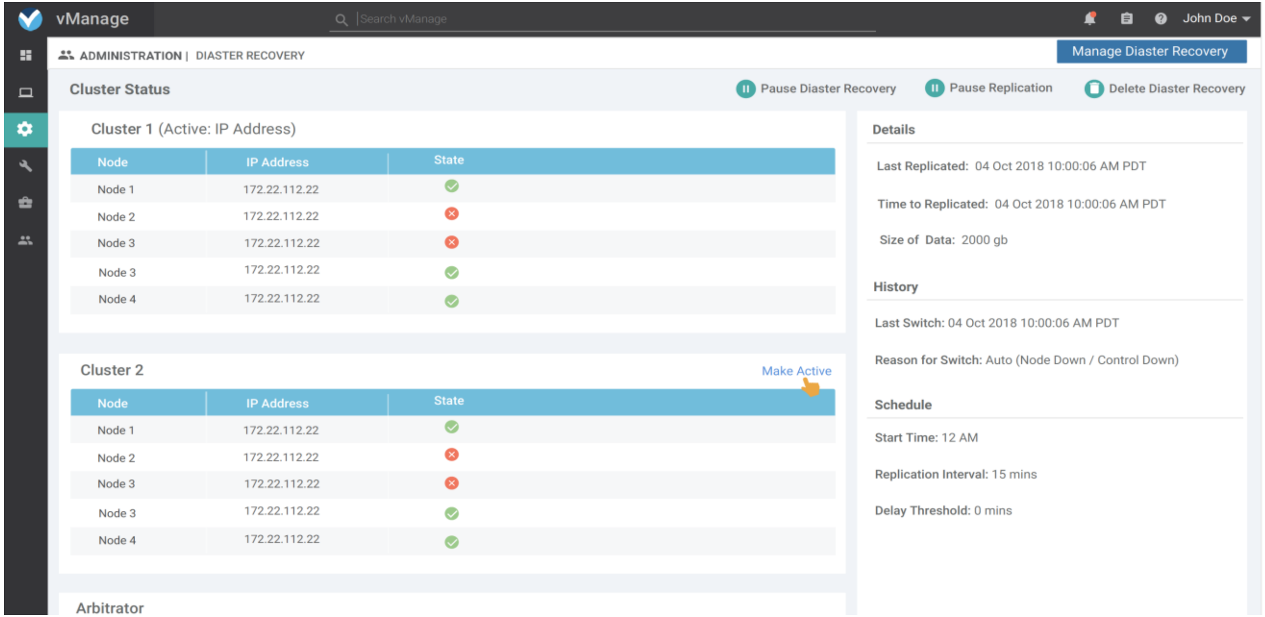
Active vManage Cluster Redundancy

Database Synchronization and Cluster Monitoring



vManage Service	Traffic Direction	Protocol	Port
Application Server	Bidirectional	TCP	443
Netconf	Bidirectional	TCP	830
Consul	Bidirectional	TCP	18600, 18500, 18501, 18301, 18302, 18300

vManage Redundancy Configuration
Configure Standby Mode and DB Synchronization



Cluster Status

Cluster 1 (Active: IP Address)

Node	IP Address	State
Node 1	172.22.112.22	✓
Node 2	172.22.112.22	✗
Node 3	172.22.112.22	✗
Node 3	172.22.112.22	✓
Node 4	172.22.112.22	✓

Cluster 2

Node	IP Address	State
Node 1	172.22.112.22	✓
Node 2	172.22.112.22	✗
Node 3	172.22.112.22	✗
Node 3	172.22.112.22	✓
Node 4	172.22.112.22	✓

Arbitrator

Details

Last Replicated: 04 Oct 2018 10:00:06 AM PDT

Time to Replicated: 04 Oct 2018 10:00:06 AM PDT

Size of Data: 2000 gb

History

Last Switch: 04 Oct 2018 10:00:06 AM PDT

Reason for Switch: Auto (Node Down / Control Down)

Schedule

Start Time: 12 AM

Replication Interval: 15 mins

Delay Threshold: 0 mins

Cisco SD-WAN
The Control Plane

Overlay Management Protocol

High Level Description

- Path Vector Routing Protocol specifically designed for overlay networks
- Natively Multiprotocol, Multipath and VPN/Segment Aware
- Peer Auto-discovery w/ Zero line config for basic operation
- Inherent Route Target Constraint Capability
- Automatic Distribution of targeted local routing
- Overlay and Legacy Domain Loop Avoidance capabilities
- Reliable and Secure Transport (SSL)
- Broad Attribute Support
  - Preference
  - Identification
  - Legacy Source Protocol Information
- Consistent Routing and Encryption Synchronization
- Multi-domain capable

Overlay Management Protocol

Distribution of Routing Information for Topology-driven Routing

vRoutes

Branch Routing
into Overlay
Routing
+
Attributes

TLOCs

WAN Attachment:
Private IP/Public IP
Color / Encap
Encryption Keys
+
Attributes

Services

Services:
Type of Service
Location (TLOC)
Forwarding
Information

Policies

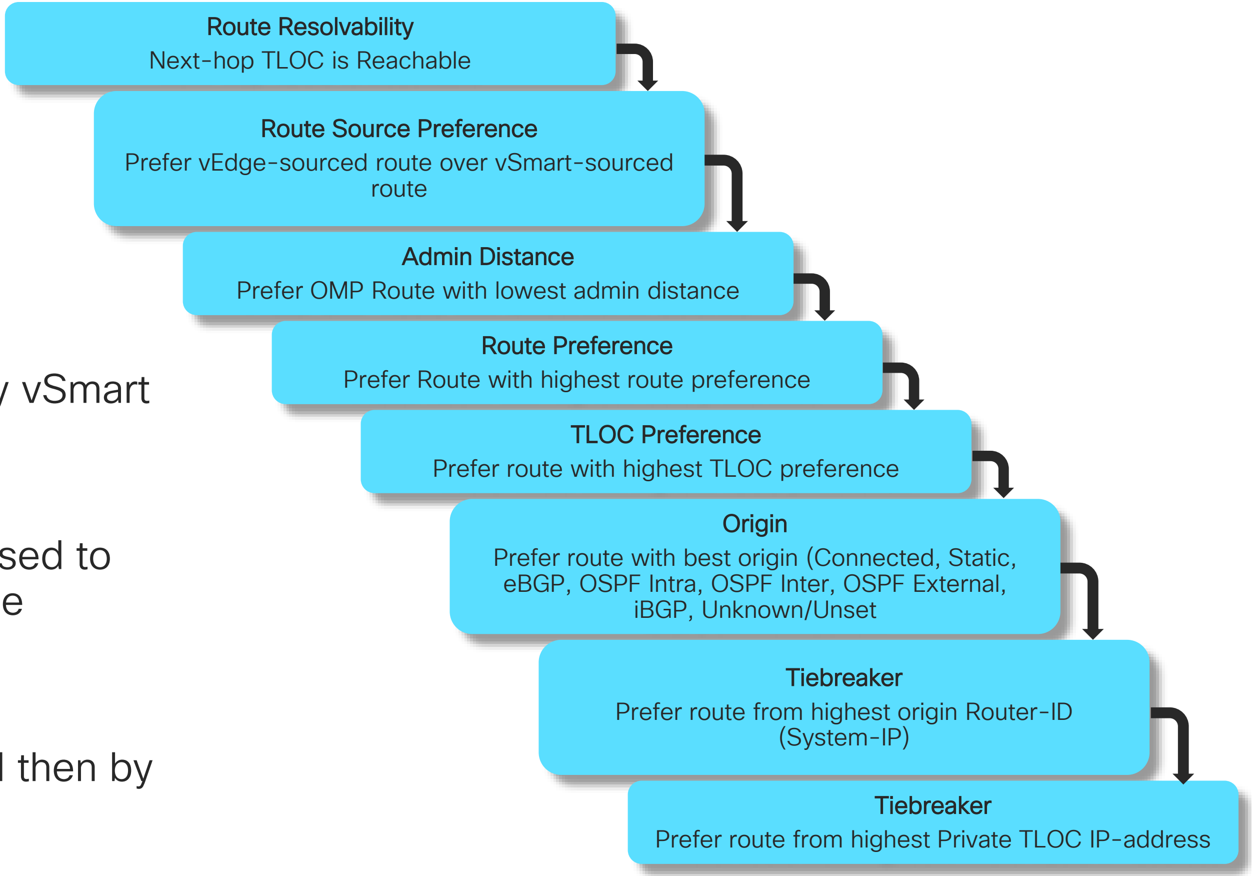
Data Policy
App-Route Policy
VPN Membership
cFlowd Template

Distribution of Routing Information and Policies subject to endpoint push

Updates sent only on changes – Routing engine operates as with existing protocols (BGP)

Overlay Management Protocol

Path Selection



Route Resolvability
Next-hop TLOC is Reachable

Route Source Preference
Prefer vEdge-sourced route over vSmart-sourced route

Admin Distance
Prefer OMP Route with lowest admin distance

Route Preference
Prefer Route with highest route preference

TLOC Preference
Prefer route with highest TLOC preference

Origin
Prefer route with best origin (Connected, Static, eBGP, OSPF Intra, OSPF Inter, OSPF External, iBGP, Unknown/Unset

Tiebreaker
Prefer route from highest origin Router-ID (System-IP)

Tiebreaker
Prefer route from highest Private TLOC IP-address

- Default: 4 paths advertised by vSmart

```
omp
 Send-path-limit [1-16]
```

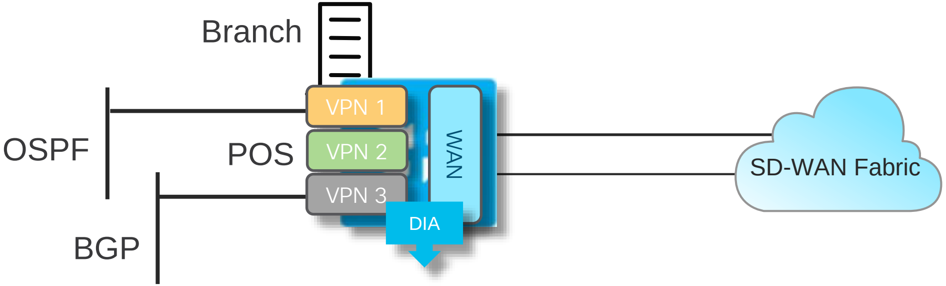
- Backup routes can be advertised to vEdges for faster convergence

```
omp
 Send-backup-paths
```

- Origin by Admin Distance and then by Protocol Cost / Metric

Dynamic Routing for VPN Segments

OMP Overlay Routing in relation to local Routing



Global: Generic setting for node

VPN Specific: Overrides Global

```
vpn 1
 router
  ospf
   redistribute omp
   area 0
    interface ge0/3
    exit
   exit
  !
 !
```

```
vpn 3
 router
  bgp 123
   address-family ipv4-unicast
    redistribute omp
   !
   neighbor 1.1.1.1
    no shutdown
    remote-as 321
   !
```

No redistribution of OMP into OSPF/BGP is enabled by default

Node Global OMP Configuration

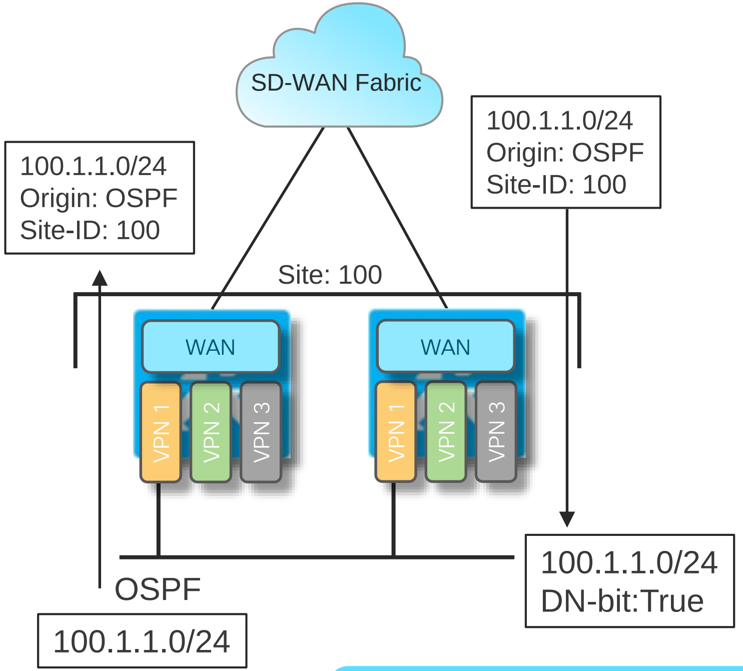
```
omp
 no shutdown
 graceful-restart
 advertise bgp
 advertise connected (default)
 advertise ospf external
 advertise static (default)
```

VPN Specific OMP Configuration

```
vpn 1
 omp
  advertise aggregate <prefix>
  advertise bgp
  advertise connected
  advertise network <prefix>
  advertise ospf external
  advertise static
```

SD-WAN Overlay Routing

LAN Side Routing Loop Avoidance



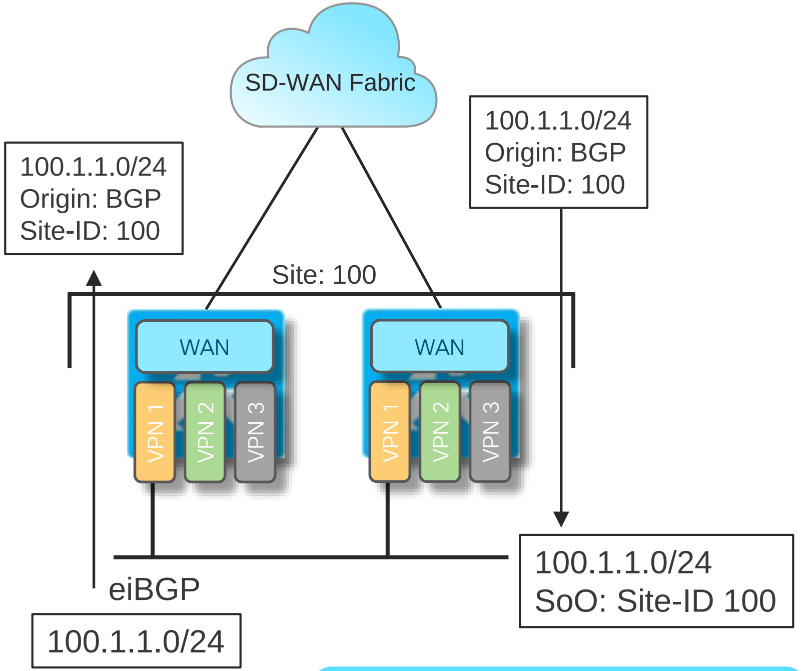
100.1.1.0/24
Origin: OSPF
Site-ID: 100

100.1.1.0/24
Origin: OSPF
Site-ID: 100

100.1.1.0/24
DN-bit:True

100.1.1.0/24

OSPF:
Set DN-bit for any redistributed prefix from OMP to OSPF



100.1.1.0/24
Origin: BGP
Site-ID: 100

100.1.1.0/24
Origin: BGP
Site-ID: 100

100.1.1.0/24
SoO: Site-ID 100

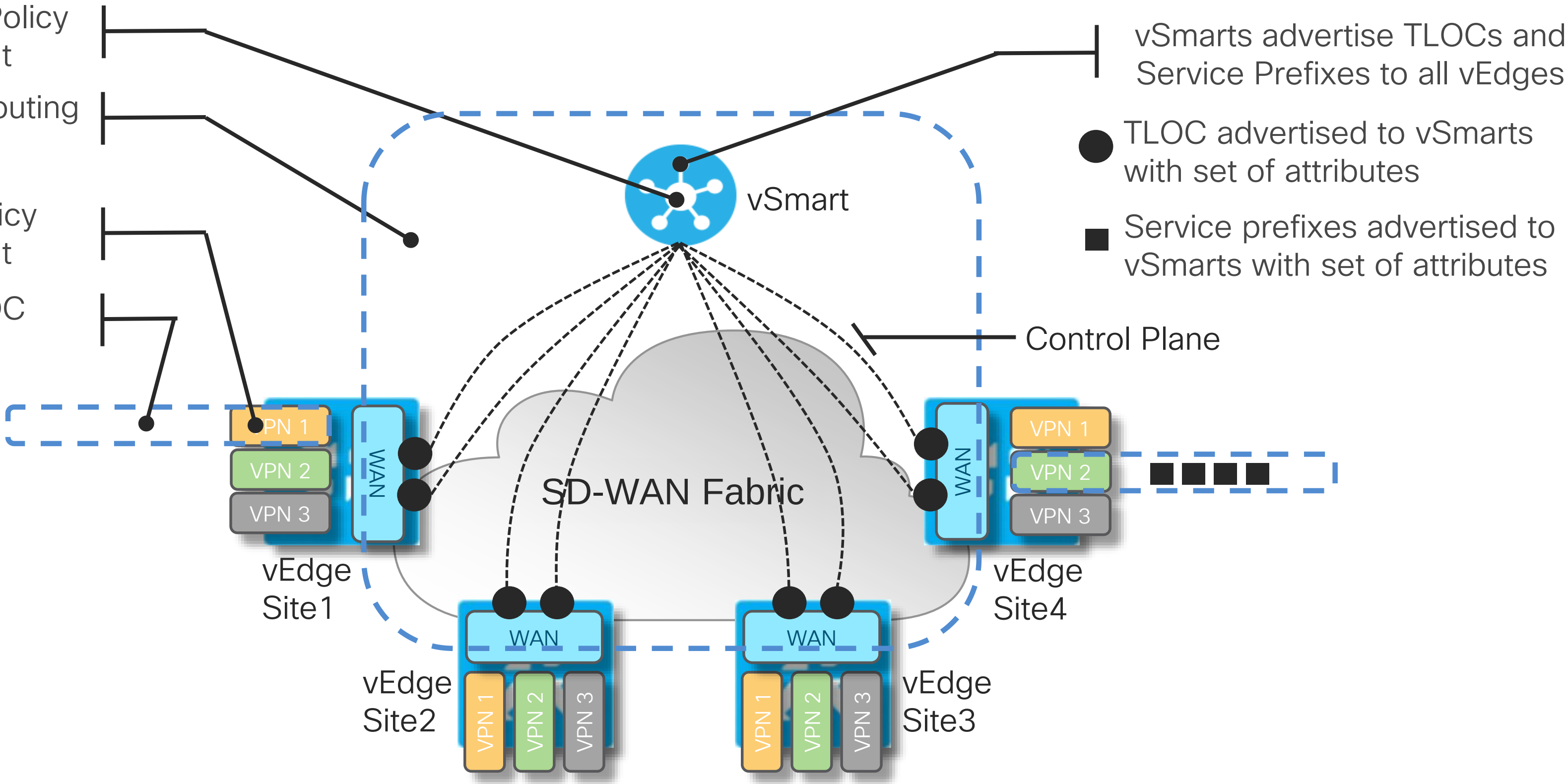
100.1.1.0/24

BGP:
Set SoO to indicate Site-of-Origin for OMP to BGP

Cisco SD-WAN Overlay Routing - Design Considerations

Cisco SD-WAN Overlay Routing

Multi-domain Routing Fabric



Overlay Routing Policy Enforcement Point

Core SD-WAN Routing Domain

Local Routing Policy Enforcement Point

Existing Branch/DC Routing Domain

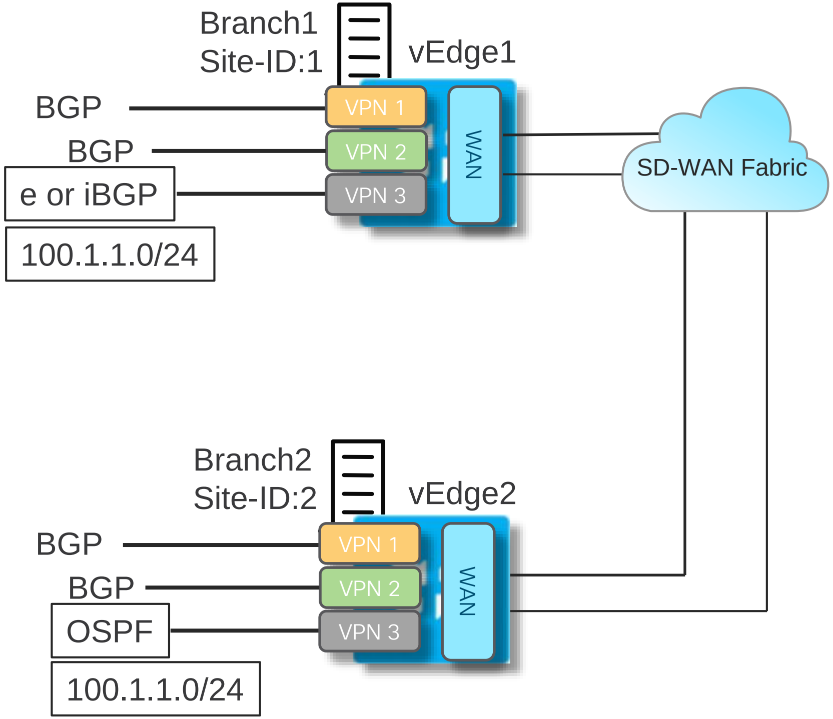
vSmarts advertise TLOCs and Service Prefixes to all vEdges

● TLOC advertised to vSmarts with set of attributes

■ Service prefixes advertised to vSmarts with set of attributes

Control Plane

Overlay Routing – Path Selection



vSmart

```
Vpn Prefix        Peer    Status
3   100.1.1.0/24  vEdge?  C,R
```

iBGP vs **OSPF**

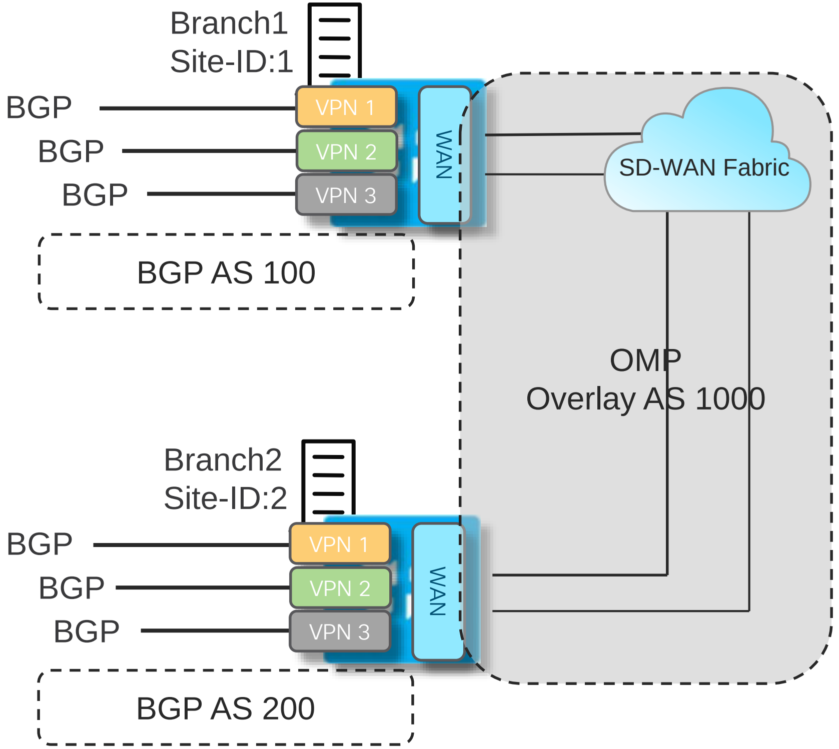
```
Vpn Prefix        Peer    Status
3   100.1.1.0/24  vEdge2  C,R
```

eBGP vs OSPF

```
Vpn Prefix        Peer    Status
3   100.1.1.0/24  vEdge1  C,R
```

SD-WAN Overlay Routing

Overlay AS / Propagate AS



```
omp
 overlay-as 1000
```

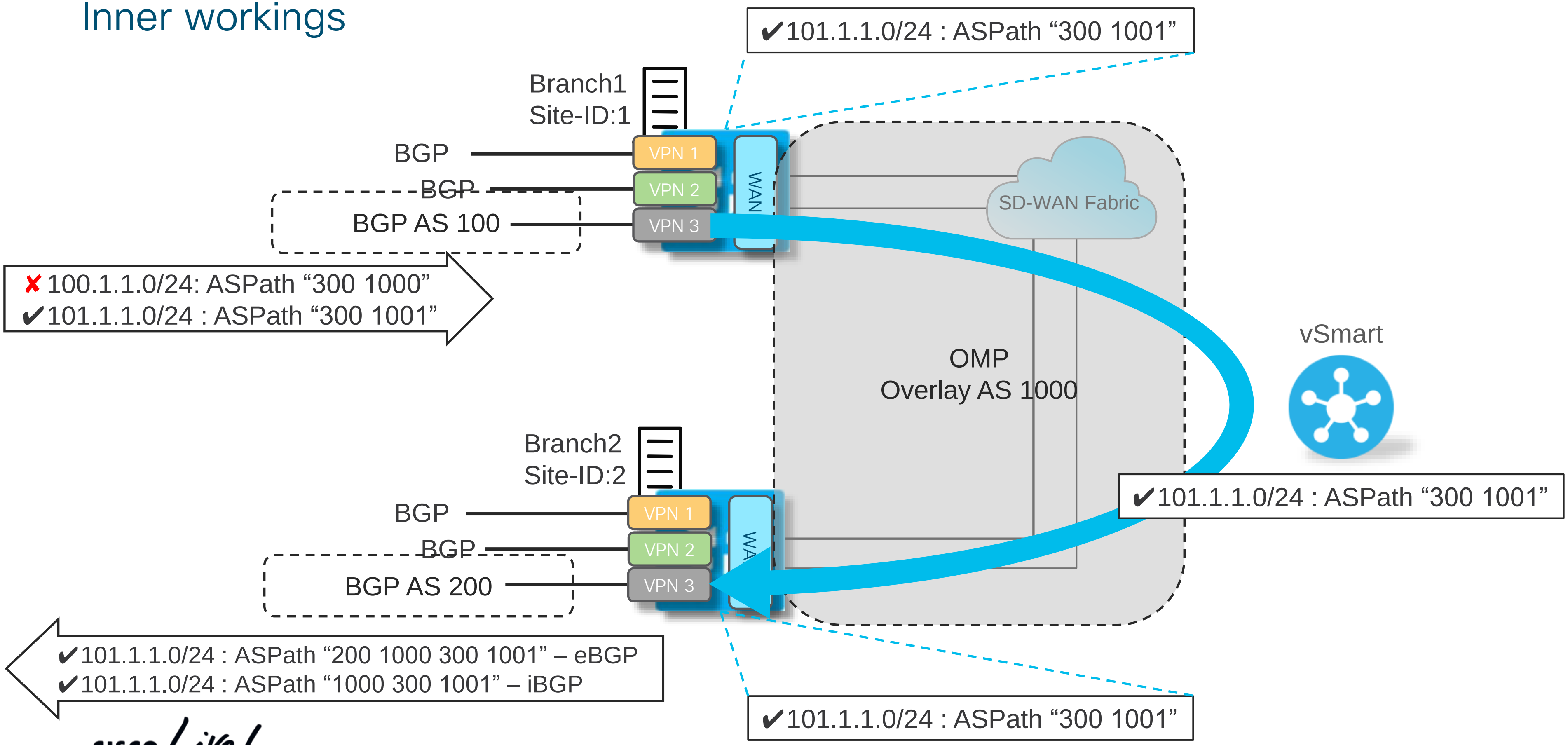
- Overlay AS used to assign an AS to the OMP Domain
- OMP AS is inserted into the AS-path when advertised downstream (iBGP + eBGP)
- Effective tool to ensure loop prevention by using existing BGP behavior

```
vpn 1
 router bgp <as>
  propagate-aspath
```

- Propagate-aspath enables propagation of AS-path for BGP prefixes across OMP domain

Overlay Routing – Overlay AS / Propagate AS

Inner workings



✔101.1.1.0/24 : ASPath “300 1001”

✘100.1.1.0/24: ASPath “300 1000”
✔101.1.1.0/24 : ASPath “300 1001”

✔101.1.1.0/24 : ASPath “300 1001”

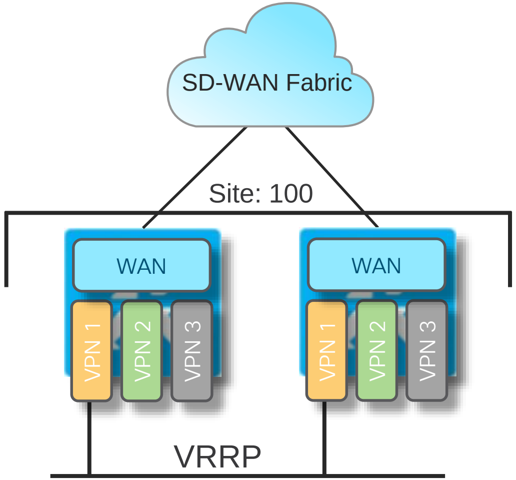
✔101.1.1.0/24 : ASPath “200 1000 300 1001” – eBGP
✔101.1.1.0/24 : ASPath “1000 300 1001” – iBGP

✔101.1.1.0/24 : ASPath “300 1001”

Site Design

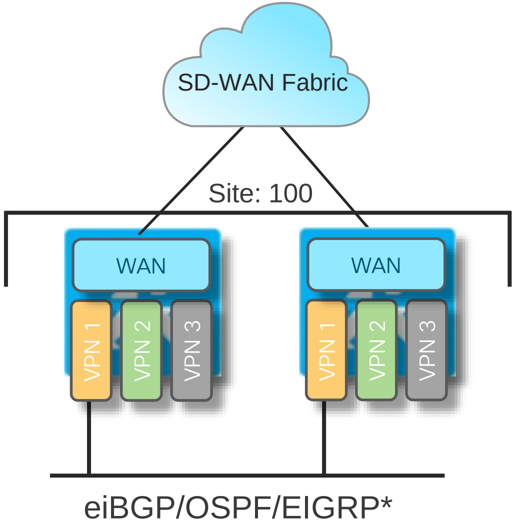
Site Redundancy

Bridged vs Routed LAN



- Layer 2 Site uses VRRP per Segment
- RFC5798 Compliant
- OMP and Prefix upstream tracking

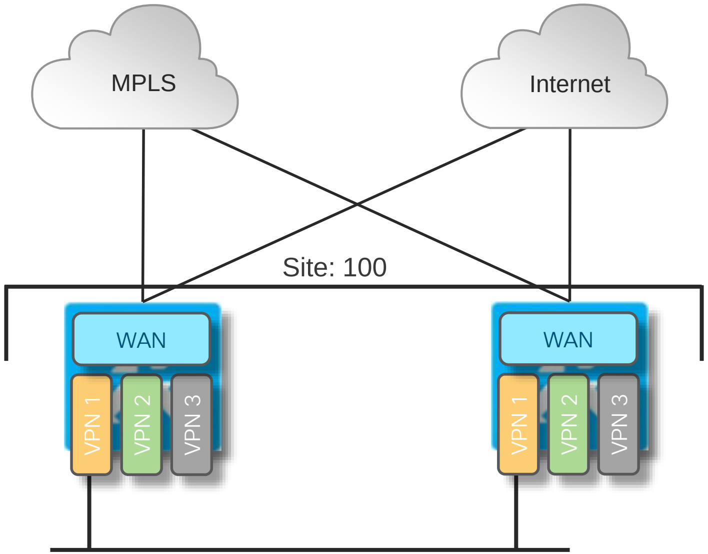
- Layer 3 Site uses L3 dynamic routing per Segment
- *EIGRP is IOS-XE Only
- Mutual OMP/LAN Distribution must be enabled if required



- Loop Avoidance via OSPF DN or BGP SoO
- Multi-pathing as provided by Routing
- WAN Multi-pathing enabled by default
- Site-ID should be identical across same site routers
- Control Policy to manage WAN path priority
- Local Policy for LAN Routing requirements

Site Redundancy

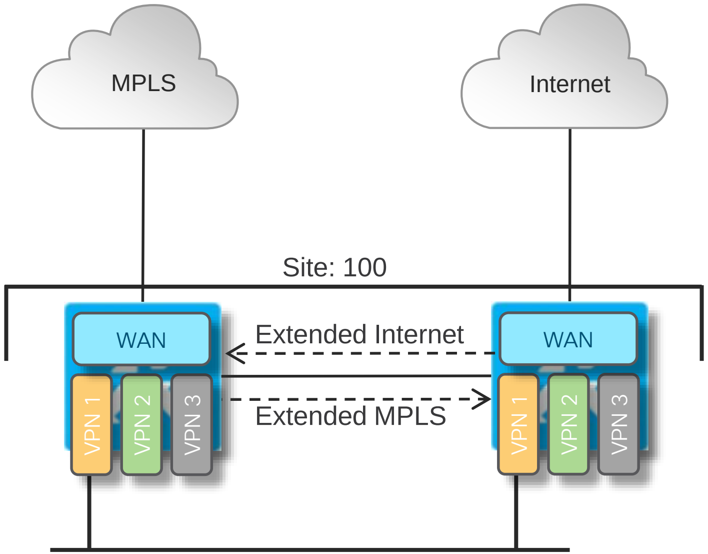
Meshed WAN Transport Attach



- All Transports directly attached to every node in branch
- Each node manages WAN control and data plane independently
- Only simple static default routing required for each transport
- WAN Dynamic Routing also supported is required (usually for certain MPLS providers)

Site Redundancy

Extended WAN Transport Attach aka TLOC Extension

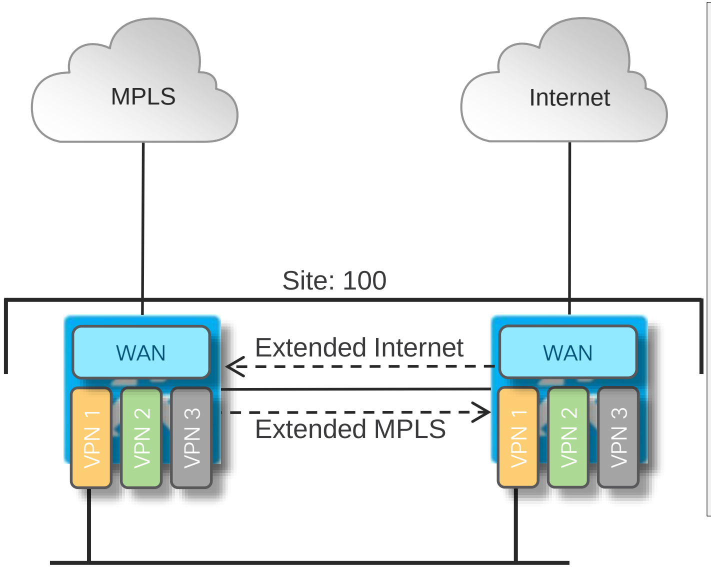


- Directly attached Transport extended to neighboring node
- Each node manages WAN control and data plane independently
- Routing through neighbor for extended TLOC
- L2 or L3 (IOS-XE Only) extension
  - vEdge: L2
  - cEdge: L2 or L3 (GRE)
- Discrete links or 802.1Q can be used between neighbors

Site Redundancy using TLOC Extension

Configuration Example

```
vpn 0
 interface ge0/0
  tunnel-interface
   color mpls
  !
 !
 interface ge0/1.10
  tunnel-interface
   color biz-internet
  !
 !
 interface ge0/1.20
  tloc-extension ge0/0
 !
 ip route 0.0.0.0/0 <nhop on ge0/0>
 ip route 0.0.0.0/0 <nhop on ge0/1.10>
```



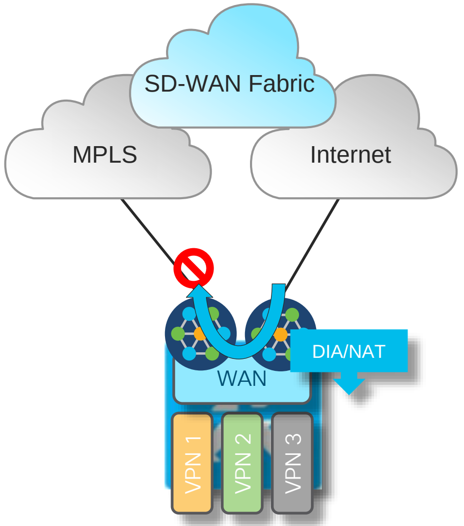
```
vpn 0
 interface ge0/0
 nat
 tunnel-interface
  color biz-internet
  !
 !
 interface ge0/1.10
  tloc-extension ge0/0
 !
 interface ge0/1.20
  tunnel-interface
   color mpls
  !
 !
 ip route 0.0.0.0/0 <nhop on ge0/0>
 ip route 0.0.0.0/0 <nhop on ge0/1.20>
```

Return traffic is handled by advertising the TLOC subnet (ge0/1.10) to MPLS

Return traffic is handled by NAT on ge0/0

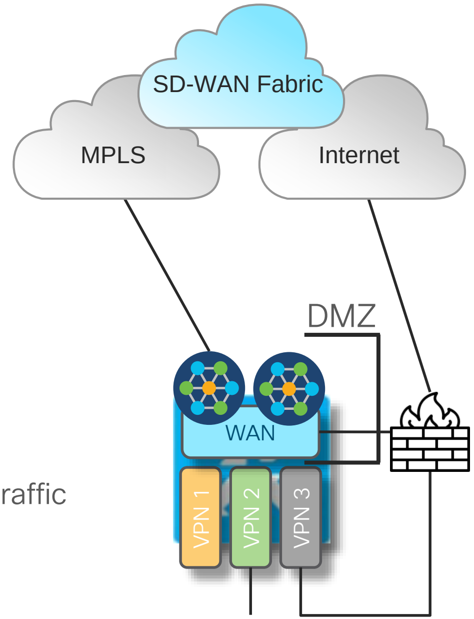
SD-WAN Edge Security Site Design

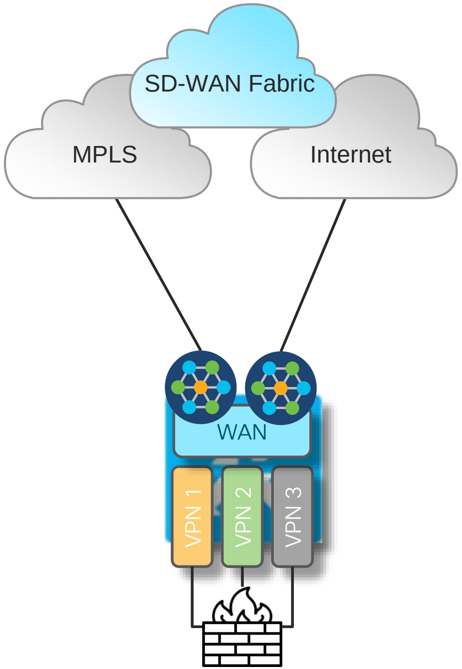
Various Integration Options



External Firewall for Internet Circuits

- FW provides NAT / vEdge does NAT traversal
- FW could be In / Offline for internal connectivity





Fabric Security

- Secures TLOC Attachment
- Prevents vEdge Transit / Inter-TLOC Traffic

DIA/NAT

Local vEdge NAT for DIA

- Port Restricted NAT
- vEdge Zone Based Firewall Protection

Service-side Firewall

- Built-in ZBFW / App-Layer FW equivalent
- External FW Securing the internal network

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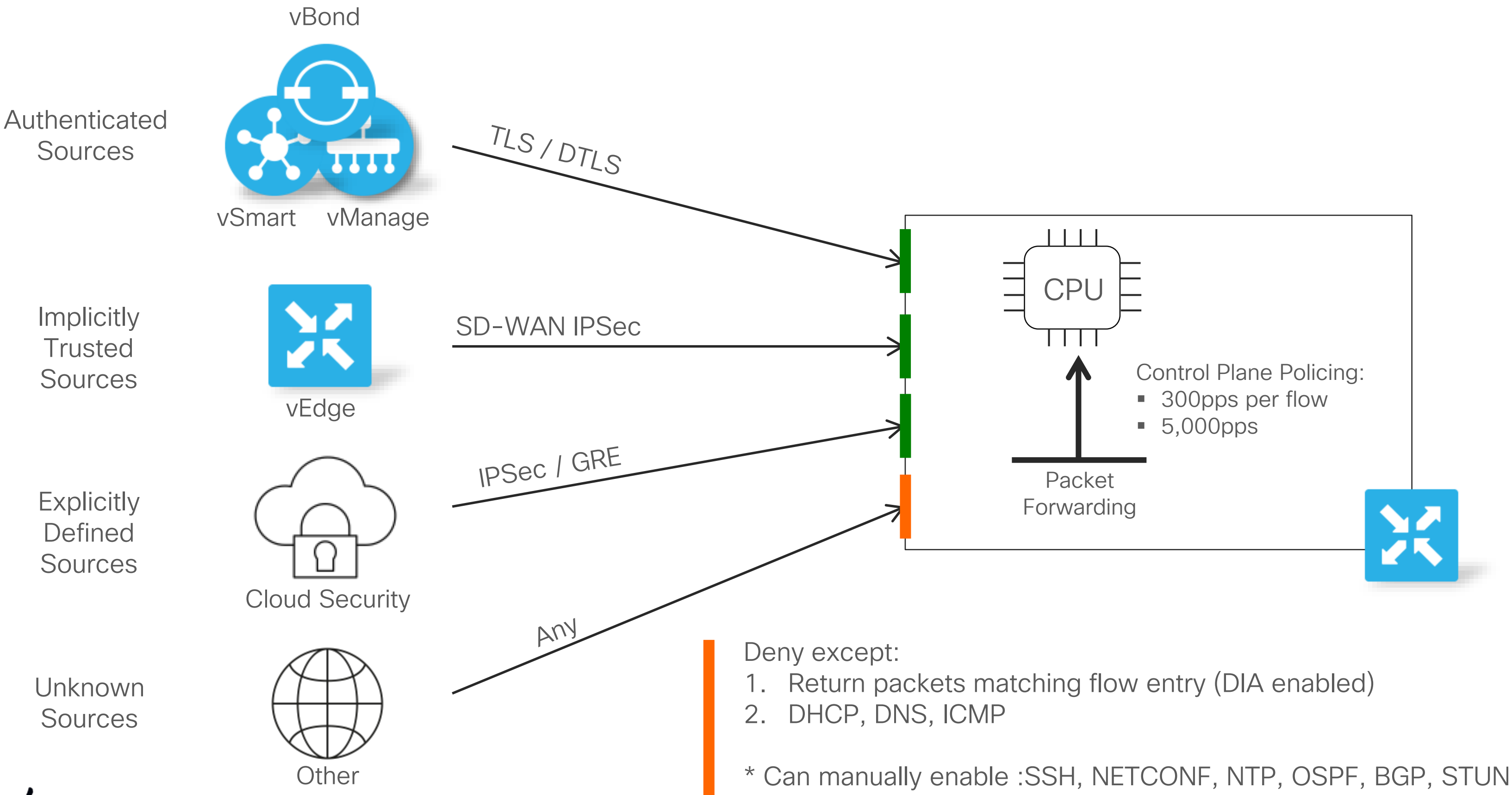
WAN Edge Fabric Security Capabilities



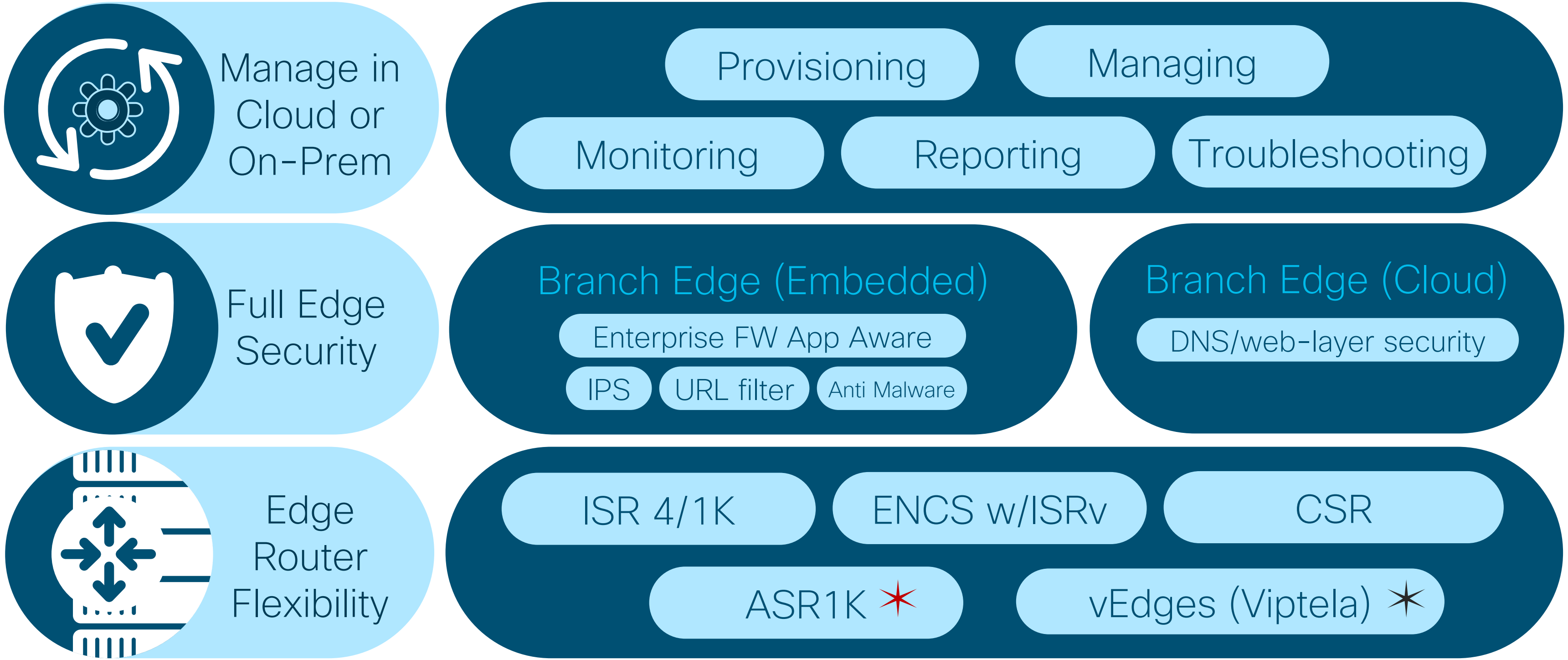
Control Plane Policing:
- 300pps per flow
- 5,000pps

Deny except:

1. Return packets matching flow entry (DIA enabled)
2. DHCP, DNS, ICMP

* Can manually enable :SSH, NETCONF, NTP, OSPF, BGP, STUN

SD-WAN Security



Manage in Cloud or On-Prem

Provisioning

Managing

Monitoring

Reporting

Troubleshooting

Full Edge Security

Branch Edge (Embedded)

Enterprise FW App Aware

IPS

URL filter

Anti Malware

Branch Edge (Cloud)

DNS/web-layer security

Edge Router Flexibility

ISR 4/1K

ENCS w/ISRv

CSR

ASR1K ✶

vEdges (Viptela) ✶

✶ Only App Aware FW and DNS/web-layer security

✶ Only FW and DNS/web-layer security

LTE Design and Deployment Options

LTE Design and Deployment Options

- Active LTE as a standard TLOC
  - Reduce control and management traffic
- Active LTE as a low bandwidth circuit
  - Reduce control/management traffic and synchronize for quite period to meet M2M requirements
- LTE as a gateway of Last Resort
  - LTE circuit is down and brought up when all other transports are down
- LTE as the ONLY circuit
  - Reduce control and management traffic plus disable many stats collection from vManage

Generic Guidelines for LTE

Reduction in control traffic

1. Control Plane Hello Interval

```
vpn 0
interface <name>
tunnel-interface hello-interval <ms>
```

Range: 100-600000 milliseconds (10 minutes)
Default: 1000 milliseconds (1 second)

2. BFD hello timer can be extended to 5 minutes

```
bfd
color <color> hello-interval <ms>
```

Range: 100-300000 milliseconds (5 minutes)
Default: 1000 milliseconds (1 second)

3. Ensure LTE is not preferred for vManage communication

```
vpn 0
interface <name>
tunnel-interface
vmanage-connection-preference <n>
```

Range: 0 through 8
Default: 5

For an LTE-only device
Ensure vManage collection of (high-volume) statistics is disabled

LTE Operation

Last Resort Circuit

- LTE interface is kept down when other transport interfaces are up

```
vpn 0
interface <name>
tunnel-interface
last-resort-circuit
```

- Convergence time - Bring-up triggered when all other WAN links are down
  - Time for bfd failure detection on other transports [7 sec]
  - Time to bring LTE up and operational (IP assigned)
  - Bring up control connections on LTE [20-30 sec]
  - Bring up BFD/IPSec connections [5-10 sec]

LTE Operation

Low-Bandwidth Circuit

- LTE interface synchronizes the control and BFD traffic
- Provides long quite periods to meet M2M requirements
- LTE circuit releases the channel during that time

```
vpn 0
interface <name>
tunnel-interface
low-bandwidth-link
```

  - This configuration command is relevant only for a spoke vEdge router in a hub-and-spoke deployment scenario
  - On the spoke router only
  - on such links, application-aware routing data is collected only when user data is transmitted from the LAN to the WAN, to reduce BFD traffic on the link

Cisco SD-WAN Data Plane - Design Considerations

Cisco SD-WAN Data Plane

Default Mode of Operation

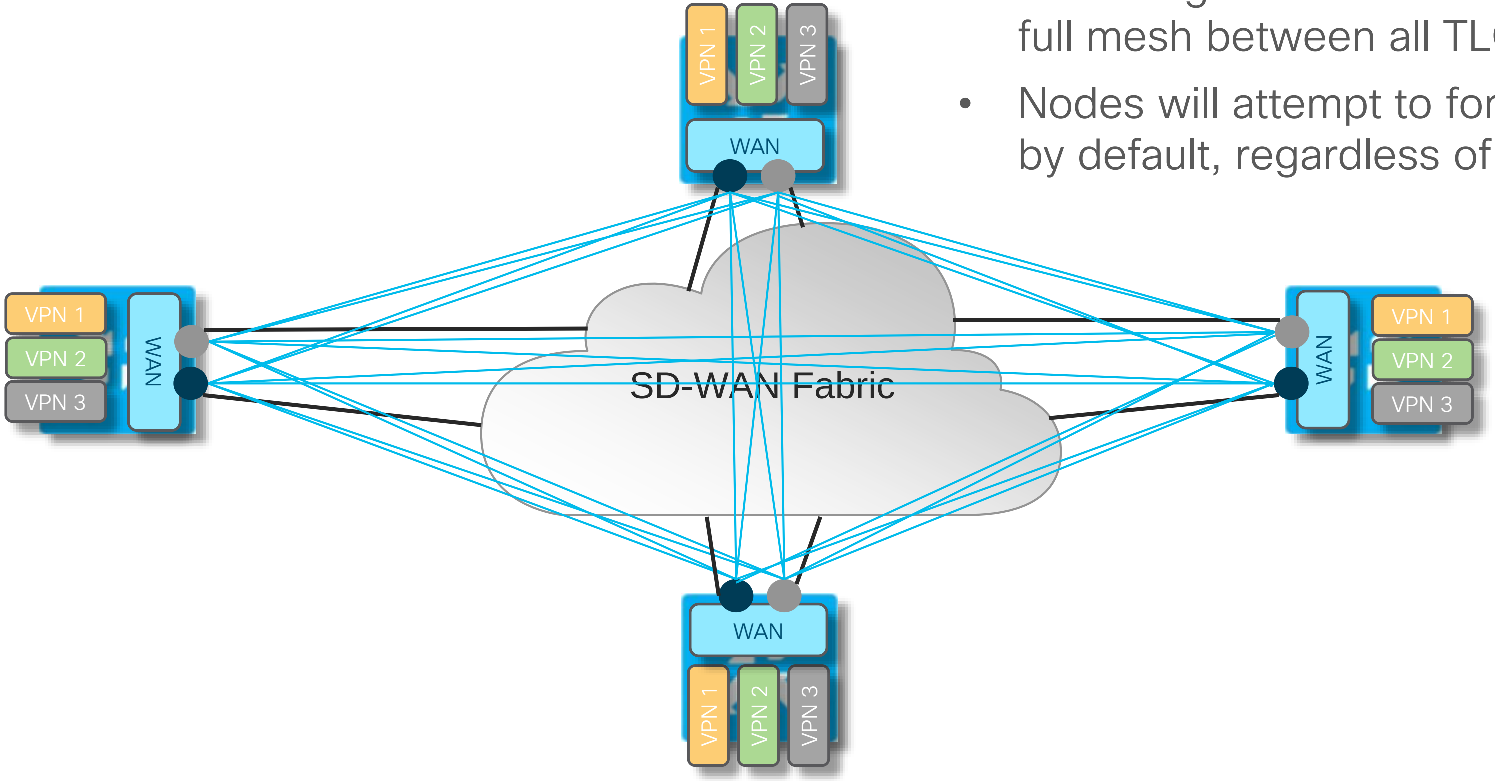
● MPLS TLOC

● Internet TLOC

— Physical Link

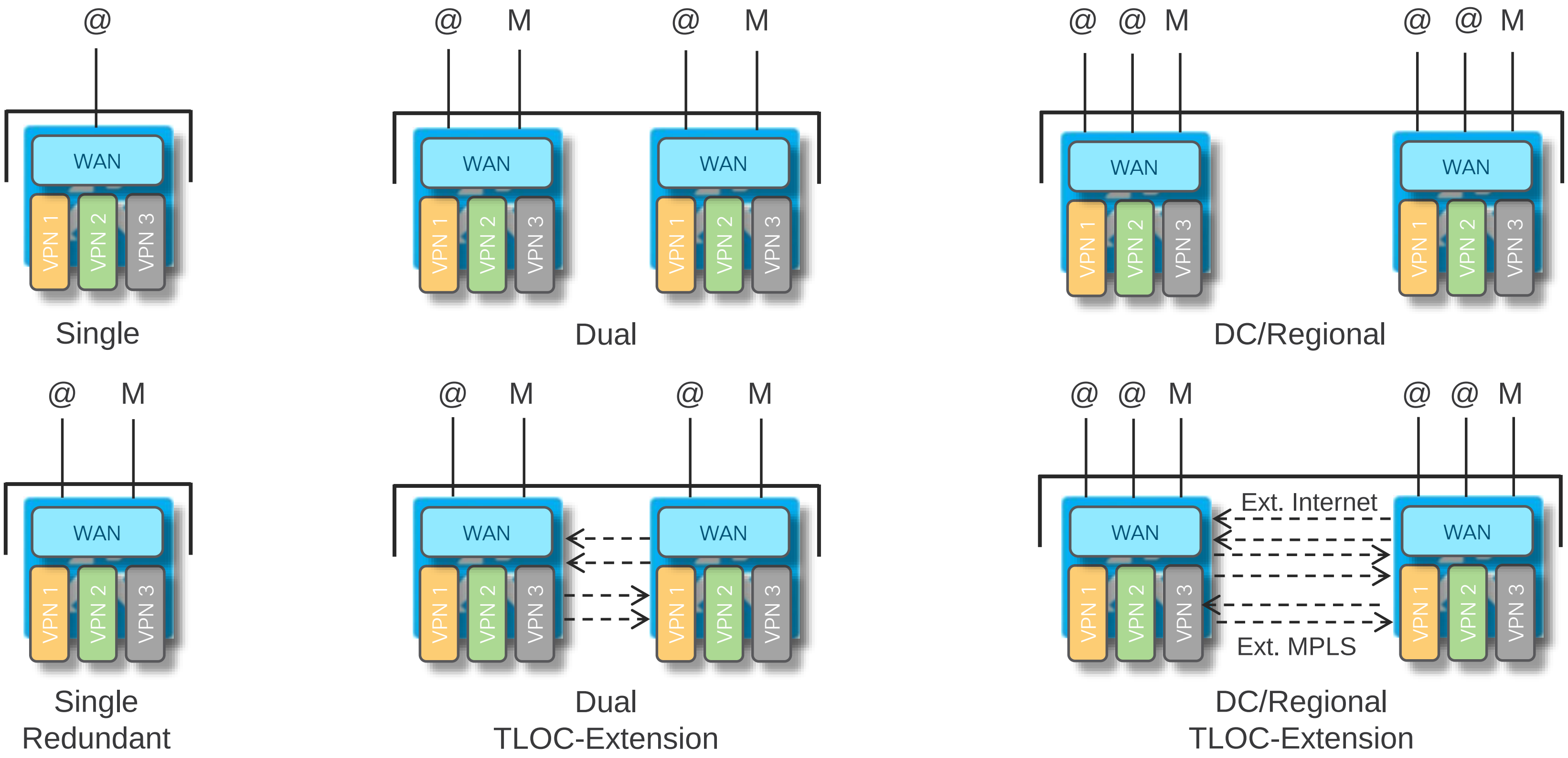
— Tunnel

- Assuming Interconnected underlays, full mesh between all TLOCs
- Nodes will attempt to form full mesh by default, regardless of TLOC color



Customer design - Site Types and Connectivity

Data Plane Design Example



Single

Dual

DC/Regional

Single Redundant

Dual TLOC-Extension

DC/Regional TLOC-Extension

BFD / Tunnel Consumption by Site Type

Customer Deployment Example

Site Type	Devices	Internet Links	MPLS Links	TLOCs	TLOC Extension	Colors
Single	1	1	0	1	No	1
Single Redundant	1	1	1	2	No	2
Dual	2	2	2	4	No	4
Dual TLOC Extension	2	2	2	8	Yes	4
DC	2	4	2	6	No	6
DC TLOC Extension	2	4	2	12	Yes	6

Source: Cisco Internal i.e. Stefan

BFD / Tunnel Consumption by Site Type

Consumption with Default Configuration

Site Type	Single	Single Redundant	Dual	Dual TLOC Extension	DC	DC TLOC Extension
Single	1/1	2/2	4/4	8/8	6/6	12/12
Single Redundant	2/2	4/4	8/8	16/16	12/12	24/24
Dual	4/4	8/8	16/16	32/32	24/24	48/48
Dual TLOC Extension	8/8	16/16	32/32	64/64	48/48	96/96
DC	6/6	12/12	24/24	48/48	36/36	72/72
DC TLOC Extension	12/12	24/24	48/48	96/96	72/72	144/144

Source: Cisco Internal i.e. Stefan

SD-WAN Data Plane Design

Tools and Techniques for defining data plane connectivity

Color Restrict

- Limit Data Plane Establishment to TLOCs of the Same Color
- Simple configuration knob that effectively limits data plane connectivity

TLOC Groups (new in 19.1 (vEdge) / 16.11.2 (cEdge))

- Configure groups that determine actual data plane topology
- Can be combined with restrict
- Define groups based on site type and connectivity requirements for scalable rollout

Control Policy

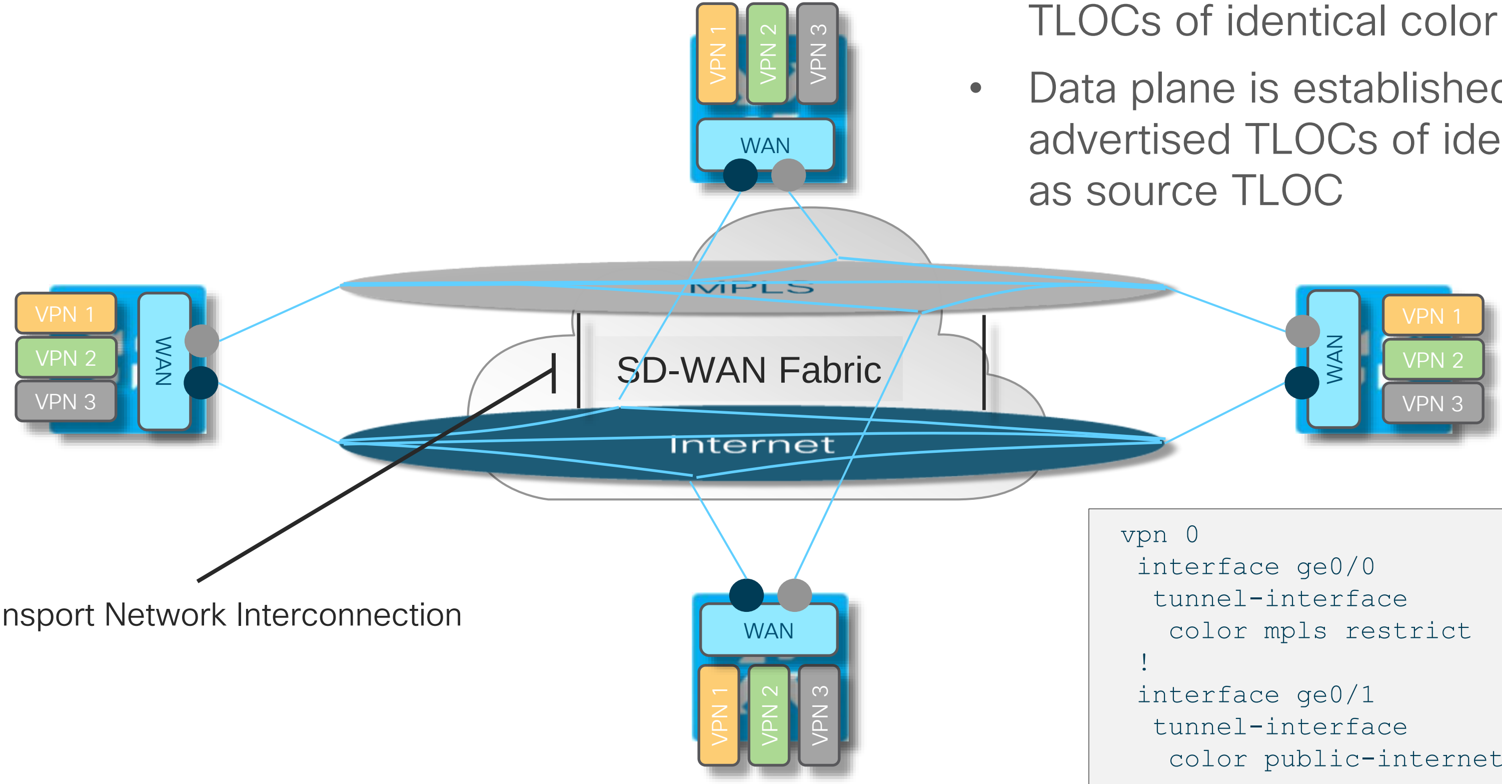
- A control policy allows for TLOC filtering and reassignments
- Can be combined with TLOC Groups and Restrict if needed
- Ultimate control over TLOC distribution, visibility, preference and connectivity model

Cisco SD-WAN Data Plane

Color Restrict

● MPLS TLOC
● Internet TLOC
Physical Link
Tunnel

- Limits data plane connectivity to TLOCs of identical color
- Data plane is established to all OMP advertised TLOCs of identical color as source TLOC



Transport Network Interconnection

```
vpn 0
 interface ge0/0
  tunnel-interface
   color mpls restrict
 !
 interface ge0/1
  tunnel-interface
   color public-internet restrict
```

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BFD / Tunnel Consumption by Site Type

Consumption with Restrict Configuration

Site Type	Single	Single Redundant	Dual	Dual TLOC Extension	DC	DC TLOC Extension
Single	1/1	1/1	1/1	2/2	1/1	2/2
Single Redundant	1/1	2/2	2/2	4/4	2/2	4/4
Dual	1/1	2/2	4/4	8/8	4/4	8/8
Dual TLOC Extension	2/2	4/4	8/8	8/8	8/8	8/8
DC	1/1	2/2	4/4	8/8	6/6	12/12
DC TLOC Extension	2/2	4/4	8/8	8/8	12/12	12/12

Source: Cisco Internal i.e. Stefan

Cisco SD-WAN Data Plane

TLOC Groups

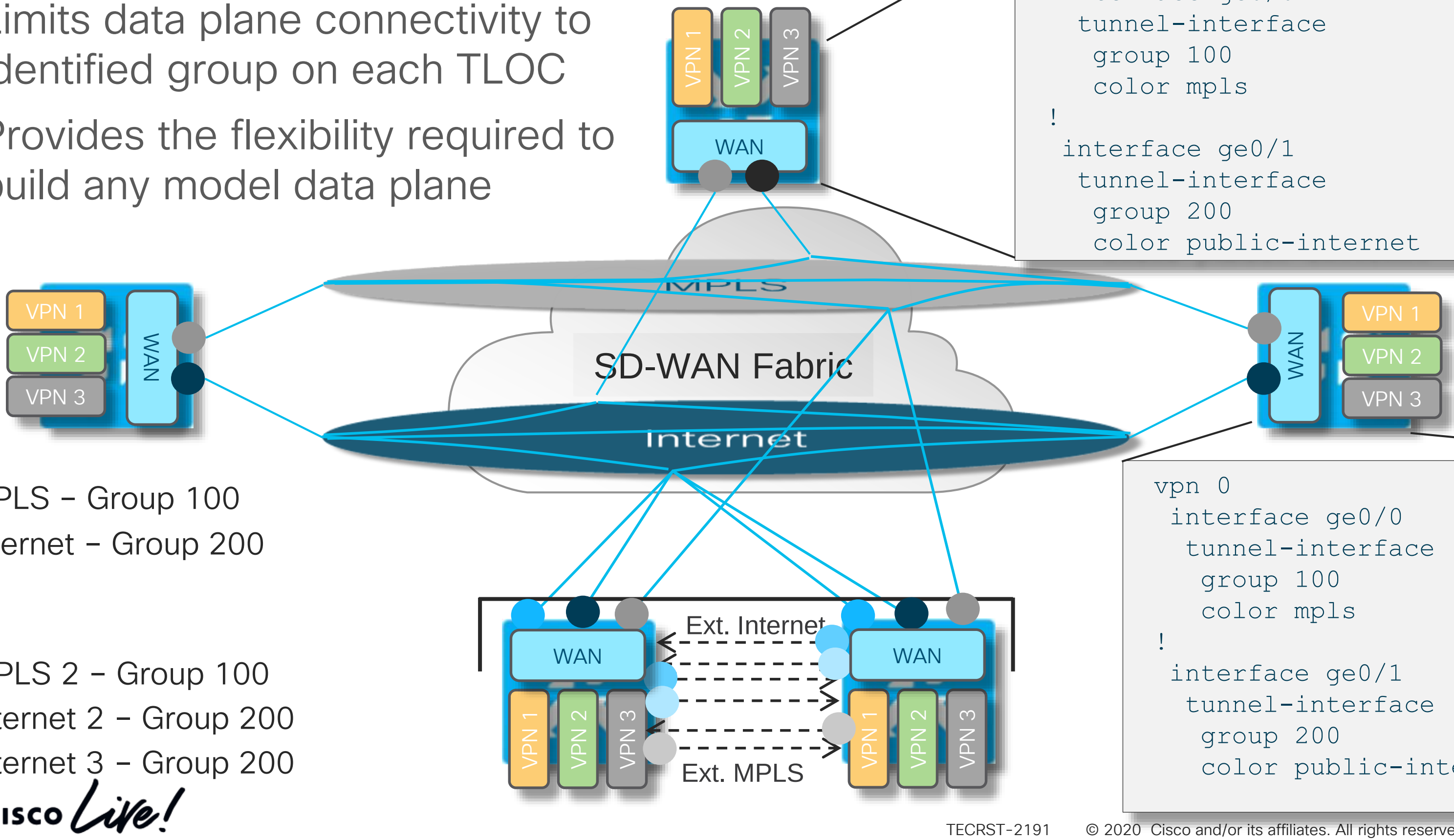
- Limits data plane connectivity to identified group on each TLOC
- Provides the flexibility required to build any model data plane

● MPLS TLOC

● Internet TLOC

— Physical Link

— Tunnel



```
vpn 0
 interface ge0/0
  tunnel-interface
   group 100
   color mpls
!
 interface ge0/1
  tunnel-interface
   group 200
   color public-internet
```

```
vpn 0
 interface ge0/0
  tunnel-interface
   group 100
   color mpls
!
 interface ge0/1
  tunnel-interface
   group 200
   color public-internet
```

● MPLS – Group 100

● Internet – Group 200

● MPLS 2 – Group 100

● Internet 2 – Group 200

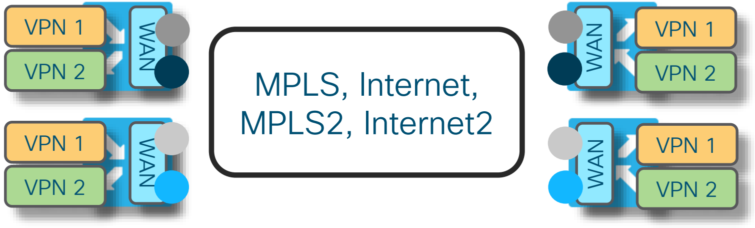
● Internet 3 – Group 200

cisco Live!

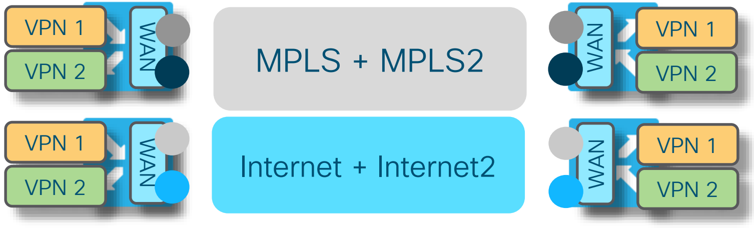
Cisco SD-WAN Data Plane

TLOC Groups and Restrict

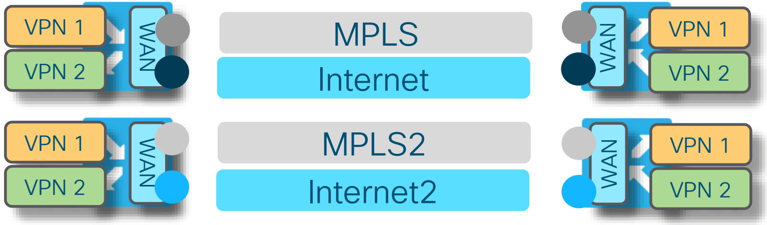
Default Behavior – Full Mesh among all colors



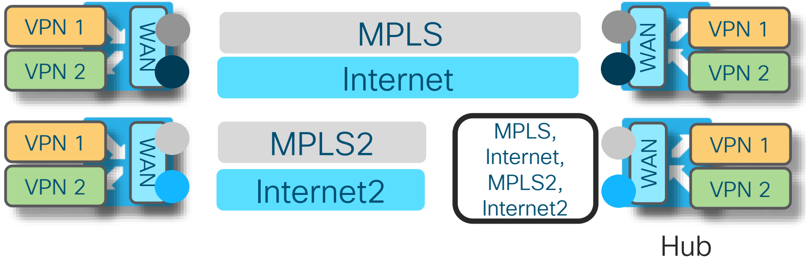
MPLS and MPLS 2 with Group 100
Internet and Internet 2 with Group 200



Restrict Configured for all Colors



Restrict for all Colors
MPLS and MPLS 2 with Group 100
Internet and Internet 2 with Group 200
Hub with No Group – Promiscuous



● MPLS – Group 100
● MPLS 2 – Group 100
● Internet – Group 200
● Internet 2 – Group 200

Cisco SD-WAN Data Plane

TLOC Groups - When to Use

- In a given WAN Edge, a color can be used only once
- This makes for a challenge in networks with multiple MPLS or Internet connections where:
  - Centralized resources are required across branches
  - Those resources aren’t connected to all underlay transports and consequently isn’t present across all colors
- Restrict becomes too restrictive - limits data plane to single color
- Control Policy Filtering doesn’t help overcome a requirement for per-color meshing combined with inter-color connectivity

Cisco SD-WAN Data Plane

Control Policy

- Control Policy can be used to:
  - Filter TLOCs to limit data plane peers per color
  - Re-assign TLOCs for vRoutes to adapt VPN connectivity to data plane
  - Assign priorities to influence path selection
- A Control Policy allows for controlling the distribution of TLOCs across the network along with attribute settings
  - TLOC present means data plane is established
  - TLOC attributes control load-balancing and path selection
- Control Policy Examples coming up

Cisco SD-WAN Data Plane

Using TLOC Attributes

- Every TLOC is advertised with some quite powerful attributes
  - Encapsulation (IPsec and/or GRE) - can be referred to in Policy
  - Weight (Relative bandwidth to other TLOCs on the originating node)

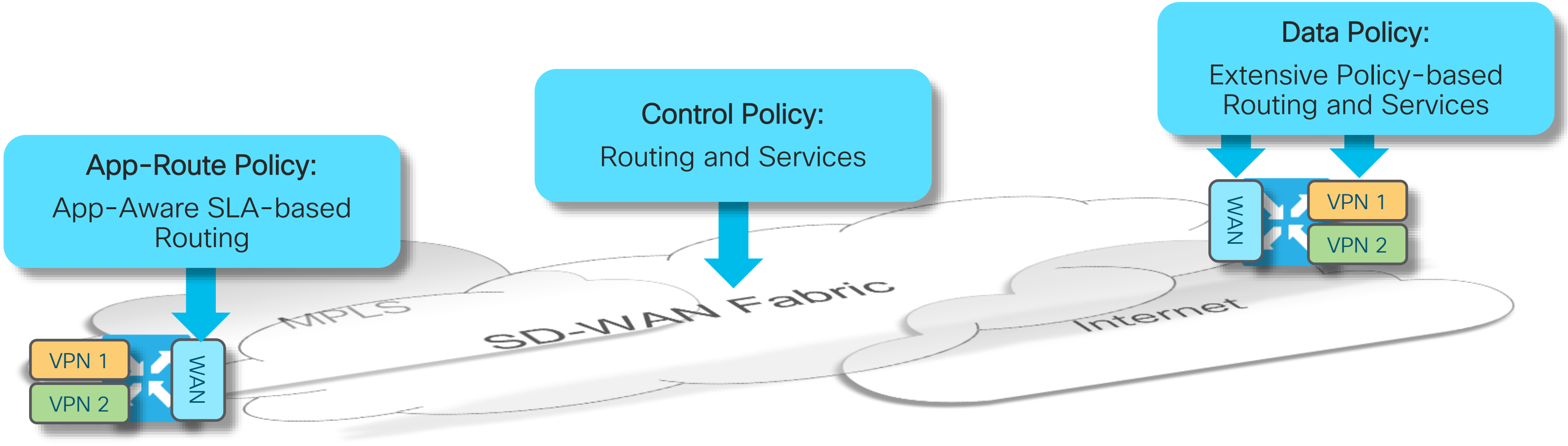
    Edge applies local and remote TLOC weight when load-balancing
  - Preference (Used in path selection)

```
vpn 0
 interface ge0/0
  tunnel-interface
   encapsulation gre preference 100 weight 10
   encapsulation ipsec preference 100 weight 10
  !
 !
!
```

Cisco SD-WAN Policy Framework - Overview

Cisco SD-WAN Policy Architecture

Suite of Policies to address different functional domains



- Control Policies are applied at vSmart: Tailors routing information advertised to vEdge endpoints
- App-Route Policies are applied at vEdge: SLA-driven path selection for applications
- Data Policies are applied at vEdge: Extensive Policy driven routing

Control Policies

Overlay Management Protocol Routing Policies

- Control policies are applied and executed on vSmart to influence routing in the Overlay domain
- Control policies filter or manipulate OMP Routing information to:
  - Enable services
  - Influence path selection
- Control Policies controls the following services:
  - Service Chaining
  - Traffic Engineering
  - Extranet VPNs
  - Service and Path affinity
  - Arbitrary VPN Topologies
  - and more …
- The Control Policy is one of the centralized and powerful tools in the Cisco SD-WAN toolbox

Data Policies

Policy-driven Routing and Service Enablement

- Data policies:
  - Applied on vSmart
  - Advertised to and executed on WAN Edge
- A Data policy acts on an entire VPN and is not interface-specific
- Data Policies are used to enable the following functions and services:
  - Application Pinning
  - NAT/DIA
  - Classification, Policing and Marking
  - and more …
- Use a Data Policy for any type of data plane centered traffic management

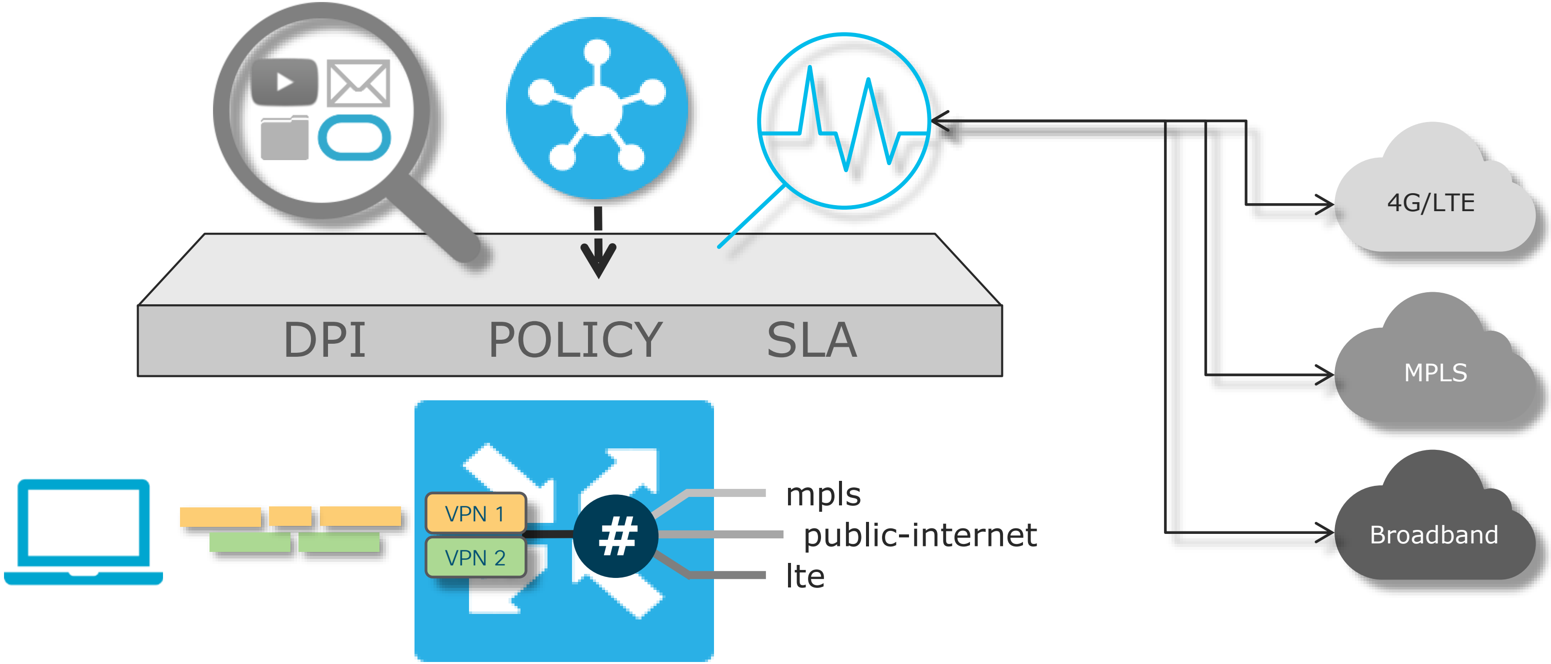
App-Route Policies

Centralized Policy for enabling SLA-driven routing on WAN Edge endpoints

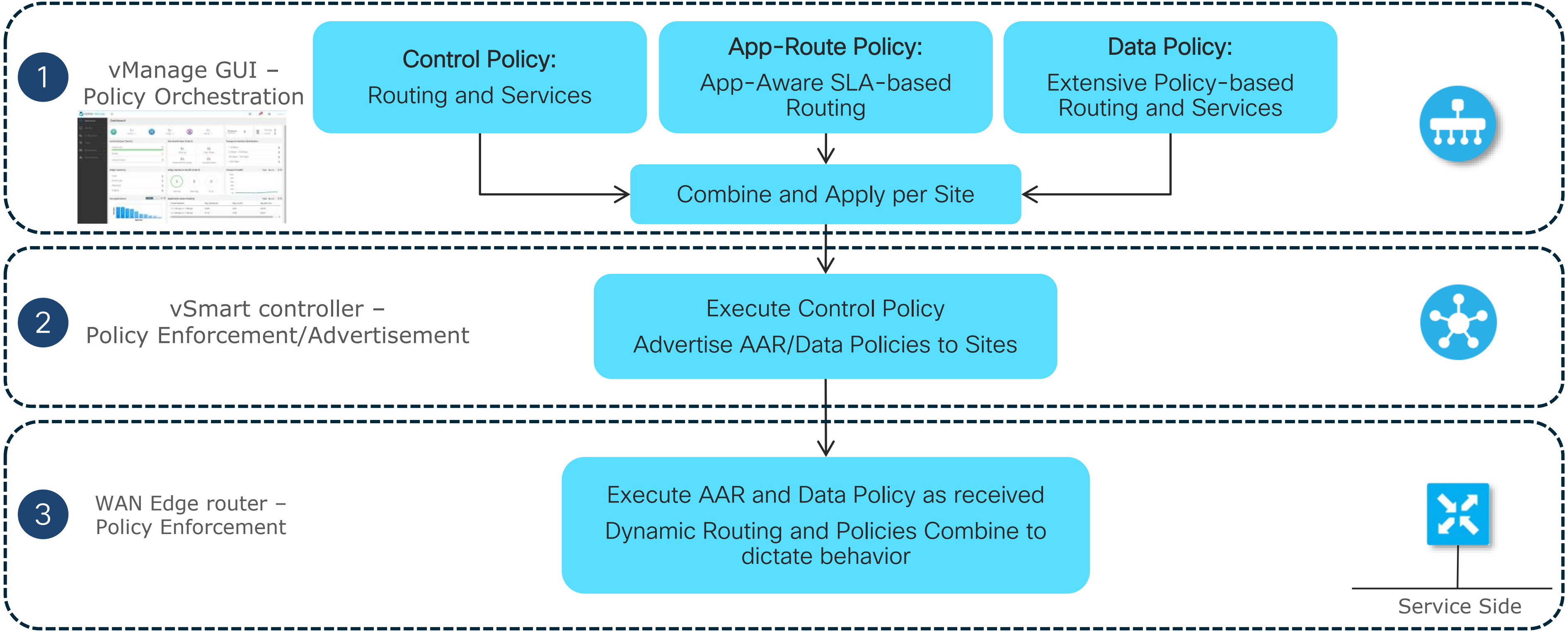
- App-route policies:
  - Applied on vSmart
  - Advertised to and executed on WAN Edge
- Monitors SLAs for active overlay paths to direct Applications along qualified paths
- Allows for the use of L3/L4 keys or DPI Signatures for application identification
- Delivers a fully distributed SLA-driven routing mechanism

App-Aware Routing Policies

SLA-Driven Routing / Performance Routing



Cisco SD-WAN Policy Orchestration Process



1 vManage GUI – Policy Orchestration

Control Policy:
Routing and Services

App-Route Policy:
App-Aware SLA-based Routing

Data Policy:
Extensive Policy-based Routing and Services

Combine and Apply per Site

2 vSmart controller – Policy Enforcement/Advertisement

Execute Control Policy
Advertise AAR/Data Policies to Sites

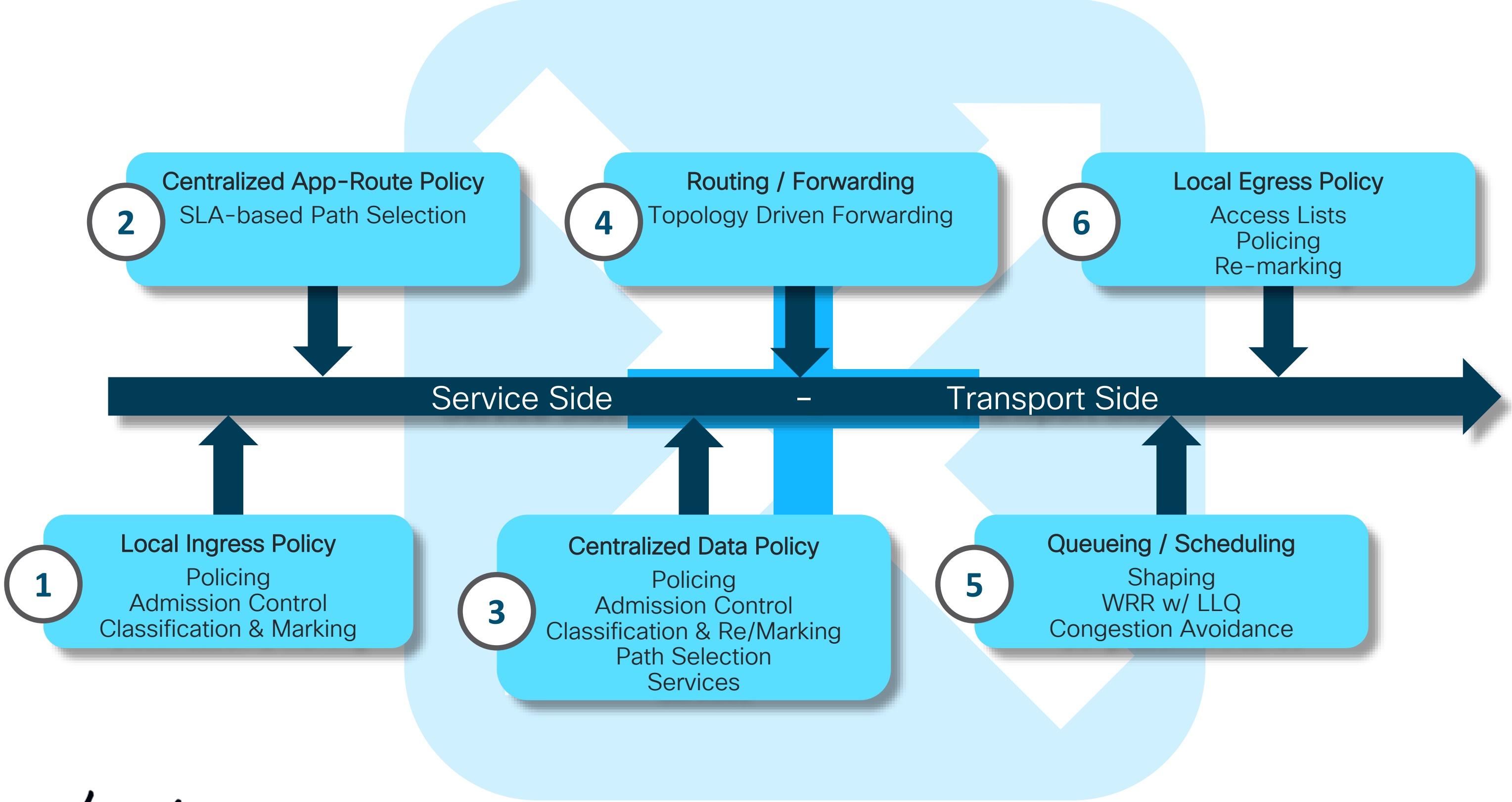
3 WAN Edge router – Policy Enforcement

Execute AAR and Data Policy as received
Dynamic Routing and Policies Combine to dictate behavior

Service Side

Cisco SD-WAN Policy Execution

Topology-driven routing and Policy execution chain



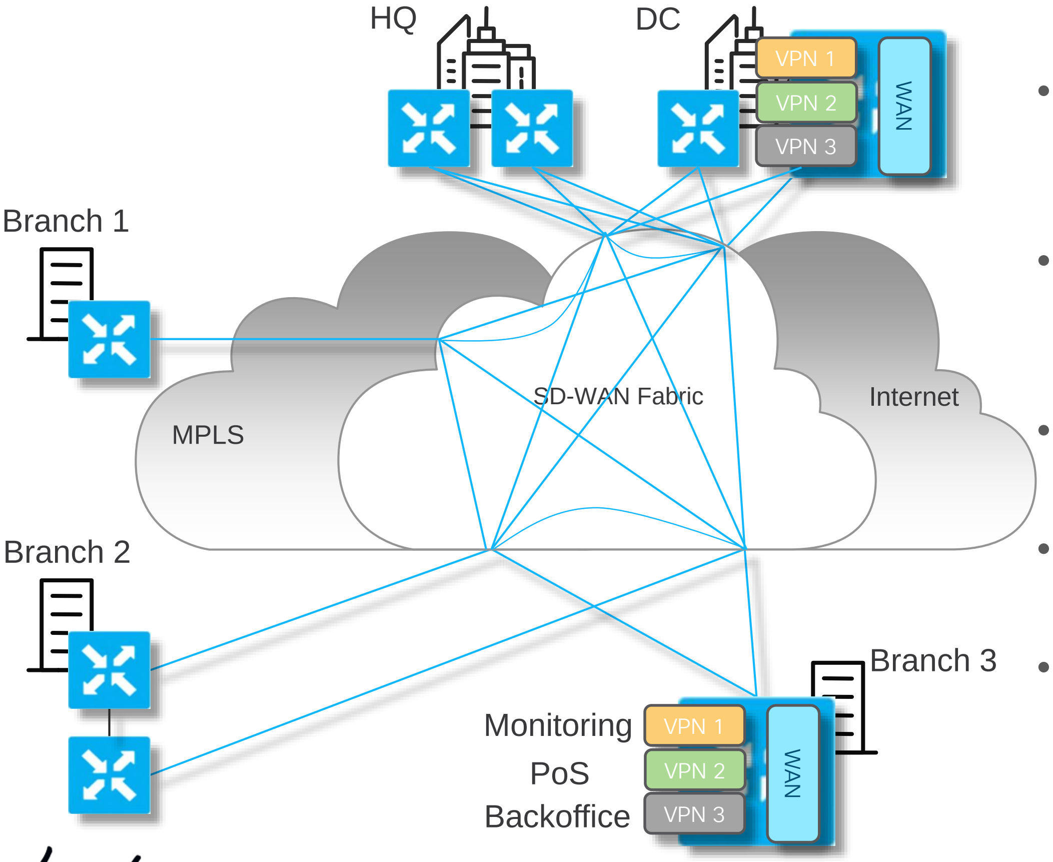
Cisco SD-WAN Common Overlay Design Options

Common **Designs** and Services

- Network Topologies and Connectivity Models
- Multiple Underlays with direct/indirect attach
- Primary and Backup path/resource definition
- Dis-contiguous Data Plane / Underlay Transport
- Multi-Domain Overlay with Regional meshing
- Mobile / LTE Attach

Network Topologies

Network Topologies - Review

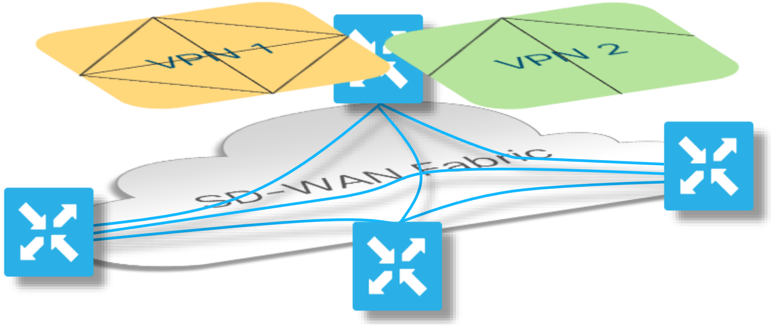


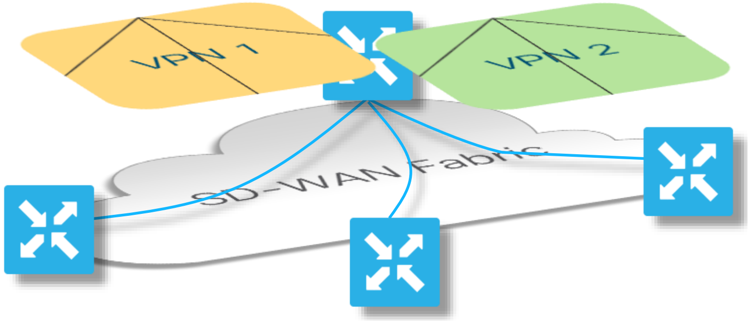
- A fully meshed Fabric Data plane and Service (VPN) plane is established by default
- This is done on the basis of TLOCs present in the OMP TLOC Table
- Every branch now has every other branch 1 hop away
- VPNs are advertised as an active service from every node
- vSmart applies route distribution constraints based on VPN service advertisements

Constructing Topologies - Data or VPN Plane

Capabilities

- Fabric Data Plane or Individual VPNs subject to specific topologies / connectivity models





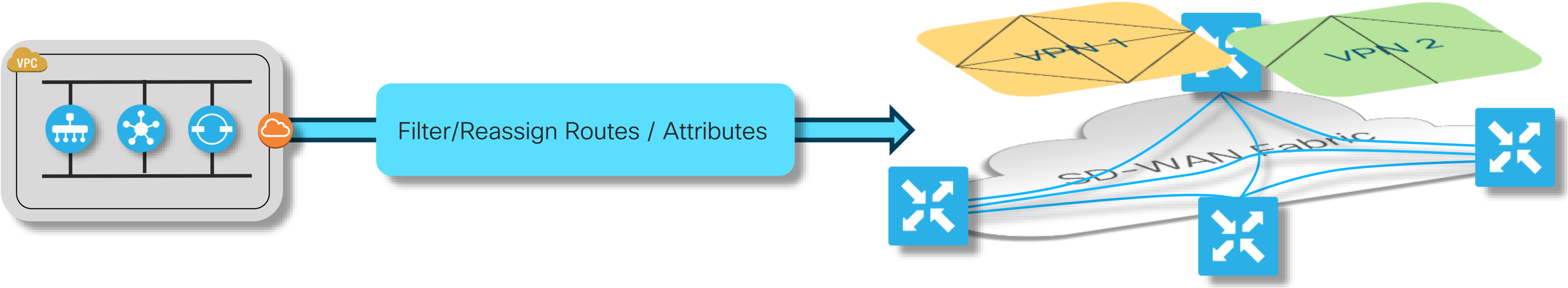
- Fully meshed fabric data plane
- Individual VPNs can use any topology

- Restricted fabric data plane
- Individual VPNs restricted to connectivity model used by underlying fabric

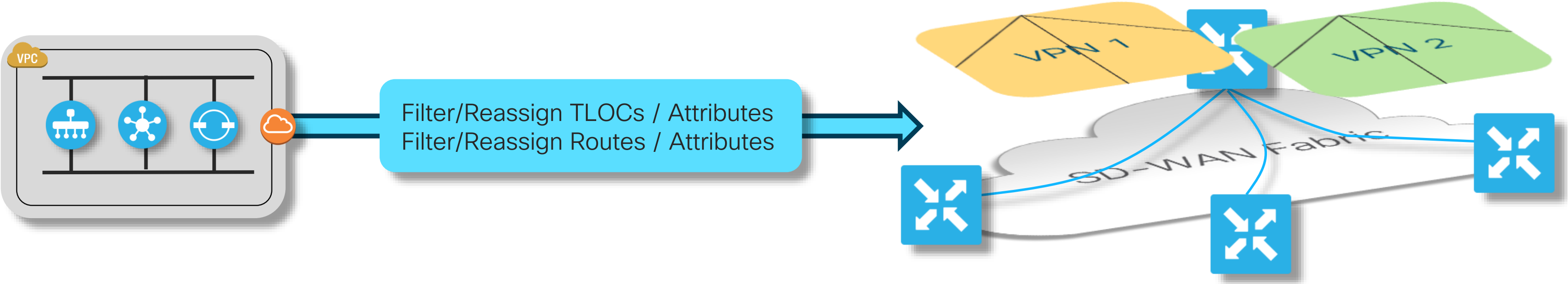
Constructing Topologies

Fabric Data Plane or VPN Plane Enforcement

- Data Plane or Individual VPNs subject to specific topologies / connectivity models

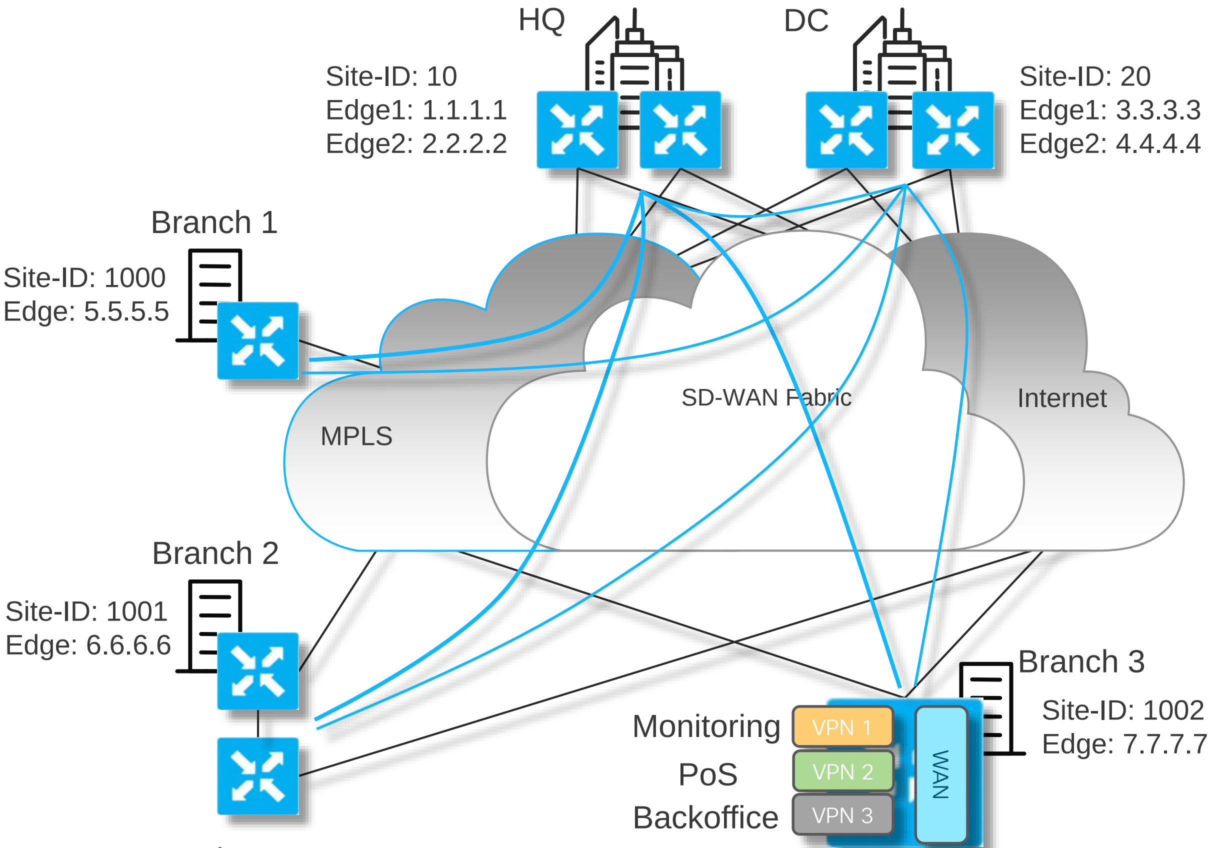


Filter/Reassign Routes / Attributes



Filter/Reassign TLOCs / Attributes
Filter/Reassign Routes / Attributes

Hub-and-Spoke Design



- Topology can be applied to the Data Plane or individual VPNs as described
- Loose and Strict options are possible as well
  - Loose: Branch to Branch via hub/DC
  - Strict: Branch to hub only

Hub-and-Spoke Topologies

Fabric Data Plane and VPN Plane Control Policy

For Your Reference

1 Define Hub Site TLOC-list

2 Declare Branches

3 Declare Hubs

```
Policy
 lists
  tloc-list hub-site_tlocs
   tloc 1.1.1.1 color biz-internet encap ipsec preference 100
   tloc 1.1.1.1 color mpls encap ipsec preference 50
   tloc 3.3.3.3 color biz-internet encap ipsec preference 100
   tloc 3.3.3.3 color mpls encap ipsec preference 50
  !
  site-list branch_sites
   site-id 1000-2000
  !
  site-list hub_sites
   site-id 1-100
  !
 !
```

4 Define the Control Policy

Advertise Hub TLOCs

Branch Prefixes

Drop Branch TLOCs

```
Policy
 control-policy restricted_data_plane
  sequence 10
   match tloc
    site-list hub_sites
   !
   action accept
   !
  !
  sequence 20
   match route
    site-list branch_sites
   !
   action accept
    set
     tloc-list hub_site_tlocs
    !
   !
  !
  sequence 30
   match tloc
   !
   action reject
   !
  !
  default-action accept
```

5 Apply Policy to the target site-list

```
apply-policy
 site-list branch_sites
  control-policy restricted_data_plane out
 !
!
```

Hub-and-Spoke Topologies

For Your Reference

VPN 1 Full Mesh and VPN 2 Hub-and-Spoke Topologies

Loose Hub-and-Spoke
Spokes communicate via hub(s)

```
Policy
 lists
  vpn-list VPN2
   vpn 2
  !
site-list branch_sites
  site-id 1000-2000
  !
 !
 control-policy vpn_multi-topology
  sequence 10
   match route
    site-list branch_sites
    vpn-list  VPN2
   !
   action accept
    set
     tloc 1.1.1.1 color mpls
    !
   !
  !
  default-action accept
```

Branch Prefixes

Hub site TLOC

Strict Hub-and-Spoke
No spoke to spoke communication

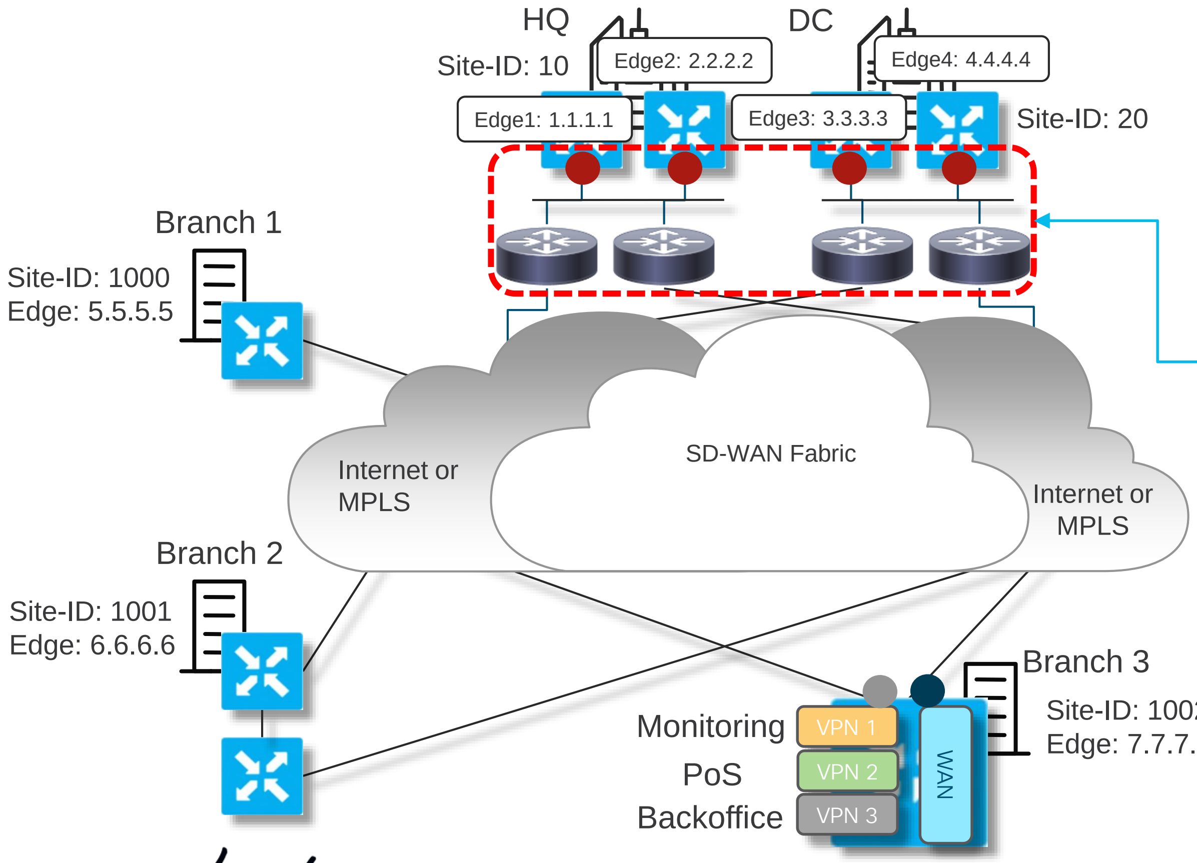
```
Policy
 lists
  vpn-list VPN2
   vpn 2
  !
site-list hub_sites
  site-id 1-100
  !
 !
 control-policy vpn_multi-topology
  sequence 10
   match route
    site-list hub_sites
    vpn-list  VPN2
   !
   action accept
  !
  sequence 20
   match route
   !
   action reject
  !
  default-action accept
```

Advertise Hub Prefixes

Drop Branch Prefixes

Multiple Underlays with direct/indirect attach

Multiple Underlays with direct/indirect attach



- Branches have multiple direct physical attachments to multiple underlays

  This is represented by multiple colors at the branch

- DC/HQ nodes aren’t directly attached to the transport but is provided an internal link

  Hence, only a single color is normally used at DC/HQ

● TLOC: MPLS

● TLOC: Public-Internet

● TLOC: X

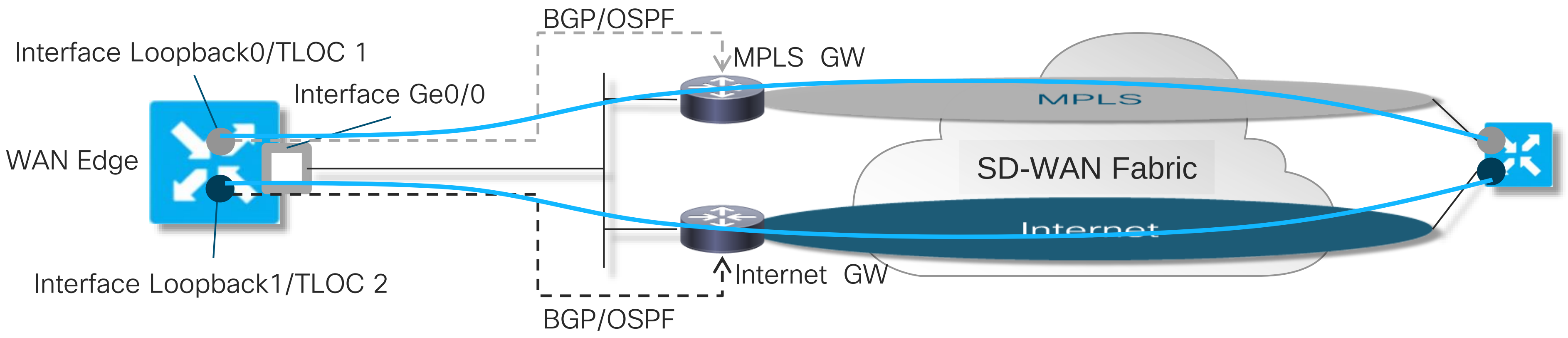
Multiple Underlays with direct/indirect attach

Challenges in Uniformly Enabling Capabilities Across the Network

- Branches typically have direct physical attach - standard operation
    - Underlay/Transport Routing and Path Preference
    - Application-Aware Routing and SLA measurements
    - Nothing changes from a standard design
- Central locations are challenged by lack of direct connectivity
    - Routing traffic per underlay
    - Path Preference - Using policies or static assignments
    - Application-aware routing measurements and switch-over

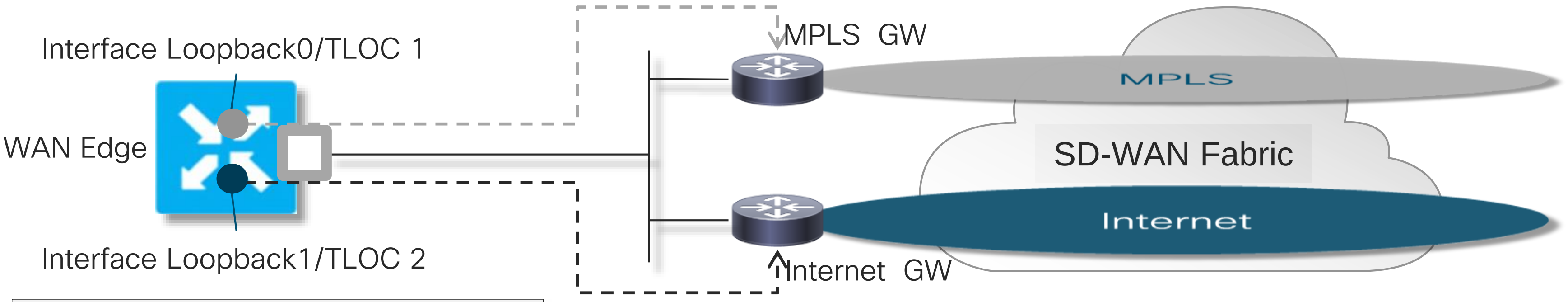
Multiple Underlays with direct/indirect attach

- Use Loopback interfaces to represent each underlay Network
- Assign IP-addressing that allows for routing to specific underlays



- BGP or OSPF can be used to share Loopback IPs with rest of network
- In case of disparate underlays, VPN 0 routing must be properly setup

Multiple Underlays with direct/indirect attach



```
vpn 0
 interface ge0/0
  ip address 192.168.1.2/24
 !
 interface loopback0
  ip address 192.169.1.1/32
   tunnel-interface
    color mpls
 !
 interface loopback1
  ip address 192.169.1.2/32
   tunnel-interface
    color public-internet
```

VPN 0 - Static Routing

```
vpn 0
 ip route 10.0.0.0/8 >> mpls-gw
 ip route 0.0.0.0/0 >> internet-gw
```

Transport - Static Routing

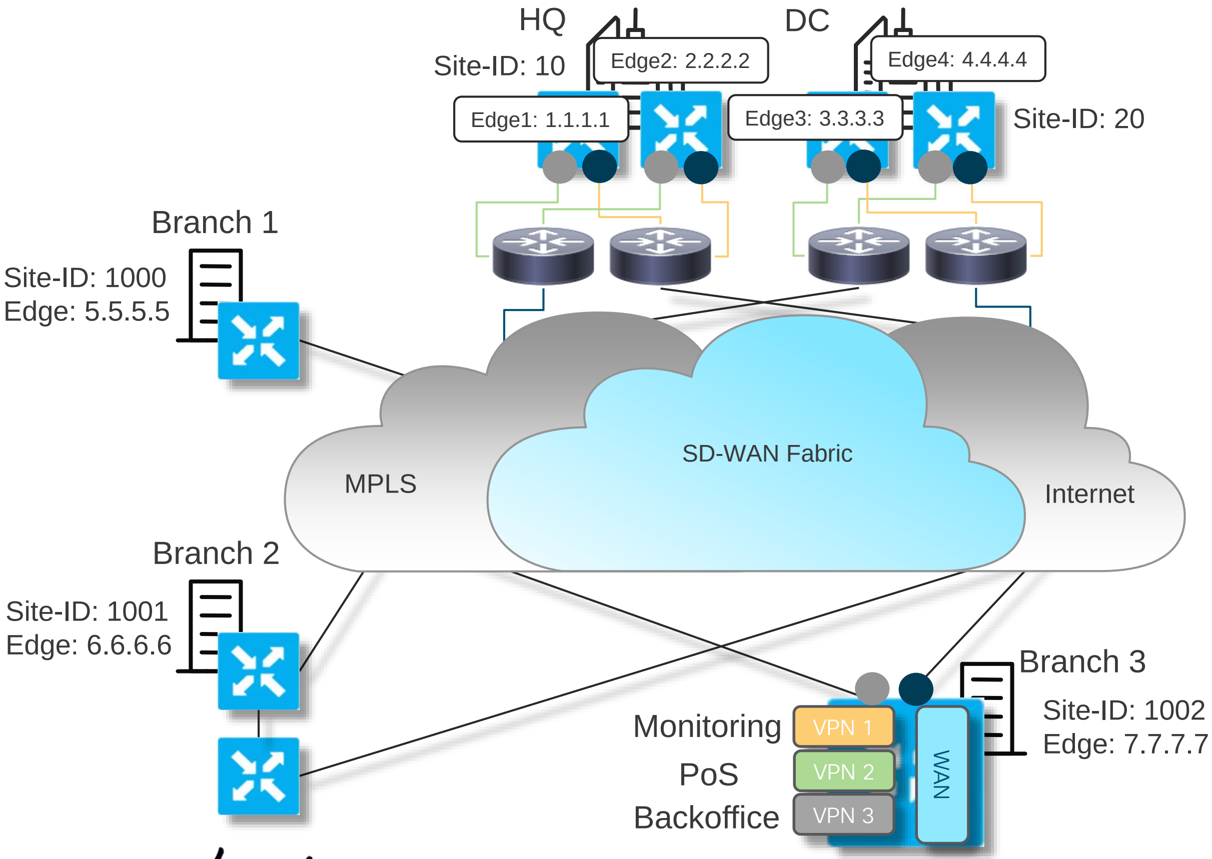
```
 ip route 192.168.1.1/32 >> WAN Edge
 ip route 192.168.1.2/32 >> WAN Edge
```

VPN 0 - OSPF

```
vpn 1
 router
  ospf
   area 0
    interface loopback0
    interface loopback1
    exit
   exit
  !
 !
```

Primary and Backup path/resource definition

Primary and Backup path/resource definition



- Default behavior is to advertise branch prefixes with every TLOC as a valid NH for ECMP
- This can cause asymmetric distribution of flows
- Several techniques can be used to manage this
- In some cases, having all transports active is a higher priority so then default is ok

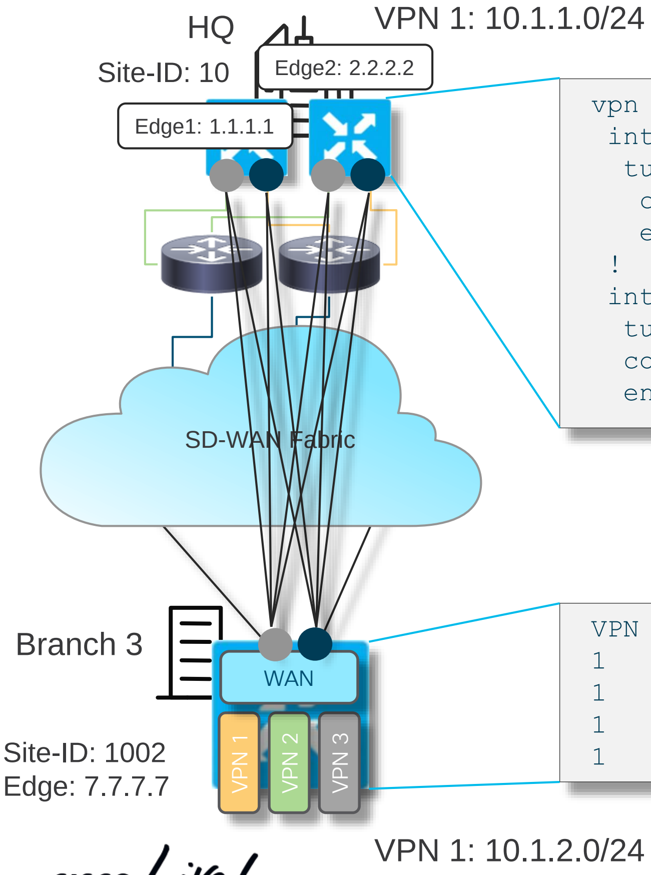
● TLOC: MPLS

● TLOC: Public-Internet

Primary and Backup path/resource definition

● TLOC: MPLS

● TLOC: Public-Internet

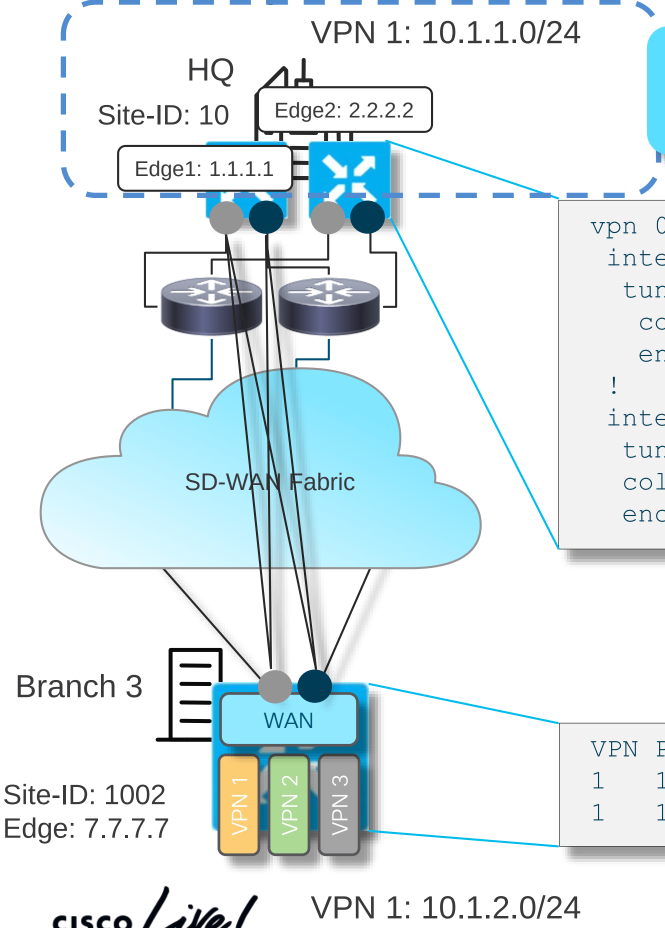


```
vpn 0
 interface ge0/0
  tunnel-interface
   color mpls
   encapsulation ipsec
 !
 interface ge0/1
  tunnel-interface
  color public-internet
  encapsulation ipsec
```

Overlay Domain – Path Preference
Default behavior is to use every available path for ECMP

```
VPN Prefix       Protocol TLOC    Color
1   10.1.1.0/24 omp      1.1.1.1 mpls
1   10.1.1.0/24 omp      2.2.2.2 mpls
1   10.1.1.0/24 omp      1.1.1.1 public-internet
1   10.1.1.0/24 omp      2.2.2.2 public-internet
```

Primary and Backup path/resource definition



- ● TLOC: MPLS
- ● TLOC: Public-Internet

Site Domain - Local Policy
Use routing metrics to assign primary and backup transit node

```
vpn 0
 interface ge0/0
  tunnel-interface
   color mpls
   encapsulation ipsec preference 100
 !
 interface ge0/1
  tunnel-interface
  color public-internet
  encapsulation ipsec preference 100
```

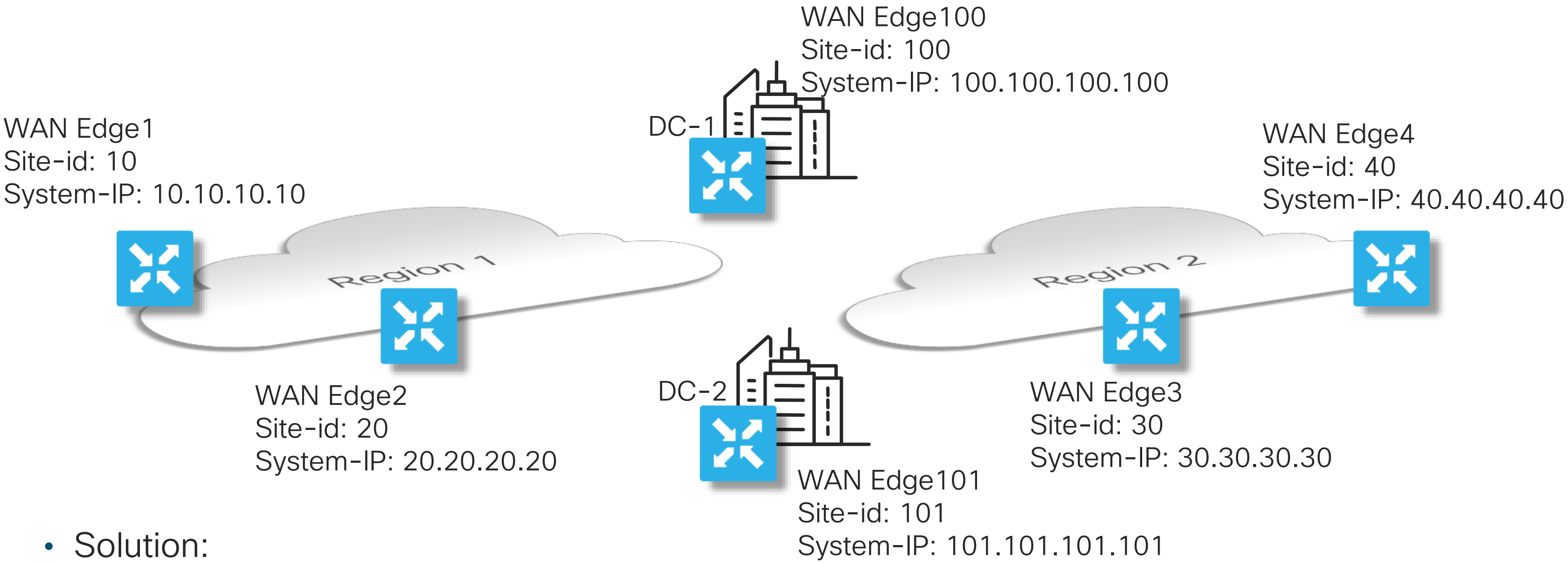
Overlay Domain - TLOC Preference

- Influence OMP path selection to impose Primary and Backup Path
- Preference setting causes local TLOCs to be advertised with higher preference
- Higher preference is better and path selection will fall back to lower preference paths in case of failure

```
VPN Prefix       Protocol TLOC    Color
1   10.1.1.0/24 omp      2.2.2.2 mpls
1   10.1.1.0/24 omp      2.2.2.2 public-internet
```

Primary and Backup path/resource definition

Network Resource (e.g. Data Center) Preference or Active/Backup



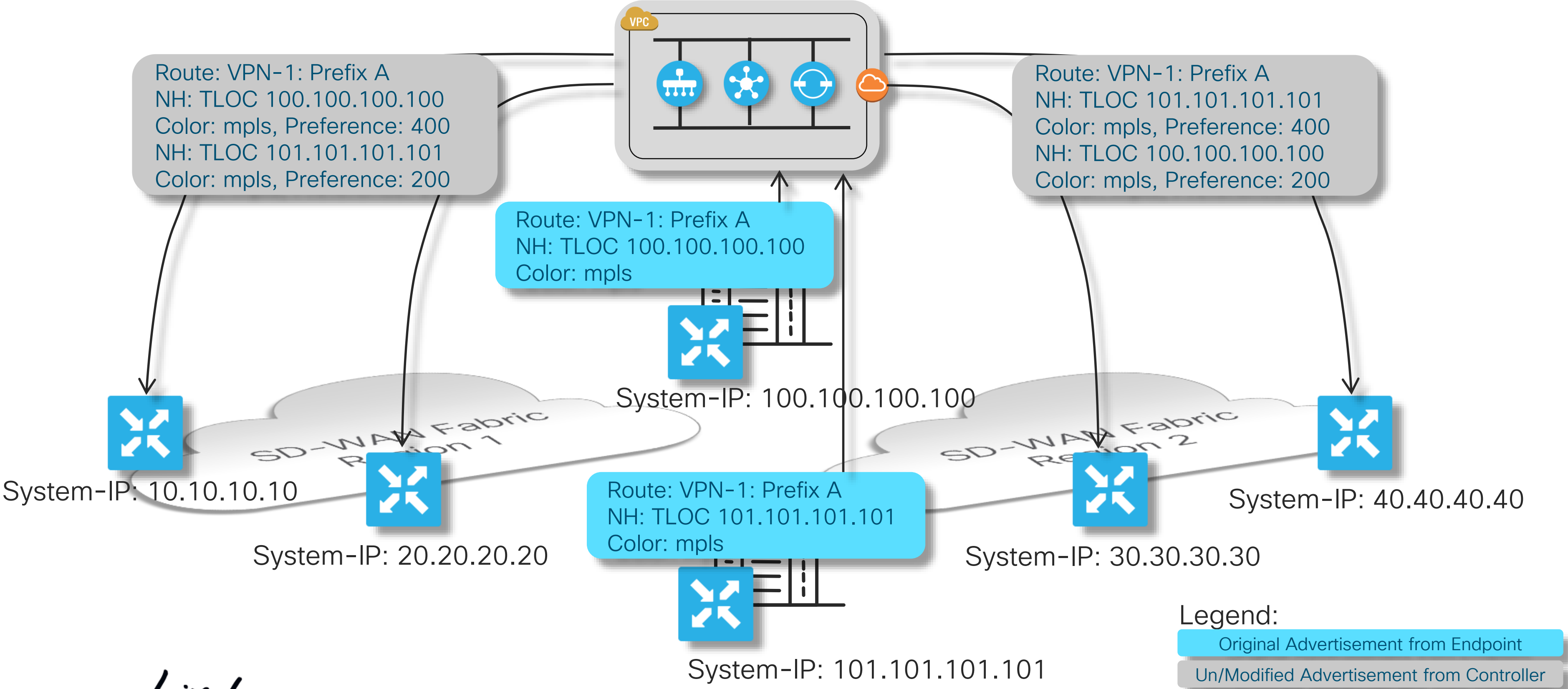
- Solution:

  Identify regions by Site-Id and associate Primary and Backup DC locations with the regions

  A control policy is used to make the associations and defining DC preference

Primary and Backup path/resource

Control Policy Operation



Route: VPN-1: Prefix A
NH: TLOC 100.100.100.100
Color: mpls, Preference: 400
NH: TLOC 101.101.101.101
Color: mpls, Preference: 200

Route: VPN-1: Prefix A
NH: TLOC 101.101.101.101
Color: mpls, Preference: 400
NH: TLOC 100.100.100.100
Color: mpls, Preference: 200

Route: VPN-1: Prefix A
NH: TLOC 100.100.100.100
Color: mpls

Route: VPN-1: Prefix A
NH: TLOC 101.101.101.101
Color: mpls

Legend:
- Original Advertisement from Endpoint
- Un/Modified Advertisement from Controller

Primary and Backup path/resource definition

For Your Reference

Control Policy Configuration

1 Define Data Center TLOC-lists

```
policy
 lists
  tloc-list dc-preference-west
   tloc 100.100.100.100 color mpls encap ipsec preference 400
   tloc 101.101.101.101 color mpls encap ipsec preference 200
  !
  tloc-list dc-preference-east
   tloc 100.100.100.100 color mpls encap ipsec preference 200
   tloc 101.101.101.101 color mpls encap ipsec preference 400
  !
  site-list sites-region-west
   site-id 1-20
  !
  site-list sites-region-east
   site-id 21-40
  !
  site-list dc-sites
   site-id 100-101
```

2 Declare Regions

3 Declare Data Centers

```
apply-policy
 site-list sites-region-west
  control-policy adv-dc-preference-west out
 !
 site-list sites-region-east
  control-policy adv-dc-preference-east out
 !
!
```

5 Apply Policies to the target site-lists

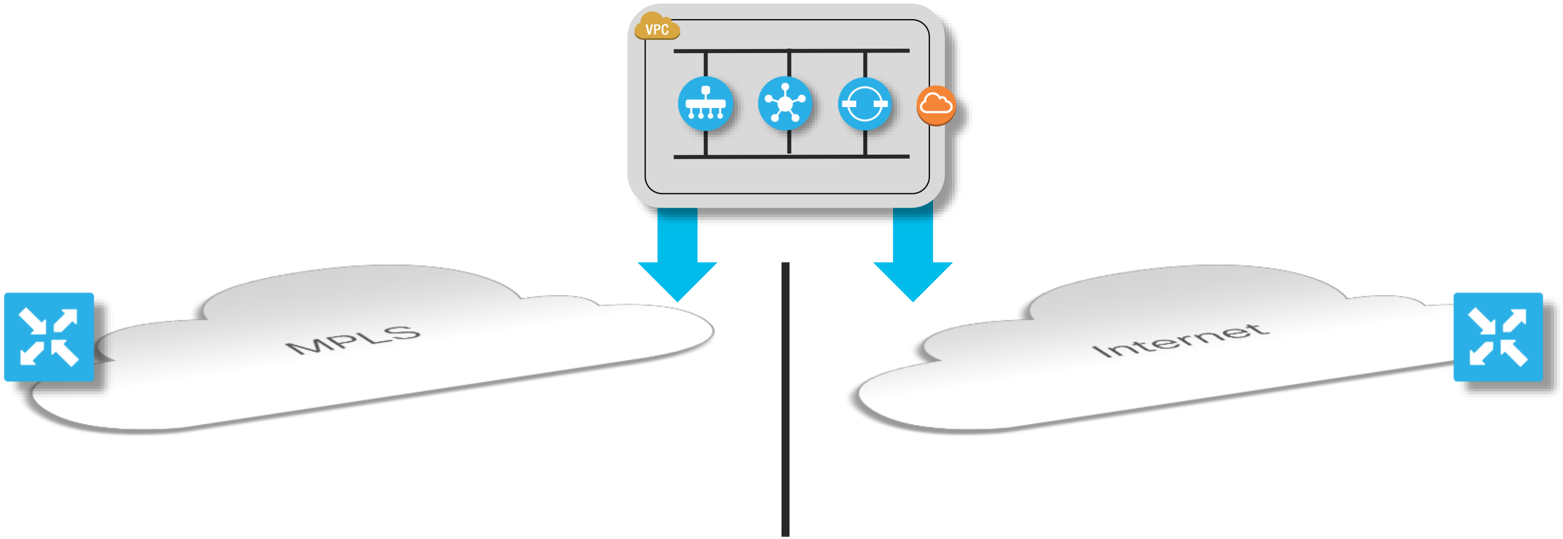
```
control-policy adv-dc-preference-west
  sequence 10
   match route
    site-list dc-sites
   !
   action accept
    set
     tloc-list dc-preference-west
    !
   !
  !
  default-action accept
 !
 control-policy adv-dc-preference-east
  sequence 10
   match route
    site-list dc-sites
   !
   action accept
    set
     tloc-list dc-preference-east
    !
   !
  !
  default-action accept
 !
!
```

4 Define the Control Policies

Interconnecting Dis-contiguous Data Planes

Interconnecting Dis-contiguous Data Planes

Interconnecting nodes single-homed to different underlays

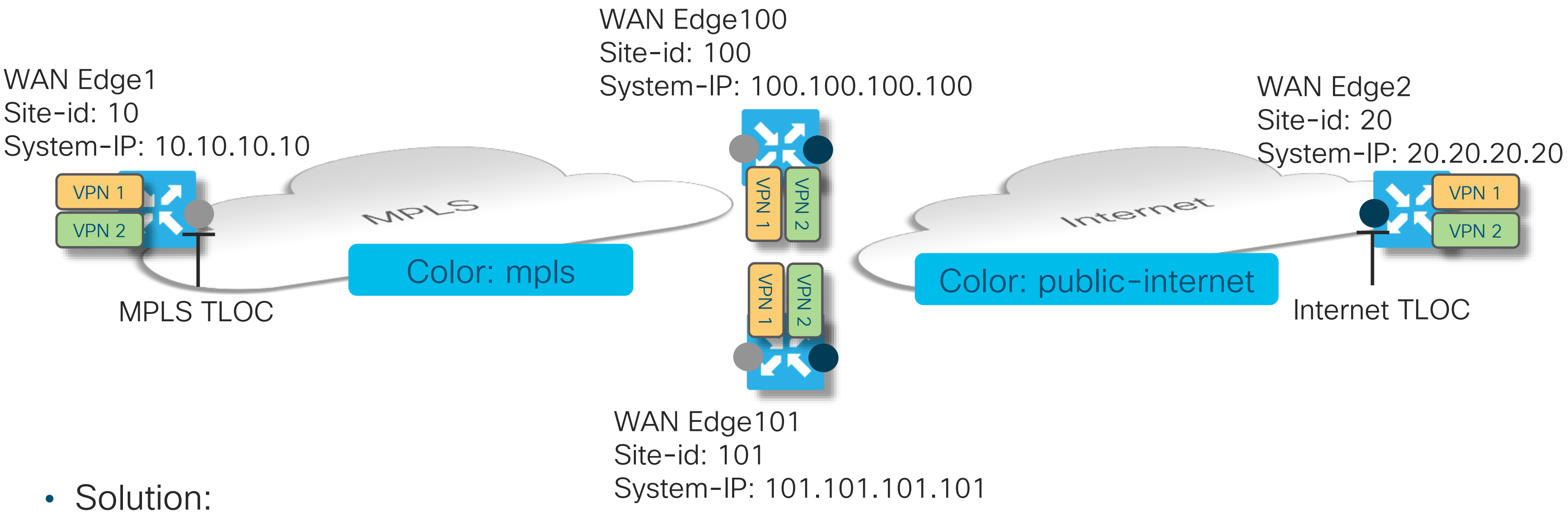


- Problem:

Overlay with a dis-contiguous data plane and endpoints need to communicate end-to-end

Interconnecting Dis-contiguous Data Planes

Interconnecting nodes single-homed to different underlays



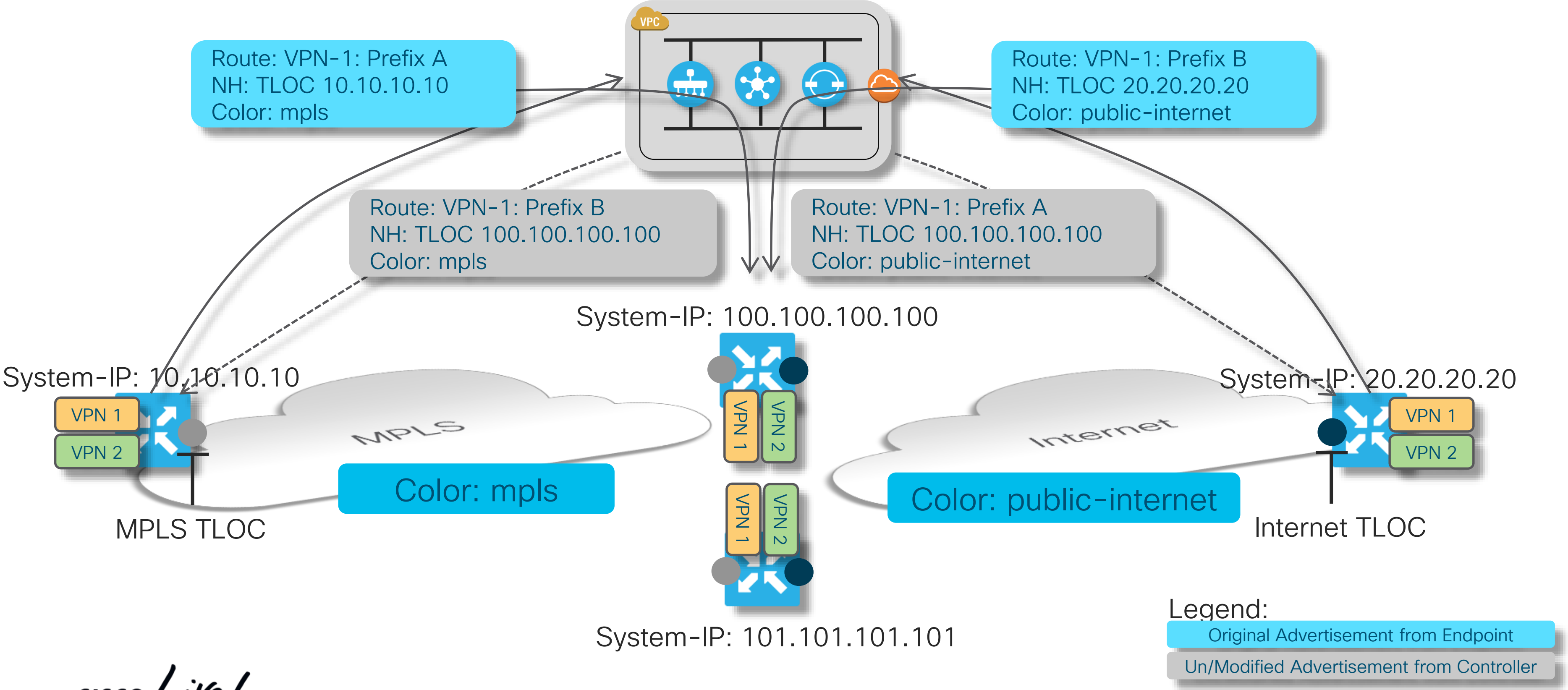
- Solution:

  Identify one or more multi-homed sites to bridge the data plane gap and act as gateways

  Use a control policy to enable distribution of routing information between domains enabling gateway-supported paths

Interconnecting Dis-contiguous Data Planes

Control Policy Operation



Route: VPN-1: Prefix A
NH: TLOC 10.10.10.10
Color: mpls

Route: VPN-1: Prefix B
NH: TLOC 20.20.20.20
Color: public-internet

Route: VPN-1: Prefix B
NH: TLOC 100.100.100.100
Color: mpls

Route: VPN-1: Prefix A
NH: TLOC 100.100.100.100
Color: public-internet

System-IP: 100.100.100.100

System-IP: 10.10.10.10

System-IP: 20.20.20.20

System-IP: 101.101.101.101

Color: mpls

Color: public-internet

MPLS TLOC

Internet TLOC

Legend:

Original Advertisement from Endpoint

Un/Modified Advertisement from Controller

Interconnecting Dis-contiguous Data Planes

Control Policy Configuration

For Your Reference

1 Define Gateway TLOC-lists

2 Declare Target Sites

```
policy
 lists
  tloc-list internet-gateways
   tloc 100.100.100.100 color mpls encap ipsec
   tloc 101.101.101.101 color mpls encap ipsec
  !
  tloc-list mpls-gateways
   tloc 100.100.100.100 color public-internet encap ipsec
   tloc 101.101.101.101 color public-internet encap ipsec
  !
  site-list internet-sites
   site-id 20
  !
  site-list mpls-sites
   site-id 10
```

4 Apply Policies to the target site-lists

```
apply-policy
 site-list internet-sites
  control-policy announce-mpls-sites out
 !
 site-list mpls-sites
  control-policy announce-internet-sites out
 !
!
```

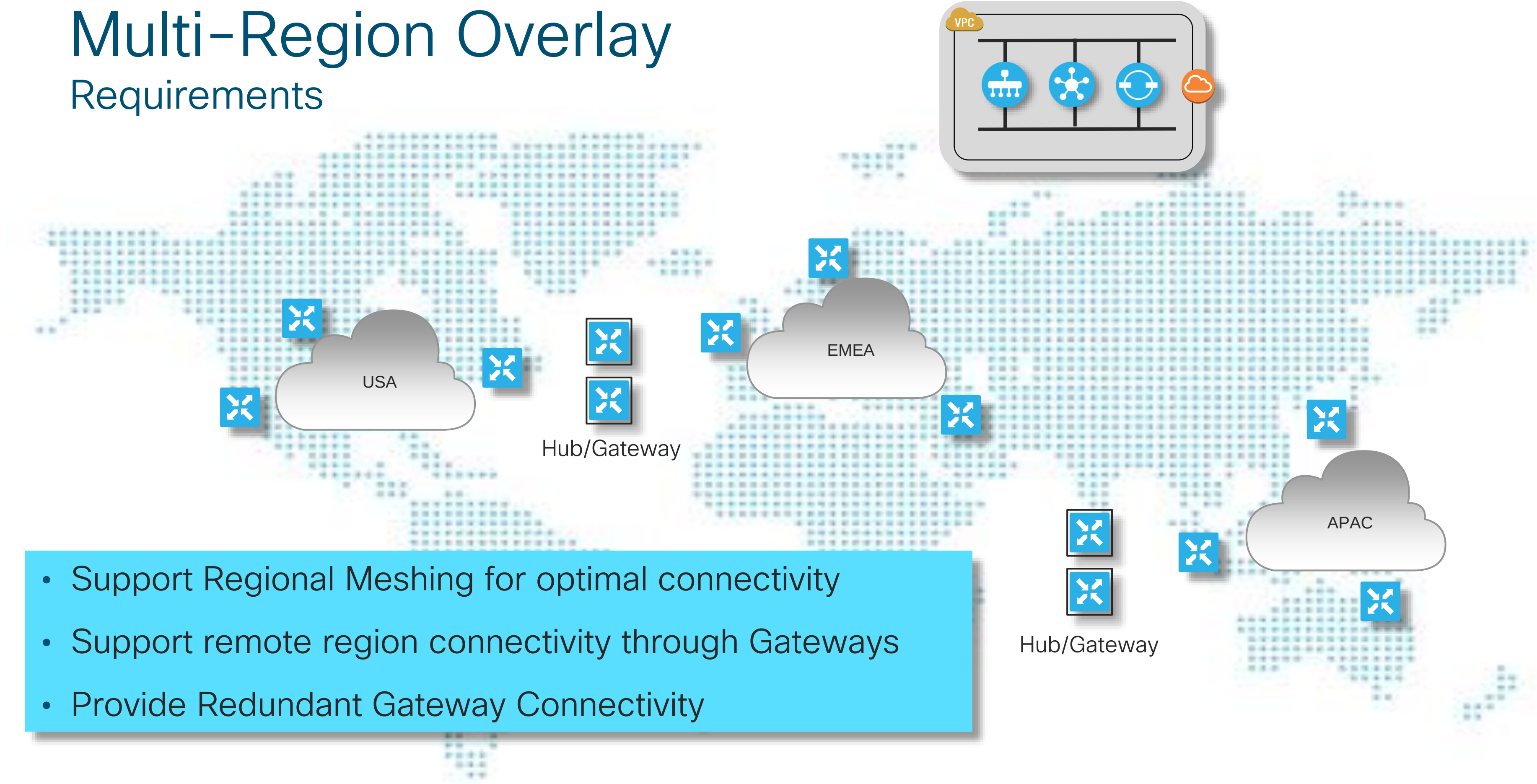
3 Define the Control Policies

```
control-policy announce-internet-sites
  sequence 10
   match route
    site-list internet-sites
   !
   action accept
    set
     tloc-list internet-gateways
    !
   !
  !
  default-action accept
 !
 control-policy announce-mpls-sites
  sequence 10
   match route
    site-list mpls-sites
   !
   action accept
    set
     tloc-list mpls-gateways
    !
   !
  !
  default-action accept
 !
!
```

Multi-Region Overlay

Multi-Region Overlay

Requirements



- Support Regional Meshing for optimal connectivity
- Support remote region connectivity through Gateways
- Provide Redundant Gateway Connectivity

Multi-Region Overlay

Definitions and Dependencies

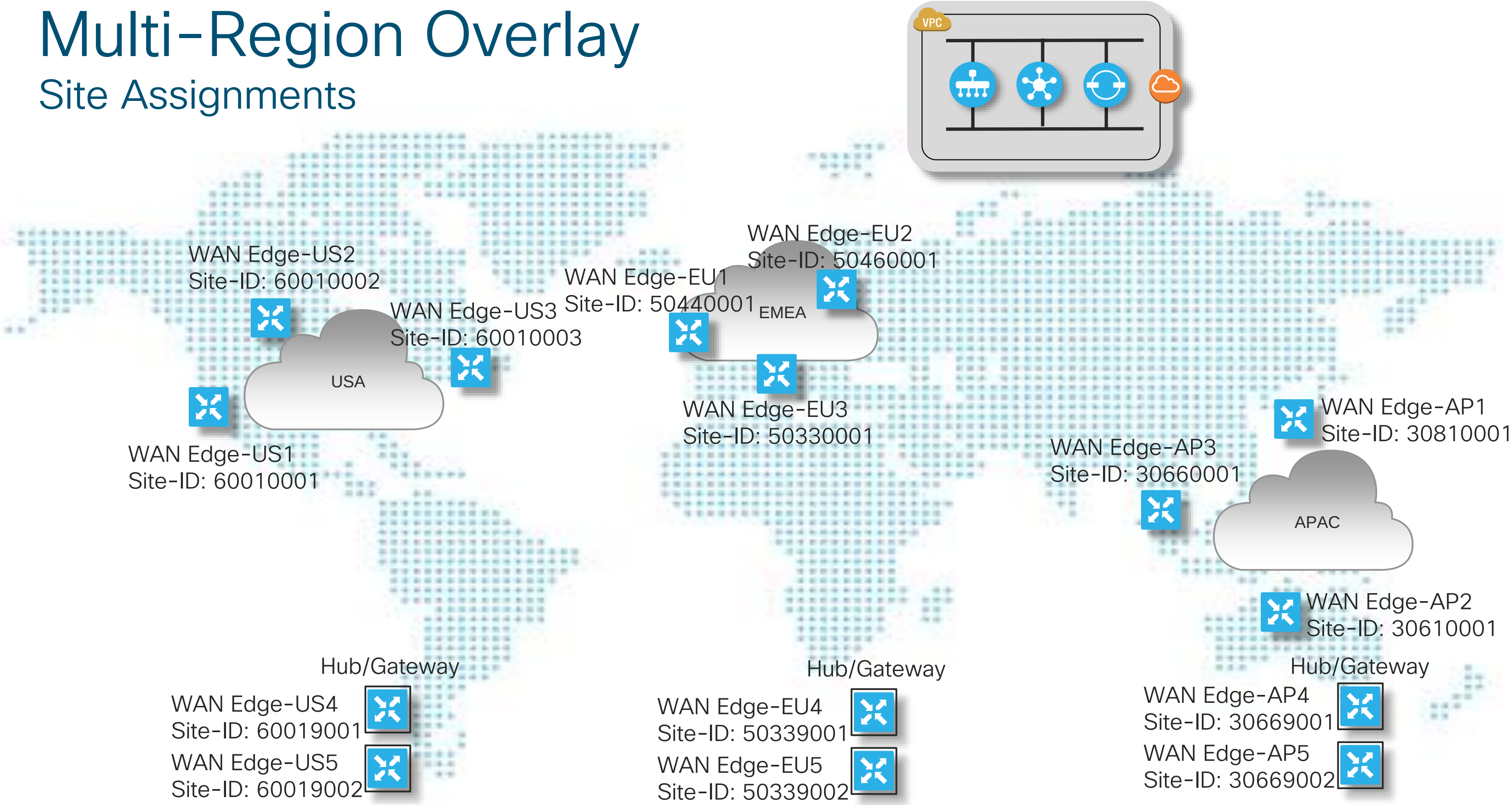
- Site-ID assignment allowing for Site identification – 32 bits

	Continent	Country	Site number
	X	YYY	ZZZZ
	1-7	1-999	1-9999
Example	Europe	Sweden	Site
	5	046	1000

- TLOC Colors illustrating how sites are attached
- System-IP identifying individual nodes

Multi-Region Overlay

Site Assignments



VPC

WAN Edge-US2
Site-ID: 60010002

WAN Edge-US3
Site-ID: 60010003

USA

WAN Edge-US1
Site-ID: 60010001

Hub/Gateway

WAN Edge-US4
Site-ID: 60019001

WAN Edge-US5
Site-ID: 60019002

WAN Edge-EU1
Site-ID: 50440001

WAN Edge-EU2
Site-ID: 50460001

EMEA

WAN Edge-EU3
Site-ID: 50330001

Hub/Gateway

WAN Edge-EU4
Site-ID: 50339001

WAN Edge-EU5
Site-ID: 50339002

WAN Edge-AP1
Site-ID: 30810001

WAN Edge-AP3
Site-ID: 30660001

APAC

WAN Edge-AP2
Site-ID: 30610001

Hub/Gateway

WAN Edge-AP4
Site-ID: 30669001

WAN Edge-AP5
Site-ID: 30669002

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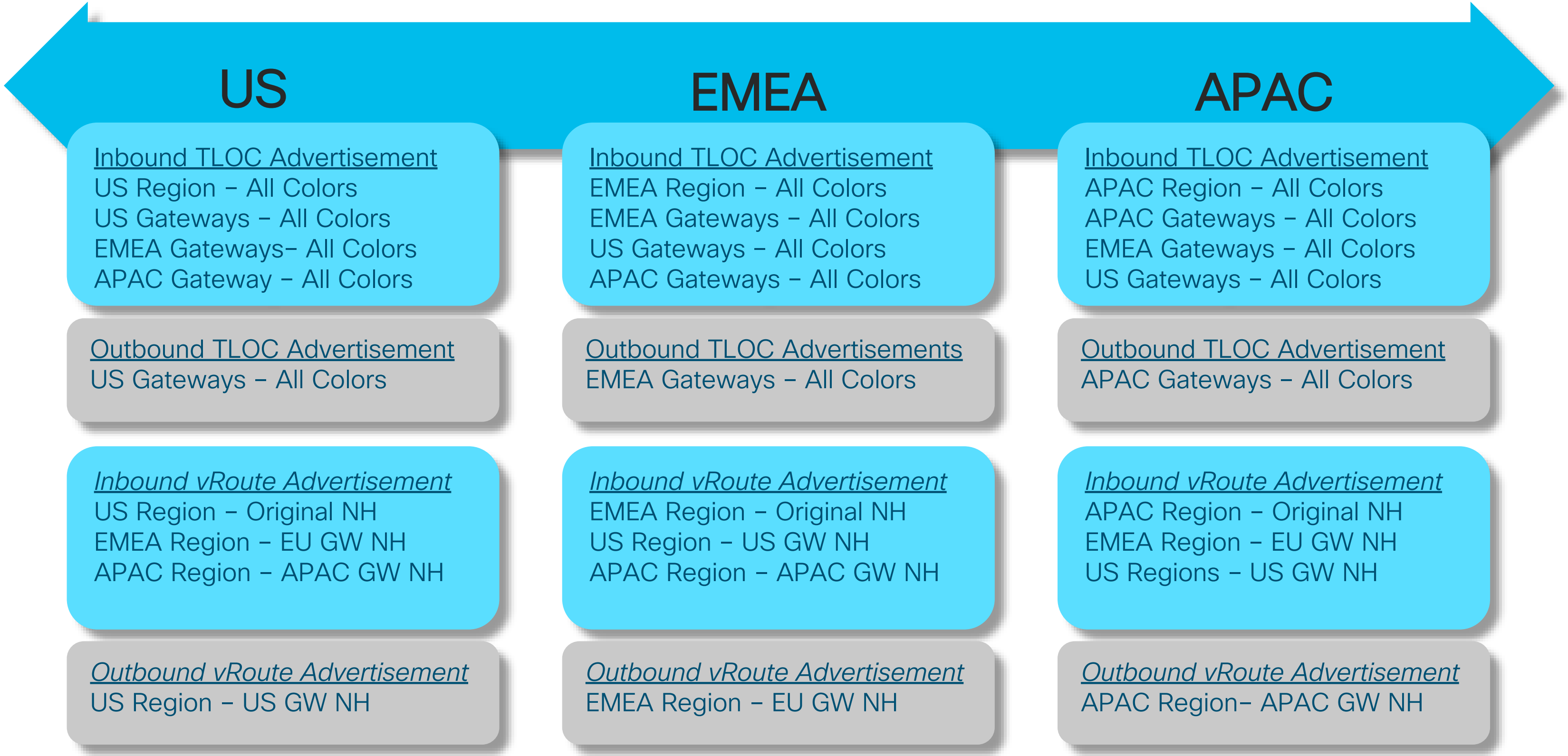
Control Policy Case Study

Reachability Information Distribution Requirements



US

Inbound TLOC Advertisement
US Region – All Colors
US Gateways – All Colors
EMEA Gateways– All Colors
APAC Gateway – All Colors

Outbound TLOC Advertisement
US Gateways – All Colors

Inbound vRoute Advertisement
US Region – Original NH
EMEA Region – EU GW NH
APAC Region – APAC GW NH

Outbound vRoute Advertisement
US Region – US GW NH

EMEA

Inbound TLOC Advertisement
EMEA Region – All Colors
EMEA Gateways – All Colors
US Gateways – All Colors
APAC Gateways – All Colors

Outbound TLOC Advertisements
EMEA Gateways – All Colors

Inbound vRoute Advertisement
EMEA Region – Original NH
US Region – US GW NH
APAC Region – APAC GW NH

Outbound vRoute Advertisement
EMEA Region – EU GW NH

APAC

Inbound TLOC Advertisement
APAC Region – All Colors
APAC Gateways – All Colors
EMEA Gateways – All Colors
US Gateways – All Colors

Outbound TLOC Advertisement
APAC Gateways – All Colors

Inbound vRoute Advertisement
APAC Region – Original NH
EMEA Region – EU GW NH
US Regions – US GW NH

Outbound vRoute Advertisement
APAC Region– APAC GW NH

Control Policy Case Study

Policy Definition - Lists

For Your Reference

```
policy
 lists
  site-list US_branch_sites
   site-id 60010000-60018999
  !
  site-list US_gateway_sites
   site-id 60019000-60019999
  !
  site-list EMEA_branch_sites
   site-id 50010000-50338999
   site-id 50340000-59999999
  !
  site-list EMEA_gateway_sites
   site-id 50339000-50339999
  !
  site-list APAC_branch_sites
   site-id 30010000-30668999
   site-id 30670000-39999999
  !
  site-list APAC_gateway_sites
   site-id 30669000-30669999
  !
 !
!
```

```
policy
 lists
  tloc-list US_gateway_tlocs
   tloc 1.1.1.1 color mpls encap ipsec preference 100
   tloc 1.1.1.1 color biz-internet encap ipsec preference 100
   tloc 2.2.2.2 color mpls encap ipsec preference 50
   tloc 2.2.2.2 color biz-internet encap ipsec preference 50
  !
  tloc-list EMEA_gateway_tlocs
   tloc 3.3.3.3 color mpls encap ipsec preference 100
   tloc 3.3.3.3 color biz-internet encap ipsec preference 100
   tloc 4.4.4.4 color mpls encap ipsec preference 50
   tloc 4.4.4.4 color biz-internet encap ipsec preference 50
  !
  tloc-list APAC_gateway_tlocs
   tloc 5.5.5.5 color mpls encap ipsec preference 100
   tloc 5.5.5.5 color biz-internet encap ipsec preference 100
   tloc 6.6.6.6 color mpls encap ipsec preference 50
   tloc 6.6.6.6 color biz-internet encap ipsec preference 50
  !
 !
!
```

For Your Reference

Control Policy Case Study

Policy Definition Cont’d – Control Policy – Applied to US Sites

```
policy
 control-policy us_domain
  sequence 10
   match tloc
    site-list US_branch_sites
   !
   action accept
   !
  !
  sequence 20
   match tloc
    site-list US_gateway_sites
    SNIP … (accept)
  sequence 30
   match tloc
    site-list EMEA_gateway_sites
    SNIP … (action accept)
  sequence 40
   match tloc
    site-list APAC_gateway_sites
   !
    SNIP … (action accept)
```

```
  sequence 50
   match route
    site-list US_branch_sites
   !
   action accept
   !
  sequence 60
   match route
    site-list US_gateway_sites
    SNIP … (action accept)
  sequence 70
   match route
    site-list EMEA_branch_sites
   !
   action accept
    set
     tloc-list EMEA_gateway_tlocs
    !
   !
  !
  sequence 80
   match route
    site-list EMEA_gateway_sites
    SNIP … (action accept)
```

For Your Reference

Control Policy Case Study

Policy Definition Cont'd – Control Policy - Applied to US Sites

```
   sequence 90
    match route
     site-list APAC_branch_sites
    !
    action accept
     set
      tloc-list APAC_gateway_tlocs
     !
    !
   !
   sequence 100
    match route
     site-list APAC_gateway_sites
    !
    action accept
    !
   !
   default-action accept
```

```
apply-policy
 site-list US_branch_sites
  control-policy us_domain out
 !
 site-list US_gateway_sites
  control-policy us_domain out
 !
!
```

- Policy Logic

Sequence 10: Advertise US Branch TLOCs

Sequence 20: Advertise US GW TLOCs

Sequence 30: Advertise EMEA GW TLOCs

Sequence 40: Advertise APAC GW TLOCs

Sequence 50: Advertise US Branch routes

Sequence 60: Advertise US GW routes

Sequence 70: Advertise EMEA Branch routes w/ NH of EMEA GW

Sequence 80: Advertise EMEA GW routes

Sequence 90: Advertise APAC Branch routes w/ NH of APAC GW

Sequence 100: Advertise APAC GW Routes

Cisco SD-WAN
Common Overlay Services

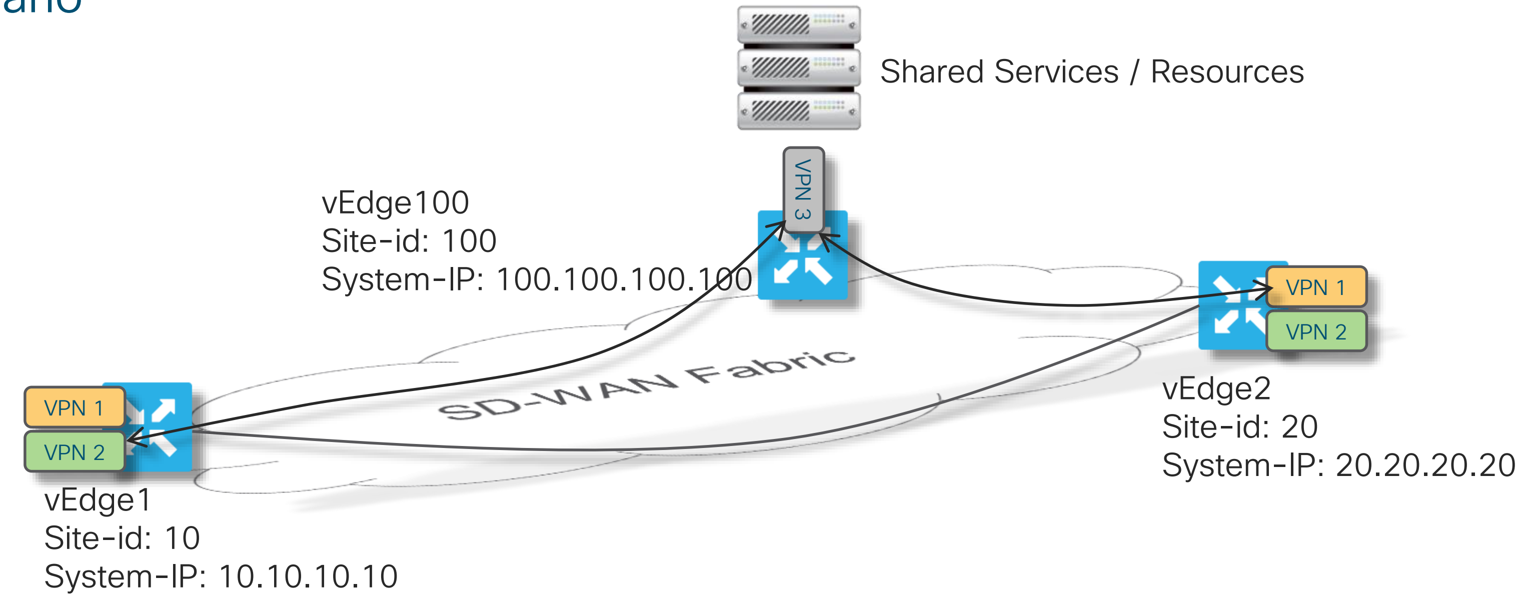
Common Designs and **Services**

- Extranet Service
- Quality of Service
- Application Pinning
- Internet Breakout
- SLA-driven Path Selection

Extranet Service

Providing Extranet Services

Scenario



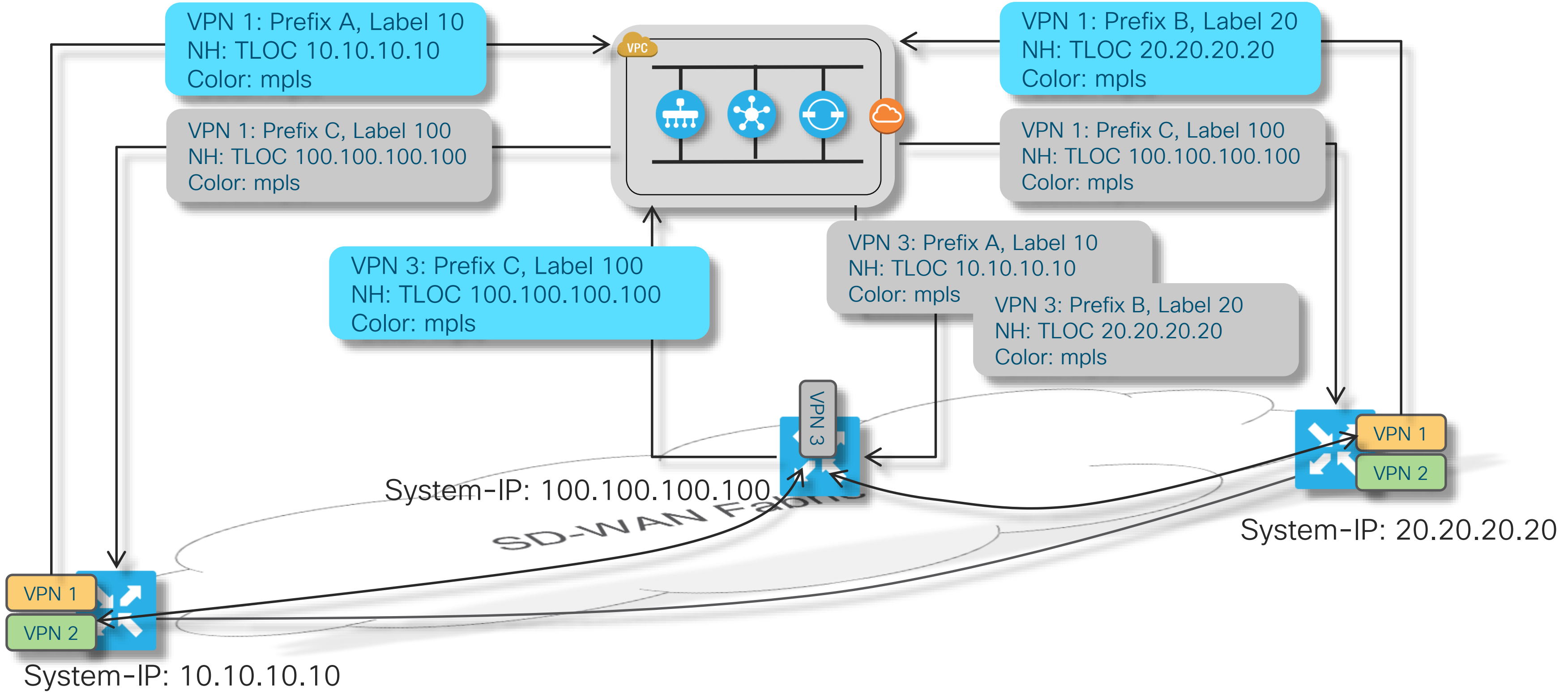
- Problem: Shared Services to be consumed from Extranet VPN hosted location
- Solution: Provision Extranet Access from other overlay VPNs

Providing Extranet Services

Control Policy Operation

Legend:

- Original Advertisement from Endpoint
- Un/Modified Advertisement from Controller



VPN 1: Prefix A, Label 10
NH: TLOC 10.10.10.10
Color: mpls

VPN 1: Prefix C, Label 100
NH: TLOC 100.100.100.100
Color: mpls

VPN 1: Prefix B, Label 20
NH: TLOC 20.20.20.20
Color: mpls

VPN 1: Prefix C, Label 100
NH: TLOC 100.100.100.100
Color: mpls

VPN 3: Prefix C, Label 100
NH: TLOC 100.100.100.100
Color: mpls

VPN 3: Prefix A, Label 10
NH: TLOC 10.10.10.10
Color: mpls

VPN 3: Prefix B, Label 20
NH: TLOC 20.20.20.20
Color: mpls

Providing Extranet Services + VPN NAT

Control Policy Configuration

For Your Reference

```
policy
 lists
  prefix-list natpools
   ip-prefix 192.168.0.0/16 le 32
  !
  site-list consumers
   site-id 3002
   site-id 3003
   site-id 3004
  !
 !
```

1 Declare Consumers

```
apply-policy
 site-list consumers
  control-policy extranet in
 !
!
```

4 Apply Control Policy

2 Export NAT Pool To Service VPN

```
policy
 control-policy extranet
  sequence 10
   match route
    prefix-list natpools
    vpn 1
   !
   action accept
    export-to
     vpn 3
    !
   !
  !
  sequence 20
   match route
    vpn 3
   !
   action accept
    export-to
     vpn 1
    !
   !
  !
  default-action accept
 !
!
```

3 Export Service Prefixes to Consumer VPN

Service Plane NAT
NAT across sites at VPN Layer

```
policy data-policy Srvc_Plane_NAT
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.1/32
    !
    action accept
     nat pool 1
    !
   !
   default-action accept
  !
```

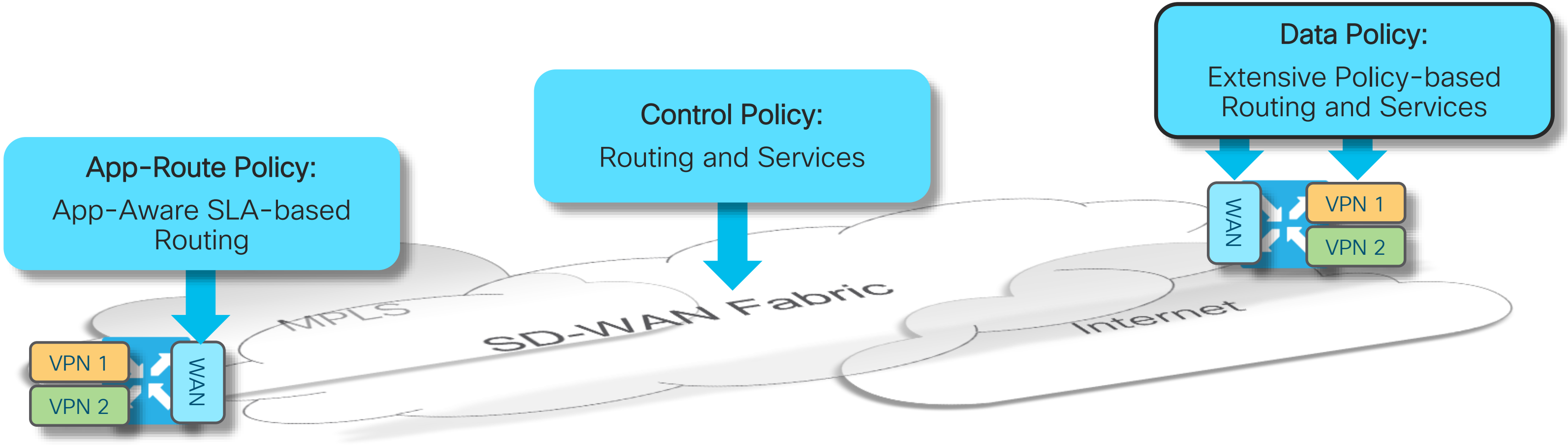
```
WAN-Edge
vpn 1
 interface natpool1
  ip address 192.168.1.1/32
  no shutdown
 !
```

Optional Service Plane NAT

Introduction to Data Policies

Cisco SD-WAN Policy Architecture

Suite of Policies to address different functional domains



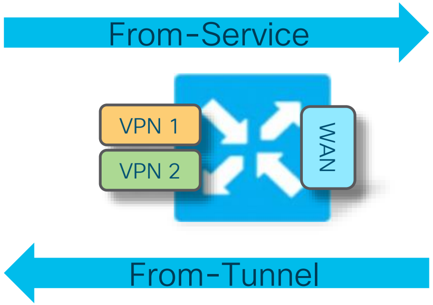
- Control Policies are applied at vSmart: Tailors routing information advertised to vEdge endpoints
- App-Route Policies are applied at vEdge: SLA-driven path selection for applications
- Data Policies are applied at vEdge: Extensive Policy driven routing

Data Policy Application

Direction of Processing

- A Data Policy can be applied in three modes:
  - From-service (Upstream)
  - From-tunnel (Downstream)
  - All (Up and Downstream)
- Different Data-policies can be applied to the same site if they apply to different directions

Upstream Traffic matched by Data-policy

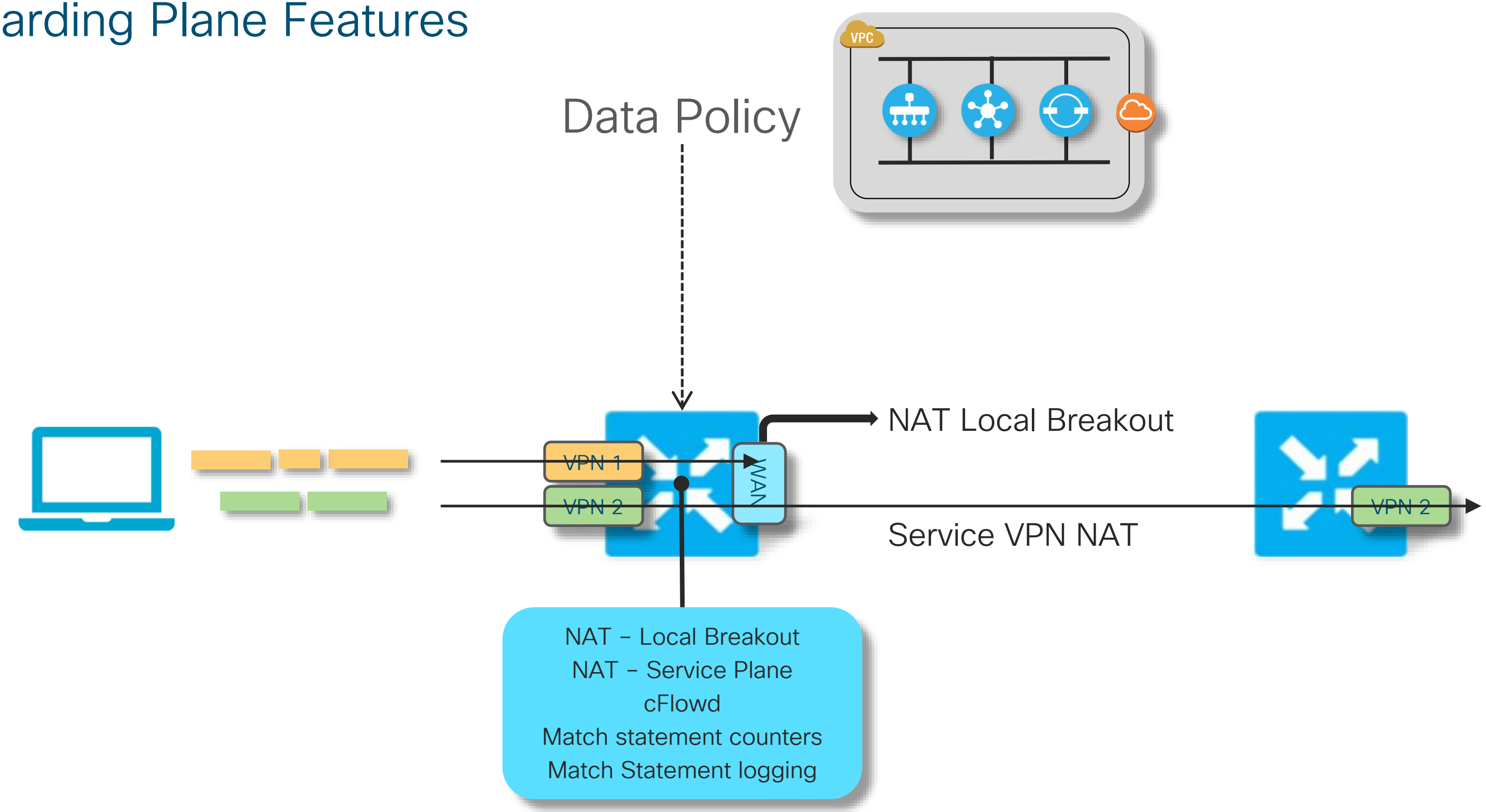


Downstream Traffic matched by Data-policy

```
apply-policy site-list <name>
  data-policy <name> all | from-service | from-tunnel
```

Data Policy Capabilities

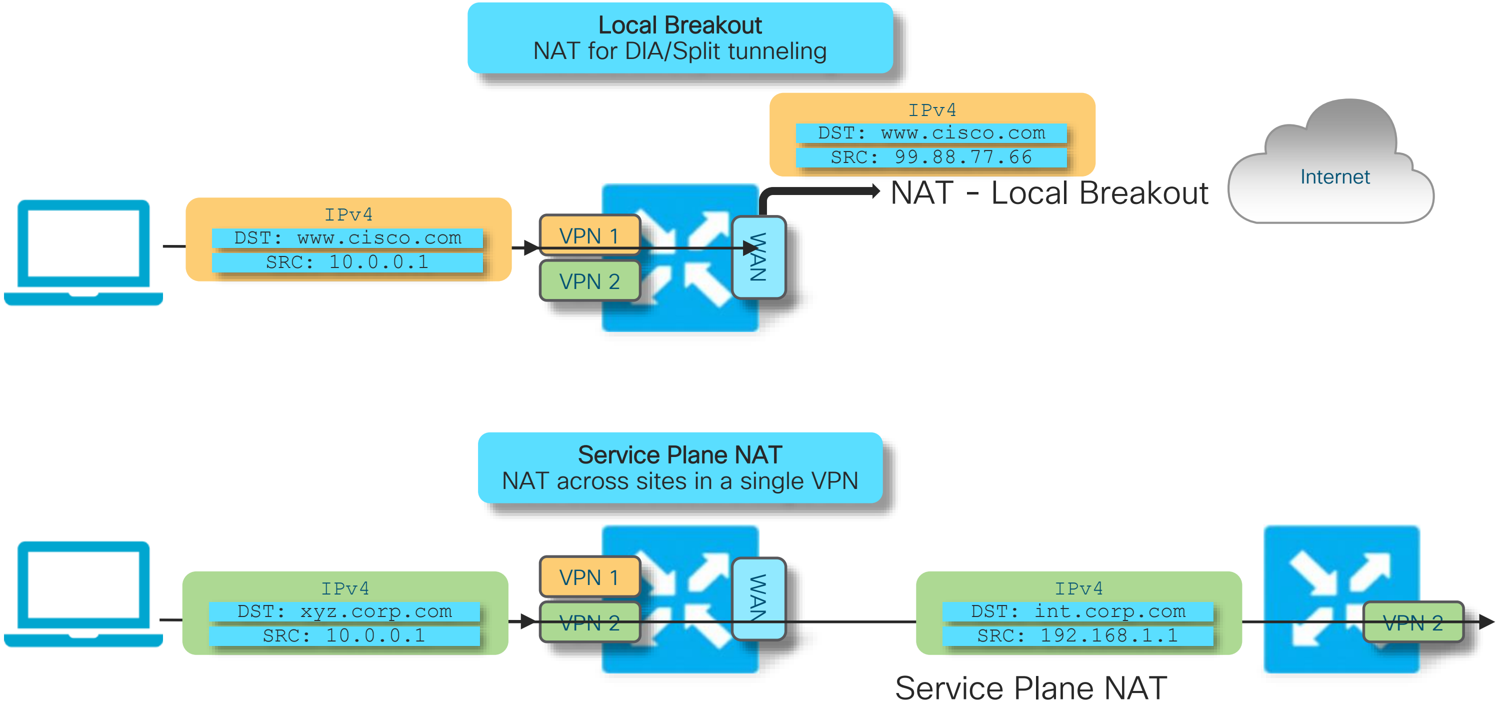
Forwarding Plane Features



NAT – Local Breakout
NAT – Service Plane
cFlowd
Match statement counters
Match Statement logging

Data Policy Case #1

Forwarding Plane Features – NAT for DIA and Service VPN



For Your Reference

Data Policy Capabilities

Forwarding Plane Feature Enablement – Policy Structure

Service Plane NAT
NAT across sites in a single VPN

```
policy data-policy Srvc_Plane_NAT
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.1/32
    !
    action accept
     nat pool 1
    !
   !
   default-action accept
  !
```

```
vEdge
vpn 1
 interface natpool1
  ip address 192.168.1.1/32
  no shutdown
  !
```

Local Breakout
NAT for DIA/Split tunneling

```
policy data-policy DIA_NAT
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.1/32
    !
    action accept
     nat use-vpn 0
    !
   !
   default-action accept
  !
```

```
vEdge
vpn 0
 interface ge0/0
  ip address 192.168.1.1/32
  no shutdown
  nat
 !
```

Data Policy Capabilities

For Your Reference

Forwarding Plane Feature Enablement – Policy Structure

Local Breakout
cFlowd and Counting

```
policy data-policy DIA_NAT
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.1/32
    !
    action accept
     cflowd
     count local-breakout-traffic
     nat use-vpn 0
    !
   !
   default-action accept
  !
```

- Counters visible using GUI/Realtime or via CLI

```
show policy data-policy-filter
```

- Use cflowd template for export-destination configuration

Local Breakout
Logging breakout traffic

```
policy data-policy DIA_NAT
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.1/32
    !
    action accept
     log
     nat use-vpn 0
    !
   !
   default-action accept
  !
```

```
vEdge
System
 logging
  server syslog.company.com
   vpn 1
   source-interface loopback1
  exit
 !
```

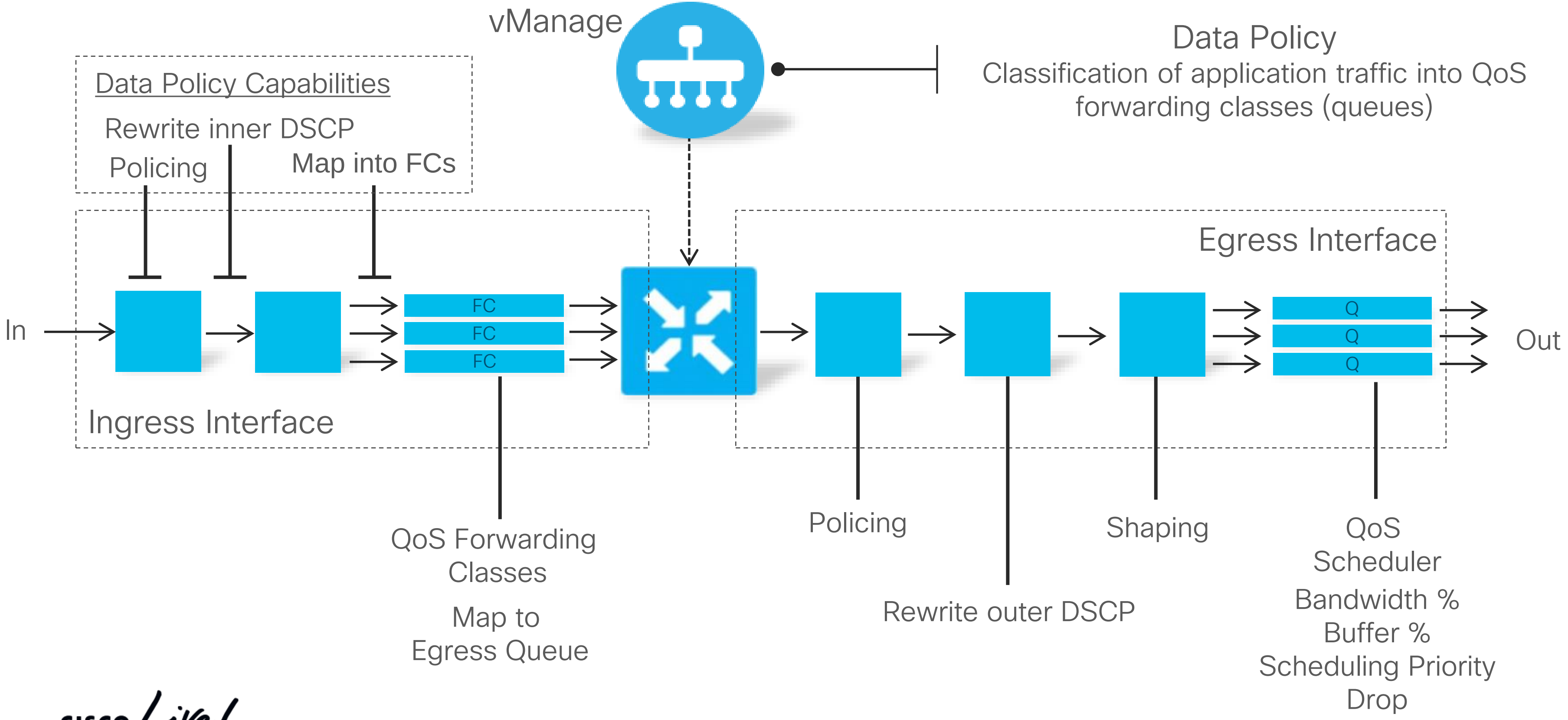
```
vEdge
policy
 log-frequency <number>*
```

* Default is every 1000 packets

Quality of Service

WAN Edge Router Device QoS Overview

WAN Edge Router



Data Policy

Classification of application traffic into QoS forwarding classes (queues)

Data Policy for QoS

Quality of Service – Policy Structure

For Your Reference

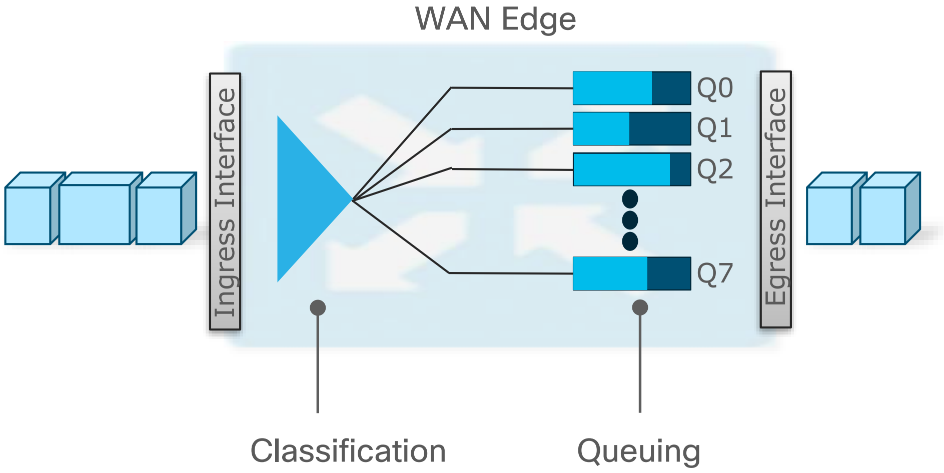
```
policy
 data-policy enterprise_traffic
  vpn-list VPN1
   sequence 10
    match app-list audio-video
    !
    action accept
     set
      dscp 46
      forwarding-class EF-class
     !
    !
   !
  !
 data-policy DIA
  vpn-list VPN10
   sequence 10
    match source-ip 10.0.0.0/8
    !
    action accept
     set
      policer police_DIA
     !
    !
   !
   default-action accept
  !
```

- App-list consists of DPI signature references
- Forwarding-class referring to configured QoS-class
  (Ref: qos-group in Cisco IOS)

```
policy
  policer police_DIA
  rate    10000000
  burst   1000000
  exceed drop
 !
!
```

Policer configured as part of Policy

WAN Edge Router Qos Capabilities

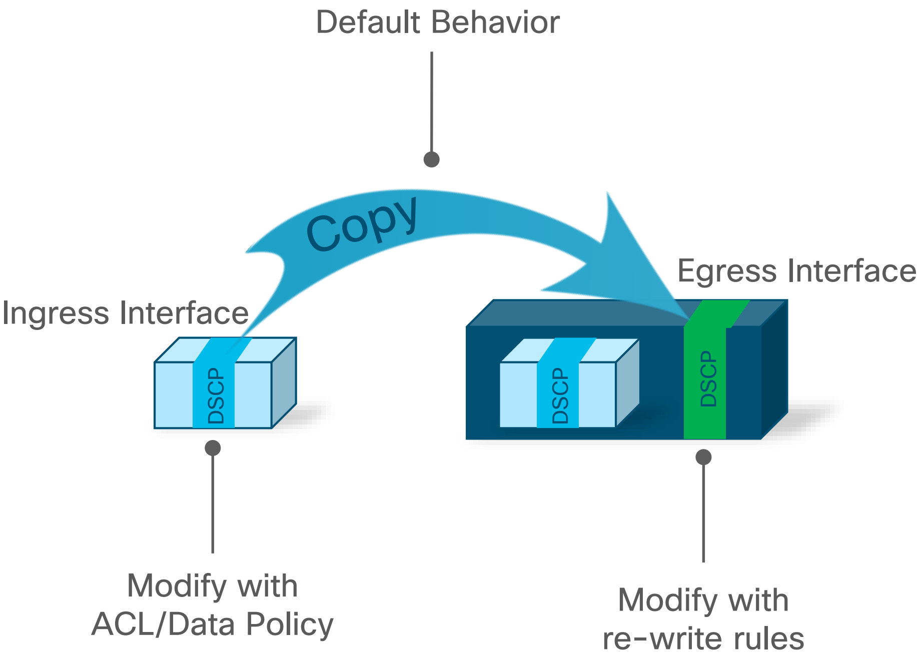


- Classification
  - Flow match on 6-tuple (ACL, Data Policy)
  - Application match on DPI (Data Policy)
- Per-Egress Interface Queuing
  - Q0 is LLQ
  - vEdge control traffic (DTLS/TLS, BFD, routing protocols) goes into Q0
    - Assign a some small value for control (5%)
- Scheduling for Q1-Q7 is WRR*
  - Bandwidth percent determines queue weight
  - Unused Q0 bandwidth is distributed between other queues
- Queue drop is RED** or tail-drop
  - Linear drop probability, i.e. X% queue depth results in X% drop probability

* Weighted Round-Robin
** Random Early Discard

Marking and Remarking

Supporting Enterprise and Provider DSCP schemes concurrently



- Comply with service providers provisioned classes of service
- Ingress Classification
  - DPI or 6 tuple matching using centralized or localized data policy
- Ingress interface marks/re-marks inner DSCP bits
- Inner DSCP bits are copied to the outer DSCP bits
- Egress interface re-write rules remark outer DSCP bits

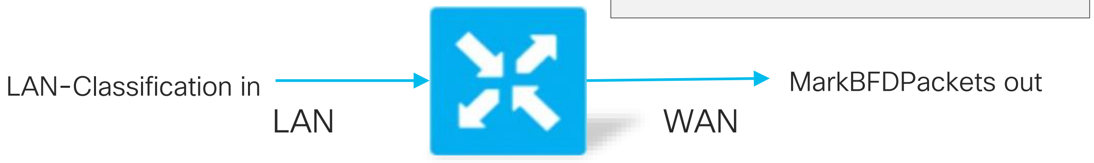
Re-Marking the BFD to match Application Traffic

Supporting Control and Critical traffic E2E

```
access-list LAN-Classification
  ….
  sequence 50
   match
    dscp 48
   !
   action accept
    class NetworkControl
   !
  !
  default-action accept
!
```

```
access-list MarkBFDPackets
  sequence 10
   match
    class NetworkControl
   !
   action accept
   !
  !
  sequence 20
   match
    dscp     48
    protocol 17
   !
   action accept
    set
     dscp 46
    !
   !
  !
  default-action accept
!
```

- WAN Edge QoS Default Behavior
  - All user traffic get mapped to Q2
  - All control traffic mapped to Q0 LLQ
    - Controller traffic
    - BFD Packets
    - Marked with DSCP of 48
- 100ms of buffer per port – Buffer Allocation can be configured per queue
- Recommendation
  - Always reserve minimum of 5% of BW and buffer for LLQ



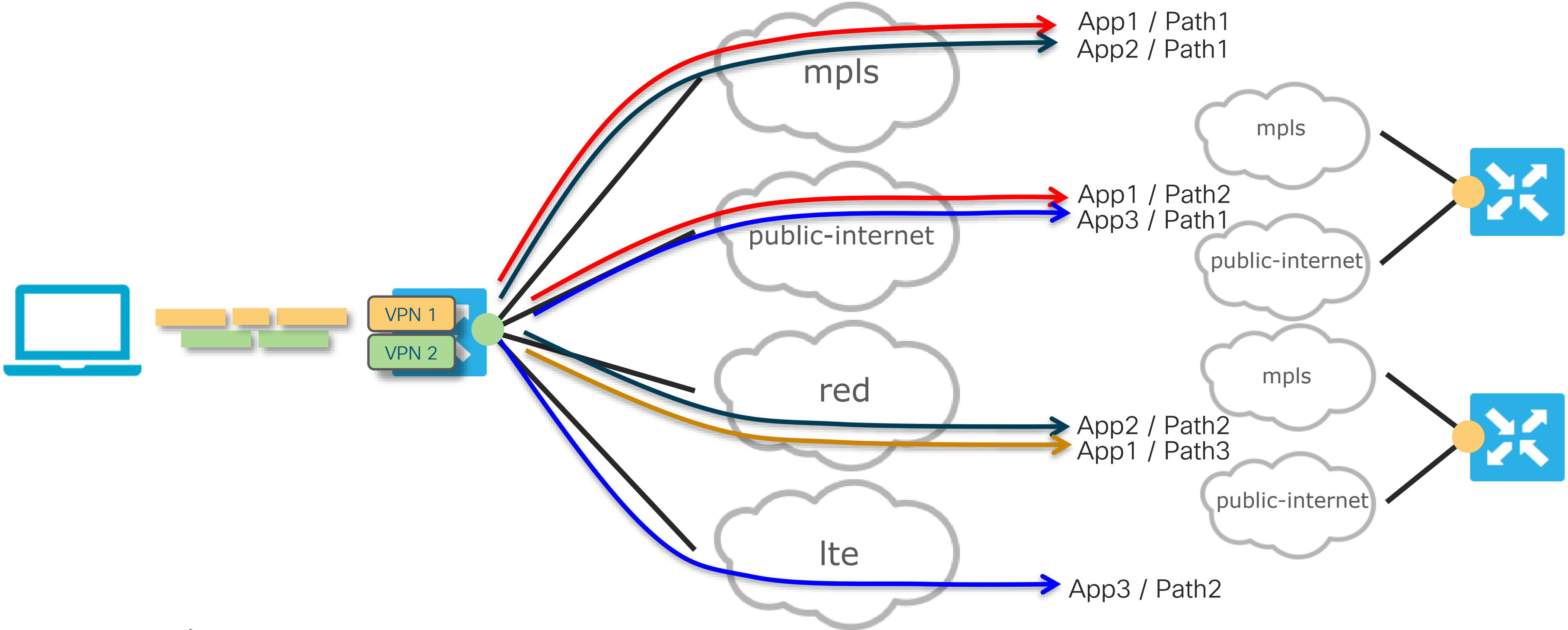
Application Pinning

Application Pinning

Transport selection per Application

● Local TLOC Selection: Loose preference, falls back to routing upon failure

● Remote TLOC Selection: Strict preference, traffic dropped upon failure



Application Pinning

Data Policy Configuration

Local TLOC
Prefer Local Underlay Path

```
vSmart
policy
 data-policy local-tloc-preference
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.0/8
    !
    action accept
     local—tloc red blue
```

- local-tloc – Loose match that will fall back to routing if all TLOCs in list are down
- tloc-list refers to specific remote TLOCs and will not fall back to routing

(Remote) TLOC
Prefer a remote Node/TLOC

```
vSmart
policy
 data-policy local-tloc-preference
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.0/8
    !
    action accept
     set
      tloc 1.1.1.1 color biz-internet

Or
    action accept
     set
      tloc-list remote-node
```

```
policy
 lists
  tloc-list remote-node
   tloc 1.1.1.1 color mpls encap ipsec preference 100
   tloc 1.1.1.1 color biz-internet encap ipsec preference 50
```

Internet Breakout - DIA / DCA

Internet Breakout / DIA

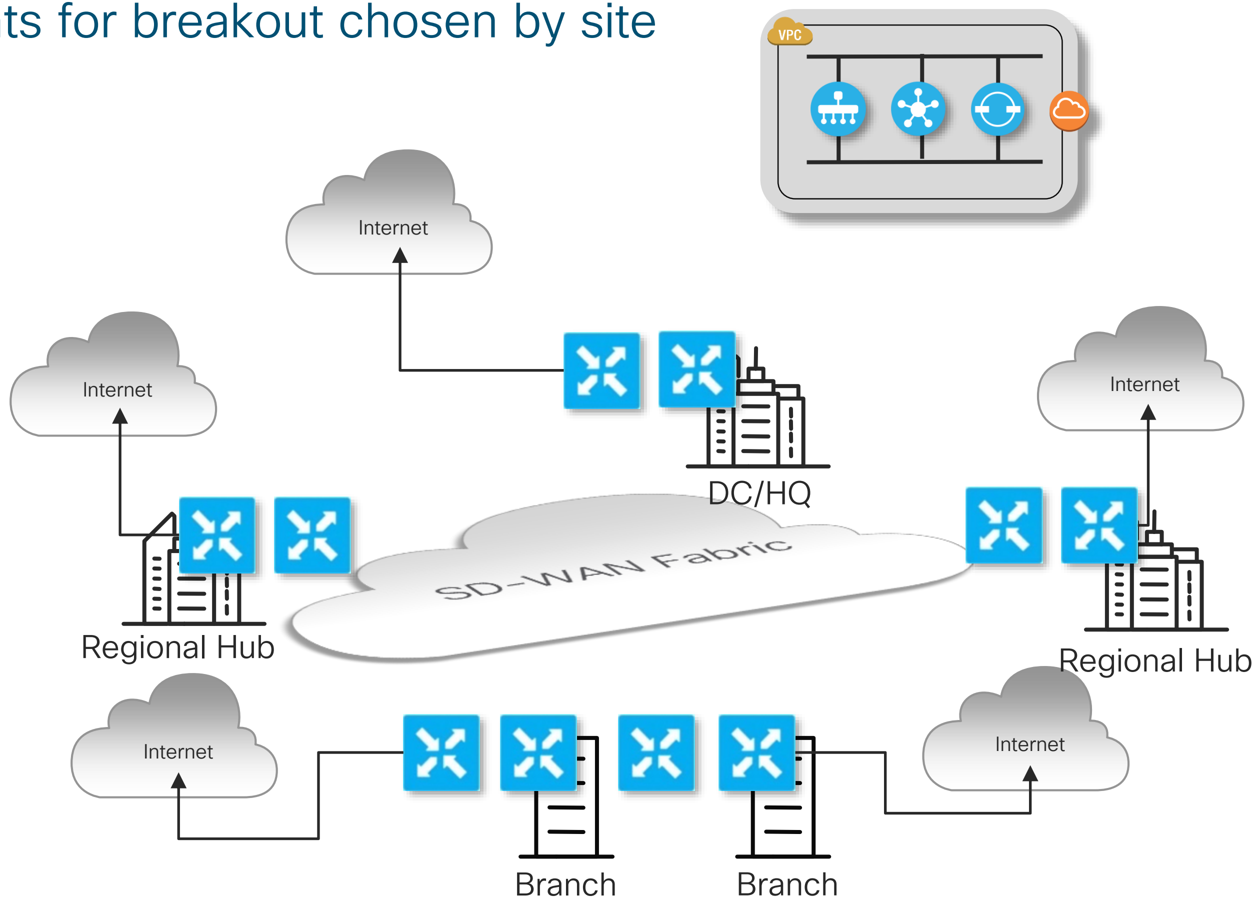
Routing and/or Policy-driven Capabilities

- The Cisco SD-WAN Architecture provides a lot of flexibility in enabling DIA
- Breakouts can be presented via:
  - Routing
  - Policy
  - In combination, with Preference and Backup options
  - Cloud-based Security as a Local Service using a Policy
- NAT is a required feature when providing a local breakout
- Service-side breakouts can be provided in case NAT is not needed or special care is needed for public addressing
- Can be deployed in combination with Service Chaining for monitoring/security/processing requirements

Internet Breakout Leverage

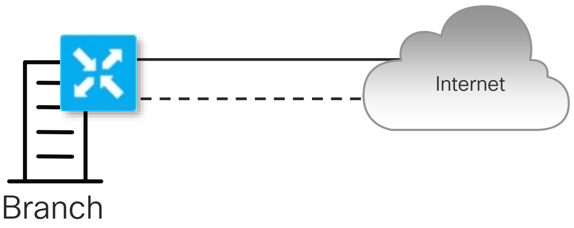
Most appropriate points for breakout chosen by site

- Enterprises can gradually progress from centralized to distributed breakouts
- Routing plane enables primary/backup as needed
- Policies further enhance selection and breakout granularity
- Align well with deployment of Cloud-based Security solutions



SD-WAN Internet Breakout Options

Local Breakout using a Default Route



```
vpn 0
 interface ge0/0
  nat
  tracker my_tracker
 !
vpn 1
 ip route 0.0.0.0/0 vpn 0
```

```
System
 tracker my_tracker
 endpoint-ip 1.2.3.4
 Interval 5
 Multiplier 3
 Threshold 500
```

- Static route in Service VPN
  - Can be default or more granular
- Redirects traffic to interfaces in VPN 0:
  - Interfaces must have NAT enabled
  - Multiple interfaces enables per-flow load-sharing
  - Relies on VPN 0 routing table
- Can be complemented with a Tracker to monitor Internet availability beyond first hop gateway

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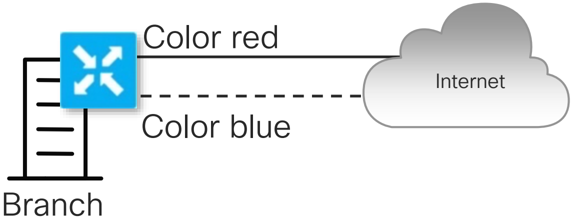
SD-WAN Internet Breakout Options

Local Breakout using Data Policy



```
vEdge
vpn 0
 interface ge0/0
  nat
```

```
vSmart
policy
 data-policy internet-breakout
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.0/8
    !
    action accept
     nat use-vpn 0
     local–tloc public-internet
```

- Policy now redirects instead of static route
  - In case local exit fails, lookup can fall back to local service VPN routing table
- Redirects traffic to interfaces in VPN 0:
  - Interfaces must have NAT enabled
  - Multiple interfaces enables per-flow load-sharing
  - Relies on VPN 0 routing table
- Can be complemented with a Tracker to monitor Internet availability beyond first hop gateway
- Local TLOC to be used can be specified

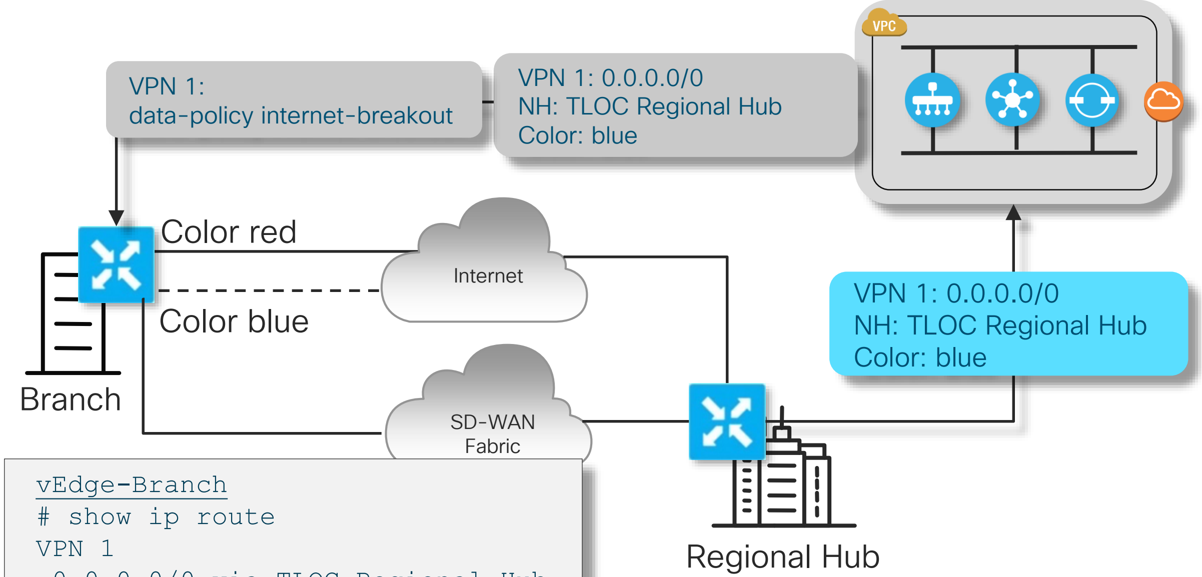
SD-WAN Internet Breakout Options

Joint Local and Regional Breakout using Data Policy + Routing

Legend:

Original Advertisement from Endpoint

Un/Modified Advertisement from Controller



VPN 1:
data-policy internet-breakout

VPN 1: 0.0.0.0/0
NH: TLOC Regional Hub
Color: blue

VPN 1: 0.0.0.0/0
NH: TLOC Regional Hub
Color: blue

```
vSmart
policy
 data-policy internet-breakout
  vpn-list VPN1
   sequence 10
    match source-ip 10.0.0.0/8
    !
    action accept
     nat use-vpn 0
     local—tloc red blue
```

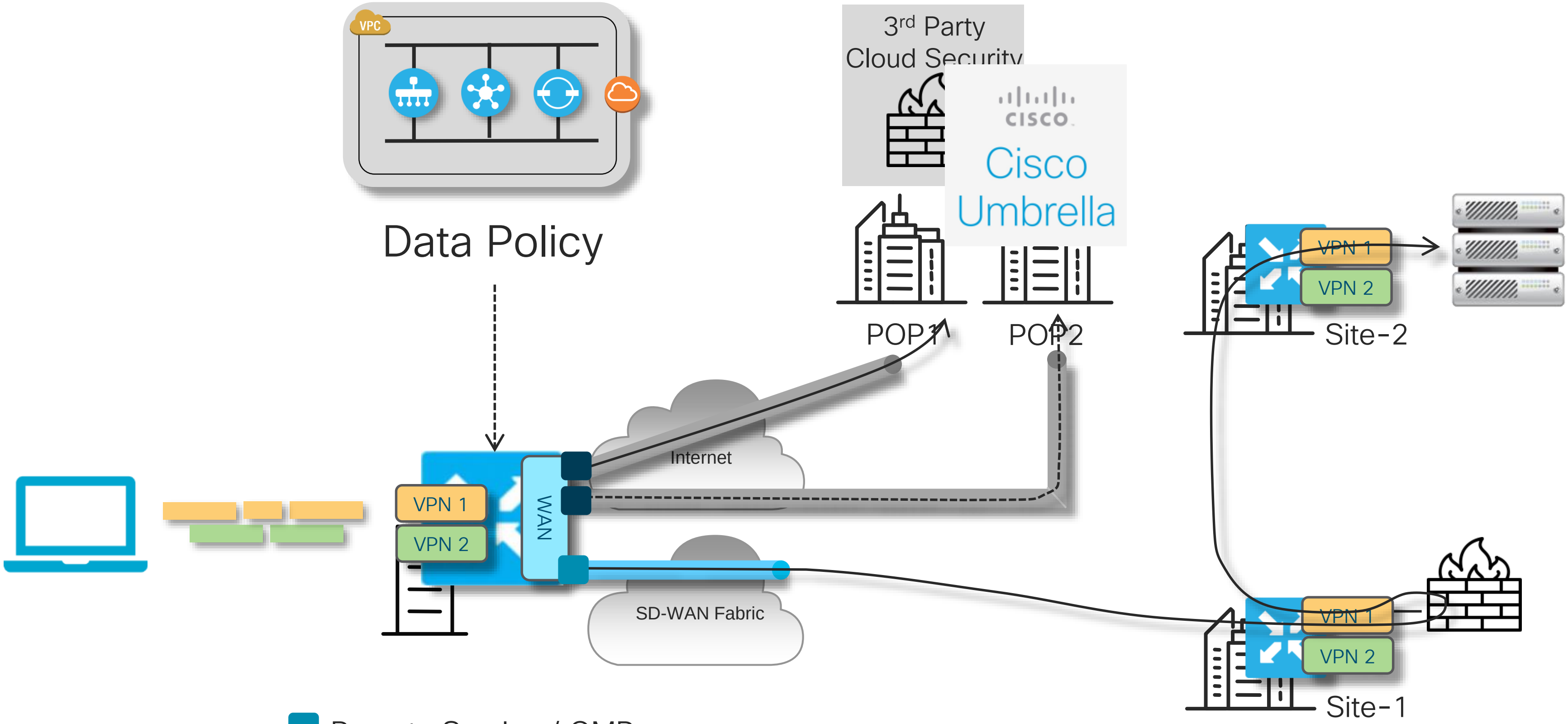
```
vEdge-Regional Hub
VPN 1
 ip route 0.0.0.0/0 null0 or
 default from OSPF/BGP
```

```
vEdge-Branch
# show ip route
VPN 1
 0.0.0.0/0 via TLOC Regional Hub
```

- Data Policy allows for granular breakout policy matching L3/L4/L7 information
  - Data Policy takes precedence
  - Default route from Regional Hub acts as backup in case TLOC Red & Blue are both down

SD-WAN Internet Breakout Options

Service Chaining – Cloud Security and Shared Services



🟦 Remote Service / OMP
■ Local Service

For Your Reference

SD-WAN Internet Breakout Options

Service Chaining – Local Services – Policy Configuration

```
vSmart
policy
 data-policy Cloud_Security
  vpn-list vpn_all
   sequence 10
    match protocol 6
    match destination-port 80 443
    !
    action accept
     set
      service FW local
     !
    !
   !
   default-action accept
```

2 Match Traffic

3 Apply Local Service

```
WAN Edge
vpn 1
 service FW interface gre1 gre2
vpn 0
 interface ge0/0
  ip address 99.88.77.66/32
  no shutdown
  nat
 !
 interface gre1
  ip address 12.13.14.15/24
  tunnel-source-interface ge0/0
  tunnel-destination 123.123.123.123
  no shutdown
 !
 interface gre2
  ip address 16.17.18.19/24
  tunnel-source-interface ge0/0
  tunnel-destination 124.124.124.124
  no shutdown
```

1 Define Local Service FW

Primary Tunnel

Backup Tunnel

- Data Policy redirection to locally configured service
- Service represented by local GRE or IPsec tunnel pre-configured on each WAN Edge

For Your Reference

SD-WAN Internet Breakout Options

Service Chaining – Remote Services – Policy Configuration

```
vSmart
policy
 data-policy Central_Security
  vpn-list vpn_all
   sequence 10
    match protocol 6
    match destination-port 80 443
    !
    action accept
     set
      service FW vpn 1
     !
    !
   !
   default-action accept
```

2 Match Traffic

3 Apply OMP FW Service

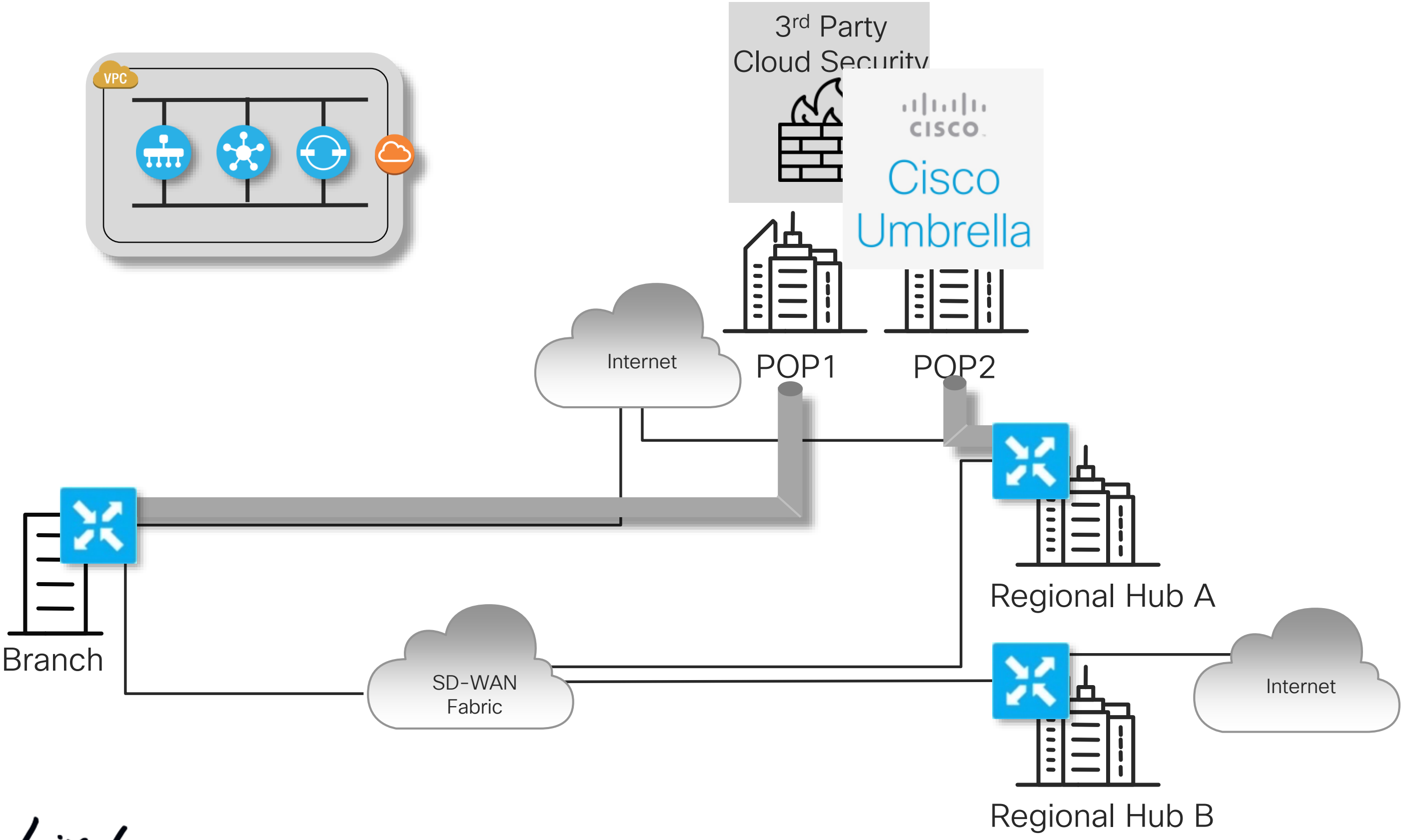
```
WAN Edge - Site1
vpn 1
 service FW address 12.13.14.100
 !
 interface ge0/0
  ip address 12.13.14.15/24
  no shutdown
```

1 Define Service FW for OMP Announcement

- Data Policy redirection to remotely configured service
- Service represented by OMP advertised service identifier
- Service association can be specified via TLOC or TLOC-list (with priorities) if needed

SD-WAN Internet Breakout Options

Joint Local and Regional Breakout using Data Policy and Cloud Security + Routing Preference



SD-WAN Internet Breakout Options

For Your Reference

Joint Local and Regional Breakout using Data Policy and Cloud Security + Routing Preference

```
vSmart
policy
 data-policy Cloud_Security
  vpn-list vpn_all
   sequence 10
    match
     destination-data-prefix-list internal-prefixes
    !
    action accept
    !
   !
   sequence 20
    match
    !
    action accept
     count count_fw
     set
      service FW local [restrict]
     !
```

Exclude Internal Prefixes from Internet Breakout

Any other traffic sent to Internet Breakout

Drop Traffic if Service Down

```
policy
 lists
  data-prefix-list internal-prefixes
   ip-prefix 10.0.0.0/8
   ip-prefix 172.16.0.0/12
   ip-prefix 192.168.0.0/16
```

```
WAN-Edge-Branch
vpn 1
 service FW interface gre1
vpn 0
 interface gre1
  ip address 12.13.14.15/24
  tunnel-source-interface ge0/0
  tunnel-destination 123.123.123.123
  no shutdown
```

```
WAN-Edge-Regional_Hub_A
vpn 1
 service FW interface gre1
 ! ip route 0.0.0.0/0 null0 or
 ! default from OSPF/BGP
```

```
WAN-Edge-Regional_Hub_B
vpn 1
 ! ip route 0.0.0.0/0 null0 or
 ! default from OSPF/BGP
```

SD-WAN Internet Breakout Options

For Your Reference

Joint Local and Regional Breakout using Data Policy and Cloud Security + Routing Preference

vSmart Control Policy

```
vSmart
Policy
 lists
  prefix-list default route
   ip-prefix 0.0.0.0/0
  !
 !
 control-policy default priority
  sequence 10
   match route
    prefix-list default route
    site-id Regional Hub A
    !
    action accept
     set
      preference 100
    !
   !
  !
  default-action accept
```

Default from Hub A gets higher preference

WAN Edge Static TLOC preference

```
WAN-Edge-Regional Hub A
vpn 0
 interface ge0/0
  tunnel-interface
   encapsulation ipsec preference 100
!
vpn 1
 ! ip route 0.0.0.0/0 null0 or
 ! default from OSPF/BGP
```

```
WAN-Edge-Regional Hub B
vpn 0
 interface ge0/0
  tunnel-interface
vpn 1
 ! ip route 0.0.0.0/0 null0 or
 ! default from OSPF/BGP
```

SD-WAN Internet Breakout Options

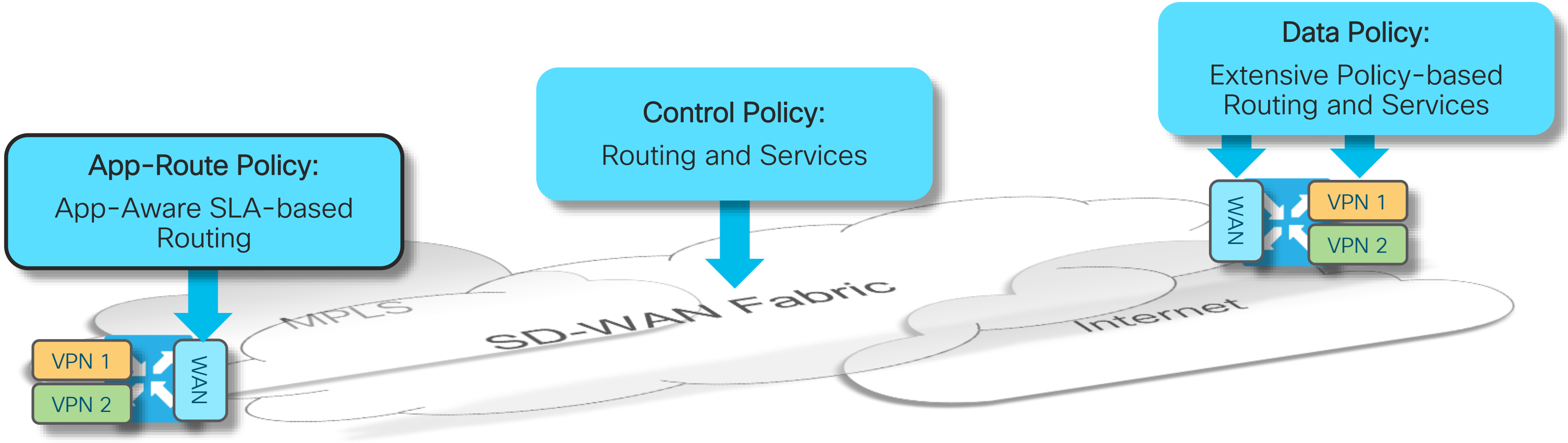
Application Specific Breakout

- The Data Policy construct can also be used to locally breakout specific applications with defined DPI signatures (e.g. O365, FaceBook, Youtube)
- Example:
  - Office365 to be locally broken out
  - All other Internet traffic via regional exit
- Arrangements required for supporting O365
  - Data Policy for breaking out locally
  - Default route from regional exit for two purposes:
    - o Breakout for all non O365 traffic
    - o O365 session establishment involves quite a few protocols beyond the core O365 protocols – A default route from somewhere is required to deal with those applications and allow for successful O365 operations
- SD-AVC support to provide Application Recognition from the first packet

SLA-Driven Path Selection using App-Route Policies

Cisco SD-WAN Policy Architecture

Suite of Policies to address different functional domains



- Control Policies are applied at vSmart: Tailors routing information advertised to Edge endpoints
- App-Route Policies are applied at WAN Edge: SLA-driven path selection for applications
- Data Policies are applied at WAN Edge: Extensive Policy driven routing

App-Route Policies

App-route Components and Dependencies

BFD Settings
BFD rx_interval and multiplier settings
(only rx_interval is relevant to AAR)

```
bfd
 color <color>
  hello-interval <msec>
  multiplier <number>
```

App-route algorithm configuration
Define how SLA data is used to influence path selection

```
bfd
 app-route
  multiplier <number>
  poll-interval <msec>
```

App-route Policy Definition
Define SLA-classes, Application associations, VPN applicability and Policy actions/preferences

```
SLA-classes
Policy Construct
 match
 action
```

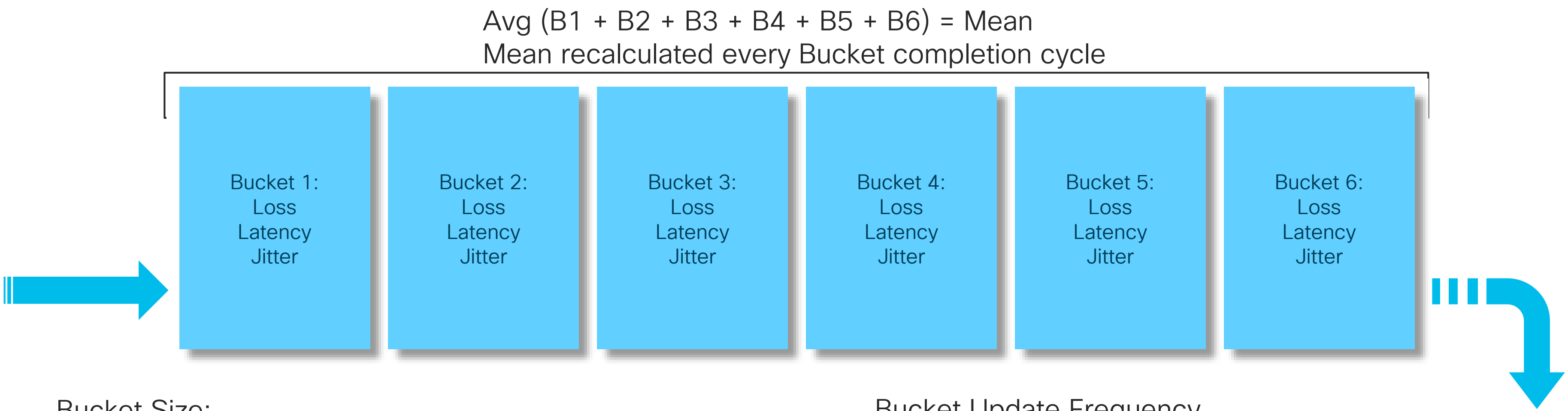
DPI Engine Enablement
AAR relies on DPI for L7 signatures

```
policy
 app-visibility
```

*https://sdwan-docs.cisco.com/Product_Documentation/Software_Features/Release_18.4/07Policy_Applications/01Application-Aware_Routing/01Configuring_Application-Aware_Routing

App-Route Policies

App-route Algorithm


Avg (B1 + B2 + B3 + B4 + B5 + B6) = Mean
Mean recalculated every Bucket completion cycle
Bucket 1: Loss Latency Jitter
Bucket 2: Loss Latency Jitter
Bucket 3: Loss Latency Jitter
Bucket 4: Loss Latency Jitter
Bucket 5: Loss Latency Jitter
Bucket 6: Loss Latency Jitter

Bucket Size:

```
bfd
 app-route poll-interval
```

(default 600,000 ms)

# of Buckets:

```
bfd
 app-route multiplier
```

(default 6)

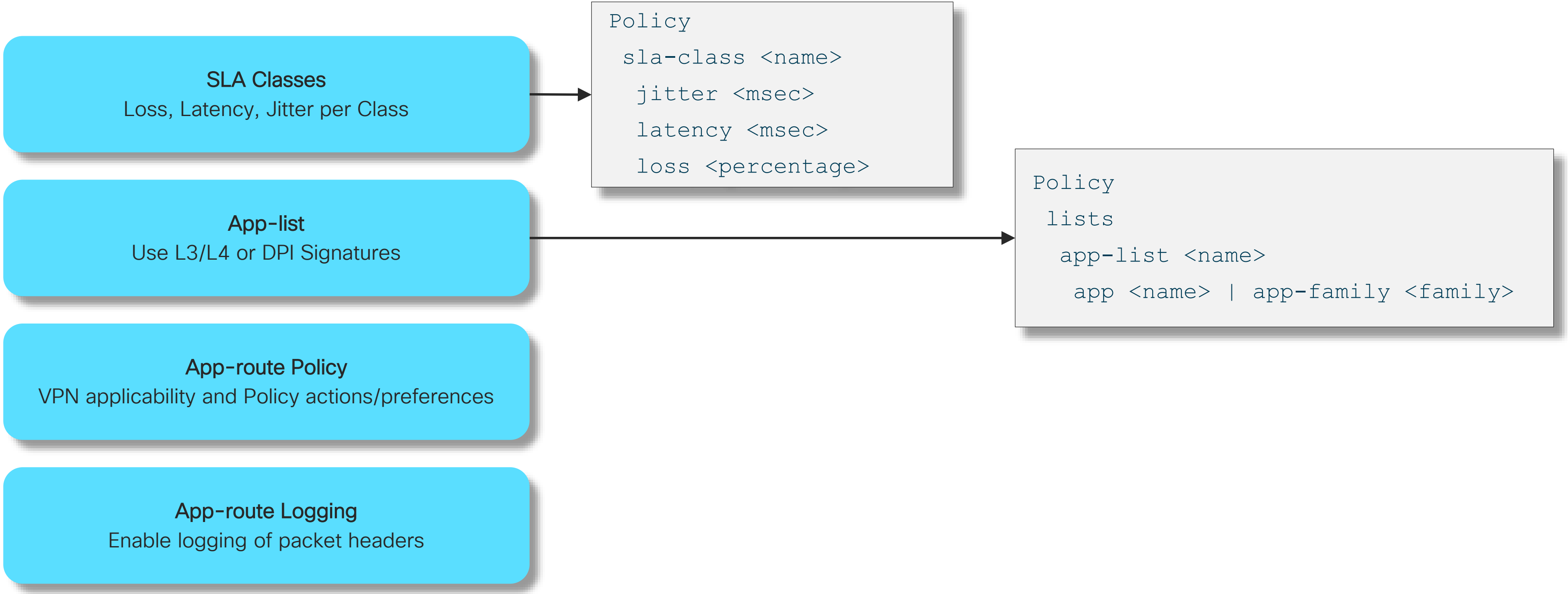
Bucket Update Frequency

```
bfd
 hello-interval
```

(default 1000ms)

App-Route Policies

App-route Policy Definition



SLA Classes
Loss, Latency, Jitter per Class

```
Policy
 sla-class <name>
  jitter <msec>
  latency <msec>
  loss <percentage>
```

App-list
Use L3/L4 or DPI Signatures

```
Policy
 lists
  app-list <name>
   app <name> | app-family <family>
```

App-route Policy
VPN applicability and Policy actions/preferences

App-route Logging
Enable logging of packet headers

App-Route Policies

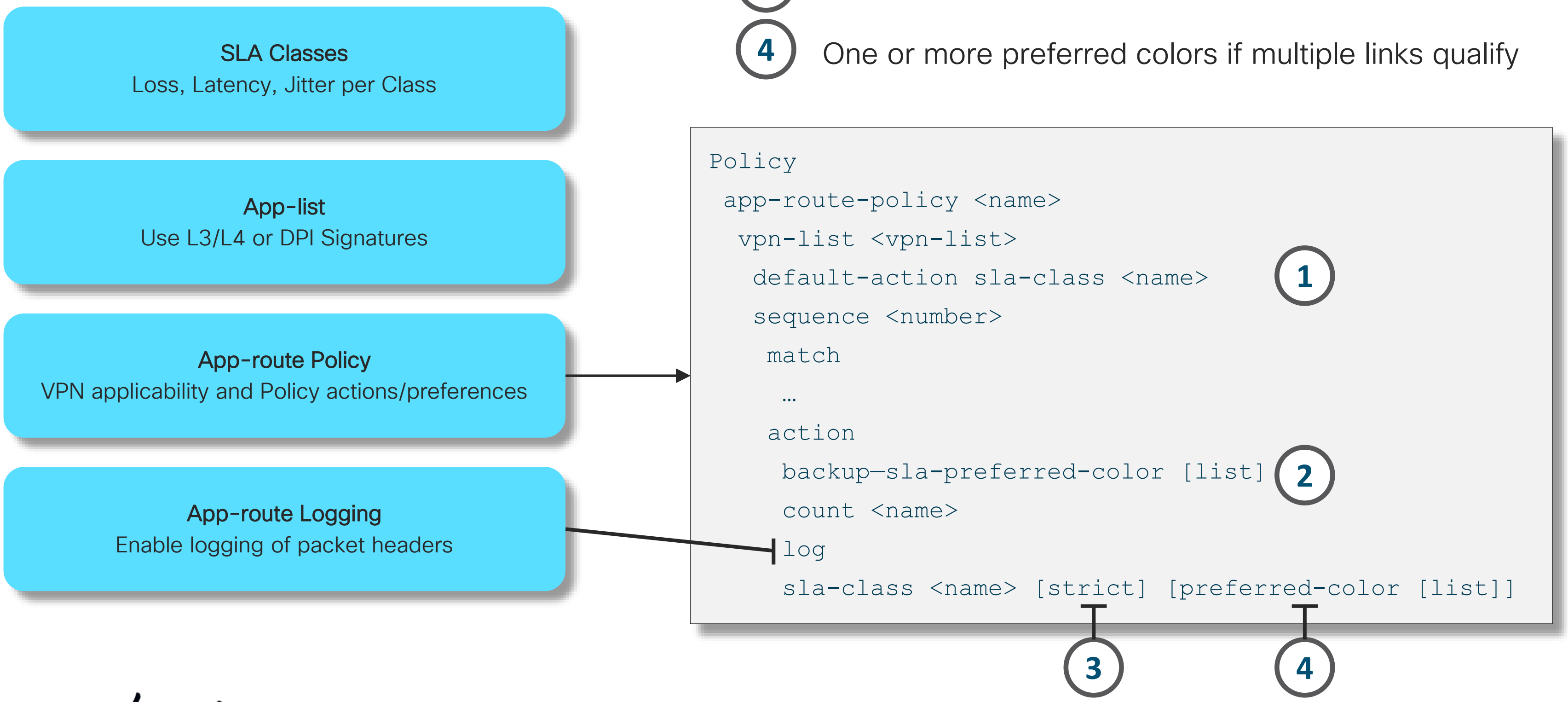
App-route Policy Definition

1 For traffic not explicitly matched in policy

2 For traffic with an SLA-class disqualified across all links

3 Drop traffic if SLA-class is disqualified

4 One or more preferred colors if multiple links qualify



SLA Classes
Loss, Latency, Jitter per Class

App-list
Use L3/L4 or DPI Signatures

App-route Policy
VPN applicability and Policy actions/preferences

App-route Logging
Enable logging of packet headers

```
Policy
 app-route-policy <name>
  vpn-list <vpn-list>
   default-action sla-class <name>
   sequence <number>
    match
     …
    action
     backup—sla-preferred-color [list]
     count <name>
     log
     sla-class <name> [strict] [preferred-color [list]]
```

For Your Reference

App-Route Policies

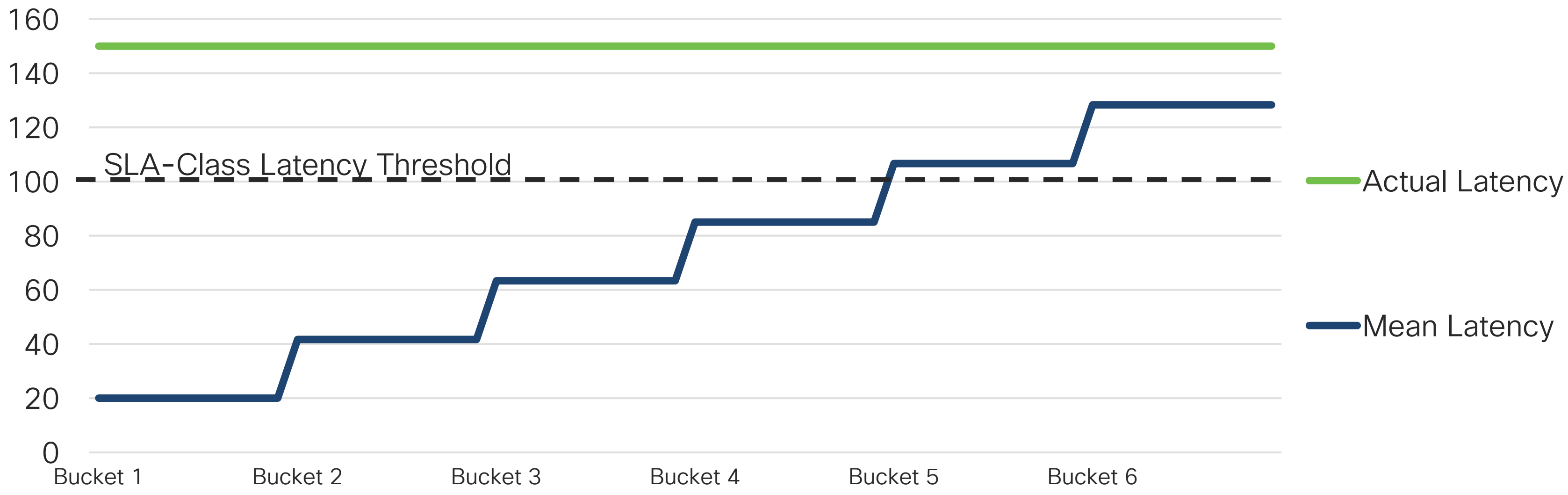
Policy Example

```
policy
 lists
  vpn-list VPN1
   vpn 1
  !
  site-list app-route-sites
   site-id 3003
  !
  app-list AVV
   app-family audio_video
  !
  app-list SFDC
    app salesforce
  !
```

```
apply-policy
 site-list app-route-sites
  app-route-policy SLA-Routing
```

```
Policy
 sla-class EF
  loss    1
  latency 100
 !
 sla-class Biz-apps
  loss    2
  latency 150
 !
 app-route-policy SLA-Routing
  vpn-list VPN1
   sequence 10
    match app-list AVV
    !
    action
     sla-class EF
    !
   !
   sequence 20
    match app-list SFDC
    !
    action
     sla-class Biz-apps
    !
   !
```

App-route Policy Path Convergence

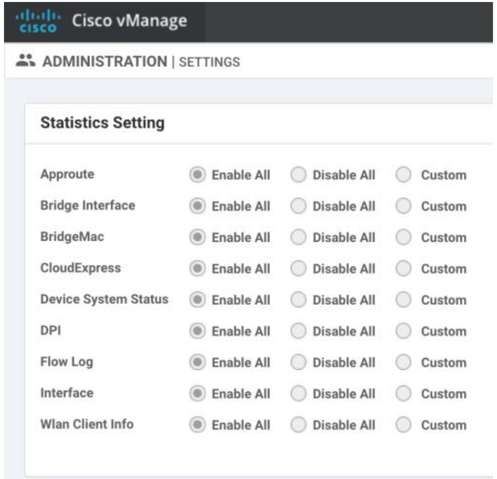


Current Mean Latency is 20ms, when Latency jumps to 150ms as Bucket 1 collection starts

Recommended Settings and Operational Best Practices

vManage Statistics Collection

Configuration and Volumes



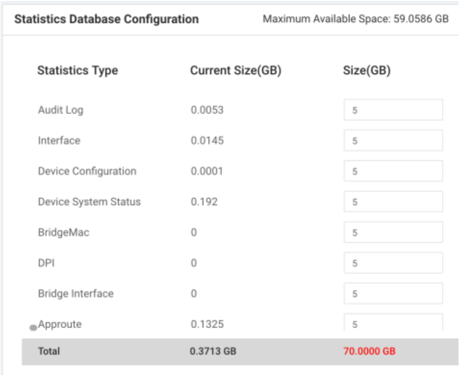
Cisco vManage

ADMINISTRATION | SETTINGS

Statistics Setting

Approute	● Enable All	○ Disable All	○ Custom
Bridge Interface	● Enable All	○ Disable All	○ Custom
BridgeMac	● Enable All	○ Disable All	○ Custom
CloudExpress	● Enable All	○ Disable All	○ Custom
Device System Status	● Enable All	○ Disable All	○ Custom
DPI	● Enable All	○ Disable All	○ Custom
Flow Log	● Enable All	○ Disable All	○ Custom
Interface	● Enable All	○ Disable All	○ Custom
Wlan Client Info	● Enable All	○ Disable All	○ Custom

- Configure collection per category and per device
- Custom allows to control collection of each category on a per device basis



Statistics Database Configuration Maximum Available Space: 59.0586 GB

Statistics Type	Current Size(GB)	Size(GB)
Audit Log	0.0053	5
Interface	0.0145	5
Device Configuration	0.0001	5
Device System Status	0.192	5
BridgeMac	0	5
DPI	0	5
Bridge Interface	0	5
Approute	0.1325	5
Total	0.3713 GB	70.0000 GB

- Storage can be assigned for individual categories to reflect:
  - Collection not being enabled
  - Storage assignments and data lifetime

Overlay and vEdge Recommended Settings

Useful Settings to get Right the First Time

- System-IP
  - Pick a range for the entire network that does not overlap with other addressing
  - Not routed but significant to anything present in VPN 0 / Transport
  - An incorrectly chosen range or System-IP setting can cause connectivity issues
- Site-ID
  - The target for policy application and identifier of routing sources (ref: BGP AS)
  - Several schemes documented and one is discussed later on
- Vmanage connection preference
  - Determines which TLOC is used for vManage traffic (statistics upload etc)
  - Advised to use the highest bandwidth link and avoid cellular interfaces
- Max-control-connections
  - Determines how many vSmart sessions are established per TLOC
  - For Transports without controller access, it must be set to Zero (0)

Template Creation Guidelines

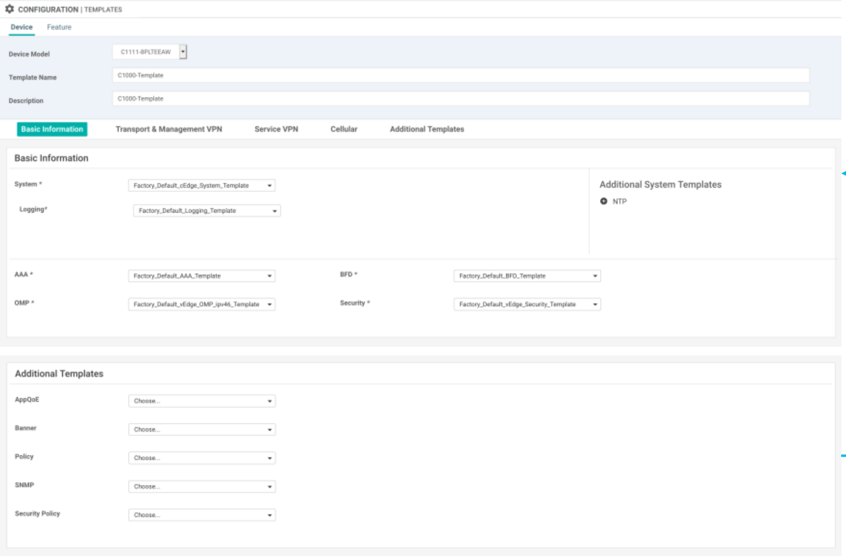
Templates are Friends

- Plan for template creation and test out features to be deployed
  - Allows for the optimization of template structure and maintenance
- Use a simple ”bootstrap” template for distributed devices that are not yet in production
  - The device is then in a known state and vManaged
  - Tracking events is easier if a logical name is applied
  - The local configuration of the device can’t be changed
  - The device can be moved to production (or any other state) at will from vManage
- The template can be changed at any time from within vManage
- Template Variables can be managed in several different ways:
  - Entered manually at time of template attachment
  - Stored in a .csv file that is referenced at time of template application
  - Using the REST API (possibly in conjunction with other platforms such as Infoblox)

Template Creation

Feature Template Components and Sources

Device Template - Aggregate Configuration Template



CONFIGURATION | TEMPLATES

Device | Feature

Device Model	C1111-8PLTEEAW
Template Name	C1000-Template
Description	C1000-Template

Basic Information | Transport & Management VPN | Service VPN | Cellular | Additional Templates

Basic Information

System *	Factory_Default_cEdge_System_Template		
Logging*	Factory_Default_Logging_Template		
AAA *	Factory_Default_AAA_Template	BFD *	Factory_Default_BFD_Template
OMP *	Factory_Default_vEdge_OMP_ipv46_Template	Security *	Factory_Default_vEdge_Security_Template

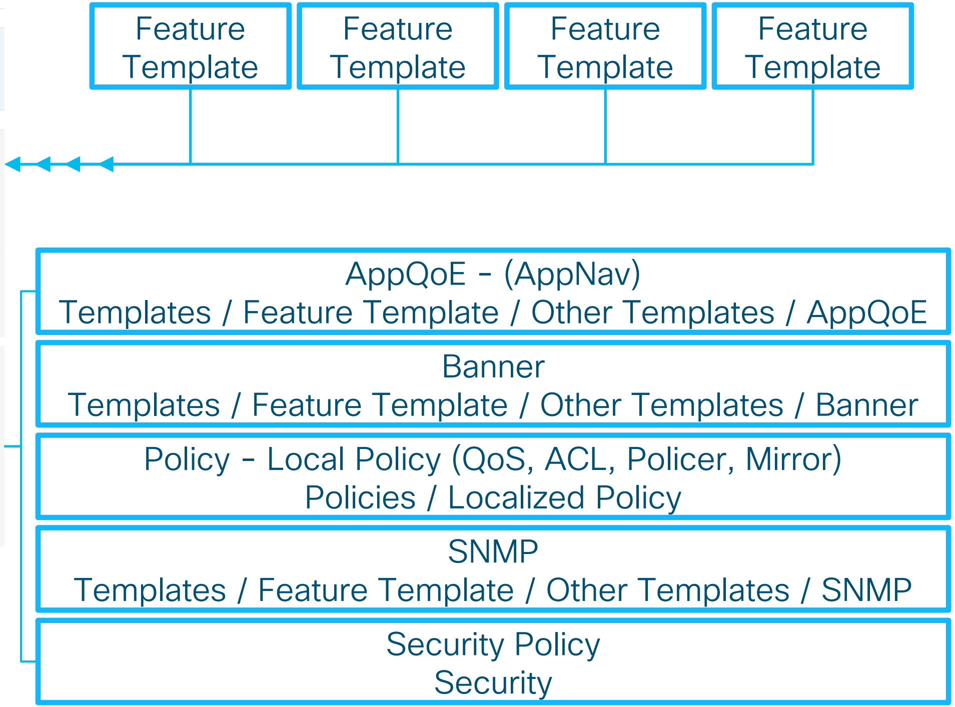
Additional System Templates

⊕ NTP

Additional Templates

AppQoE	Choose...
Banner	Choose...
Policy	Choose...
SNMP	Choose...
Security Policy	Choose...

Dedicated or Shared Feature Templates



Feature Template

Feature Template

Feature Template

Feature Template

AppQoE - (AppNav)
Templates / Feature Template / Other Templates / AppQoE

Banner
Templates / Feature Template / Other Templates / Banner

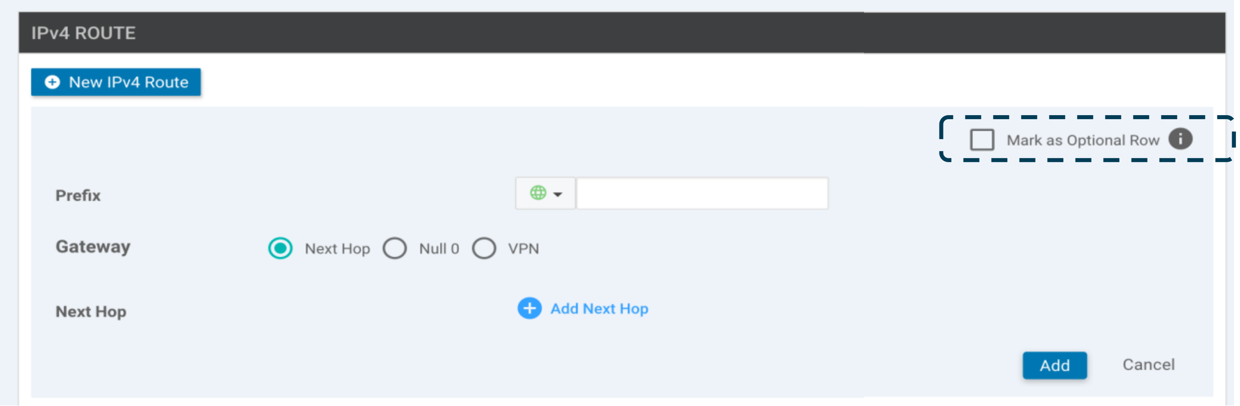
Policy - Local Policy (QoS, ACL, Policer, Mirror)
Policies / Localized Policy

SNMP
Templates / Feature Template / Other Templates / SNMP

Security Policy
Security

Template Creation - Device Template

Optimizing object use in a Device Template - Optional Objects



IPv4 ROUTE

New IPv4 Route

□ Mark as Optional Row

Prefix

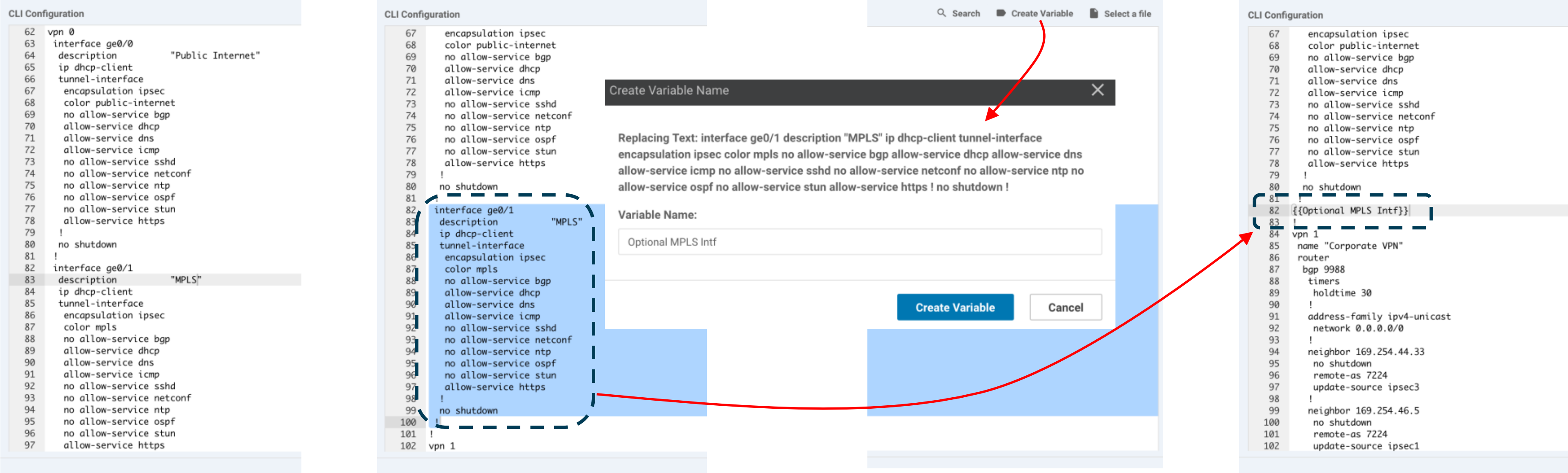
Gateway ● Next Hop ○ Null 0 ○ VPN

Next Hop

- Using Device Templates, quite a few objects can be tagged as Optional
- Simply not assigning a value at template application leaves the object out of the created configuration
- This makes Device Templates flexible to support a variety of different configurations

Template Creation - CLI Template

Optimizing object use in CLI template by means of variables



CLI Configuration

```
vpn 0
 interface ge0/0
  description          "Public Internet"
  ip dhcp-client
  tunnel-interface
   encapsulation ipsec
   color public-internet
   no allow-service bgp
   allow-service dhcp
   allow-service dns
   allow-service icmp
   no allow-service sshd
   no allow-service netconf
   no allow-service ntp
   no allow-service ospf
   no allow-service stun
   allow-service https
  !
  no shutdown
 !
 interface ge0/1
  description          "MPLS"
  ip dhcp-client
  tunnel-interface
   encapsulation ipsec
   color mpls
   no allow-service bgp
   allow-service dhcp
   allow-service dns
   allow-service icmp
   no allow-service sshd
   no allow-service netconf
   no allow-service ntp
   no allow-service ospf
   no allow-service stun
   allow-service https
```

CLI Configuration

```
   encapsulation ipsec
   color public-internet
   no allow-service bgp
   allow-service dhcp
   allow-service dns
   allow-service icmp
   no allow-service sshd
   no allow-service netconf
   no allow-service ntp
   no allow-service ospf
   no allow-service stun
   allow-service https
  !
  no shutdown
 !
 interface ge0/1
  description          "MPLS"
  ip dhcp-client
  tunnel-interface
   encapsulation ipsec
   color mpls
   no allow-service bgp
   allow-service dhcp
   allow-service dns
   allow-service icmp
   no allow-service sshd
   no allow-service netconf
   no allow-service ntp
   no allow-service ospf
   no allow-service stun
   allow-service https
  !
  no shutdown
 !
!
vpn 1
```

Create Variable Name

Replacing Text: interface ge0/1 description "MPLS" ip dhcp-client tunnel-interface encapsulation ipsec color mpls no allow-service bgp allow-service dhcp allow-service dns allow-service icmp no allow-service sshd no allow-service netconf no allow-service ntp no allow-service ospf no allow-service stun allow-service https ! no shutdown !

Variable Name: Optional MPLS Intf

CLI Configuration

```
   encapsulation ipsec
   color public-internet
   no allow-service bgp
   allow-service dhcp
   allow-service dns
   allow-service icmp
   no allow-service sshd
   no allow-service netconf
   no allow-service ntp
   no allow-service ospf
   no allow-service stun
   allow-service https
  !
  no shutdown
 !
 {{Optional MPLS Intf}}
 !
vpn 1
 name "Corporate VPN"
 router
  bgp 9988
   timers
    holdtime 30
   !
   address-family ipv4-unicast
    network 0.0.0.0/0
   !
   neighbor 169.254.44.33
    no shutdown
    remote-as 7224
    update-source ipsec3
   !
   neighbor 169.254.46.5
    no shutdown
    remote-as 7224
    update-source ipsec1
```

- In a CLI template, an arbitrary number of lines can be turned into a variable
- Assigning this variable a “;” at template application leaves the section out of the created configuration
- This makes CLI Templates flexible to support a variety of different configurations

Policy Creation and Management Guidelines

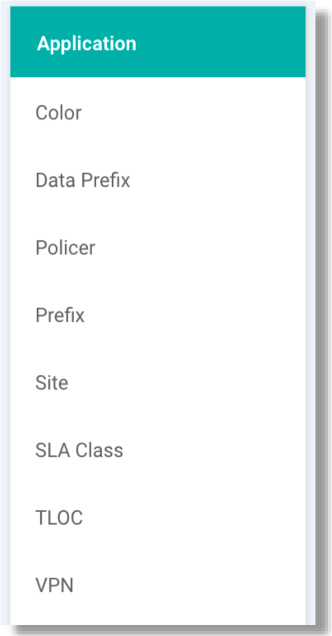
Really not different from standard operations

- Define Requirements up front
  - Important Applications
  - Segmentation and Connectivity Models
  - SLA and QoS Requirements
  - Application Pinning, Breakout, Hosting, Routing i.e. Application Management Requirements
- Use a sandbox for verification and testing
  - A separate domain where policies and requirements can be tested
  - Can be part of the production network, simply a separate Site-ID range
- Limit Policy Management to a few capable resources

Construction of SD-WAN Policies

Policy Building Blocks

Lists



Application

Color

Data Prefix

Policer

Prefix

Site

SLA Class

TLOC

VPN

Policy

```
Policy Type
```

```
Policy Sequence 1
Match <route | tloc | Application>
Action <Accept | Reject | set >
```

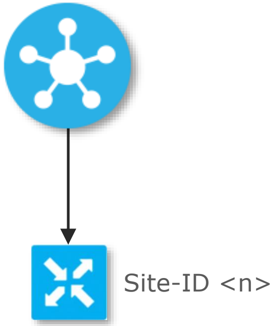
```
Policy Sequence 2
Match <route | tloc | Application>
Action <Accept | Reject | set >
```

```
Default Action
<Accept | Reject>
```

Apply Policy

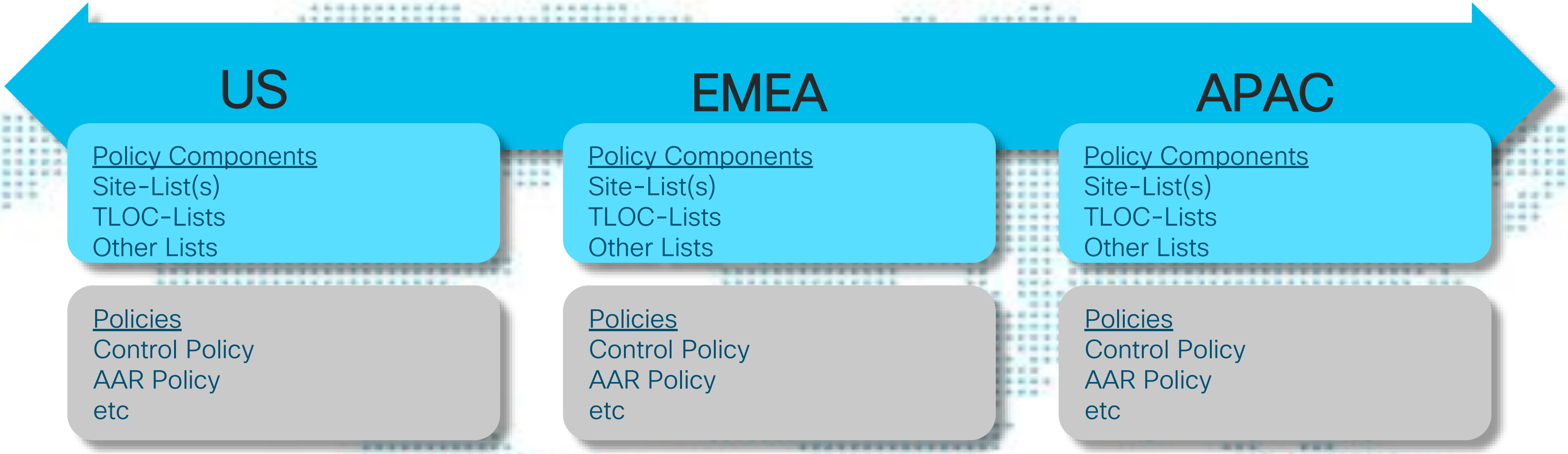
```
Site-List
```

```
Policy <type> <name>
Direction (if applicable)
```



Policy Management

Best Practices



US

Policy Components
Site-List(s)
TLOC-Lists
Other Lists

Policies
Control Policy
AAR Policy
etc

EMEA

Policy Components
Site-List(s)
TLOC-Lists
Other Lists

Policies
Control Policy
AAR Policy
etc

APAC

Policy Components
Site-List(s)
TLOC-Lists
Other Lists

Policies
Control Policy
AAR Policy
etc

- Create and Maintain separate Lists and Policies per network region (and a sandbox if possible)
- Make modifications to a copy of the original and swap the copy with the original when applying
- More complex policies can be large and updates should be tested before applied to the live network

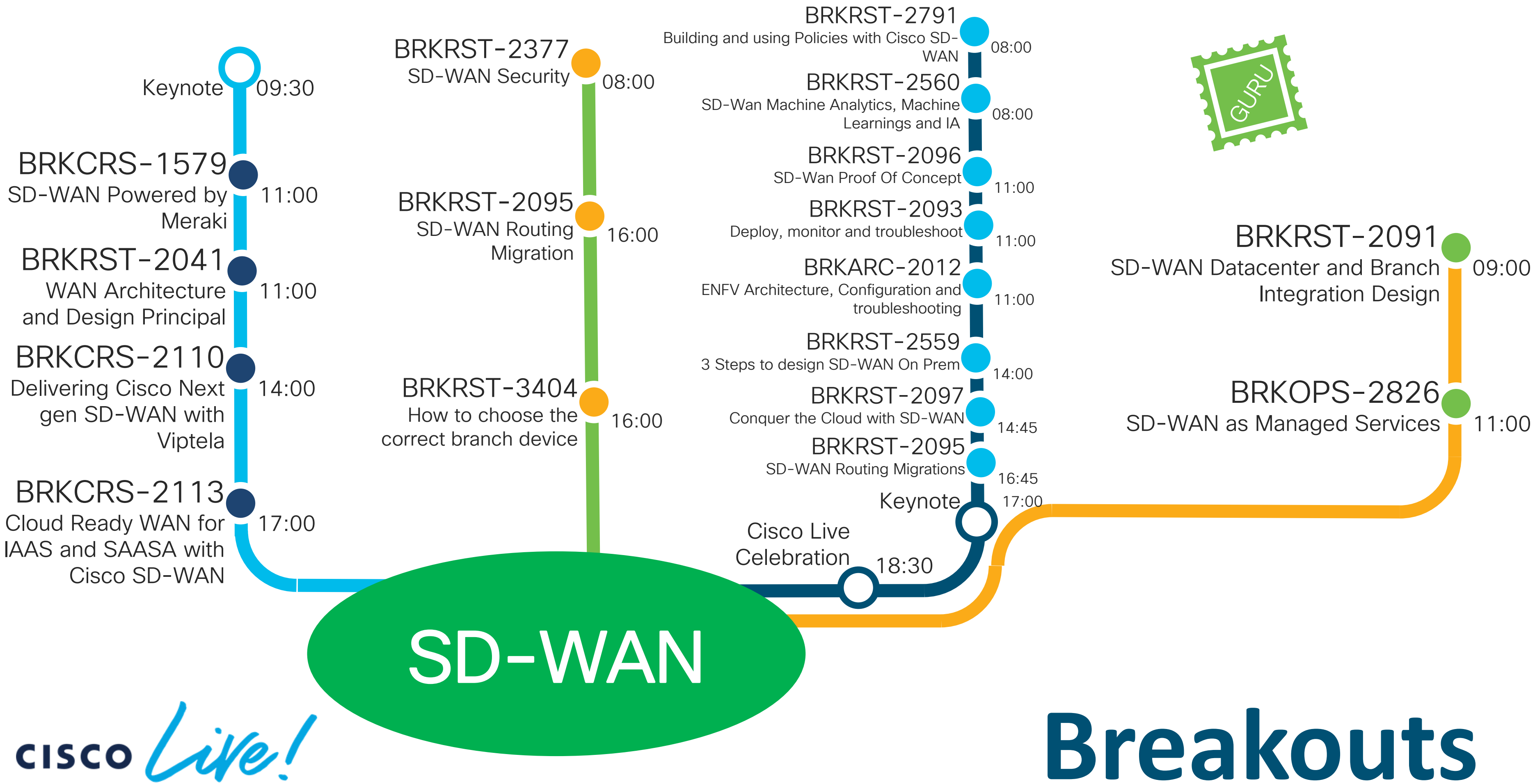
TECCRS-2014 SD-WAN Technical Deep Dive	8 Hours
TECRST – 2191 SD-WAN design, deploy and best practices	4 Hours
TECCRS-3006 ENFV Deep Dive and Hands on Lab	8 Hours

Cisco SD-WAN

GURU

Tectorials

Breakouts



Keynote 09:30

BRKCRS-1579
SD-WAN Powered by Meraki 11:00

BRKRST-2041
WAN Architecture and Design Principal 11:00

BRKCRS-2110
Delivering Cisco Next gen SD-WAN with Viptela 14:00

BRKCRS-2113
Cloud Ready WAN for IAAS and SAASA with Cisco SD-WAN 17:00

BRKRST-2377
SD-WAN Security 08:00

BRKRST-2095
SD-WAN Routing Migration 16:00

BRKRST-3404
How to choose the correct branch device 16:00

BRKRST-2791
Building and using Policies with Cisco SD-WAN 08:00

BRKRST-2560
SD-Wan Machine Analytics, Machine Learnings and IA 08:00

BRKRST-2096
SD-Wan Proof Of Concept 11:00

BRKRST-2093
Deploy, monitor and troubleshoot 11:00

BRKARC-2012
ENFV Architecture, Configuration and troubleshooting 11:00

BRKRST-2559
3 Steps to design SD-WAN On Prem 14:00

BRKRST-2097
Conquer the Cloud with SD-WAN 14:45

BRKRST-2095
SD-WAN Routing Migrations 16:45

Keynote 17:00

Cisco Live Celebration 18:30

BRKRST-2091
SD-WAN Datacenter and Branch Integration Design 09:00

BRKOPS-2826
SD-WAN as Managed Services 11:00

SD-WAN

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