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Simple Leaf/Spine with a Touch of ToR: Network

Designs for the Modern Data Center

Richard Licon, Principal Technical Marketing Engineer

BRKDCN-2667

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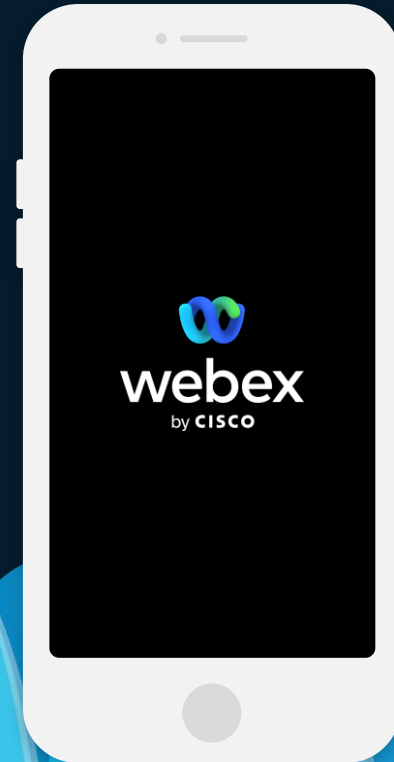
How

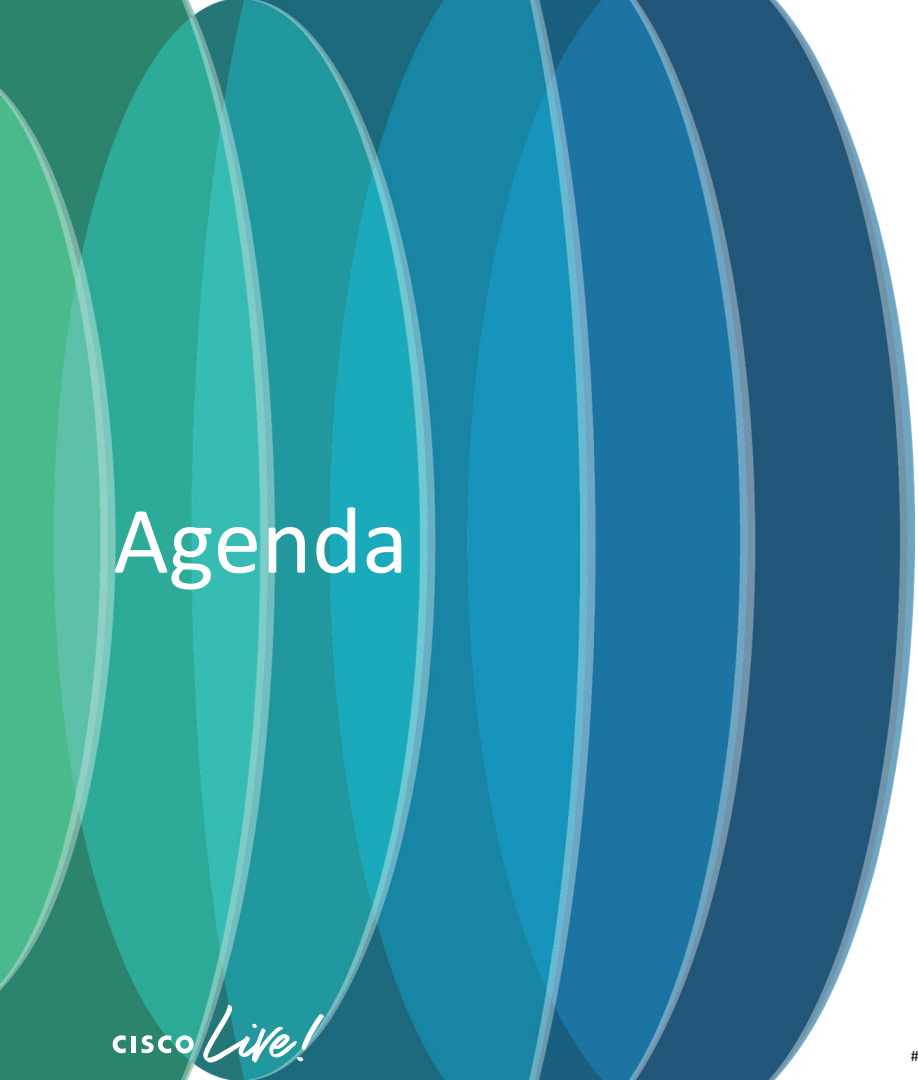
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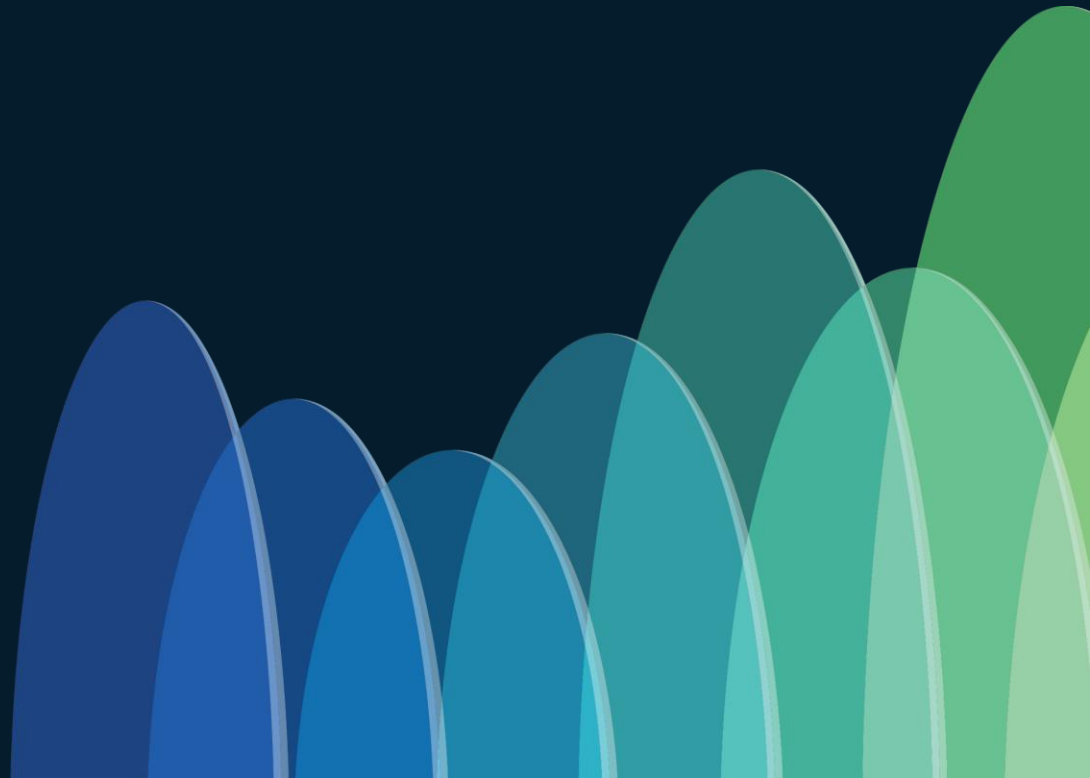




Agenda

- Introduction
- The Evolution of DC Network Designs
- Leaf-Spine “Fat Tree” Network Topologies
- Hardware Deployment Considerations
- Fundamentals of VXLAN EVPN Design
- Multi Fabric Designs – VXLAN Multi Site
- Conclusion

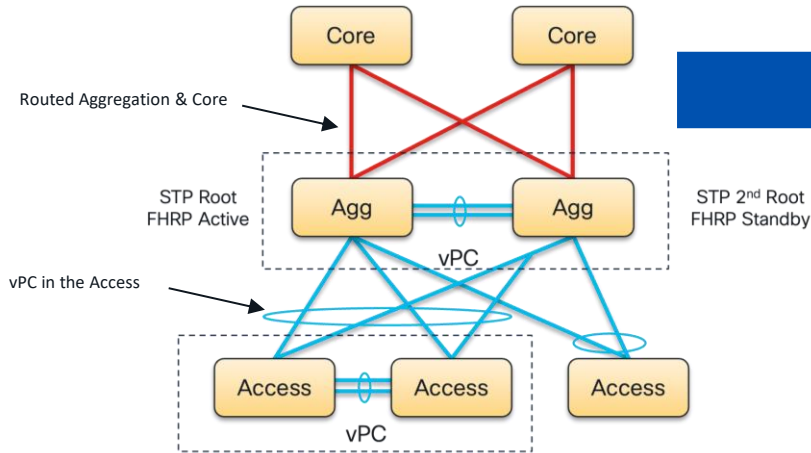
Introduction



Evolving Network Designs

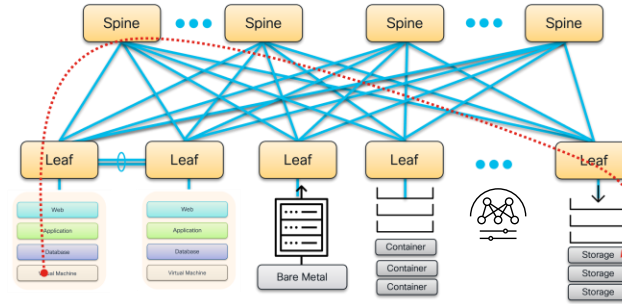
Traditional 3-Tier DC Network Design

vPC and Spanning-Tree



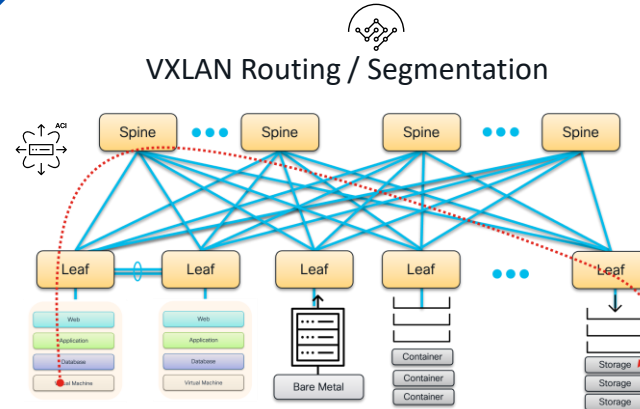
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VXLAN Bridging/Routing Services



- VXLAN Flood & Learn
- VXLAN EVPN
- Separate Management Tools (e.g. Nexus Fabric Manager)

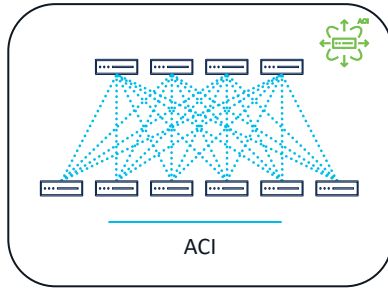
VXLAN Routing / Segmentation



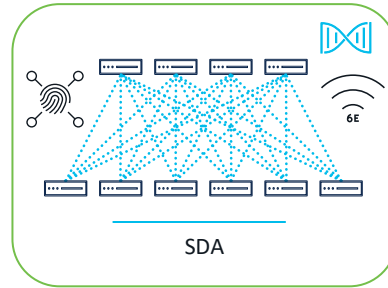
- VXLAN Routing
- Policy Controller (APIC)
- Consistent policy across physical and virtual network
- Multi-hypervisor (VMware, MSFT, OVS)
- Endpoint agnostic (bare metal, VM, container)

Cisco Fabrics (Data Center & Campus)

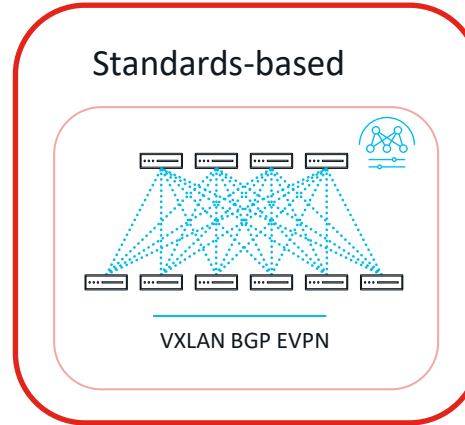
Policy-based



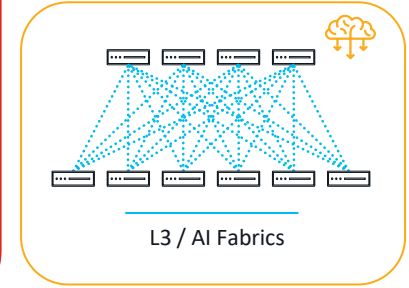
Intent-based



Standards-based



Routed



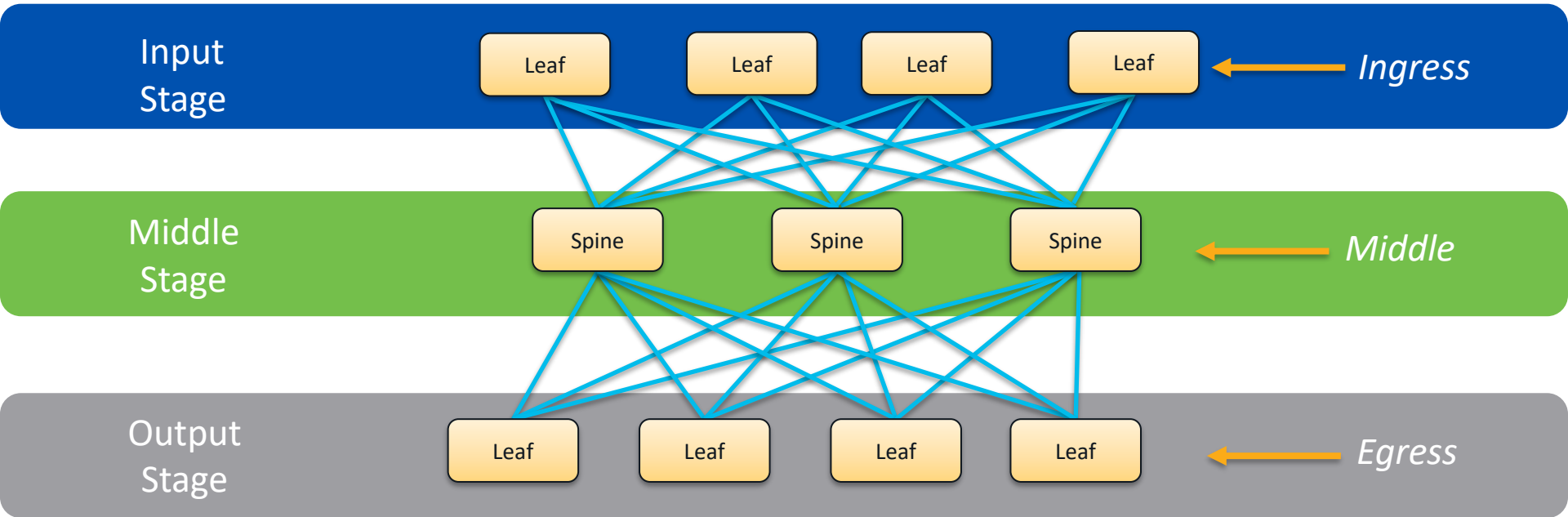
Managed by Cisco's Leading-Edge Controllers

The Evolution of DC Network Designs



Evolution of the Data Center Network

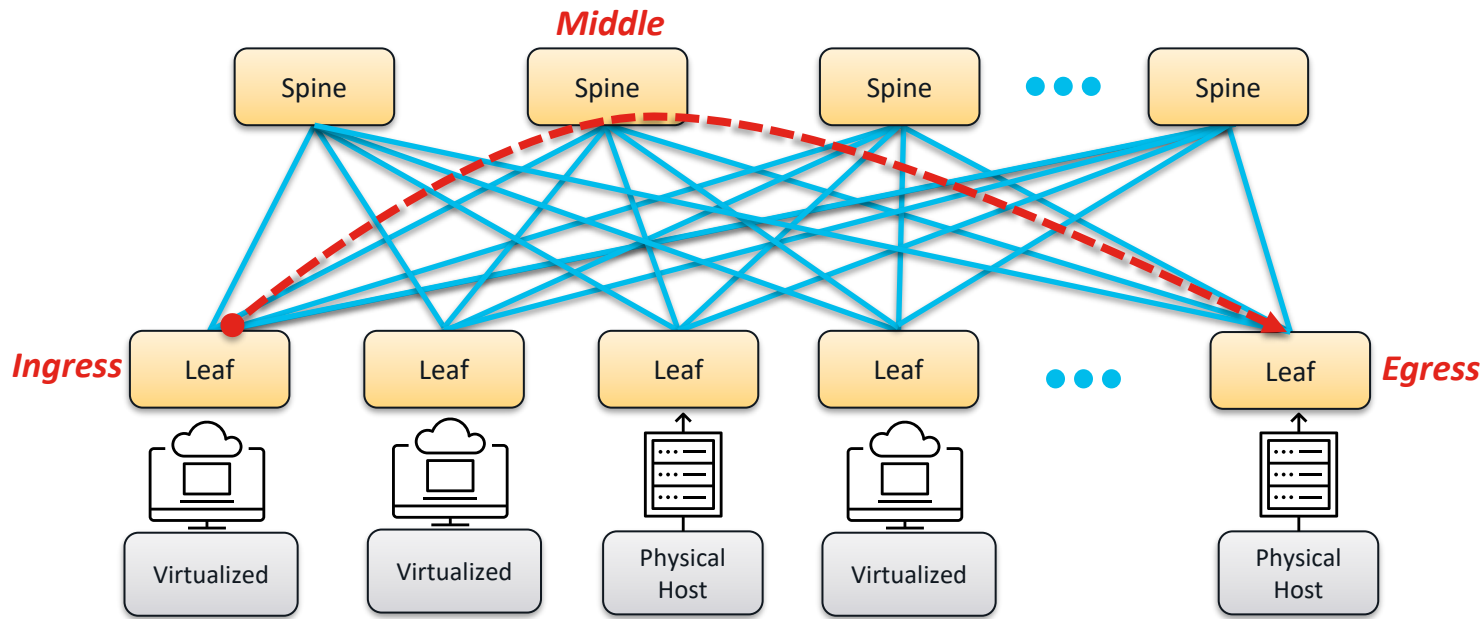
3-Stage Clos Fabric



Evolution of the Data Center Network

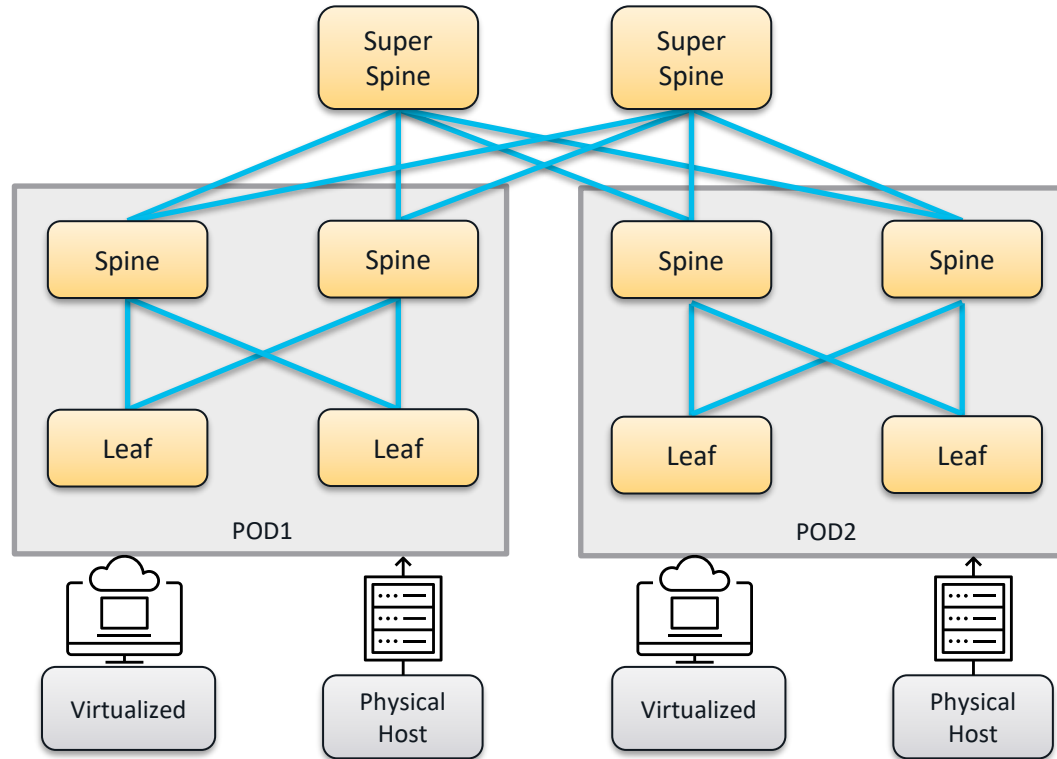
3-Stage Clos Fabric

March 1953: A Study of Non-Blocking Switching Networks. (Clos, Charles)



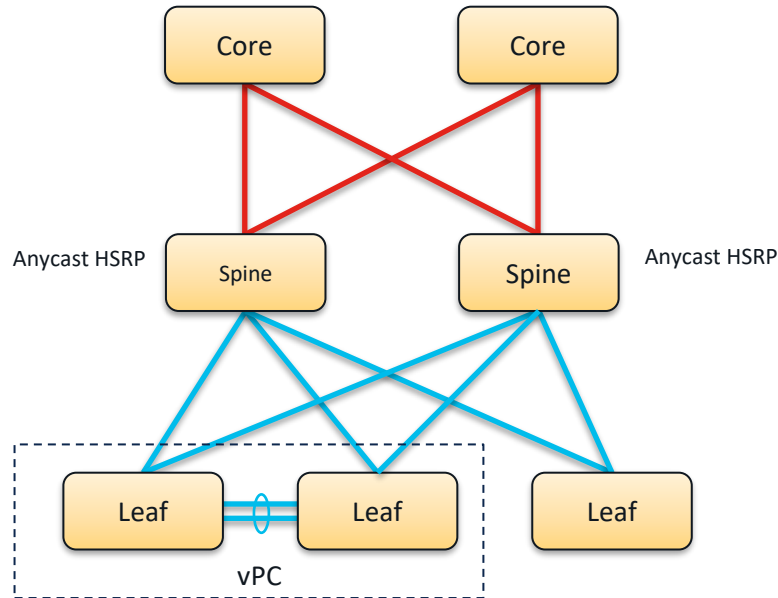
Evolution of the Data Center Network

5-Stage Fabric

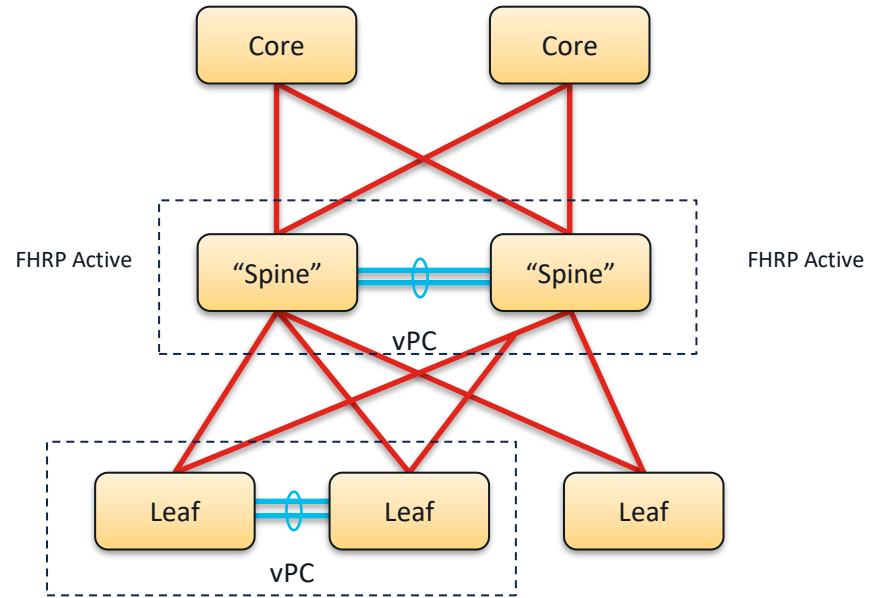


Evolution of the Data Center Network

FabricPath (MAC-in-MAC)



VXLAN Flood & Learn (MAC-in-IP)



Data Center Network Challenges

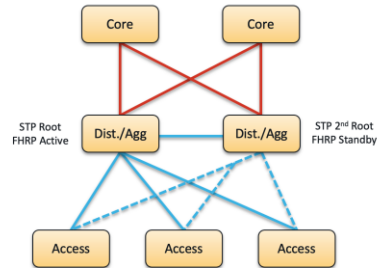
Legacy Architectures

Convergence Time:
STP high convergence time
TCN MAC Flush

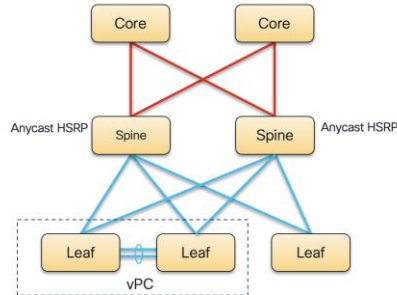
Unused Links:
STP Redundant links in
blocked state

Rigid Network Services:
L4-L7 Services placed at
Distribution Layer

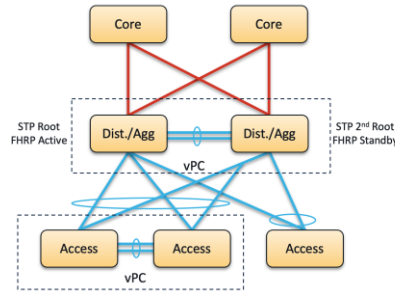
Classic Spanning-Tree



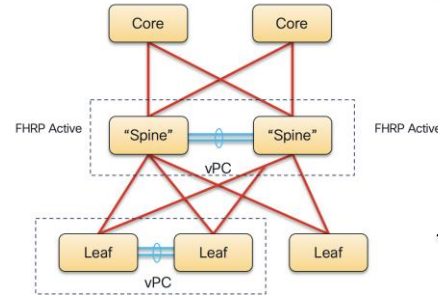
FabricPath (MAC-in-MAC)



vPC and Spanning-Tree



VXLAN Flood & Learn (MAC-in-IP)



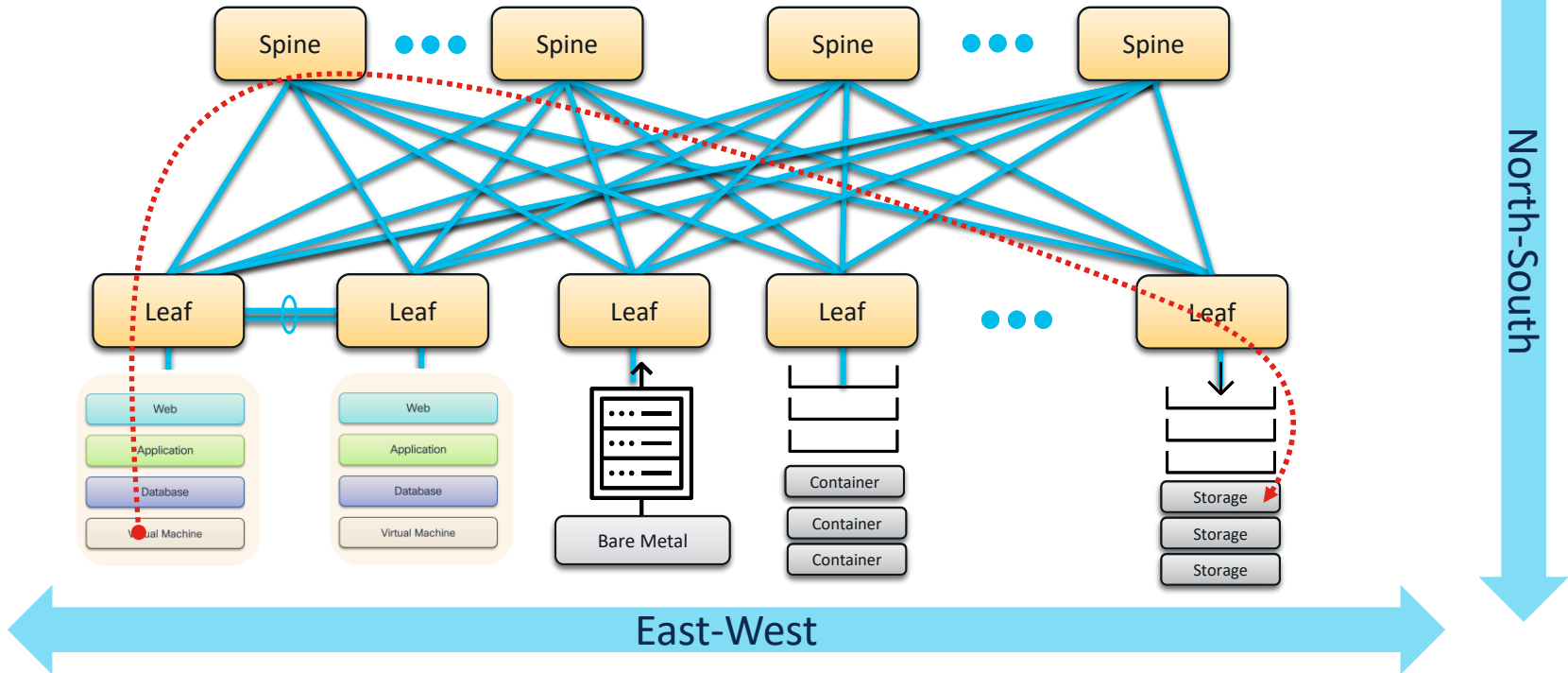
Suboptimal Forwarding:
Path defined by
Root Switch or FHRP Active

OpEx/CapEx:
Expensive to upgrade
Scale up with large Chassis

Limited Scale:
No Control Plane
Limited Workload Mobility

Evolution of the Data Center Network

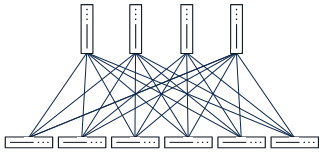
The need for network overlays



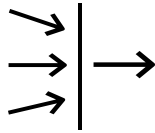
Leaf-Spine "Fat Tree" Network Topologies

Key Requirements

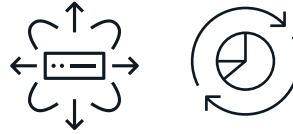
Topology
(Resiliency)



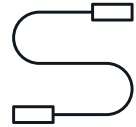
Bandwidth
(Oversubscription)



Platform Hardware
(Cost)



Optics
(Cabling)



Sustainability



Define Requirements **Before** Designing Solution

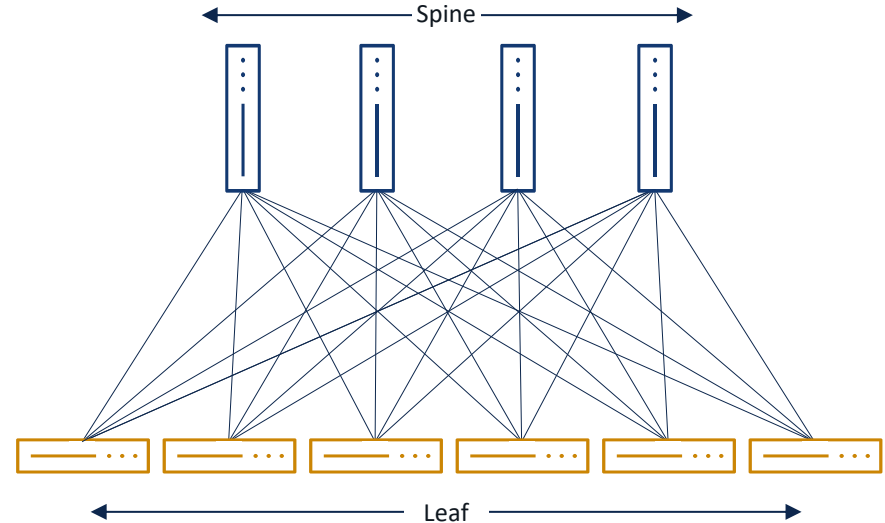


Clos Topology

A Leaf and Spine Topology

- Variations or Names of the same:
 - 2 Tier
 - Fat Tree
 - Folded Clos
 - 3 Stage Clos
 - Butterfly (5 Stage | PoD)

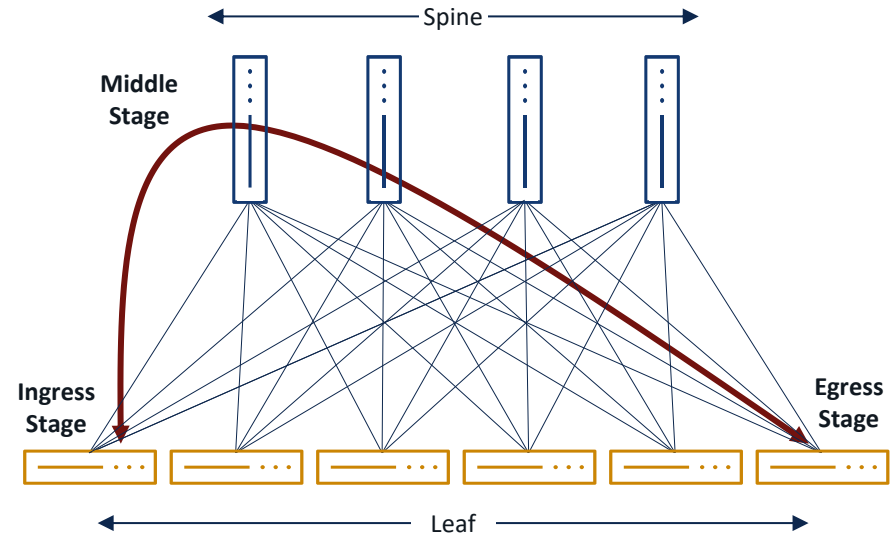
The Standard



Clos Topology

- A Leaf and Spine Topology
 - 3 Stages
 - 2 Tiers

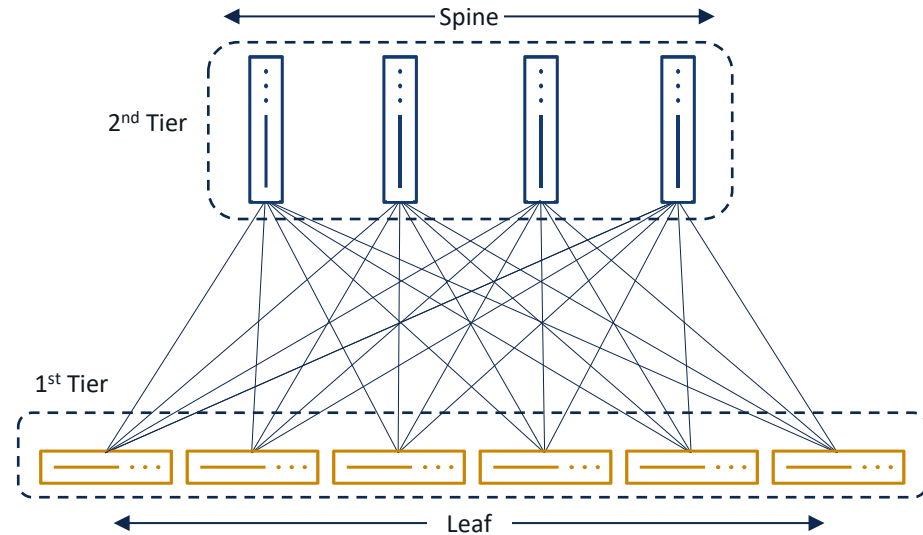
Advantages



Clos Topology

- A Leaf and Spine Topology
 - 3 Stages
 - 2 Tiers

Advantages

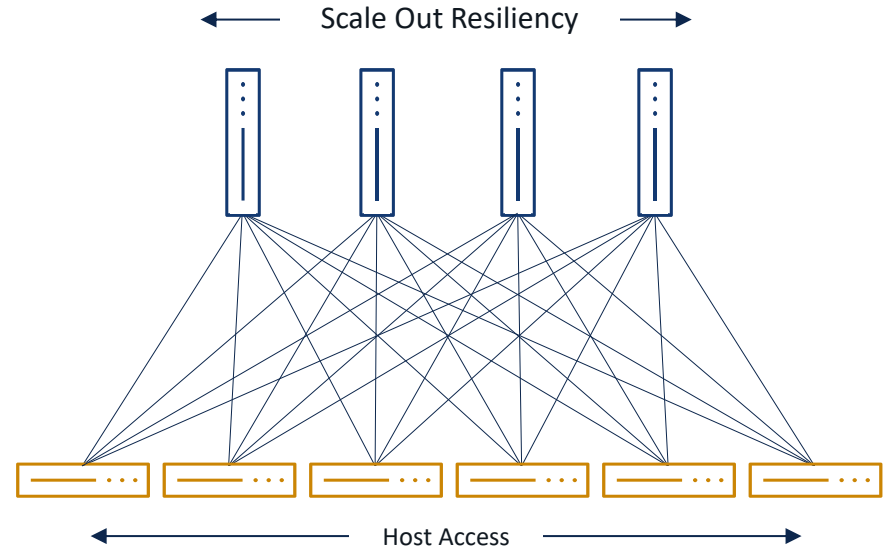


Clos Topology

Scale Out Architecture

- Adding Spines results in:
 - Increased physical path redundancy
 - > Greater Resiliency
- Increased leaf count *without increasing oversubscription ratio(s)*
 - > More Access Ports

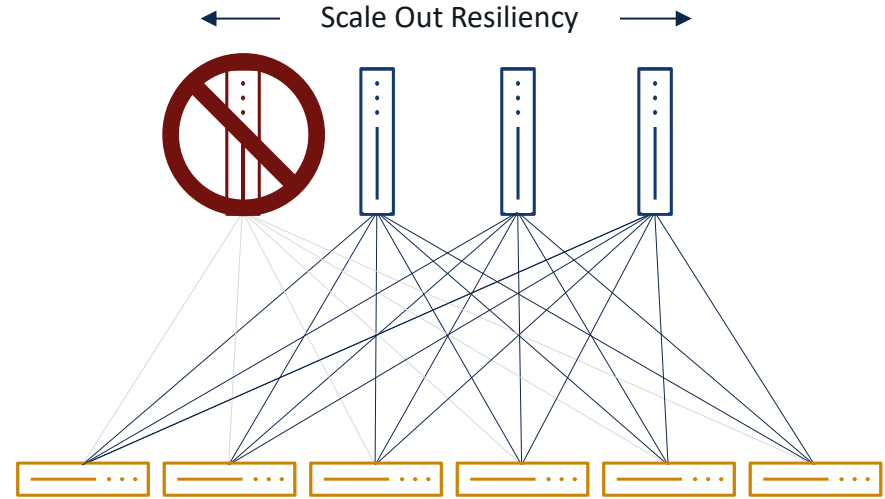
Advantages



Clos Topology

- N+1 redundancy
- **Resiliency increases when adding redundancy** to the topology
- Single spine failure
 - 4 Spine = 25% impact
 - 8 Spine = 12.5% impact
 - 12 Spine = 8.3% impact

Advantages



Clos Topology

- Modern Application Needs
 - Every (1) North to South Connection requires eight (8) East to West
 - Application frontend (User access)
 - Application backend, Database, Storage etc...

Three Tier Application

Web



App

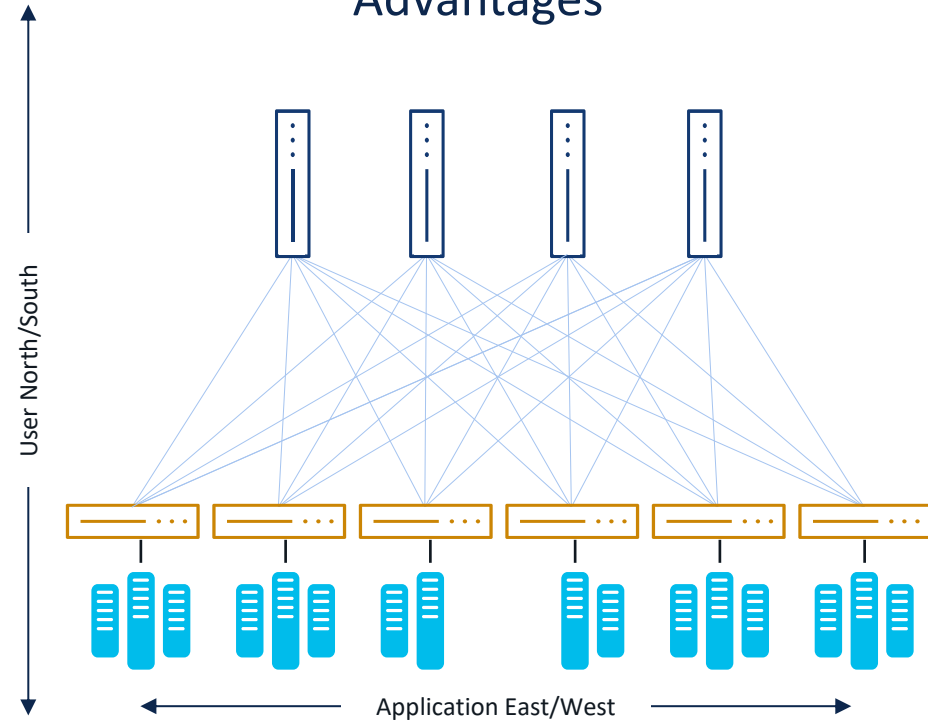


DB



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Advantages



Oversubscription

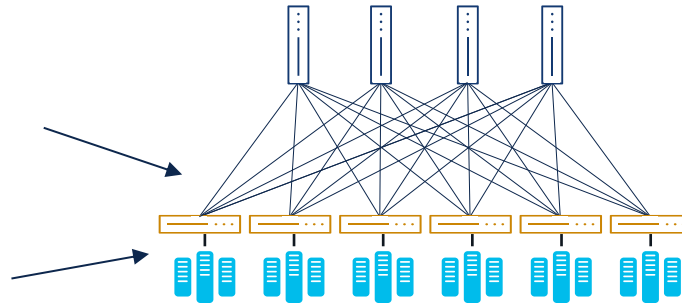
Oversubscription happens when an intermediate network device (switch) or link doesn't have enough capacity (bandwidth) to allow line rate communication between the two devices

Oversubscription Ratio

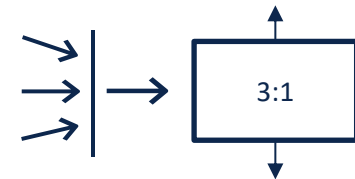
$$[\text{Number of Downlink Ports} * \text{Speed}] \div [\text{Number of Uplink to Spine} * \text{Speed}] : 1$$

Uplink Ports
 $4 \times 100\text{Gbps} = 400\text{ Gbps}$

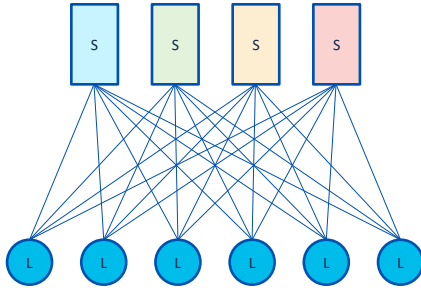
Downlink Ports
 $48 \times 25\text{Gbps} = 1.2\text{Tbps}$



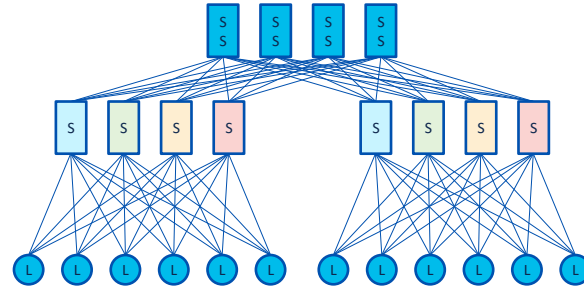
Oversubscription Ratio



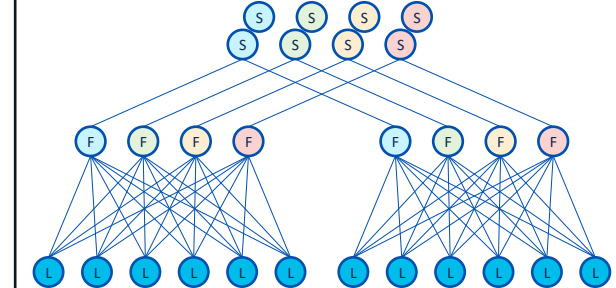
The Journey to Build Better and Further



2 Tier Leaf Spine



3 Tier Leaf-Spine-SuperSpine

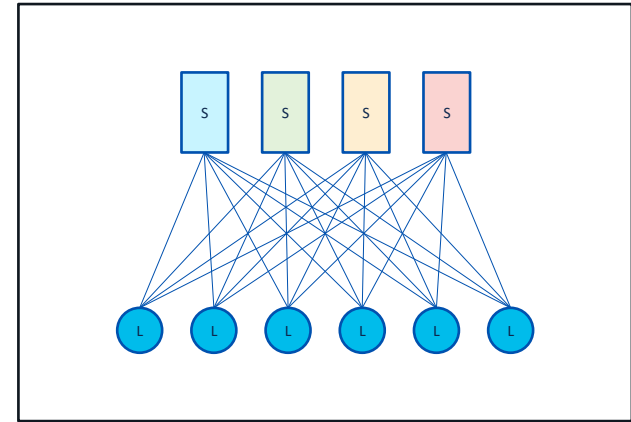


3 Tier Leaf-Fabric-Spine

Standard Design

2-Tier Leaf Spine

- A perfectly valid way
- Tends to have “Finite Scale”
 - Maximum Chassis capacity
 - Maximum Speed per Port
- Many Locations of Redundancy
 - Redundant Chassis Components
- Condensed Link and Bandwidth Presence
 - Aggregated within a Chassis



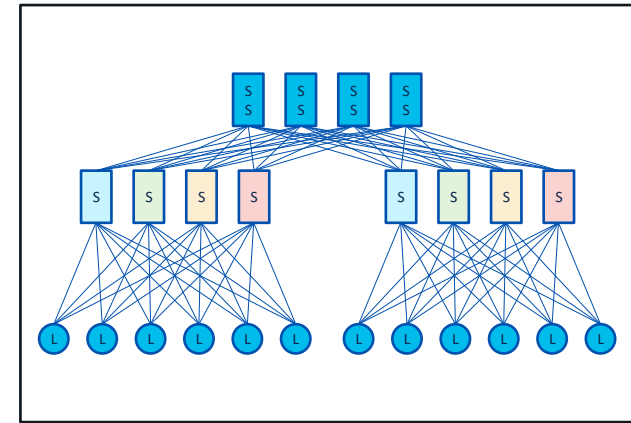
2 Tier Leaf Spine

- Use Modular Chassis at Spine
- Use Higher Density Linecards
- Use Higher Bandwidth per Port

Expanding Scale

3-Tier Multi-Site

- Avoiding Scale-Up with another Tier
- Distributed Link and Bandwidth Presence
 - Disaggregated across Tiers
- Increases the “Finite Scale”
 - No Dependency on Chassis capacity or Speed per Port
- Many Locations of Redundancy
 - Redundant Chassis Components
- Allows for Cost Optimization



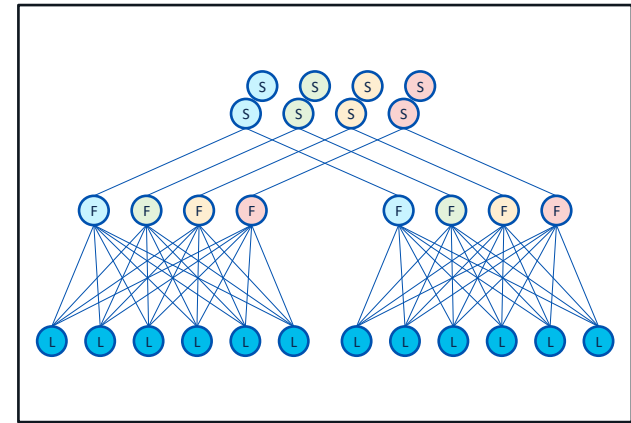
3 Tier Leaf-Spine-SuperSpine

- Scale-Out; Introduce a 3rd Tier
- Interconnect multiple 2 Tier “PODs”
- Use Modular or Fixed Spine & SuperSpine
- Use High Port Density
- Use High Bandwidth per Port

Increasing Resiliency

Multiplanar Architecture

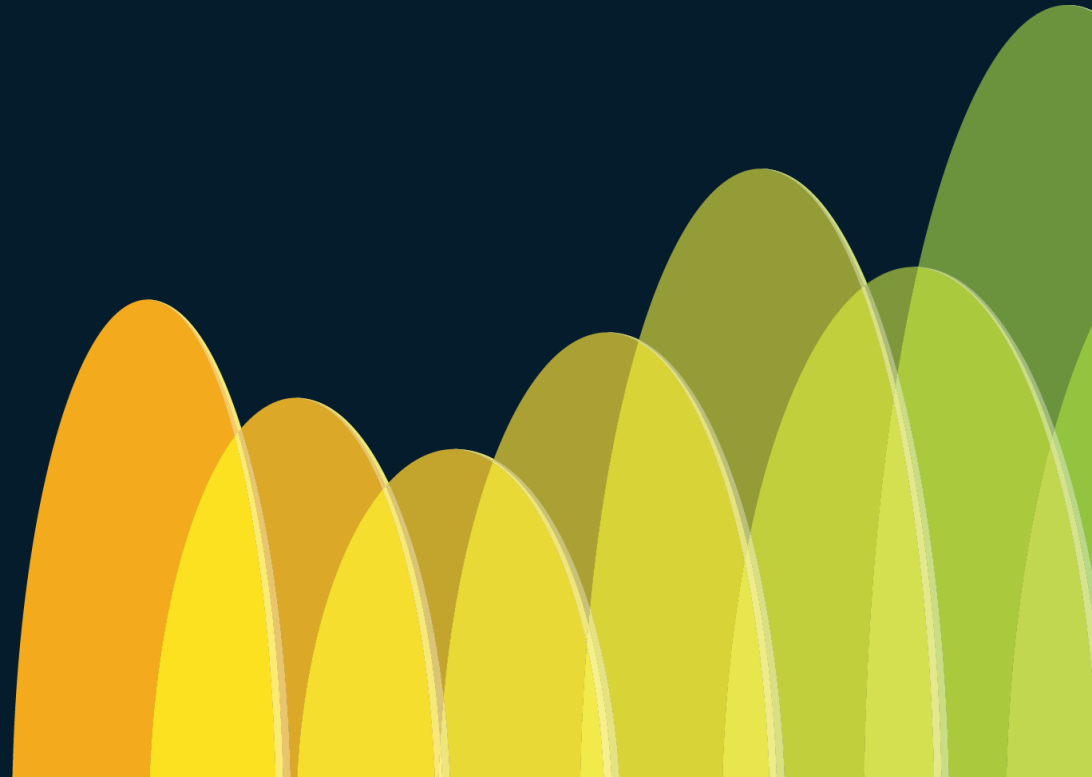
- Increasing Scale-Out in all Tiers
- Reduce to the Max
 - Simple Design Principles
- Increases the “Finite Scale”
 - Scale as You Go
- Disaggregated Redundancy
- Flexible Link and Bandwidth Distribution
- Further Possibility for Cost Optimization



3 Tier Leaf-Fabric-Spine

- To Infinity and the Beyond

Hardware Deployment Considerations

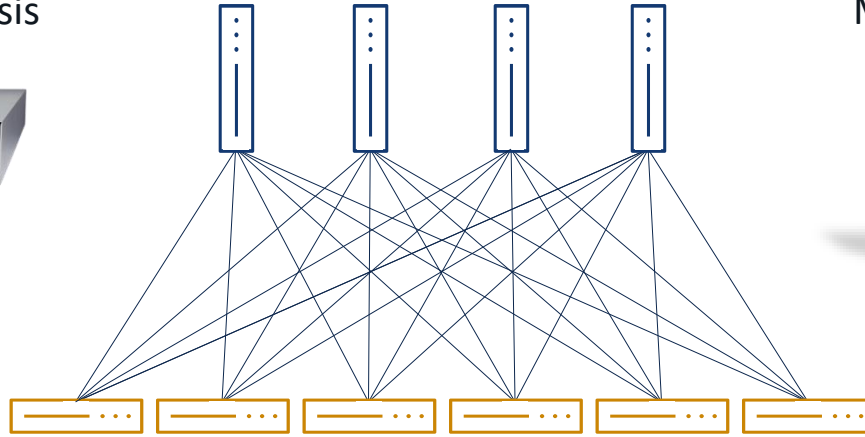


Hardware Components

What should I use for **Spines**?
Modular or Fixed Chassis



What should I use for **Leafs**?
Modular or Fixed Chassis



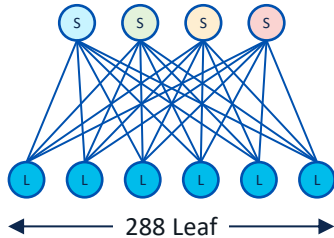
Resiliency

Oversubscription

Cost

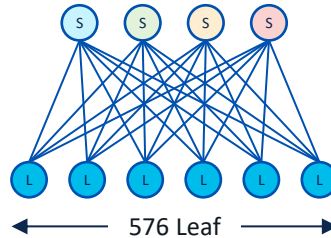
Cabling

Attributes to Scale



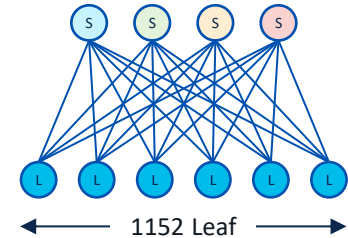
8 Slot Modular
36x 100Gbps
1:1 Oversubscription
13'828 Host Ports

Scale-Up to Fill Chassis



16 Slot Modular
36x 100Gbps
1:1 Oversubscription
27'648 Host Ports

Scale-Up to Bigger Chassis

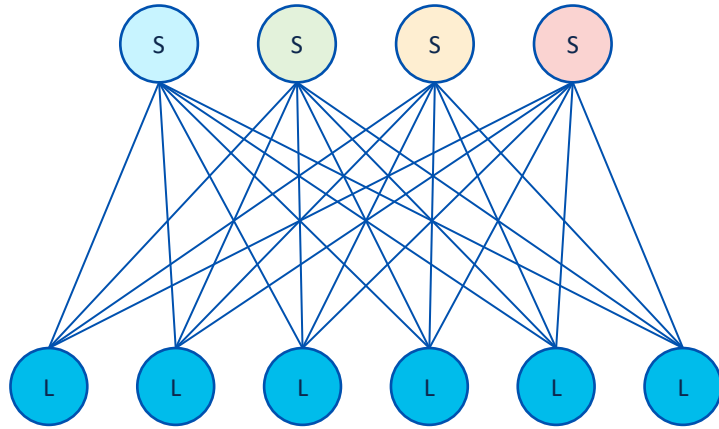


8 Slot Modular
36x 400Gbps
1:1 Oversubscription
55'296 Host Ports

Scale-Up to Faster Linecards

Oversubscription Ratio doesn't influence Host Port scale

Fixed vs Modular – Details that Matter

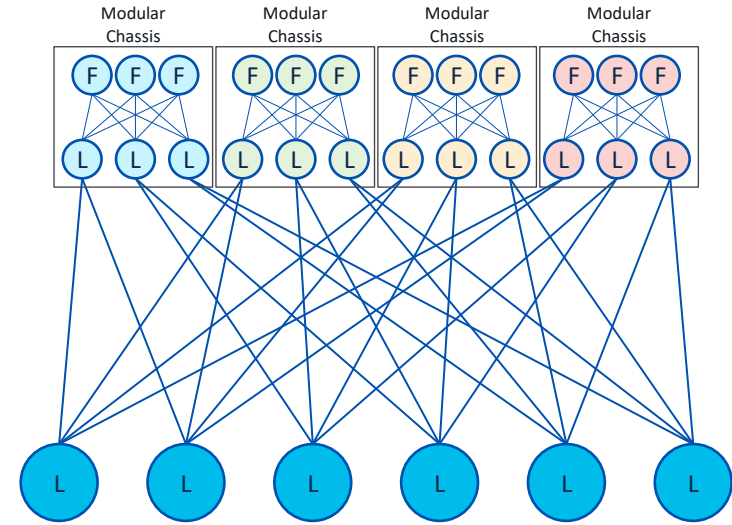


What you think you Built

2 Tier Leaf and Spine Network (3 Stage)

Spine: Modular Chassis (4 Slot, 8, Slot, 16 Slot)

Leaf: Fixed Switch (single ASIC)



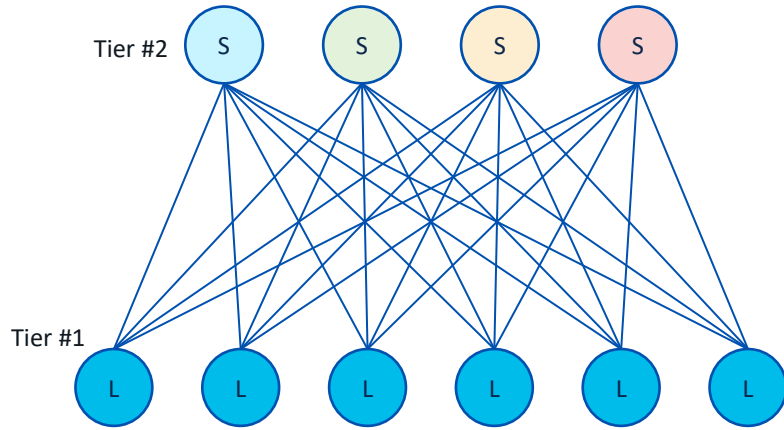
What you really Built

2 Tier Leaf and Spine Network (5 Stage)

Spine: Modular Chassis (4 Slot, 8, Slot, 16 Slot)

Leaf: Fixed Switch (single ASIC)

Fixed vs Modular – Untangling the Details

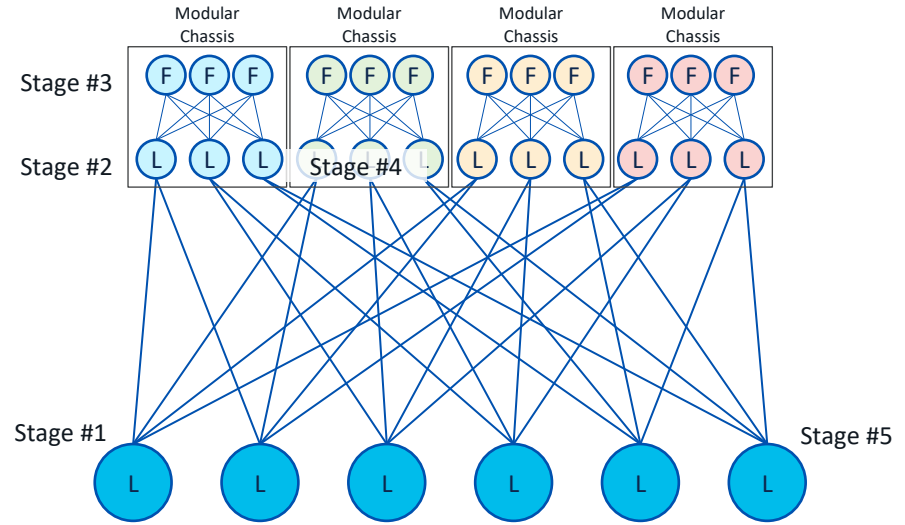


What you think you Built

2 Tier Leaf and Spine Network (3 Stage)

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What you really Built

2 Tier Leaf and Spine Network (5 Stage)

Spine: Modular Chassis (4 Slot, 8, Slot, 16 Slot)

Leaf: Fixed Switch (single ASIC)

Hardware Components - Spines

Modular



Nexus 9408

Optimized for
100G/200G/400G



Nexus 9500

Nexus 9716D-GX
16p 400G

Nexus 9736C-FX
36p 100G



Nexus 9800

Nexus 9836DM-A
36p 400G (w/ HBM)

Nexus 98900CD-A
14p 400G & 24p 100G (w/ HBM)

Fixed



Nexus 9364D-GX2A
64p 400G



Nexus 9348-GX2A
48p 400G



Nexus 9332D-GX2B
32p 400G + 2p 1/10G



Nexus 9332D-H2R
32p 400G (w/ HBM)



Nexus 93600CD-GX
28p 40/100G & 8p 400G

Resiliency

Oversubscription

Cost

Cabling

Hardware Components - Leafs

Modular



Nexus 9408

Optimized for
100G/200G/400G



Nexus 9500

Nexus 9716D-GX
16p 400G

Nexus 9736C-FX
36p 100G

Nexus 9800

Nexus 9836DM-A
36p 400G (w/ HBM)

Nexus 98900CD-A
14p 400G & 24p 100G (w/ HBM)

Fixed



Nexus 93400LD-H1
48p 10/25/50G & 4p 100/400G



Nexus 93240YC-FX2
48p 10/25G & 12p 40/100G



Nexus 93180YC-FX3
48p 10/25G & 6p 40/100G



Nexus 93360YC-FX2
96p 1/10/25G & 12p 40/100G



Nexus 93600CD-GX
28p 40/100G & 8p 400G

Resiliency

Oversubscription

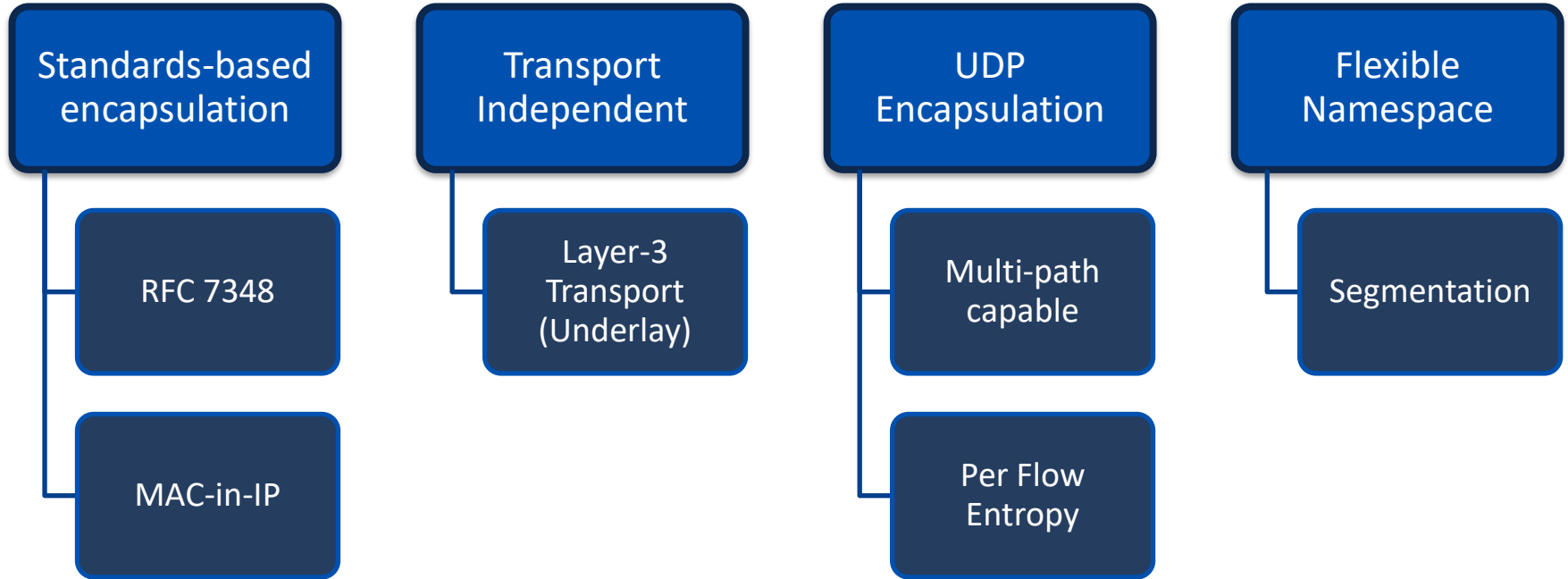
Cost

Cabling

Fundamentals of VXLAN EVPN Design



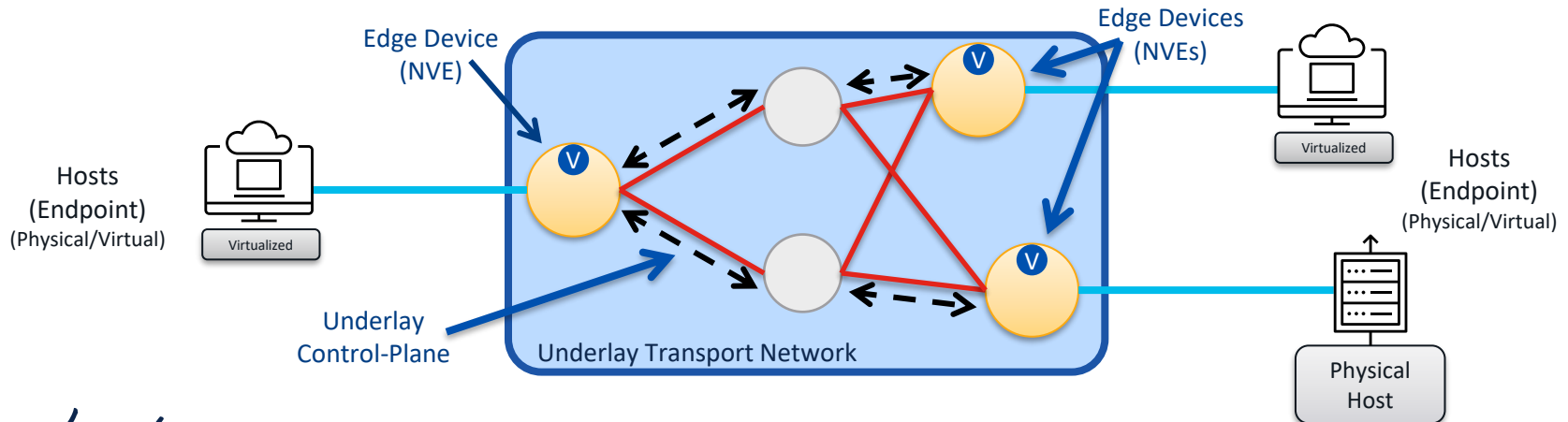
What is VXLAN?



Underlay Taxonomy

- Edge Devices host the VTEP
- Responsible for the encapsulation and decapsulation of the VXLAN Header

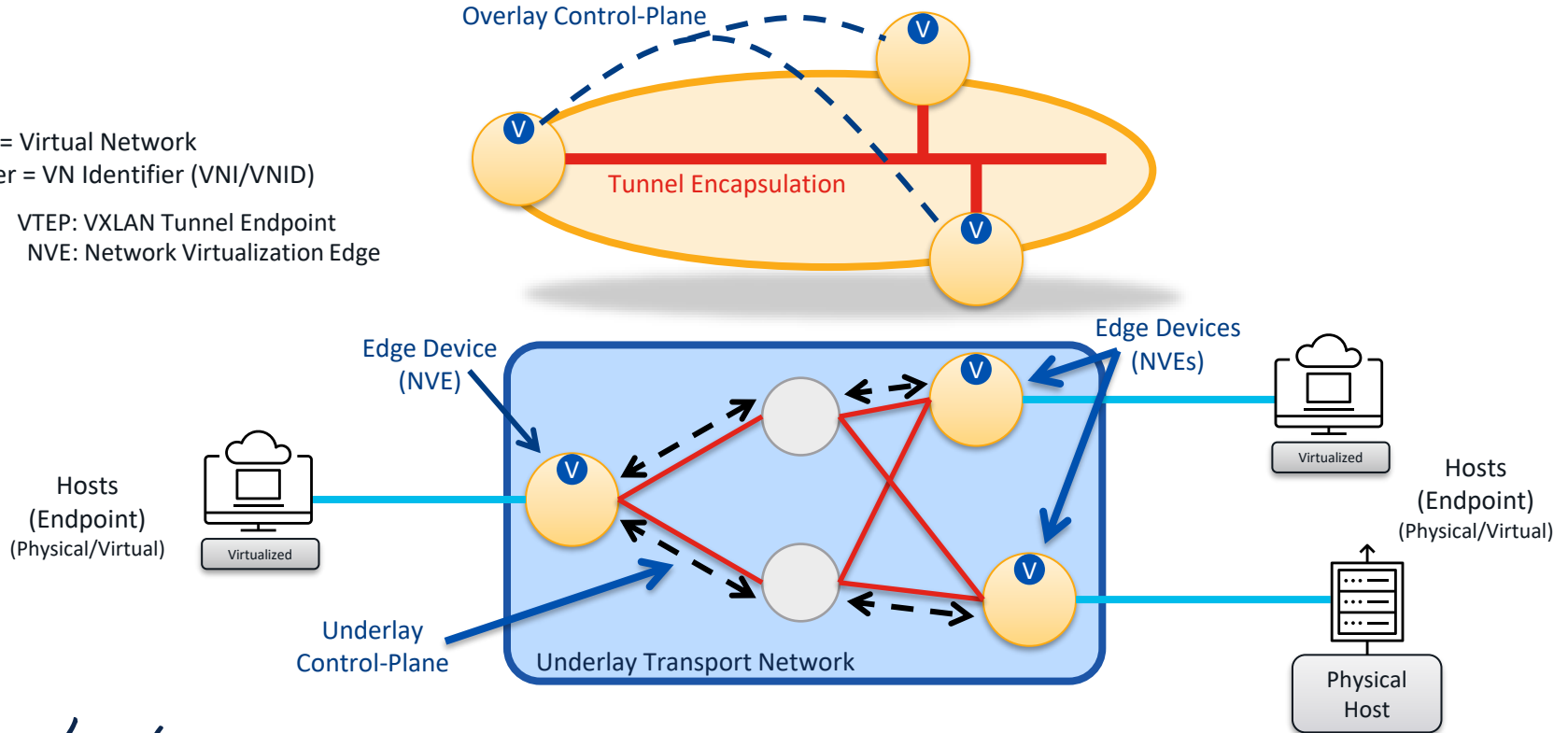
V VTEP: VXLAN Tunnel Endpoint
NVE: Network Virtualization Edge



Overlay Taxonomy

Service = Virtual Network
Identifier = VN Identifier (VNI/VNID)

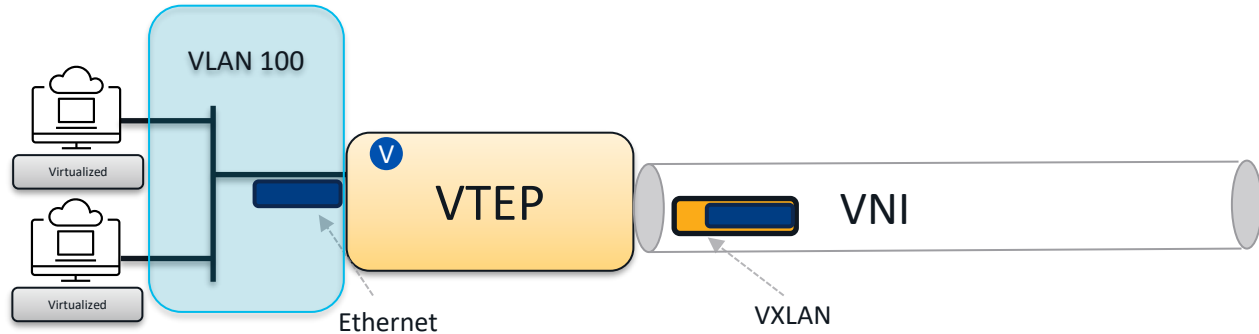
- V VTEP: VXLAN Tunnel Endpoint
- NVE: Network Virtualization Edge



Network Components of VXLAN Overlays

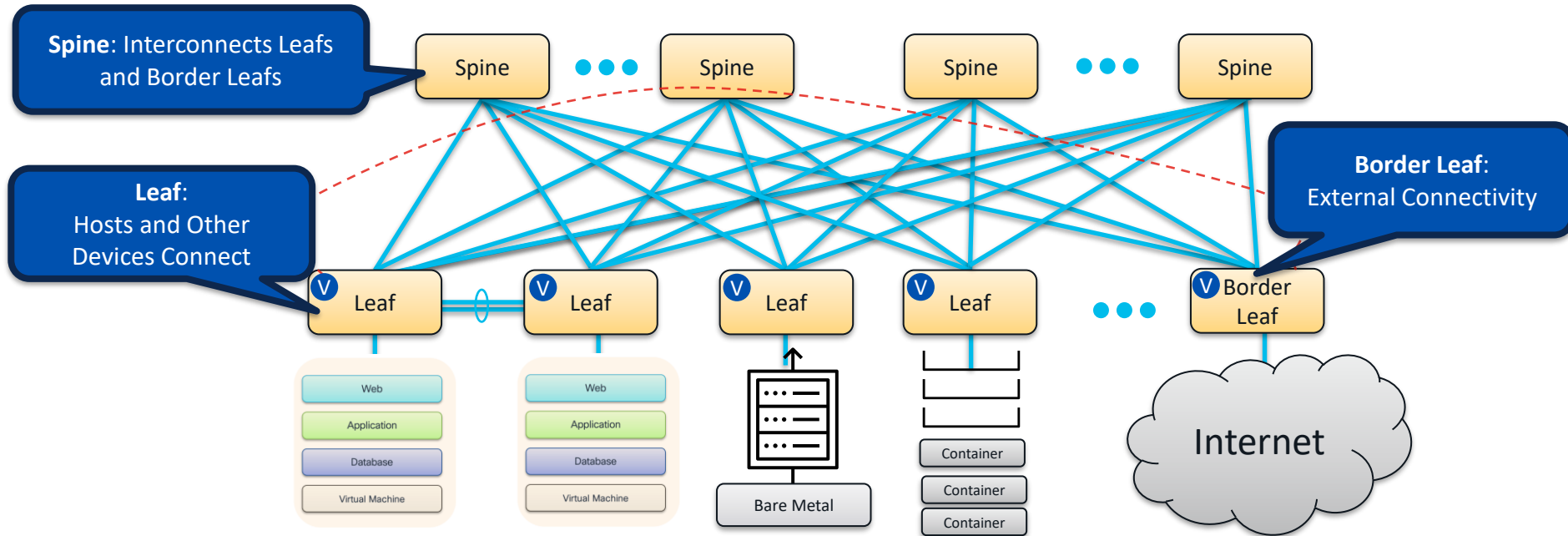
- **VXLAN Segment**
 - VXLAN overlay network. Layer 2 Broadcast Domain.
- **VXLAN Network Identifier (VNID)**
 - Each VXLAN segment is identified by a 24-bit VNID.
- **VXLAN Tunnel Endpoint (VTEP)**
 - Tunnel Endpoint. RFC term Network Virtualization Edge.
 - Each VTEP is uniquely identified by an IP address.
 - VTEP switch when forwarding packets within the same VNID and route for inter-VNI traffic.

VXLAN (or Virtual) Tunnel Endpoint VTEP



- VXLAN Tunnel Endpoint - Network Virtualization Edge
- Each VTEP is uniquely identified by an IP Address
- VTEP Discovers or learns remote VTEPs, and end hosts attached to them
- VTEP bridges when forwarding packets within the same VNI and Routes for Inter-VNI traffic

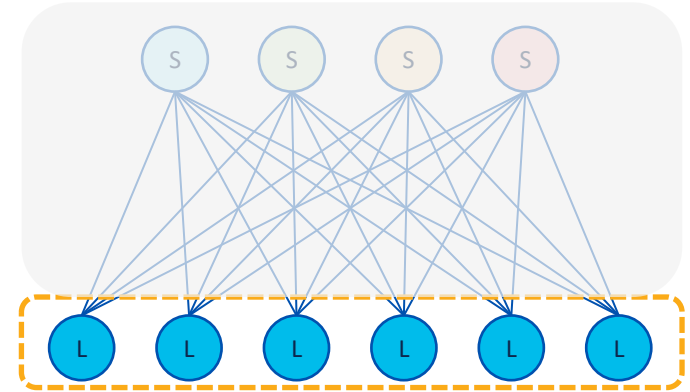
VTEP Device Roles



Components of VXLAN EVPN

Functions of Leaf

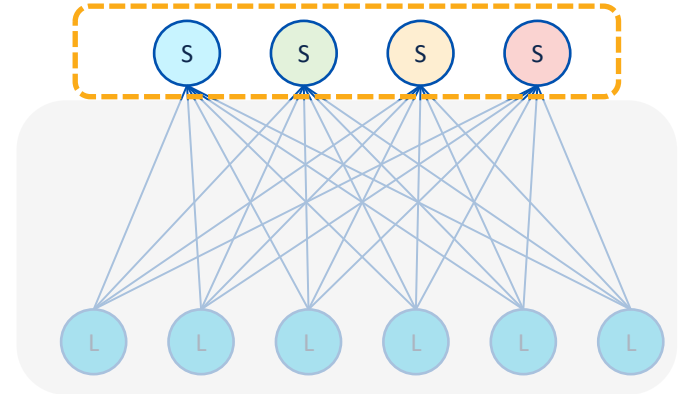
- Forms Routing Protocol adjacencies for underlay with Spines (OSPF, IS-IS, BGP)
- MP-BGP L2VPN EVPN neighborships with spines to exchange routes
- Performs VXLAN encapsulation and decapsulation
- Default Gateway Services for hosts using Distributed Anycast Gateway
- BUM replication/processing
- Connect to Non-VXLAN segments using VRF-Lite extension (Typically done on Border Leaf)



Components of VXLAN EVPN

Functions of Spine

- Forms Routing Protocol adjacencies for underlay with Leaf (OSPF, IS-IS, BGP)
- MP-BGP L2VPN EVPN neighborhoods with Leaf switches to exchange routes
- Do NOT typically do VXLAN encapsulation and decapsulation (unless it is a border or border gateway spine)
- Route Reflector for iBGP deployments
- PIM Anycast RP



VXLAN EVPN – What Is It?

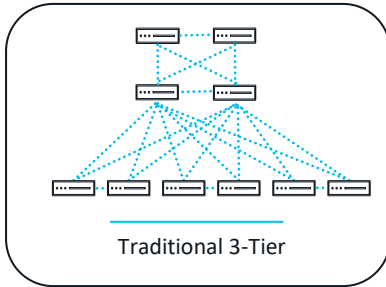
VXLAN

- Standards based Encapsulation
- RFC 7348
- Uses UDP-Encapsulation
- Transport Independent
- Layer-3 Transport (Underlay)
- Flexible Namespace
- 24-bit field (VNID) provides ~16M unique identifier
- Allows Segmentation

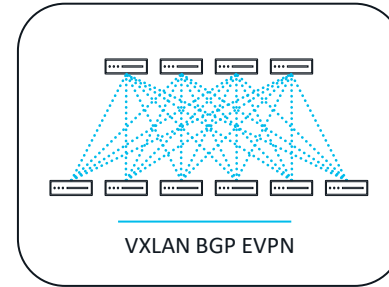
EVPN

- Standards based Control-Plane
- RFC 8365 (and RFC 7432)
- Uses Multiprotocol BGP
- Uses Various Data-Planes
- VXLAN (EVPN-Overlay), MPLS, Provider Backbone (PBB)
- Many Use-Cases Covered
- Bridging, MAC Mobility, First-Hop & Prefix Routing, Multi-Tenancy (VPN)

Customer Use Cases for Data Center Fabrics

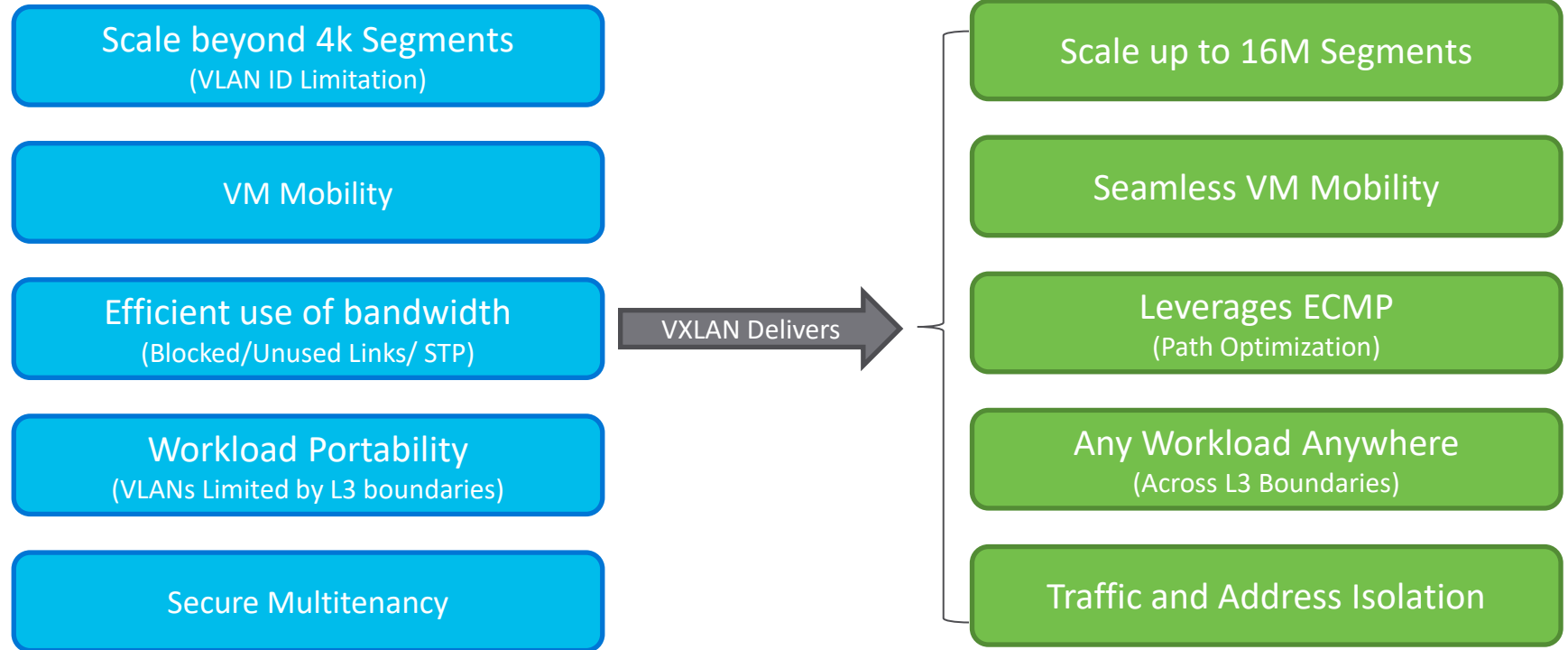


- ✓ Large **broadcast/fault domains** to support VM mobility
- ✓ Potential **Suboptimal** Forwarding
- ✓ **Scale up** behavior
- ✓ Relies on **STP** to ensure loop-free topology
- ✓ Over the top wireless



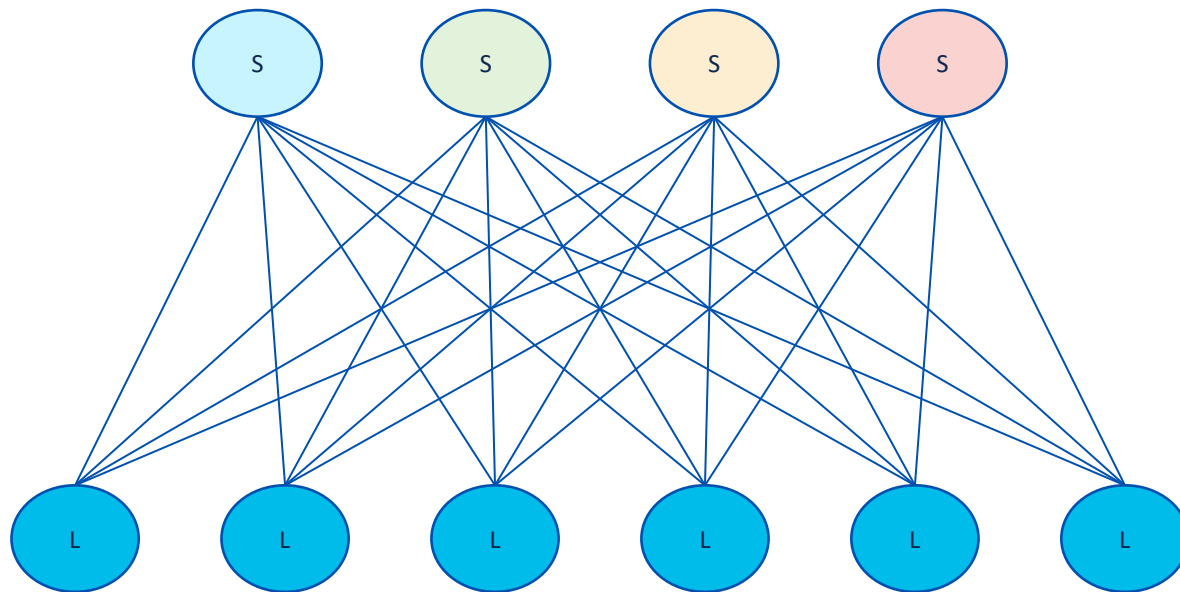
- ✓ Any workload anywhere **across L3 boundaries**
- ✓ Seamless **VM Mobility** (intra and inter-DC)
- ✓ Integrated wireless for seamless **User Mobility**
- ✓ Leverages **ECMP** for optimal path over L3 network
- ✓ Next Gen Data Center Interconnect (**DCI**)

Why VXLAN? - How did we get here?



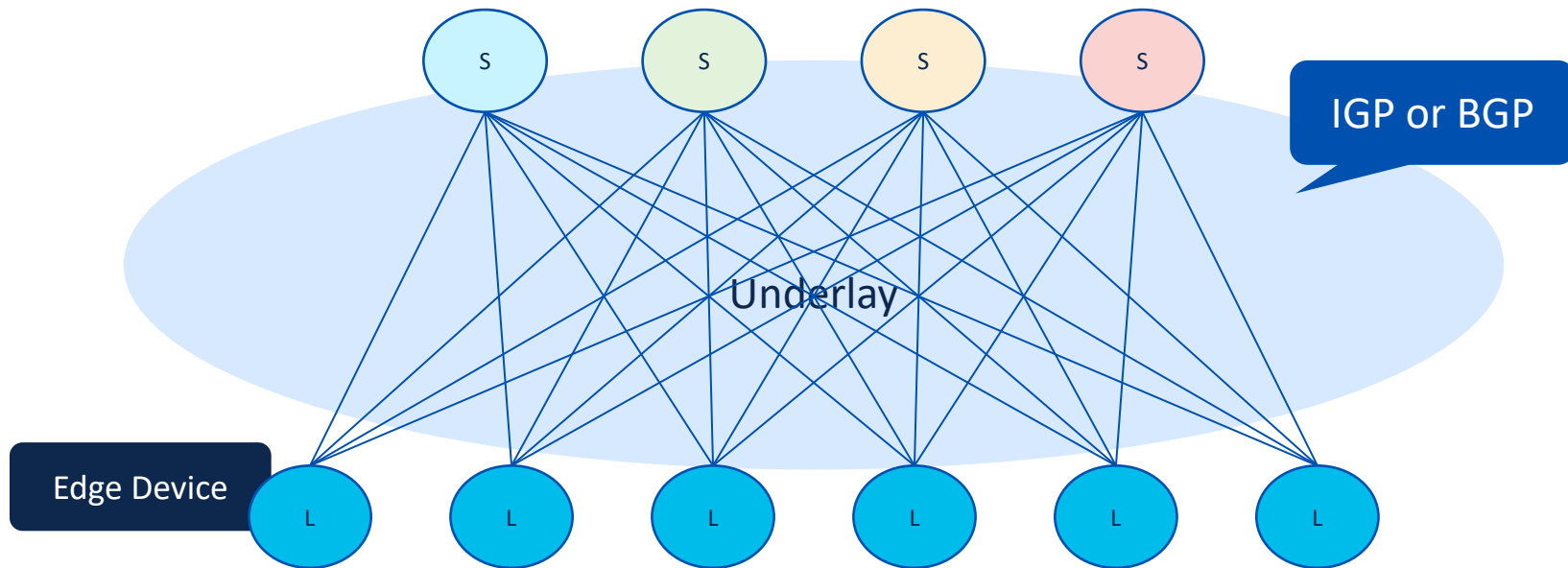
VXLAN: The Building Blocks

Underlay



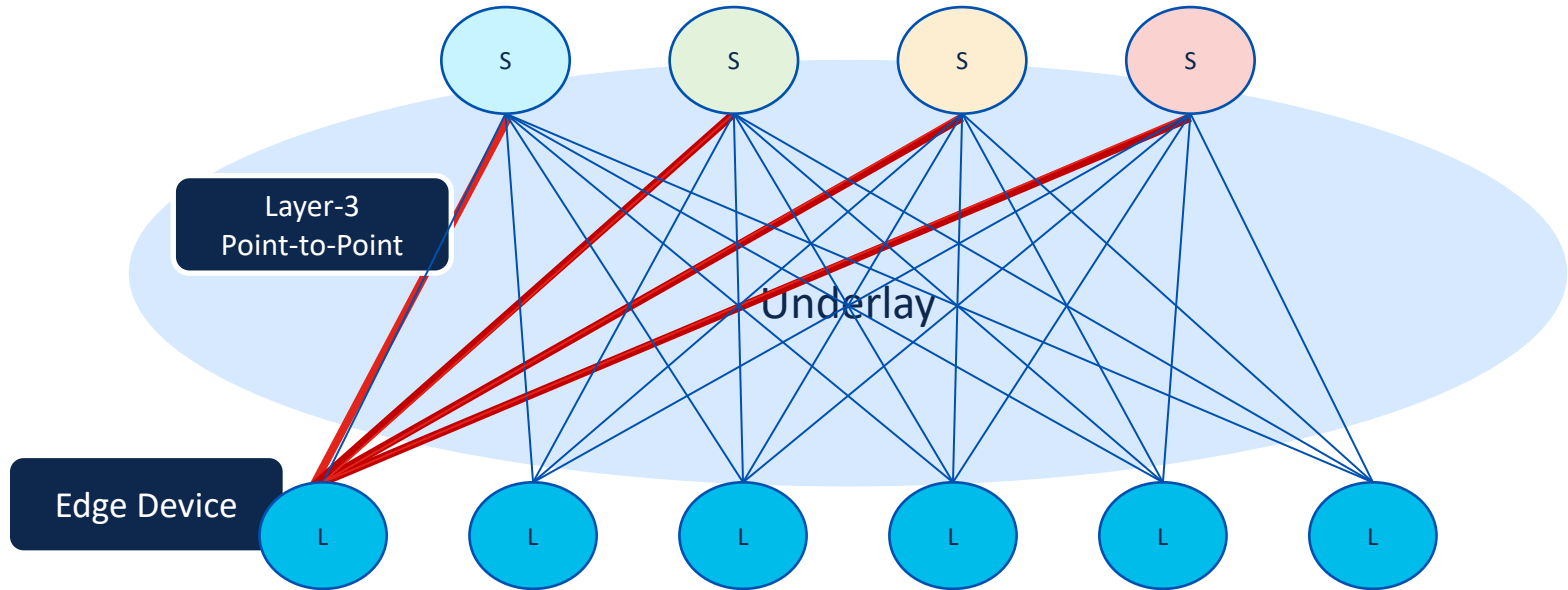
VXLAN: The Building Blocks

Underlay



VXLAN: The Building Blocks

Underlay

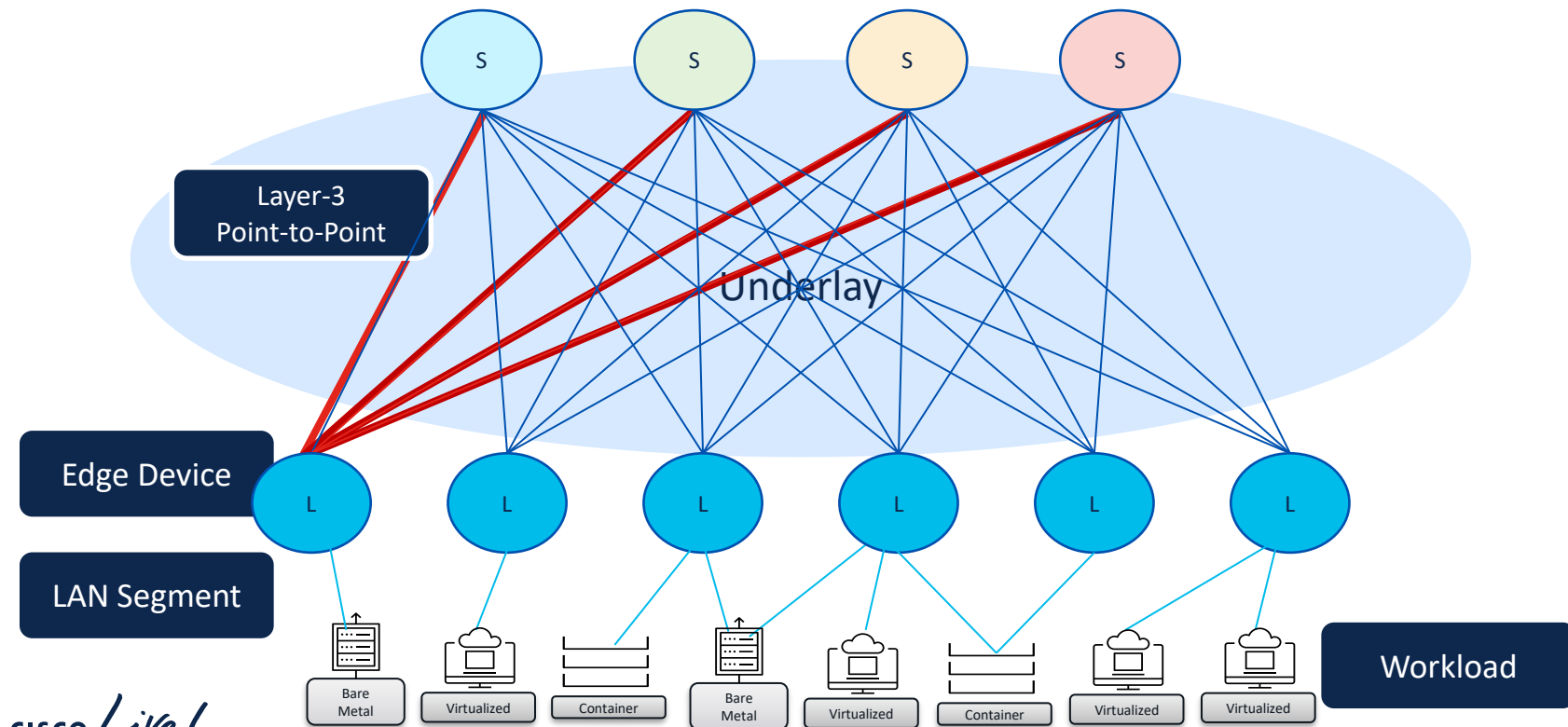


VXLAN Topology

- Typical Design used is Leaf/Spine Topology (CLOS based)
- Layer 3 Links between Leaf and Spines
- Unicast Packets are encapsulated within Unicast VXLAN Tunnels
- Broadcast Unknown Unicast and Multicast (BUM) traffic replication by Multicast or Ingress Replication (IR)

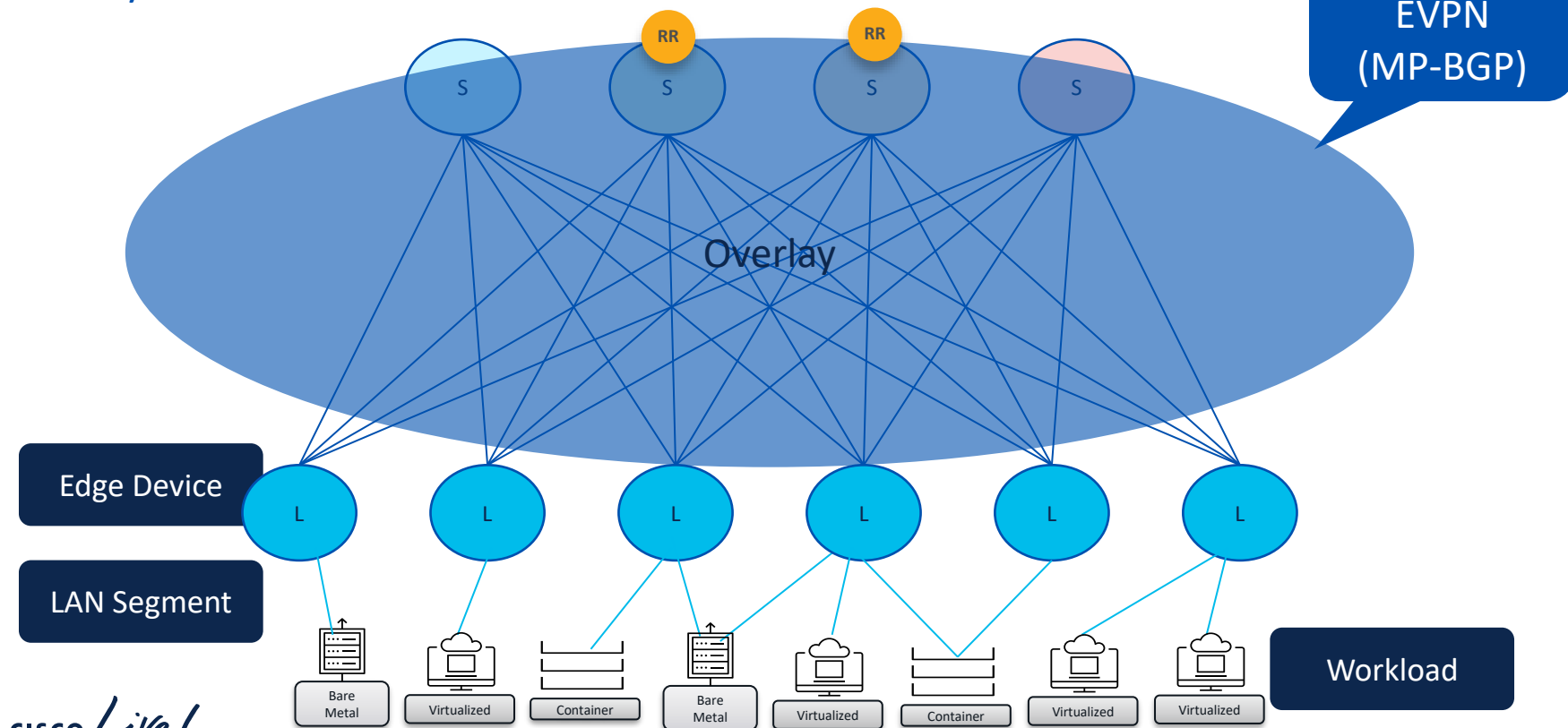
VXLAN: The Building Blocks

Underlay



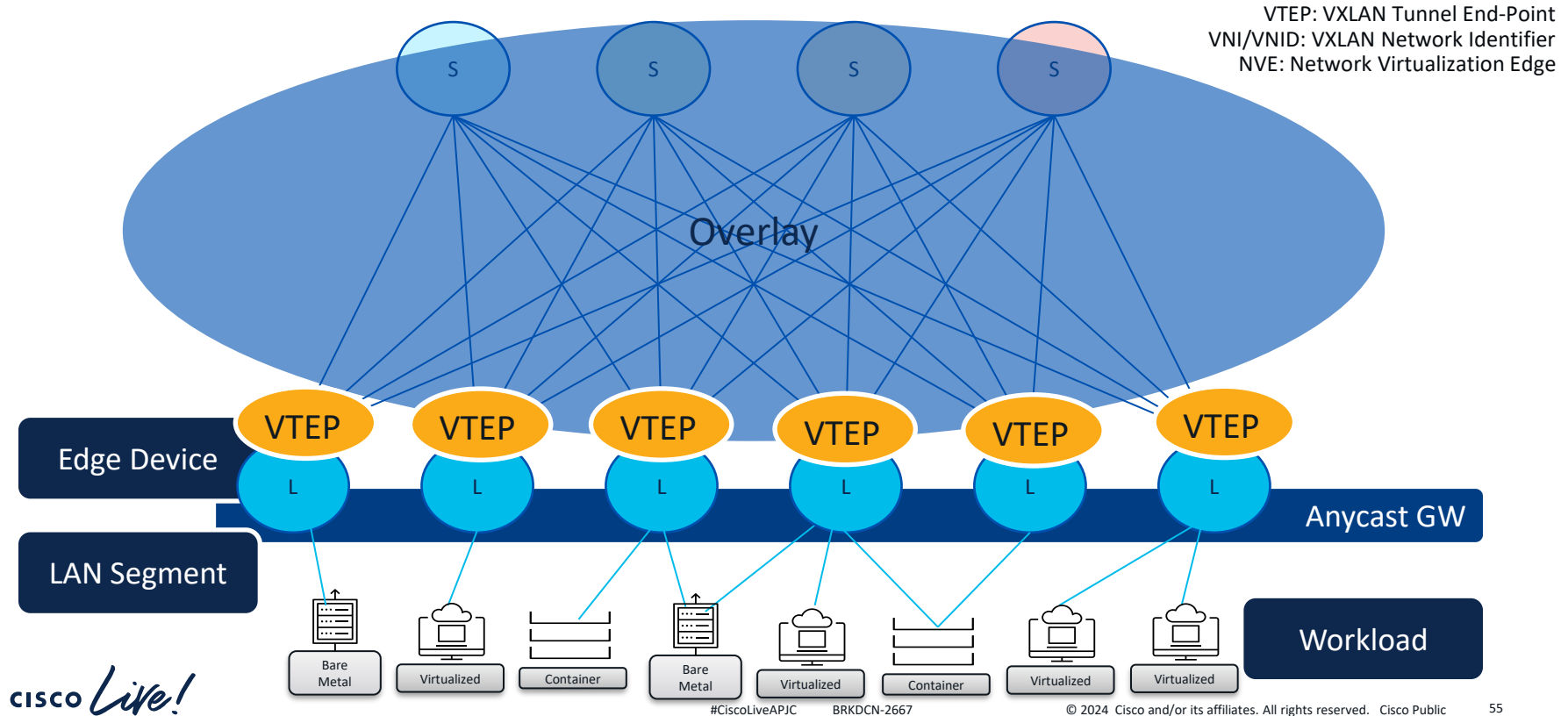
VXLAN: The Building Blocks

Overlay



VXLAN: The Building Blocks

Overlay



VXLAN: The Building Blocks

Overlay

No VTEP

VTEP: VXLAN Tunnel End-Point
VNI/VNID: VXLAN Network Identifier
NVE: Network Virtualization Edge

Tunnel Encapsulation (VNI Namespace)

Overlay

VXLAN

VTEP

VTEP

VTEP

VTEP

VTEP

VTEP

Edge Device

L

L

L

L

L

L

LAN Segment

Anycast GW

Bare Metal

Virtualized

Container

Bare Metal

Virtualized

Container

Virtualized

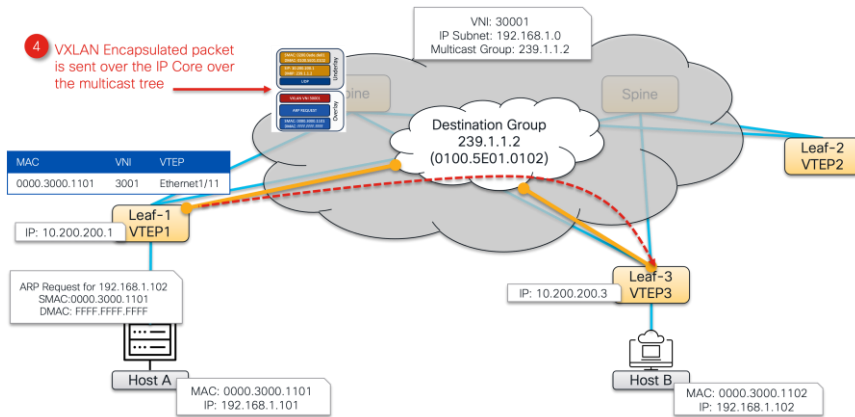
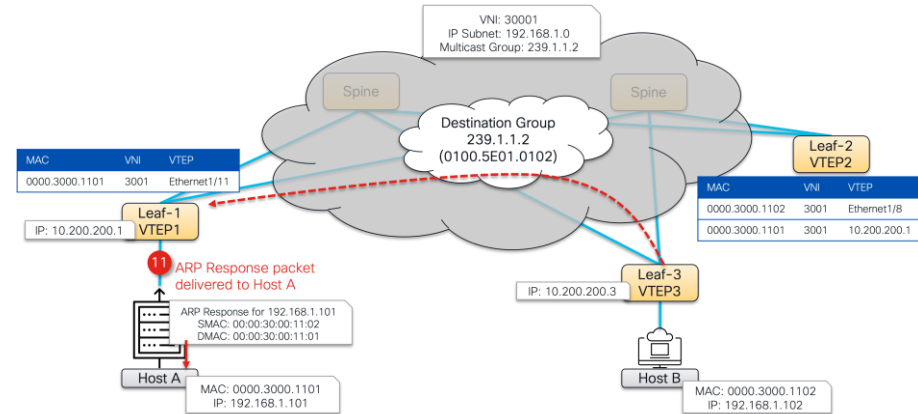
Virtualized

Virtualized

Workload

Flood & Learn Mechanism

Multidestination Traffic is “Flooded” over the VXLAN Tunnel between VTEPs to “Learn” about the Host MAC addresses located behind the VTEPs so subsequent communication is delivered via Unicast



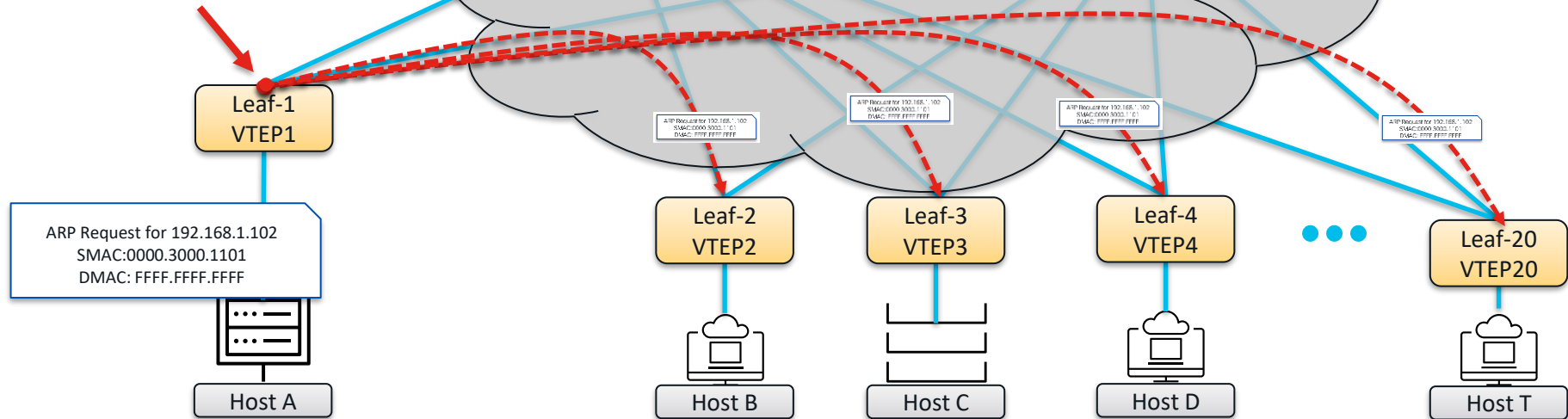
See hidden slides for packet walk

Flood & Learn Mechanism

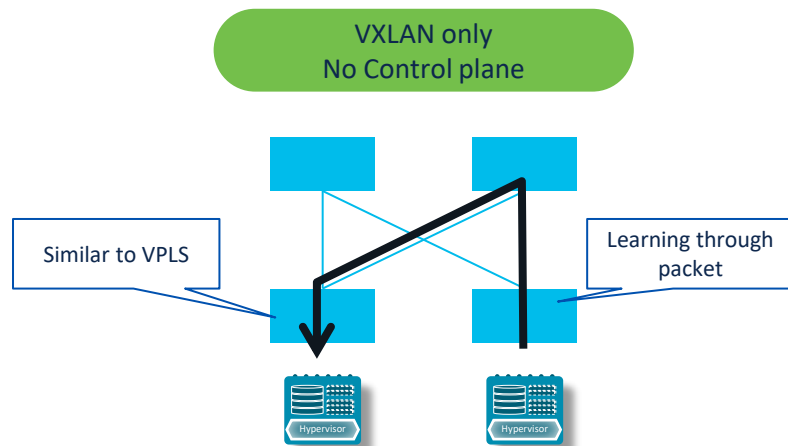
Ingress Replication or Head-End Replication

- One unicast replica per remote VTEP
- Increases traffic load throughout the network
- Example: 10MB of BUM traffic for 20 remote VTEPs = 200MB of BUM traffic

Ingress Replication
to each VTEP

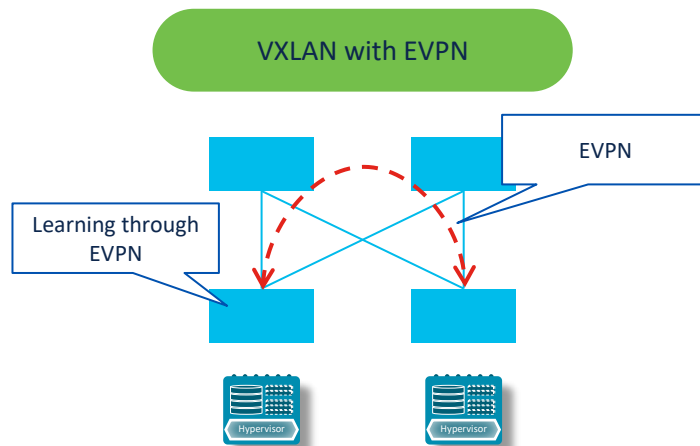


What is Ethernet VPN?



- L2+L3 multipath
- Huge address space

+And some risks

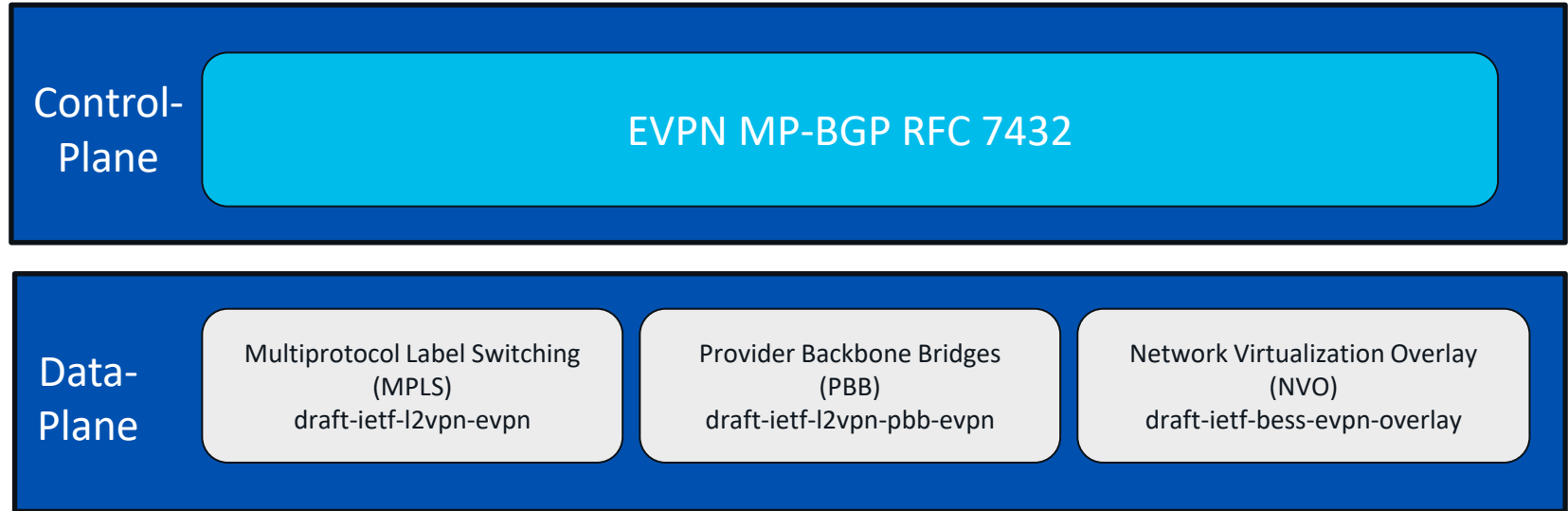


- BUM optimization
- L3 optimization
- Multi homing
- Peer auto discovery
- Peer authentication
- Host mobility etc

EVPN can bring intelligence

EVPN in the Data Center

IETF RFC/Draft for Control and Data Plane



- EVPN over NVO Tunnels (i.e., VXLAN) for Data Center Fabric Encapsulations
- Provides Layer-2 and Layer-3 Overlays over IP Networks

EVPN in the Data Center

IETF RFC/Draft for Control and Data Plane

For your reference



RFC / Draft	Title	Category
RFC 7348	Virtual Extensible Local Area Network	Data Plane
RFC 7432	BGP MPLS Based Ethernet VPNS	Control Plane
draft-ietf-bess-evpn-overlay	Network Virtualization Overlay Solution using EVPN	Control Plane
draft-ietf-bess-evpn-inter-subnet-forwarding	Integrated Routing and Bridging in EVPN	Control Plane
draft-ietf-bess-evpn-prefix-advertisement	IP Prefix Advertisement in EVPN	Control Plane
draft-tissa-nvo3-oam-fm	NVO3 Fault Management/OAM	Management Plane



BGP EVPN Route Types - RFC 7432

RFC/Draft	Route Type	Description
RFC 7432	1	Ethernet Auto-Discovery EAD Route
	2	MAC/IP Advertisement Route
	3	Inclusive Multicast Ethernet Tag Route
	4	Ethernet Segment Route
draft-ietf-bess-evpn-prefix-advertisement	5	IP Prefix Route



BGP EVPN *Route Types - RFC 7432

RFC/Draft	Route Type	Description	
RFC 7432	1	Ethernet Auto-Discovery EAD Route	BGP Based Multi-Homing Mass Withdrawal/Aliasing
	2	MAC/IP Advertisement Route	L2 VNI MAC or MAC-IP from L2 MAC Learning or ARP
	3	Inclusive Multicast Ethernet Tag Route	Dynamic Peer Discovery for EVPN Ingress Replication
	4	Ethernet Segment Route	BGP Based Multi-Homing BUM DF Election/Split-Horizon
draft-ietf-bess-evpn- prefix-advertisement	5	IP Prefix Route	IETF Draft, Advertise IP Prefixes



BGP EVPN *Route Types - RFC 7432

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draft-ietf-bess-evpn- prefix-advertisement	5	IP Prefix Route	IETF Draft, Advertise IP Prefixes

MP-BGP VPN Terminology

VPN Address Family

A Multi-Protocol BGP Extension to
Distribute VPN Routes

Virtual Routing & Forwarding (VRF)

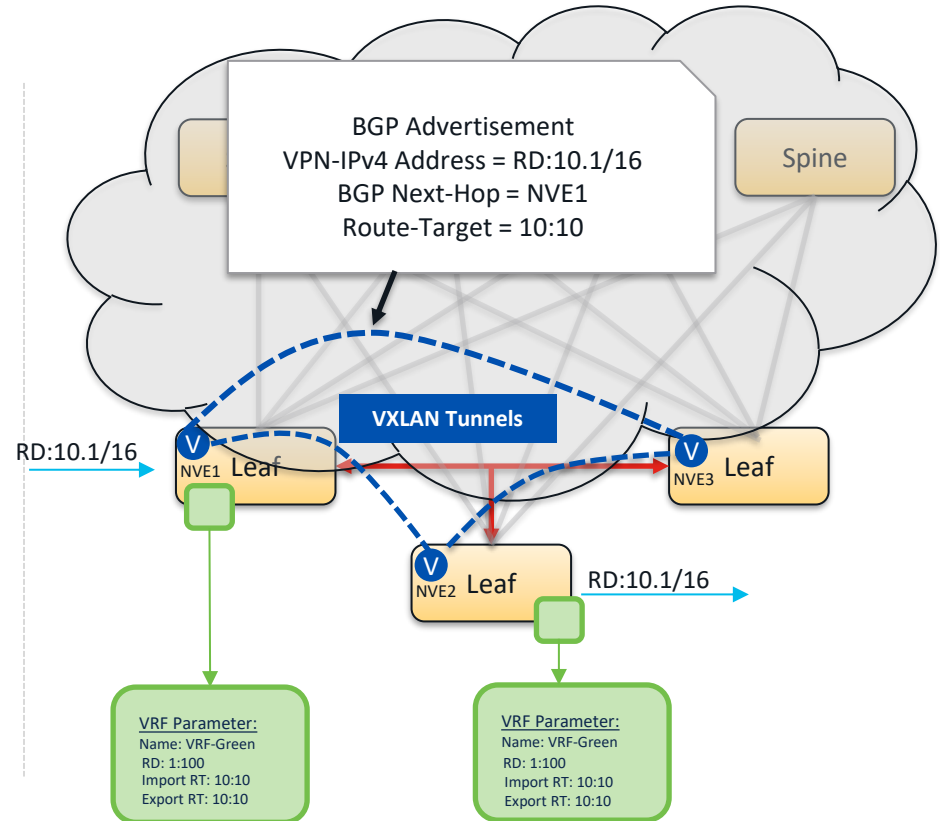
Overlay MAC or IP Routes are stored in dedicated VRF
tables (MAC or IP VRF)

Route Distinguisher (RD)

8-byte Field, VRF Parameter
Value to make the MAC or IP Routes unique
(RD + VPN prefix)

Route Target (RT)

8-byte Field, VRF Parameter
Value for the Import/Export Rules of
VPN Routes (MAC or IP) into the VRF



EVPN in the Data Center

MP-BGP for EVPN

- MP-BGP is the routing protocol for EVPN
- Multi-tenancy construct using VRF (Virtual Route & Forwarding)
 - Route Distinguisher, and Route Targets
- New Address Family “l2vpn evpn” for distributing EVPN Routes
- EVPN Routes = [MAC] + [IP]
- iBGP or eBGP Support

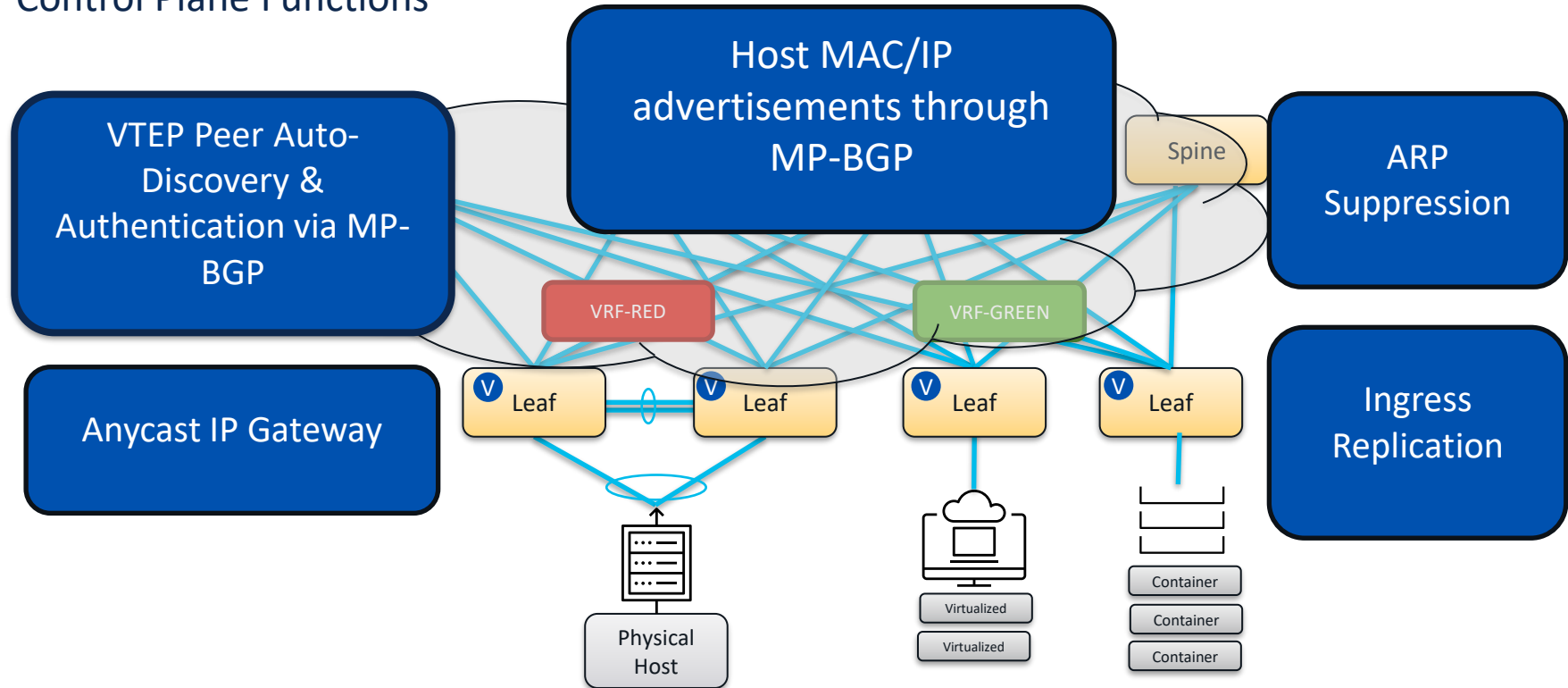
```
vrf context myvrf_50000
vni 50000
rd auto
address-family ipv4 unicast
route-target both auto
route-target both auto evpn
```

```
evpn
vni 30000 12
rd auto
route-target import auto
route-target export auto
```

```
router bgp 65101
router-id 10.2.0.1
neighbor 10.2.0.3
remote-as 65101
update-source loopback0
address-family l2vpn evpn
vrf myvrf_50000
address-family ipv4 unicast
advertise l2vpn evpn
```

EVPN in the Data Center

Control Plane Functions



BGP EVPN Overview

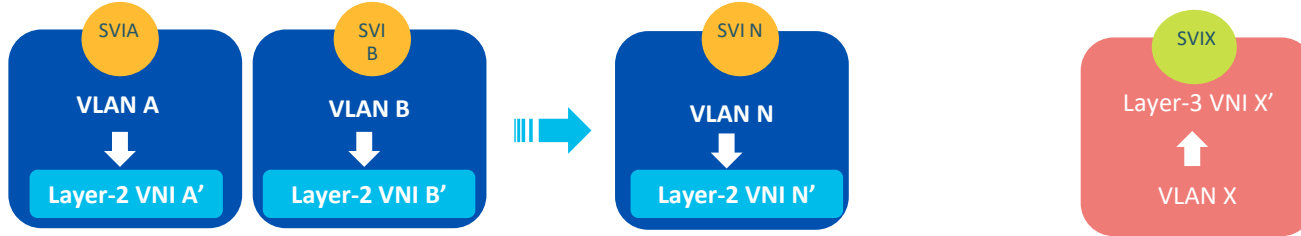
- MP-BGP EVPN AF carries following information: MAC, IP and network prefix, VRF/VNID and VTEP IP (NLRI Next Hop).
- BGP EVPN distributes MAC,IP info avoiding flooding.
- VXLAN BGP AFI=25 (Layer 2 VPN) and SAFI = 70 (EVPN).
- **VXLAN** is the **Tunnel Encapsulation Protocol** and **MP-BGP EVPN** is the **Control Plane** for overlay distributing Layer 2 and Layer 3 routing information (MAC,IP).

***NLRI:** Network Layer Reachability Information (NLRI) is exchanged between BGP peers, indicating how to reach prefixes.*

***AFI and SAFI:** AFI means Address Family Indicator and SAFI is the Subsequent Address Family Indicator. They are used in the Multiprotocol Extensions to BGP and are exchanged during neighbor capability exchange during the process for loading the peers.*

Logical Construct of Multi-Tenant VXLAN EVPN

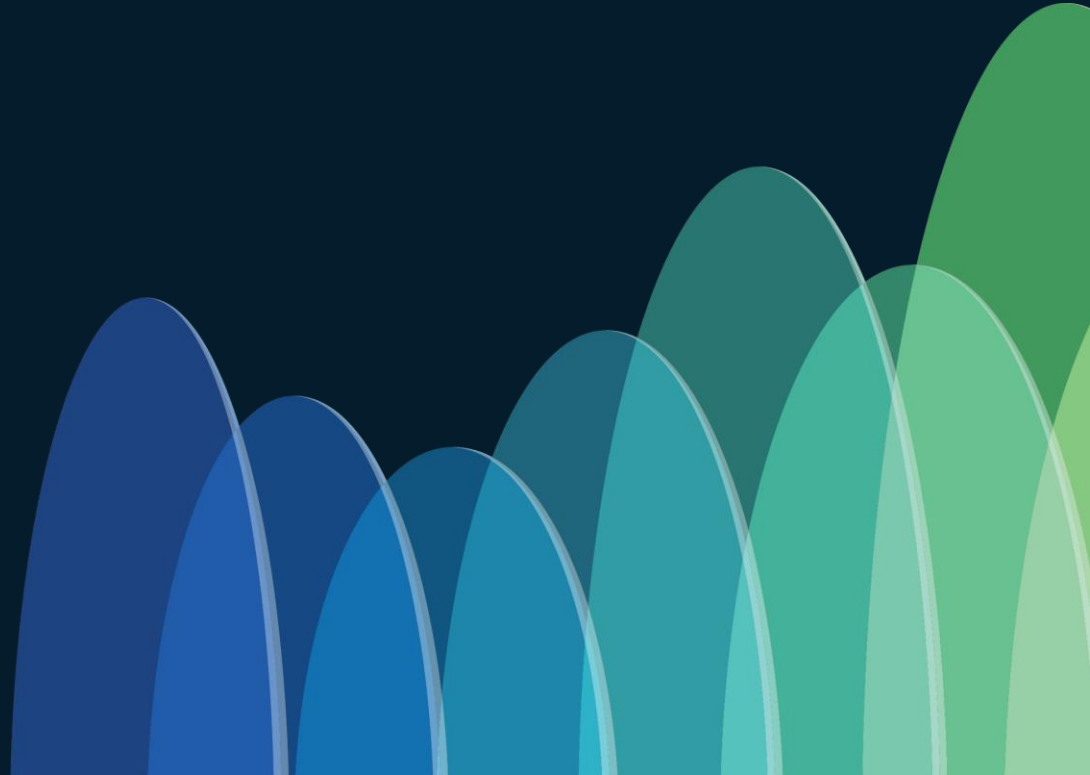
Tenant A (VRF A)



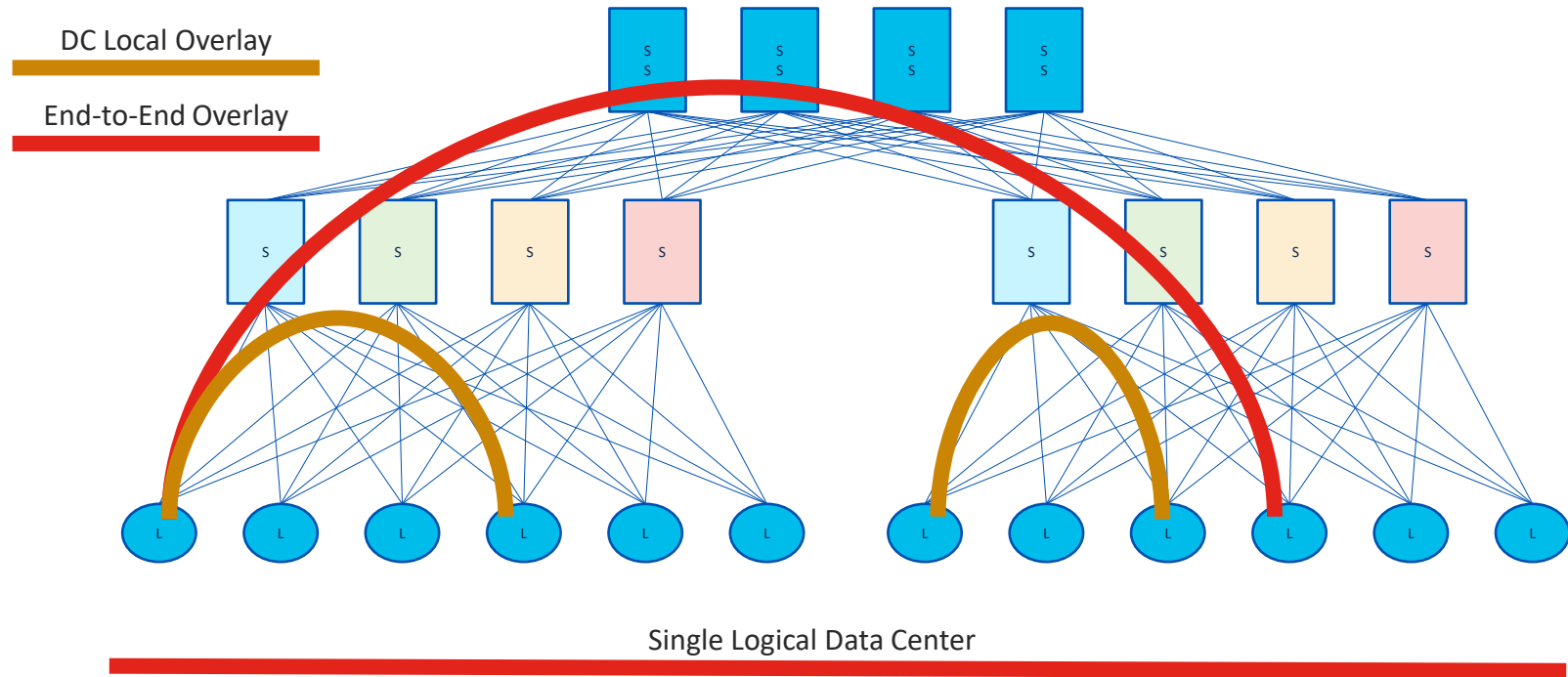
- One VLAN maps to one Layer-2 VNI per Layer-2 segment
- A Tenant can have multiple VLANs, therefore multiple Layer-2 VNIs
- Traffic within one Layer-2 VNI is bridged
- Traffic between Layer-2 VNI's is routed

- 1 Layer-3 VNI per Tenant (VRF) for routing
- VNI X' is used for routed packets

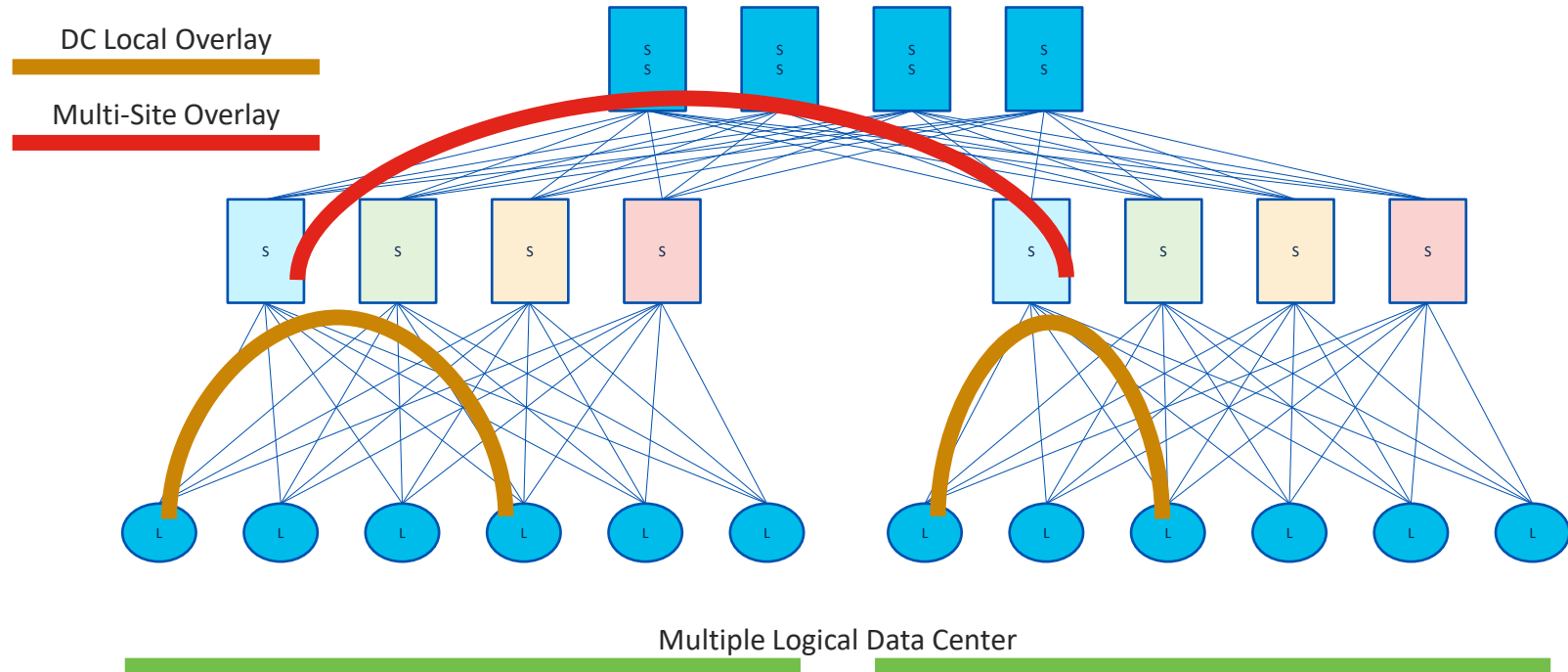
Multi Fabric Designs – VXLAN Multi Site



Multi-Pod: Overlay Spread and Extend

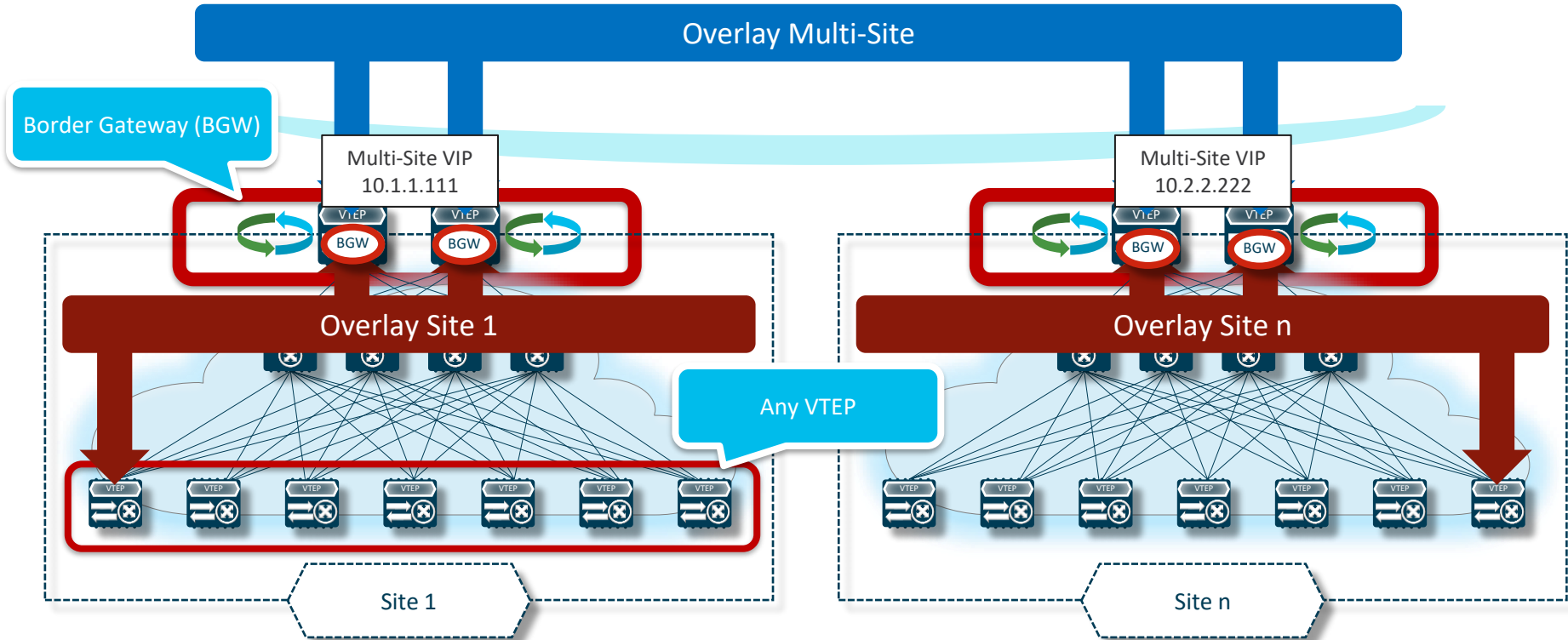


Multi-Site: A Change to Hierarchical Overlays

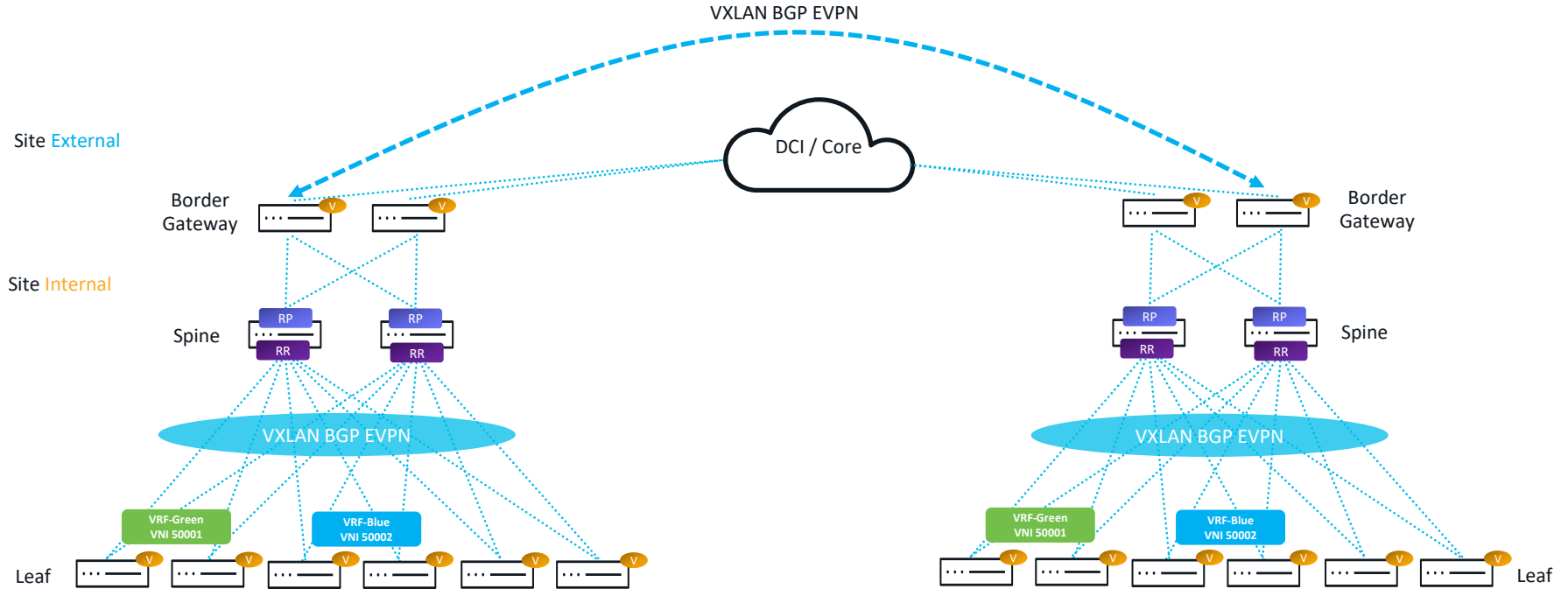


VXLAN: The Building Blocks

Hierarchical VXLAN



Connecting Multiple VXLAN EVPN Sites



VXLAN Multi-Site Characteristics

- **Multiple** Overlay Domains – Interconnected and Controlled
- **Multiple** Overlay Control-Plane Domains – Interconnected and Controlled
- **Multiple** Underlay Domains - Isolated
- **Multiple** Replication Domains for BUM – Interconnected and Controlled
- **Multiple** VNI Administrative Domains

Underlay Isolation – Overlay Hierarchies

More information available at the VXLAN Multi-Site White paper page:

<https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/white-paper-c11-739942.html>

Conclusion



Conclusion

- Requirements for Designing a data center fabric continue to evolve
- Factors such as scale, oversubscription, performance, and cost are important considerations
- Build Modern Data Center Fabrics to support:
 - Network Simplicity
 - Repeatability
 - Distributed Architectures (Minimize Failure Domains)
 - Better & Faster Troubleshooting
 - Automation and Lifecycle Management

Keynote Deep Dives

Wednesday
10:30am – 11:30am



Experiences Amplified:
How AI Can Fuel Better Employee and Customer Experiences

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Transform Data Centre and Service Provider Connectivity

Level 2
Room 203



Securing User to Application and Everything in Between

Level 2
Melbourne Room 2



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