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The bridge to possible

Introduction to VXLAN

The Future Path of Your Data Center

Richard Licon
Principal Technical Marketing Engineer

BRKDCN-1621

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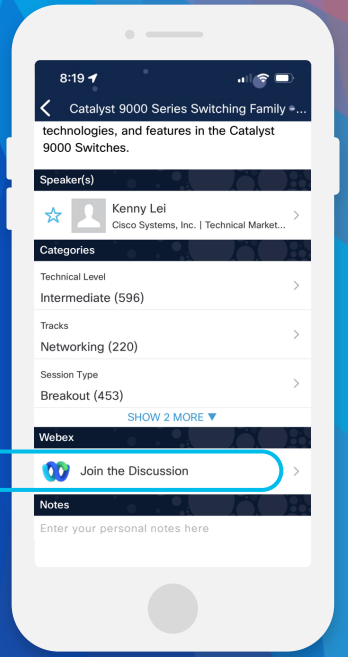

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Session Abstract

- The need for flexibility in the data center opens the door to network overlays. Several standards have been proposed and implemented to enable virtualized networks to be layered over a physical network. The data center network needs to be flexible enough to support workloads that can move from one host to another, and for new services to be deployed rapidly. VXLAN is one such technology that provides massively scalable virtual network overlays on top of existing IP infrastructures. Let's learn more about VXLAN and delve deeper into it.
- This session aims at covering what is VXLAN, how it really works, and what problems does it solve. This session will have configuration examples of how we enable a VXLAN Fabric. No prior knowledge of VXLAN is required. A basic understanding of Unicast and Multicast routing protocol is needed along with an understanding of MP BGP

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Agenda

- Evolution of the Data Center
- The Need for network overlays
- What is VXLAN?
- The Need for a Control Plane
- Configuring EVPN VXLAN
- Packet Walks
- Conclusion

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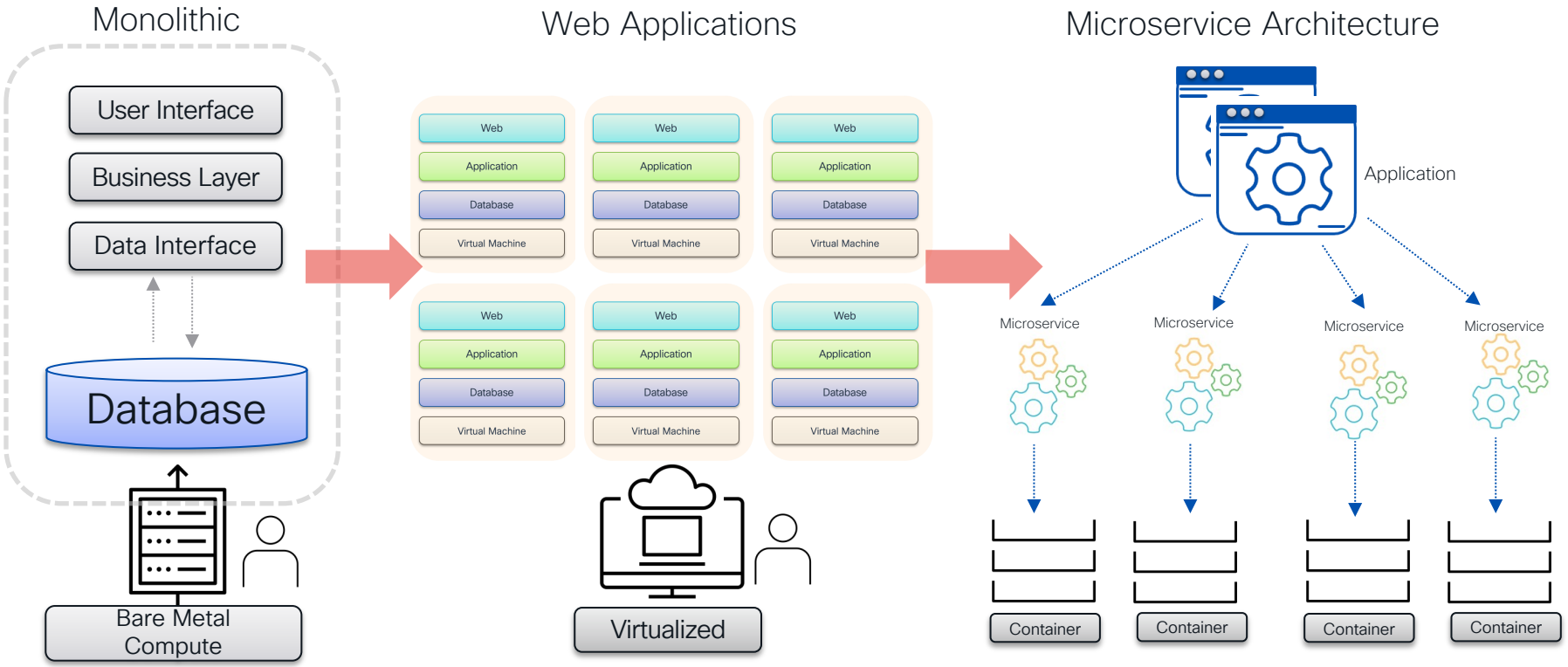
Evolution of the Application Architecture

Evolution of the Application Architectures



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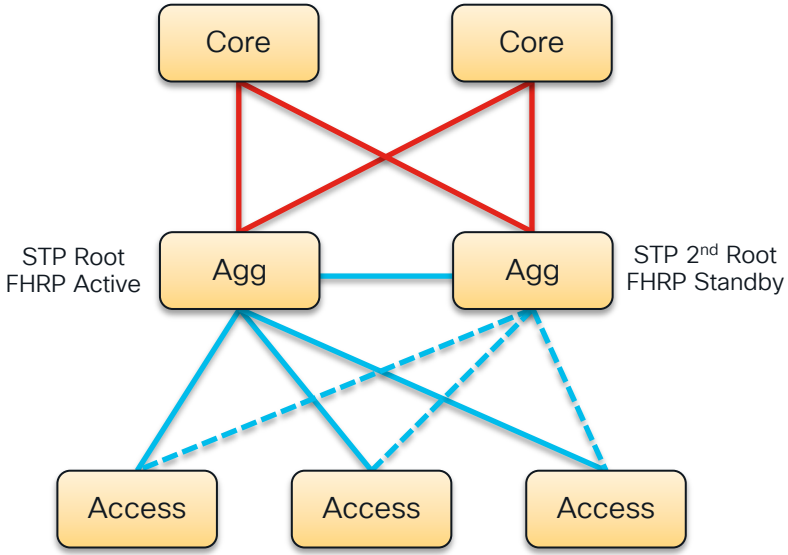
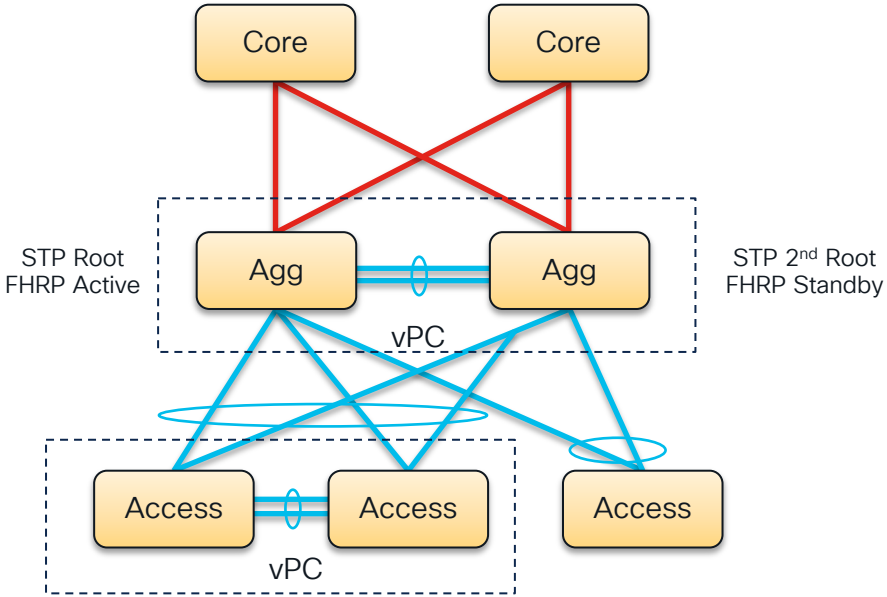
Evolution of the Data Center Network

Evolution of the Data Center Network

Classic Spanning-Tree



vPC and Spanning-Tree



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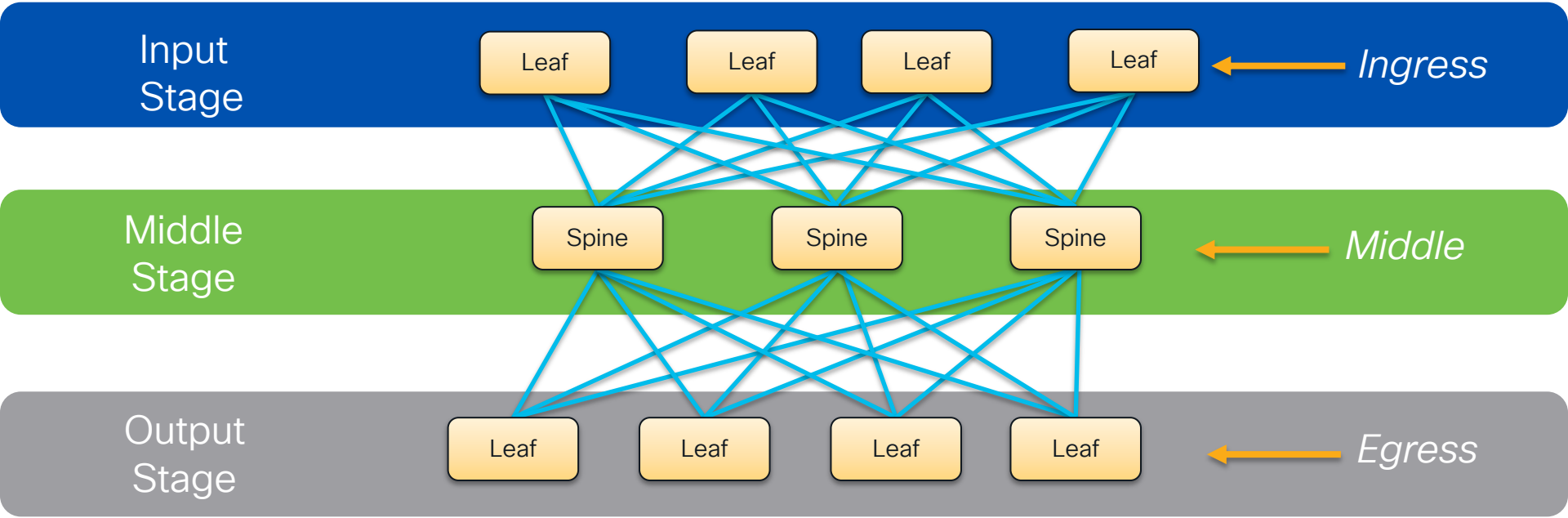
Evolution of the Data Center Network Architecture: Clos Networks

Evolution of the Data Center Network

3-Stage Clos Fabric



Invented by Edson Erwin in 1938
March 1953: A Study of Non-Blocking Switching Networks. (Clos, Charles)

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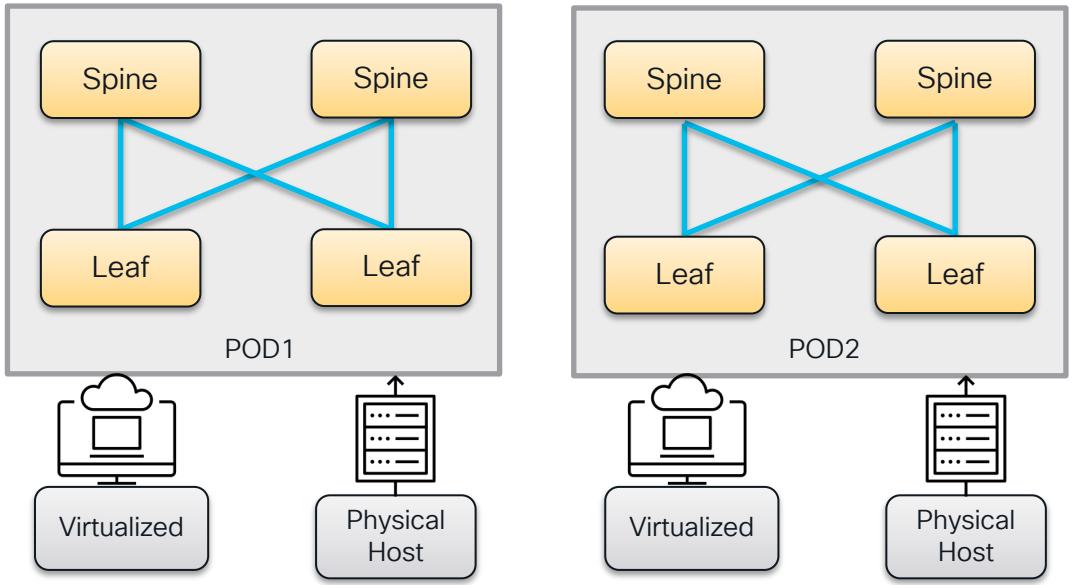
Evolution of the Data Center Network

3-Stage Fabric



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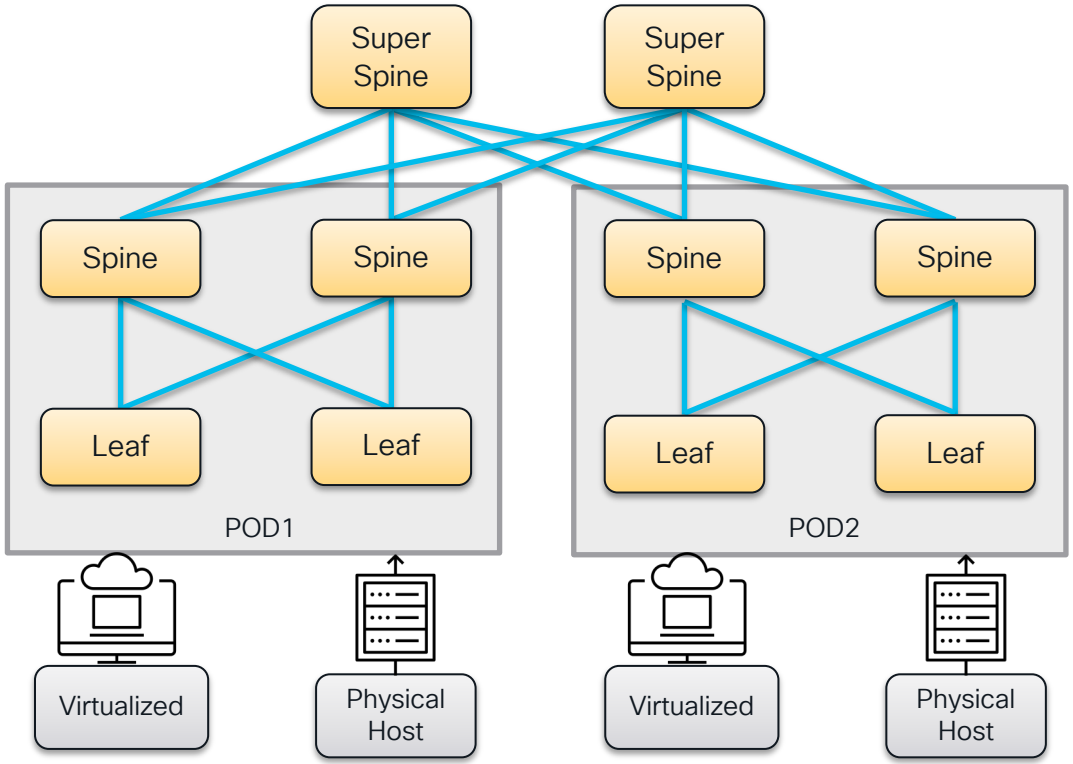
Evolution of the Data Center Network

5-Stage Fabric



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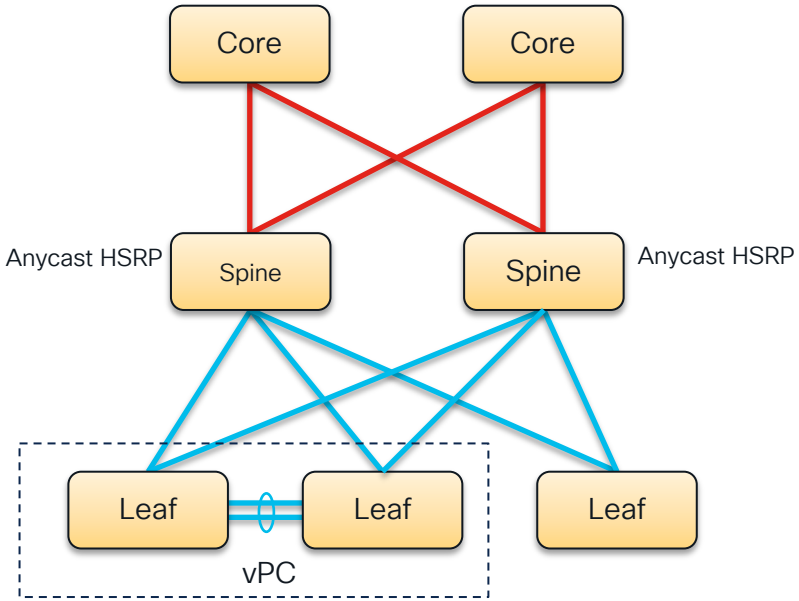
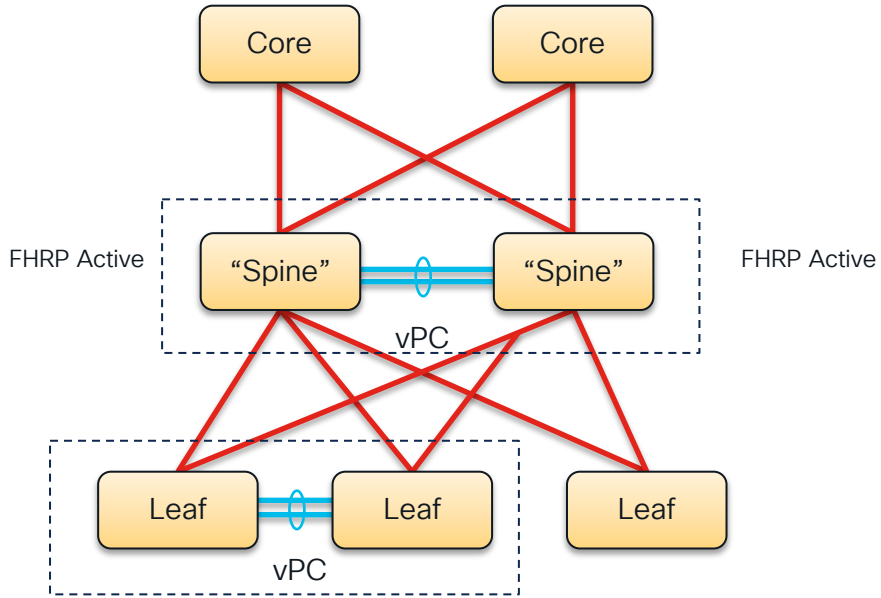
Evolution of the Data Center Network

FabricPath (MAC-in-MAC)



VXLAN Flood & Learn (MAC-in-IP)



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Data Center Network Challenges

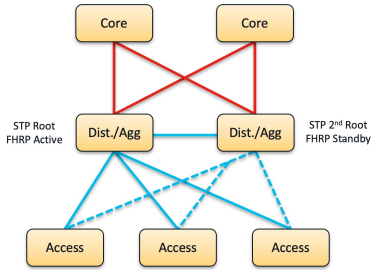
Legacy Architectures

Convergence Time:
STP high convergence time
TCN MAC Flush

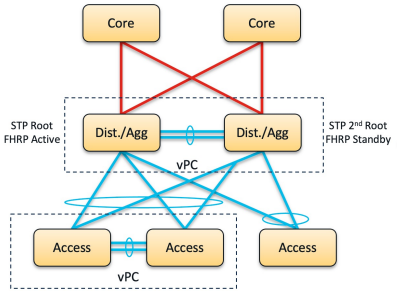
Unused Links:
STP Redundant links in blocked state

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

Classic Spanning-Tree



vPC and Spanning-Tree

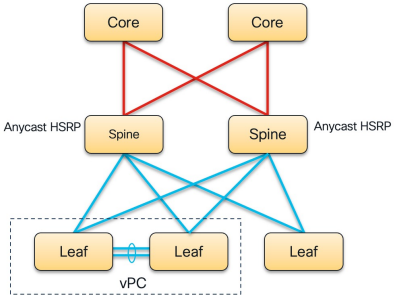


Suboptimal Forwarding:
Path defined by
Root Switch or FHRP Active

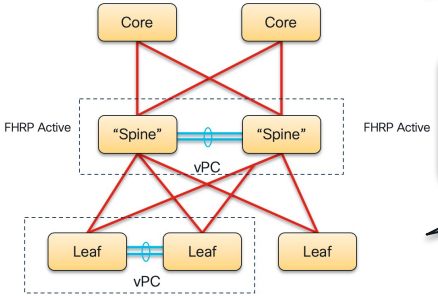
OpEx/CapEx:
Expensive to upgrade
Scale up with large Chassis

Limited Scale:
No Control Plane
Limited Workload Mobility

FabricPath (MAC-in-MAC)



VXLAN Flood & Learn (MAC-in-IP)



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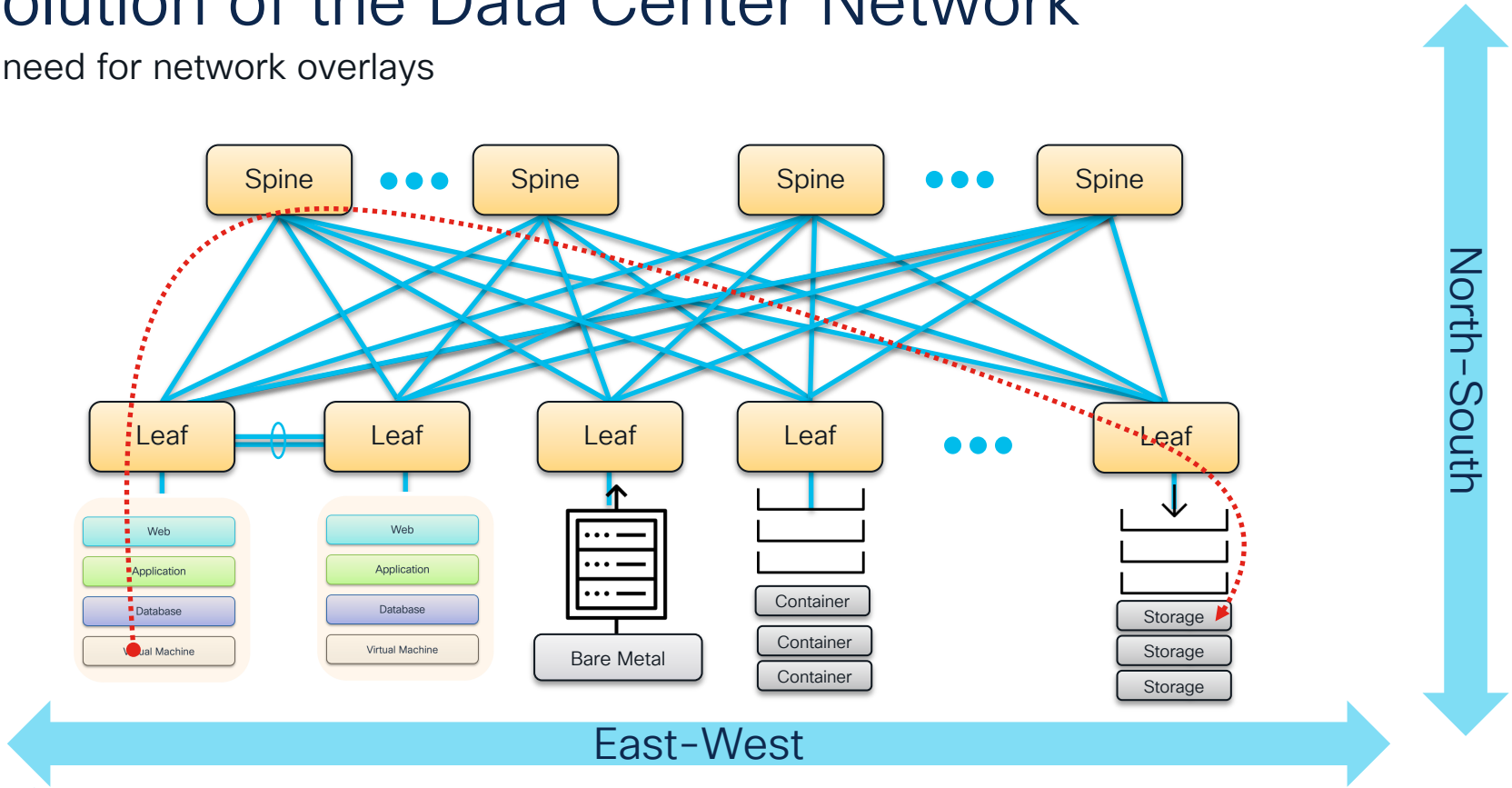
The Need for Network Overlays

Evolution of the Data Center Network

The need for network overlays



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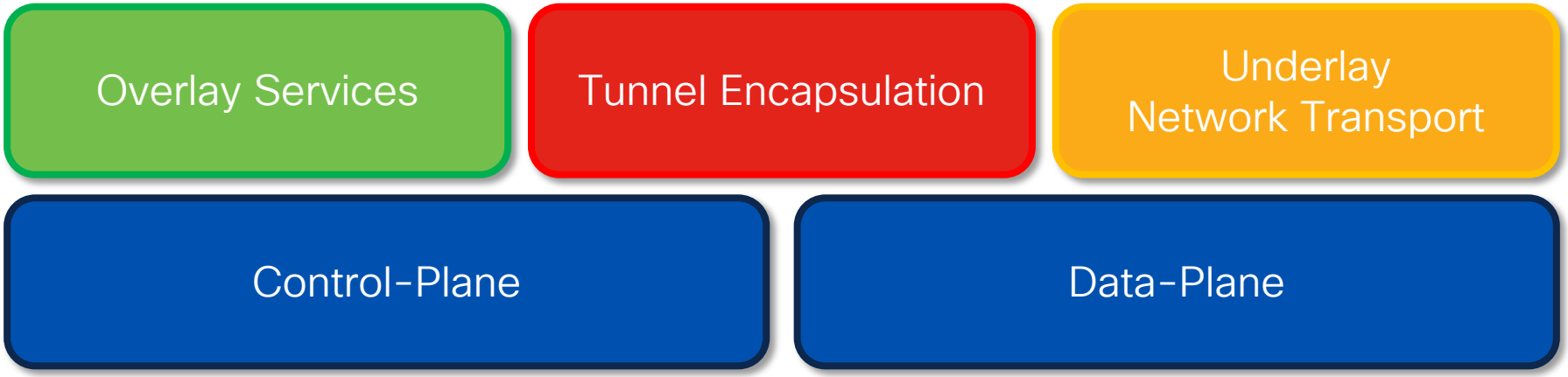
Overlay Taxonomy



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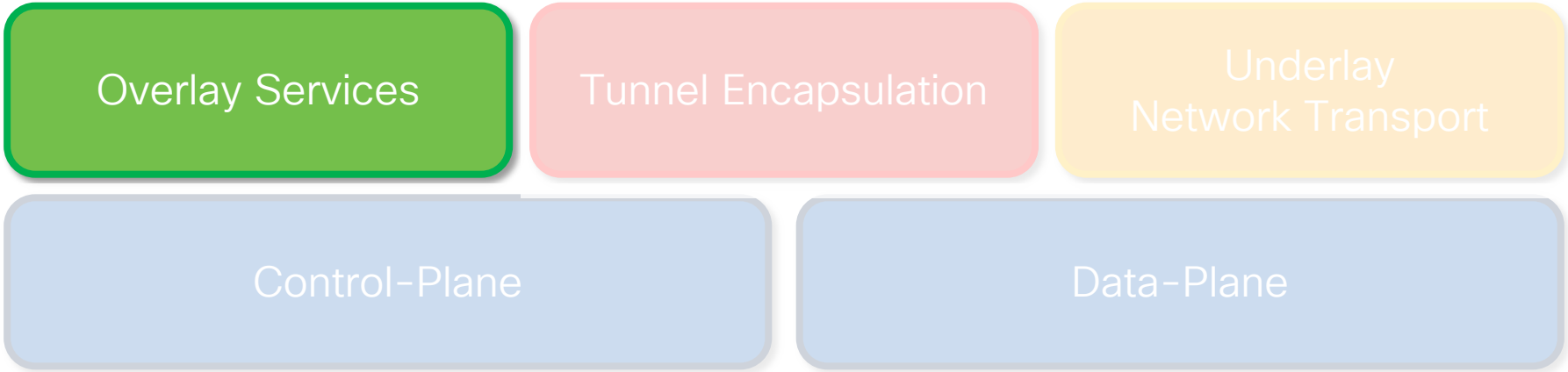
Overlay Services



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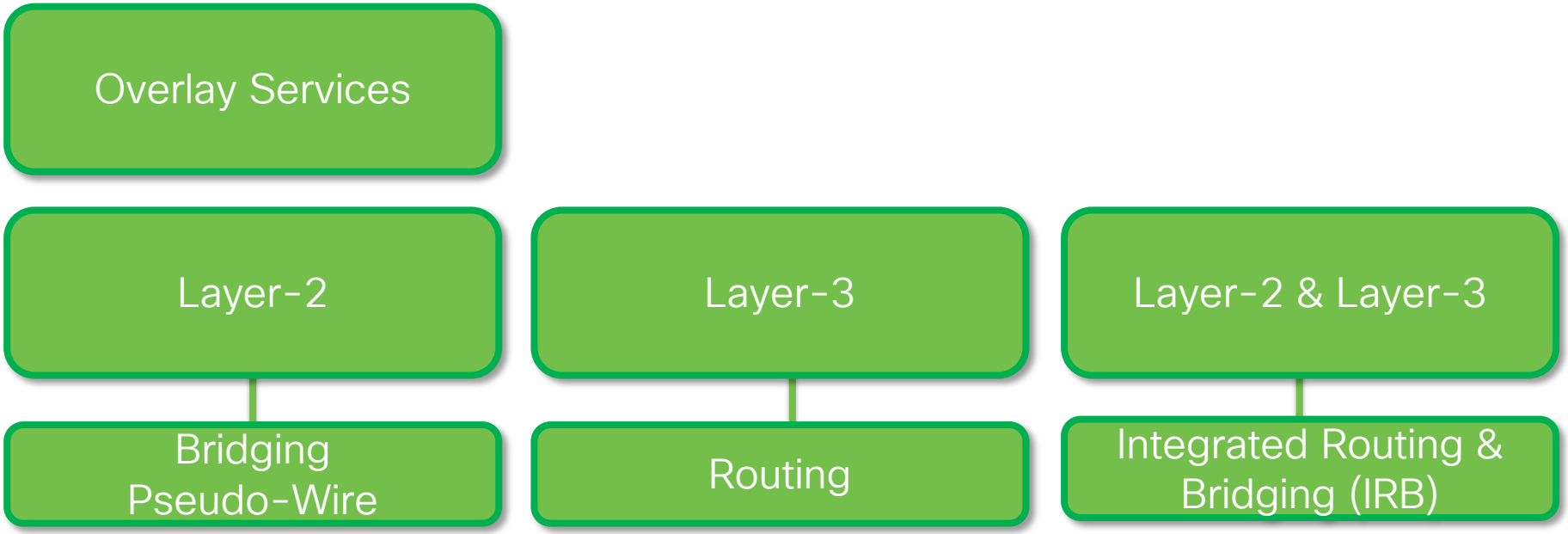
Overlay Services



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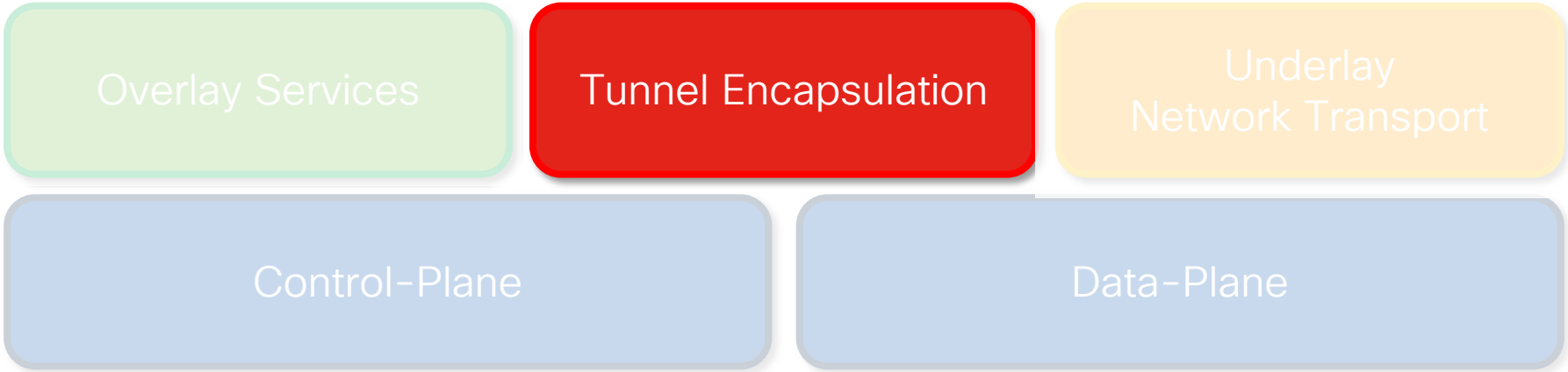
Tunnel Encapsulation



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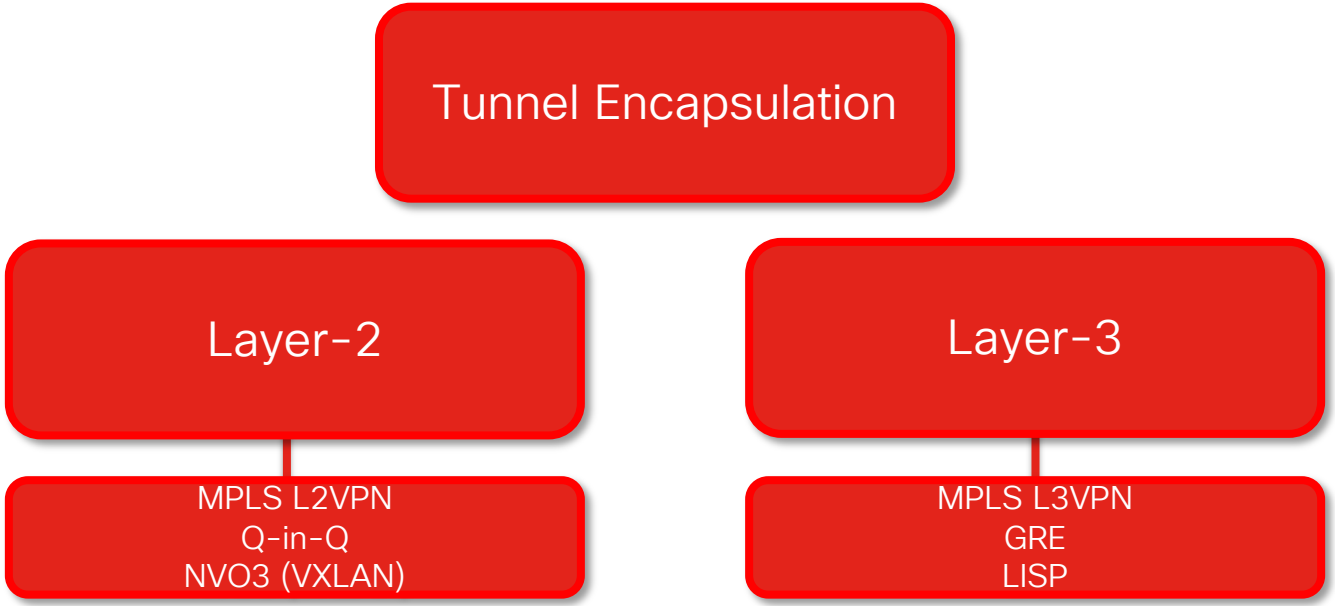
Tunnel Encapsulation



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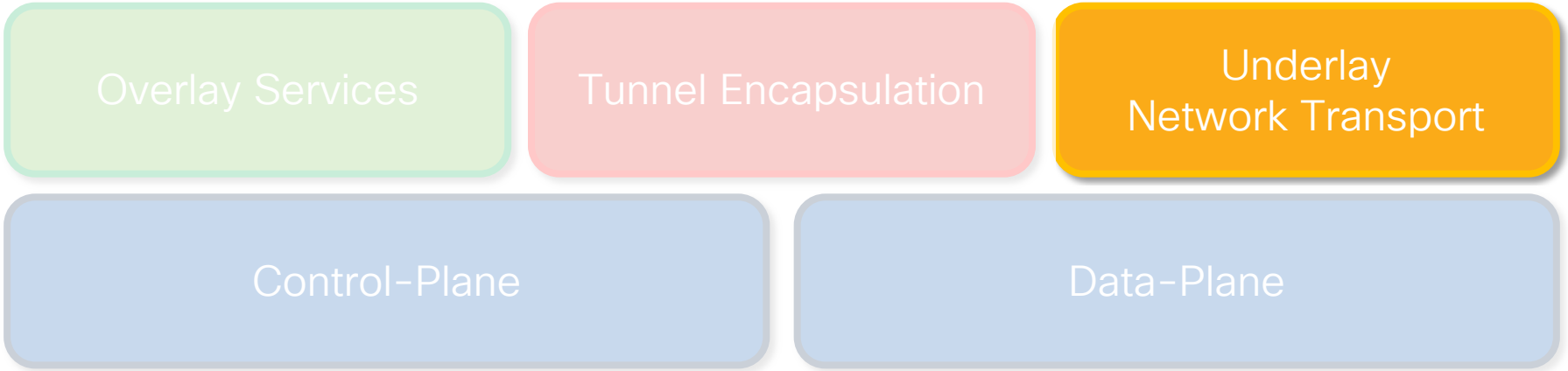
Underlay Network Transport



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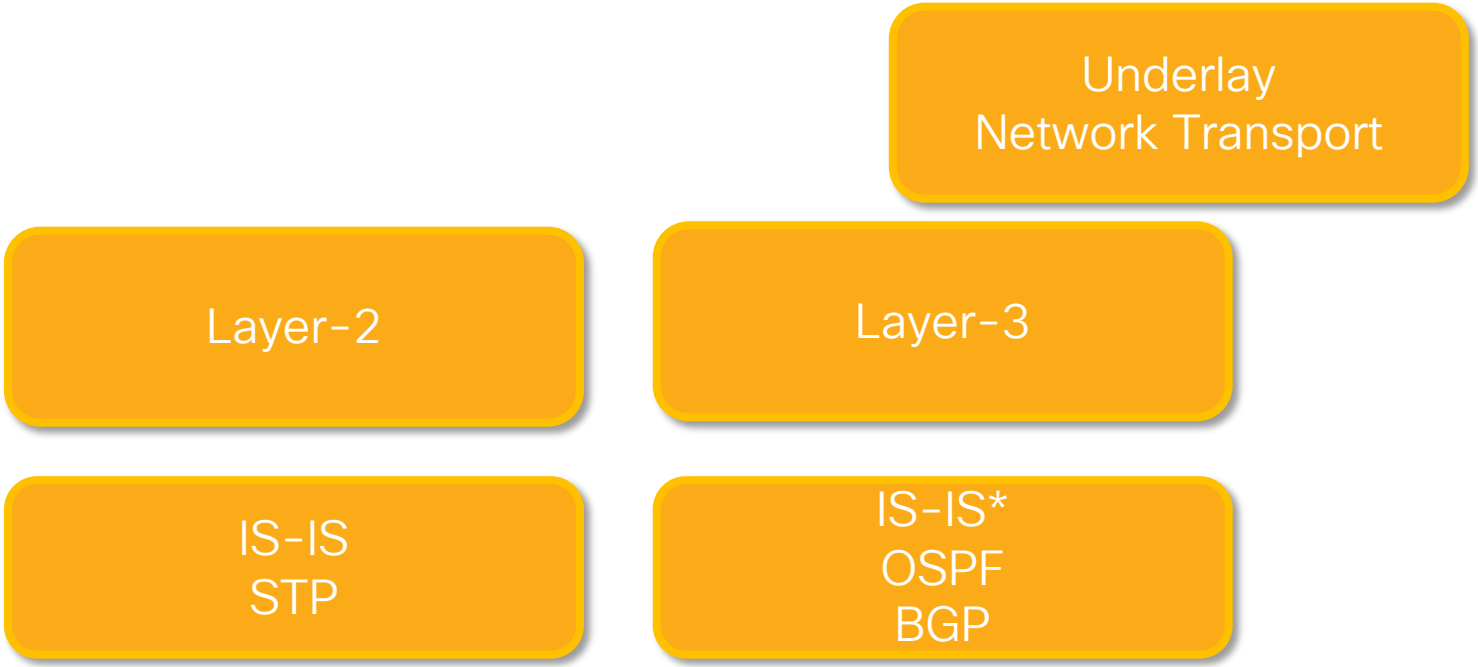
Underlay Network Transport



*IS-IS operates at L2 but transports L2 & L3

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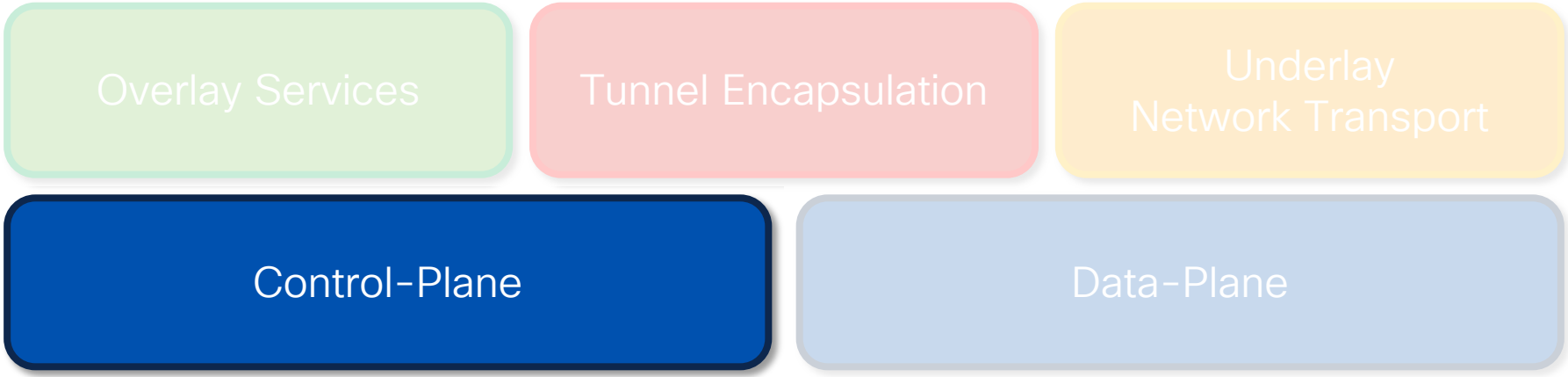
Control-Plane



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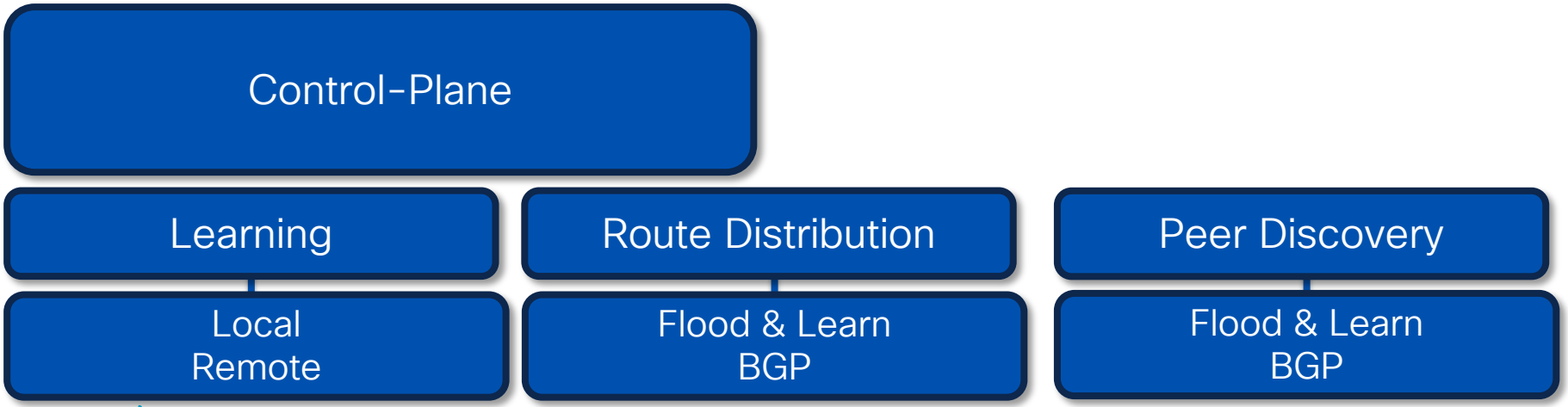
Control-Plane



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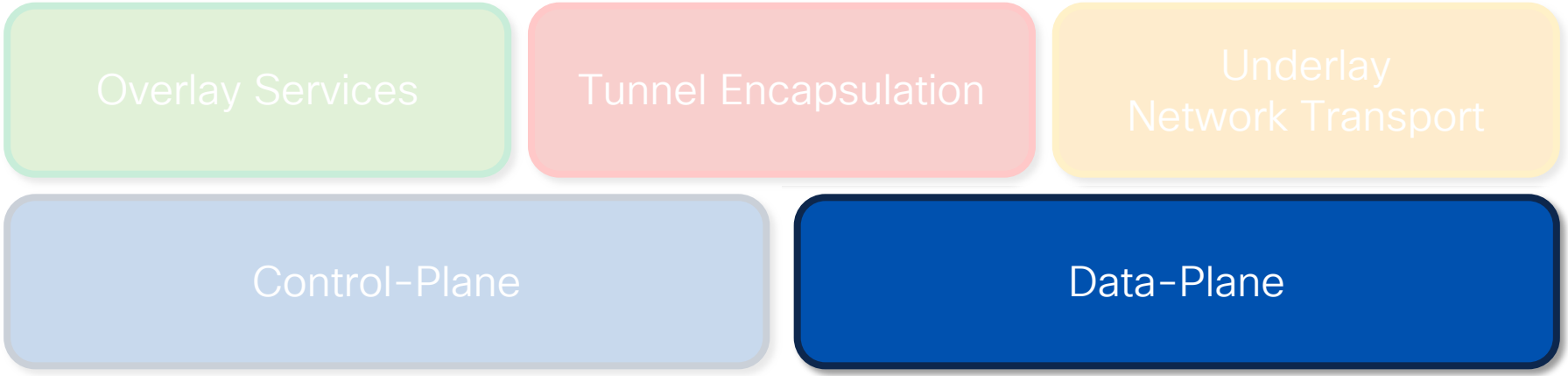
Data-Plane



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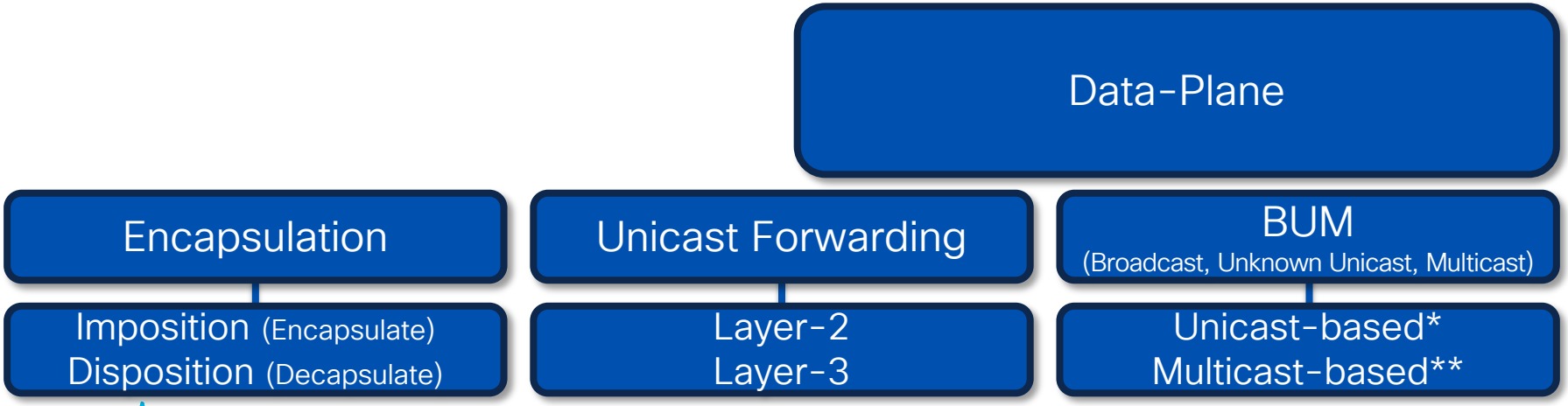
Data-Plane



*Ingress/Head-End Replication
**PIM

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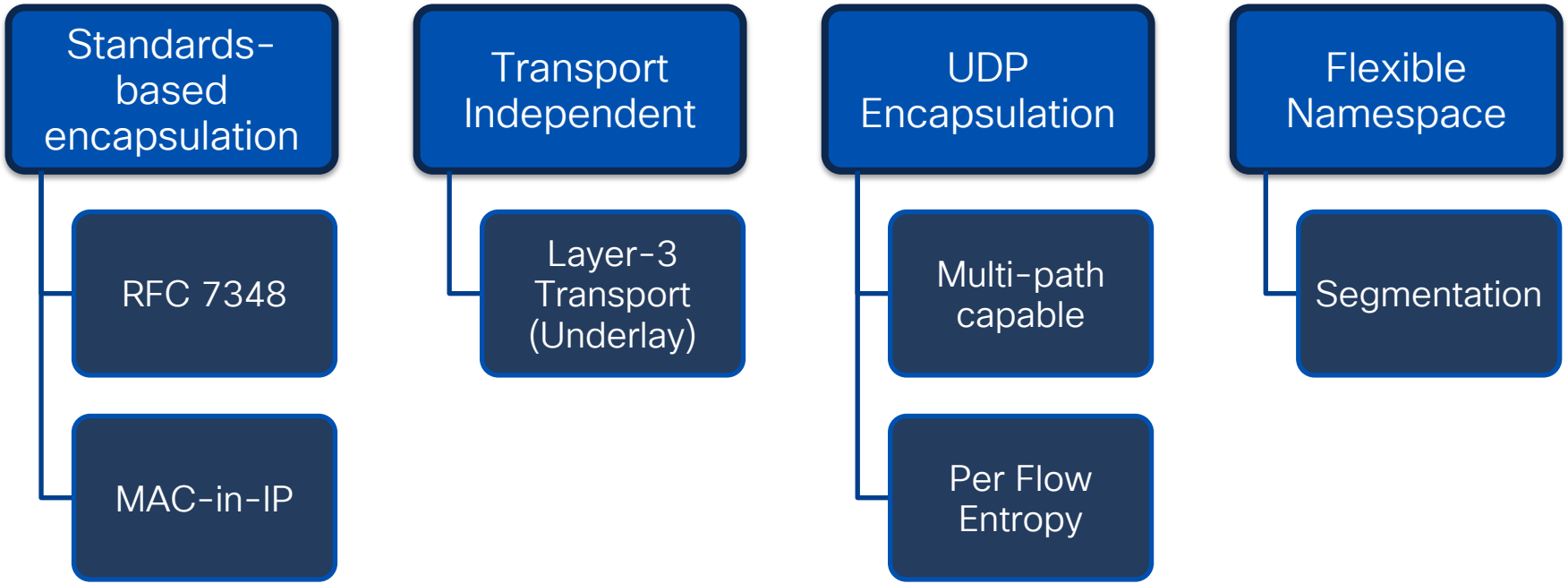
VXLAN
Virtual Extensible LAN

What is VXLAN?



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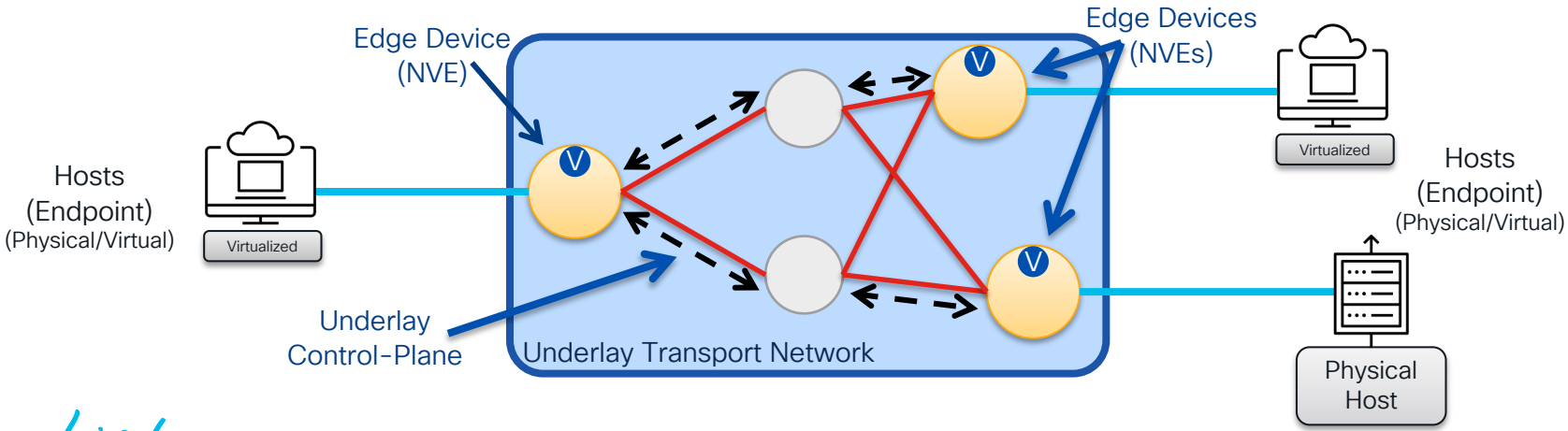
Underlay Taxonomy

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

VTEP: VXLAN Tunnel Endpoint
NVE: Network Virtualization Edge



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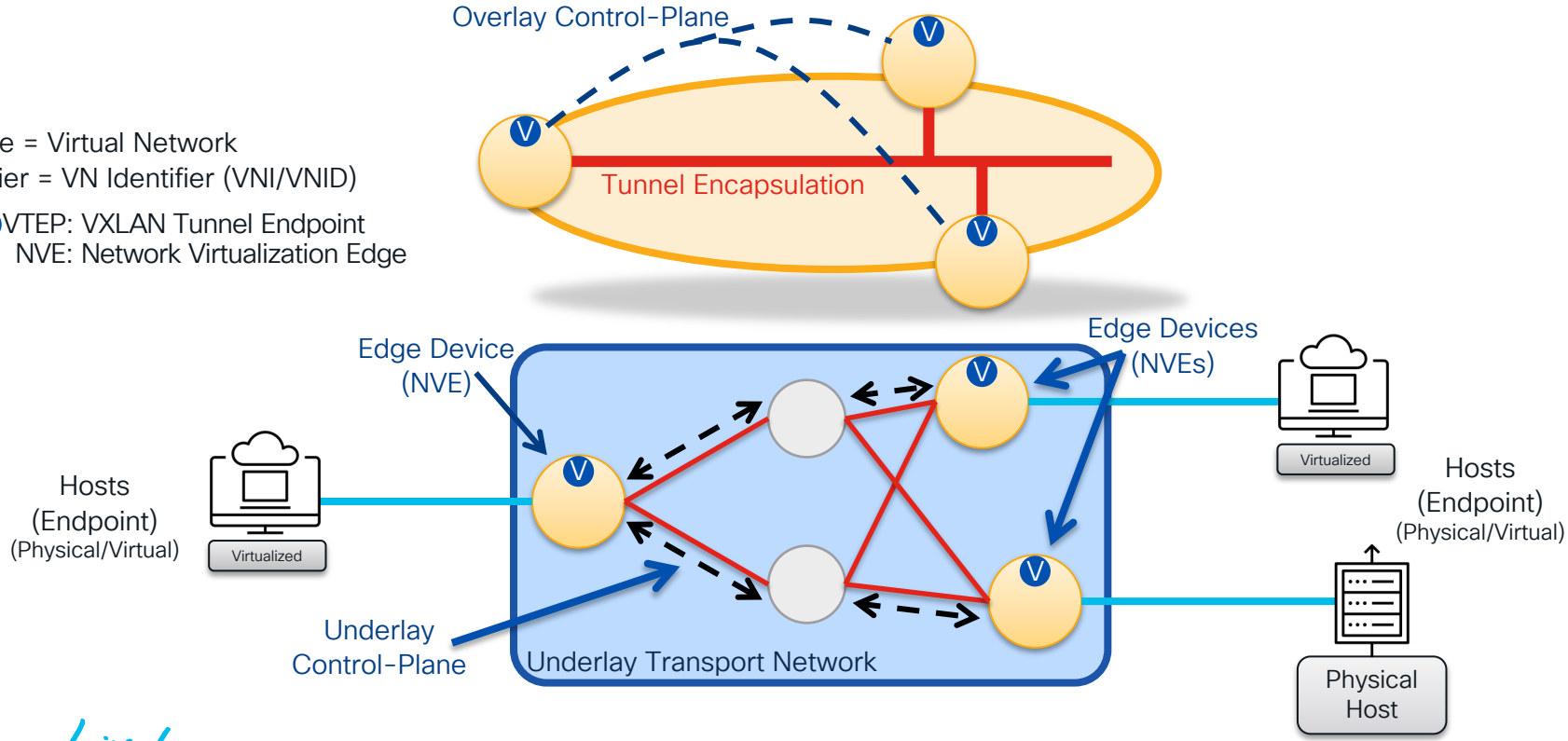
Overlay Taxonomy

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

VTEP: VXLAN Tunnel Endpoint
NVE: Network Virtualization Edge



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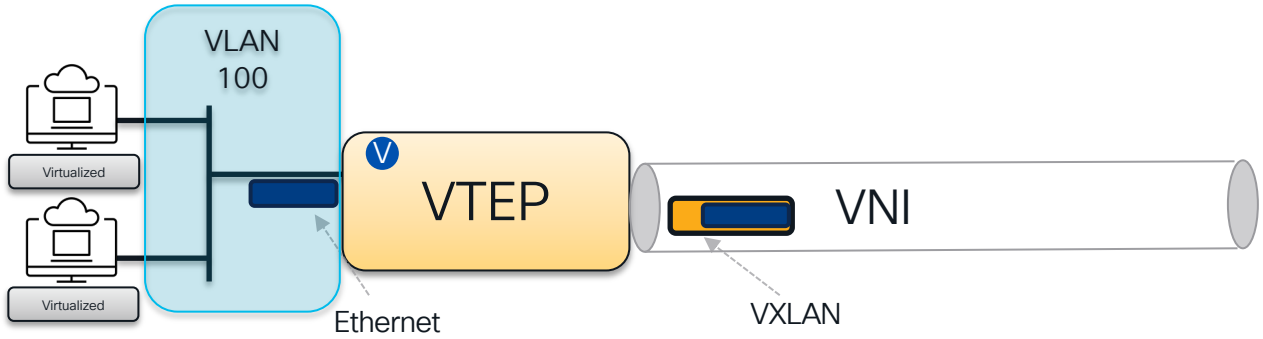
VXLAN (or Virtual) Tunnel Endpoint VTEP



- 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

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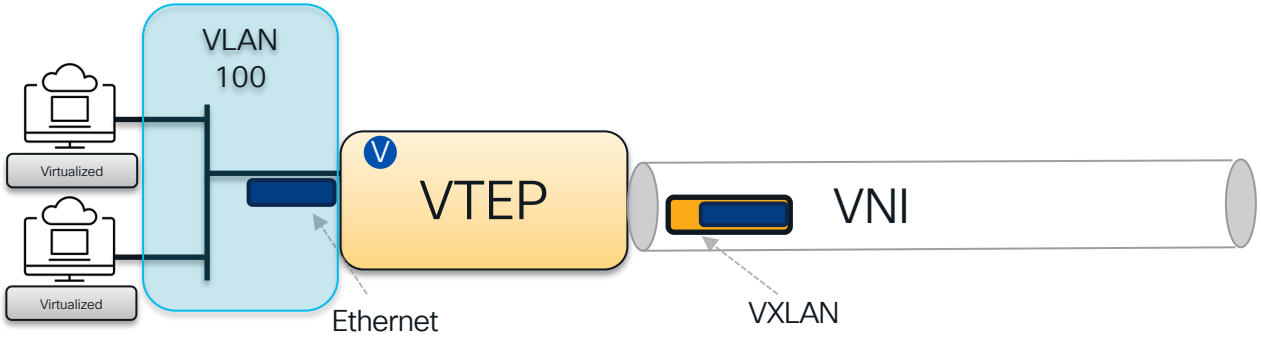
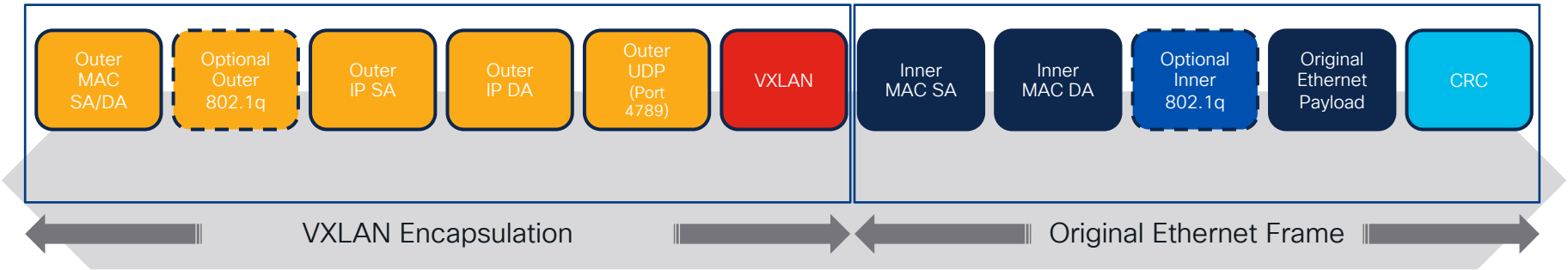
VXLAN Encapsulation / Packet Format





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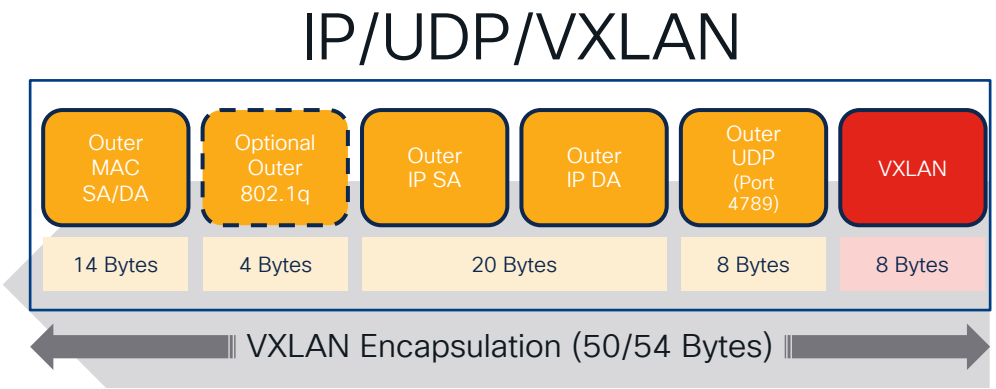
VXLAN Packet Format

- VXLAN uses MAC in UDP encapsulation



- Adds UDP and VXLAN Header before original Ethernet Frame

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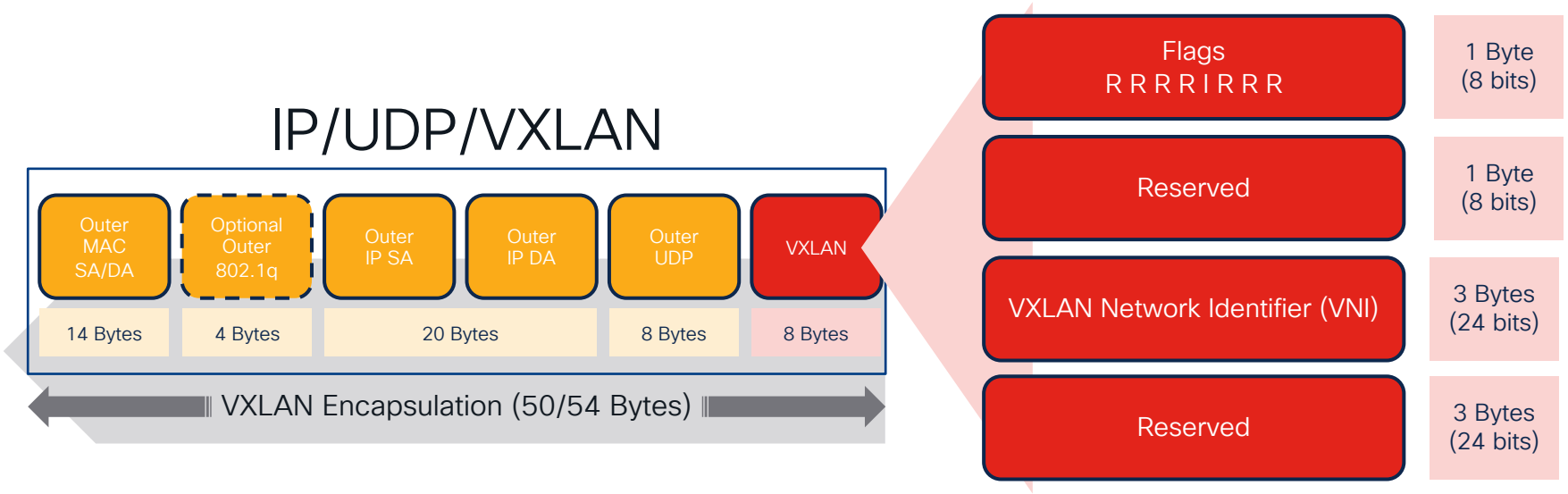
VXLAN Header Details



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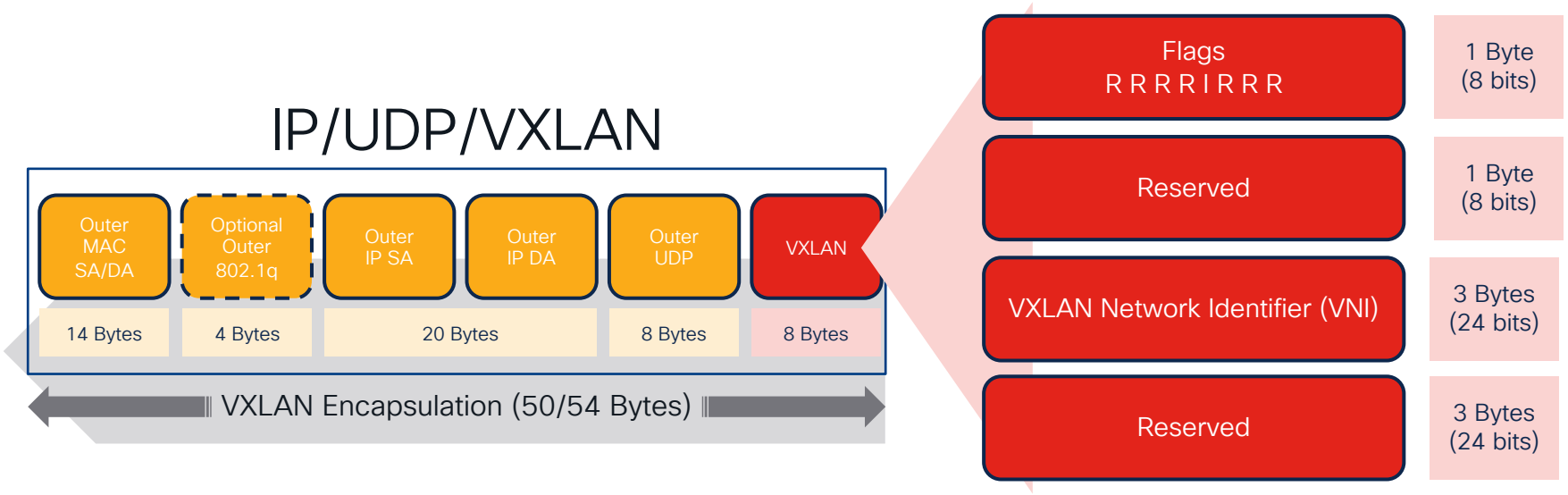
VXLAN Header Details



- Flags Field: I-flag (set to 1) for valid VNI. Other flags remain as R (set to 0)

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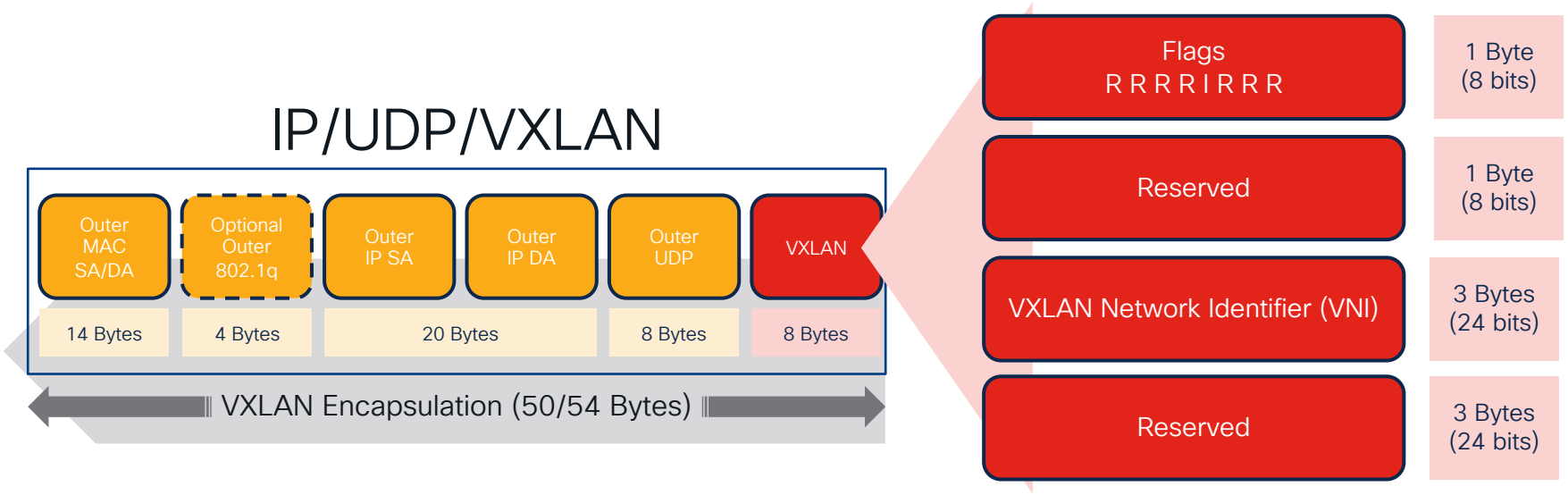
VXLAN Header Details



- Flags Field: I-flag (set to 1) for valid VNI. Other flags remain as R (set to 0)
- VNI Field: Allows VNI 1-16,777,215 (some implementation only 4096-16,777,215)

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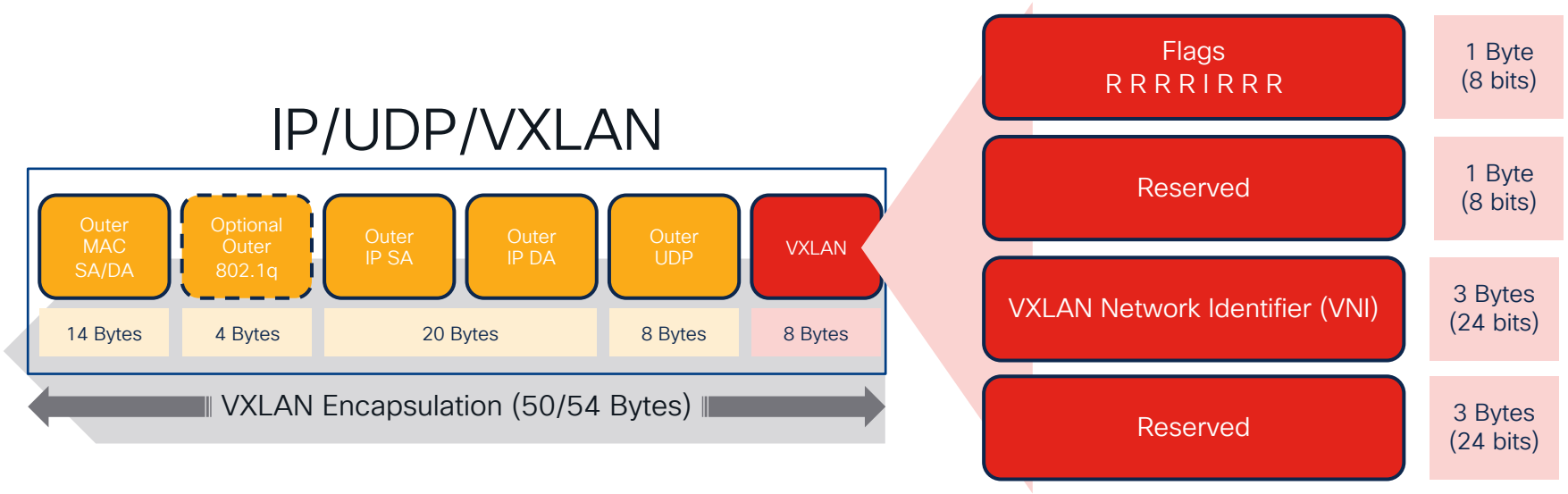
VXLAN Header Details




```
vlan 15
  vn-segment 31234
```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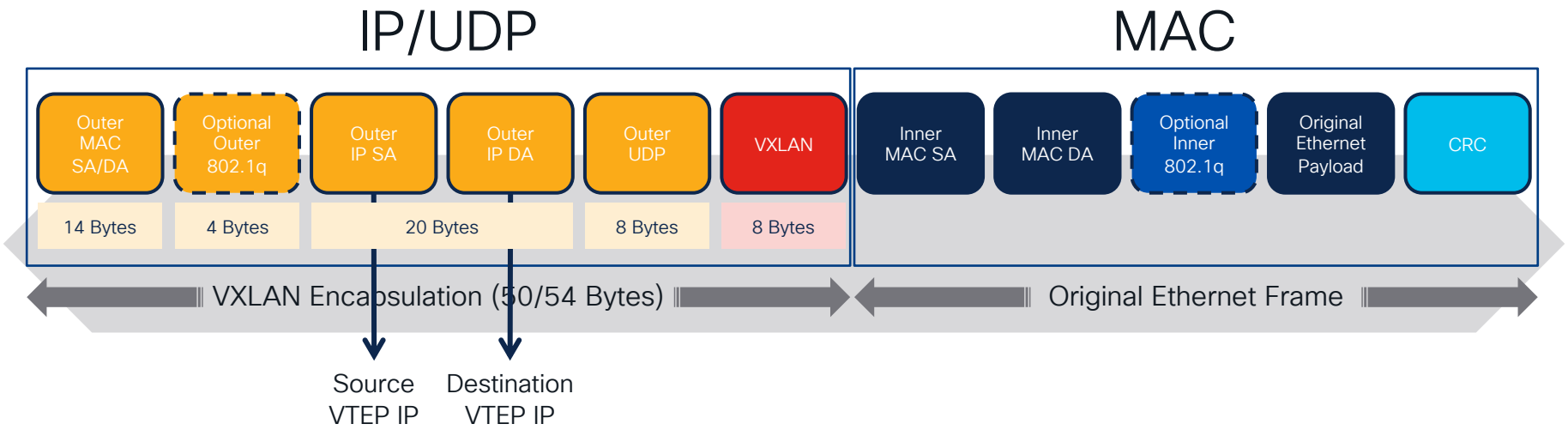
Transport Independence



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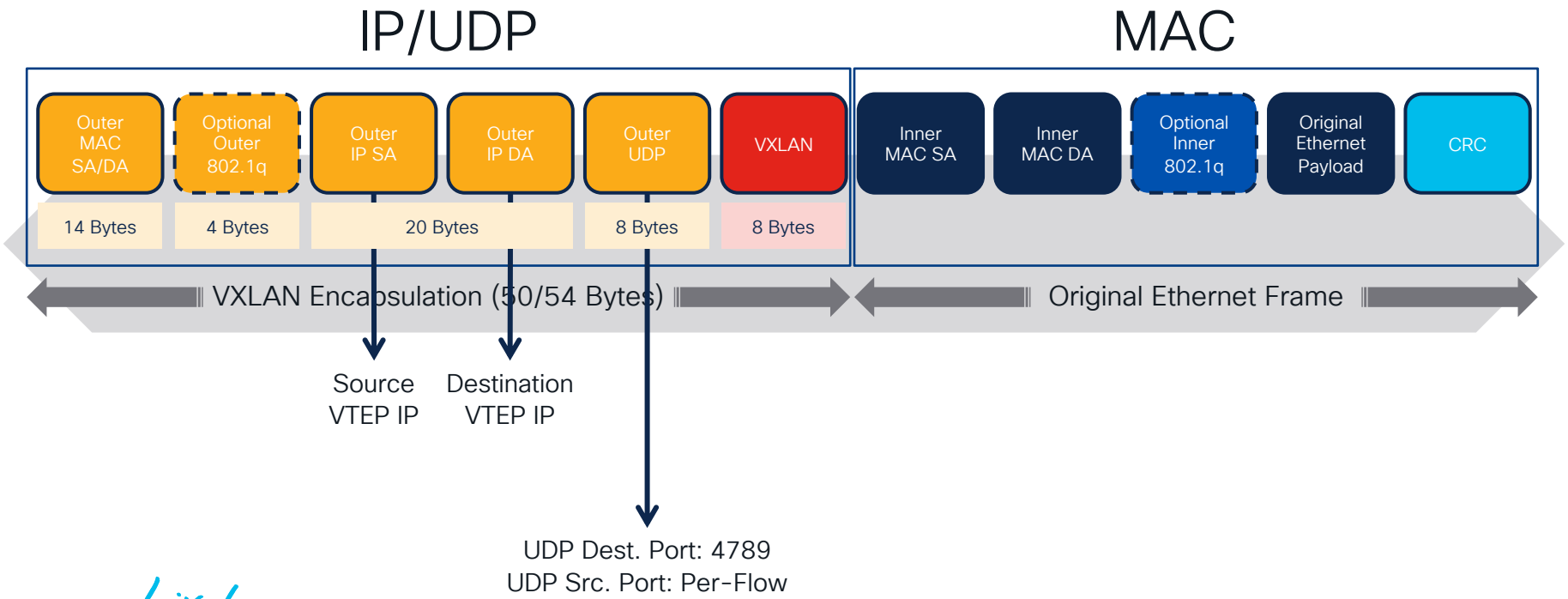
Multipath Capable



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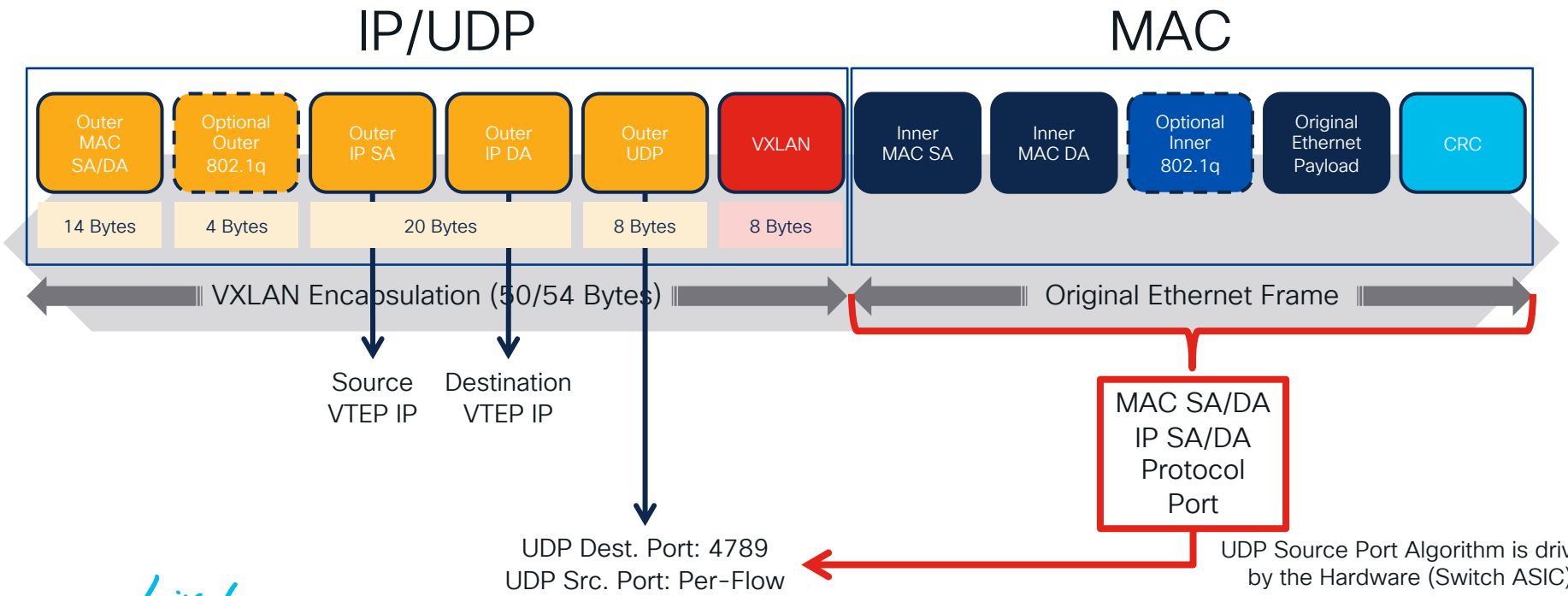
Multipath Capable



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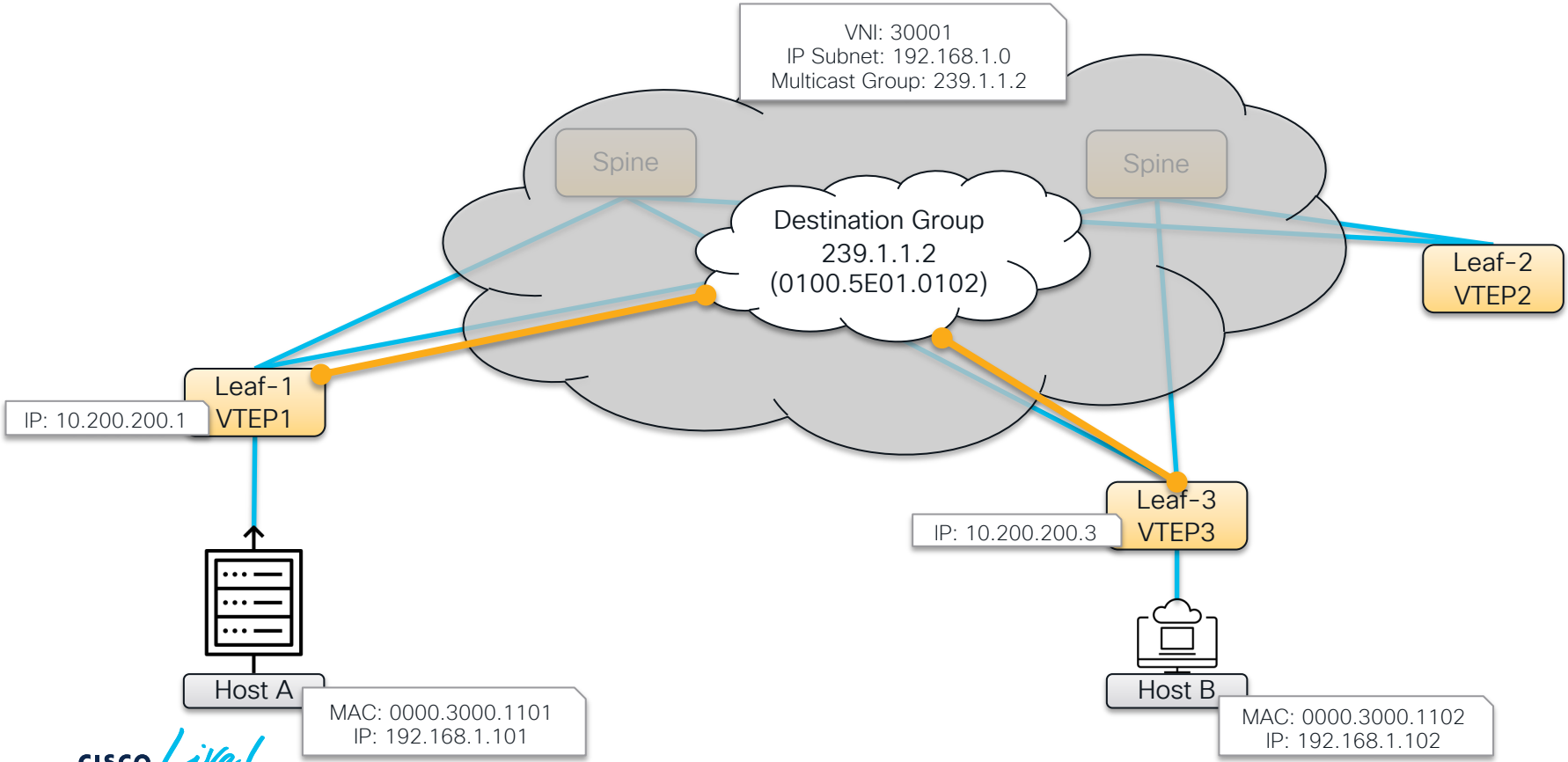
Data Plane
Flood and Learn

VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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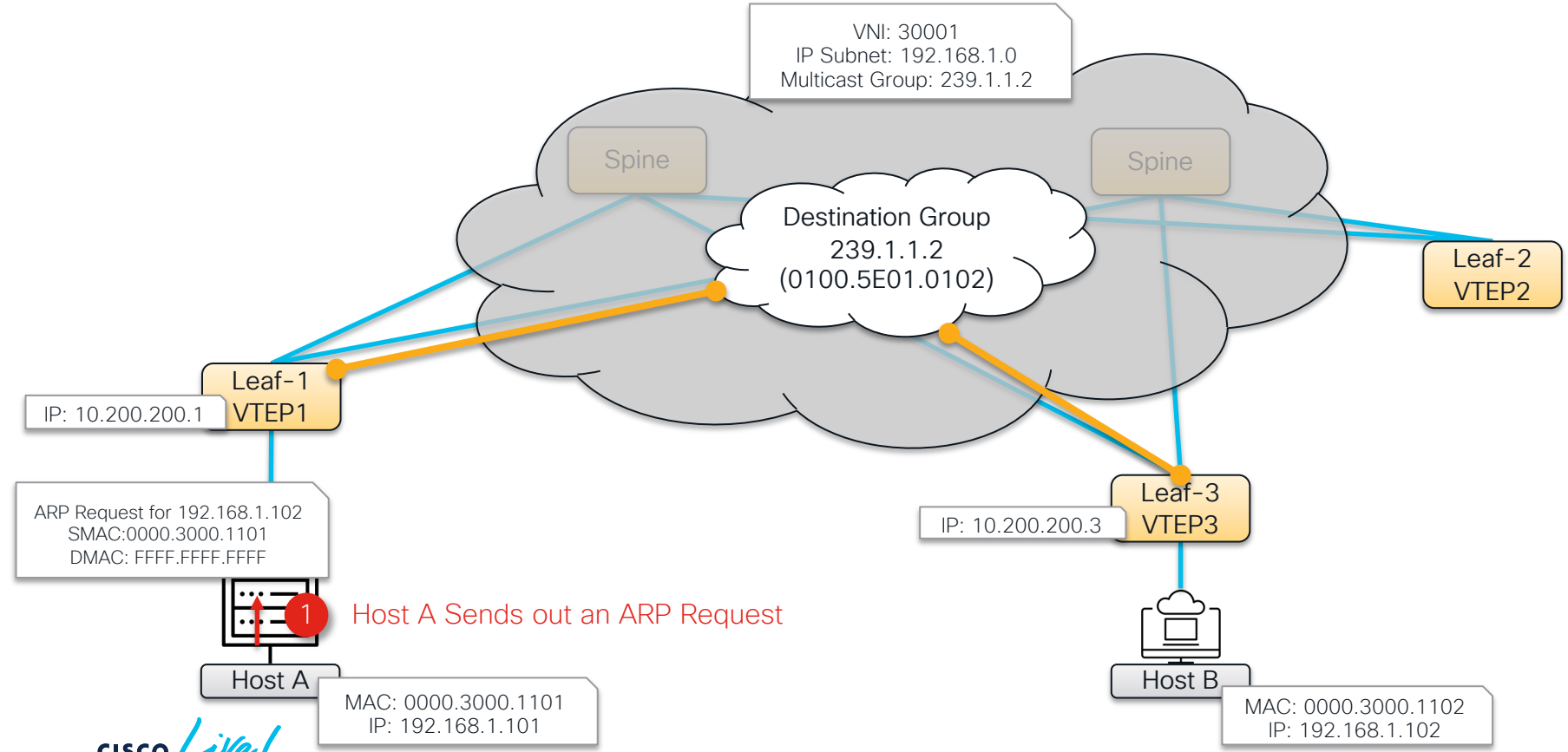
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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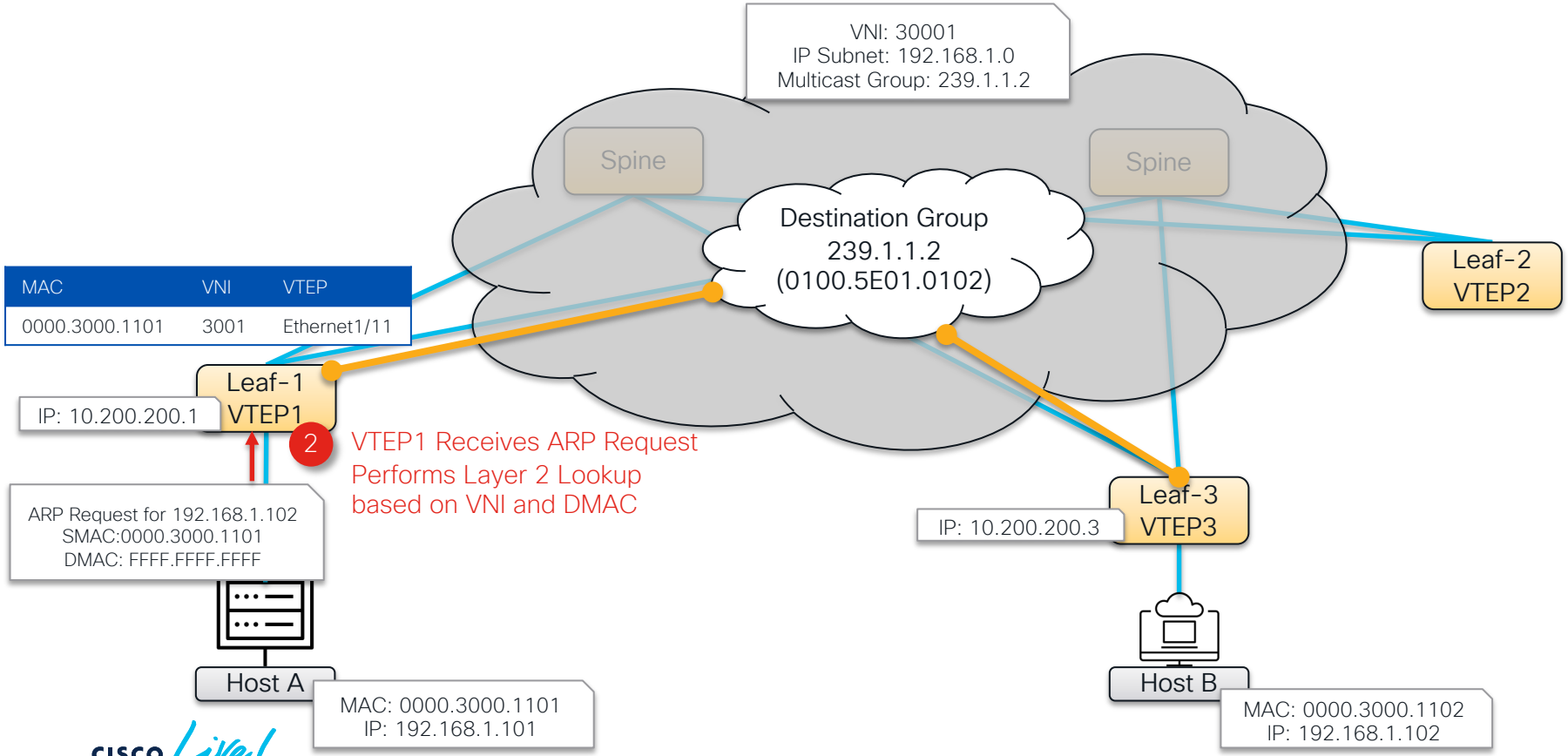
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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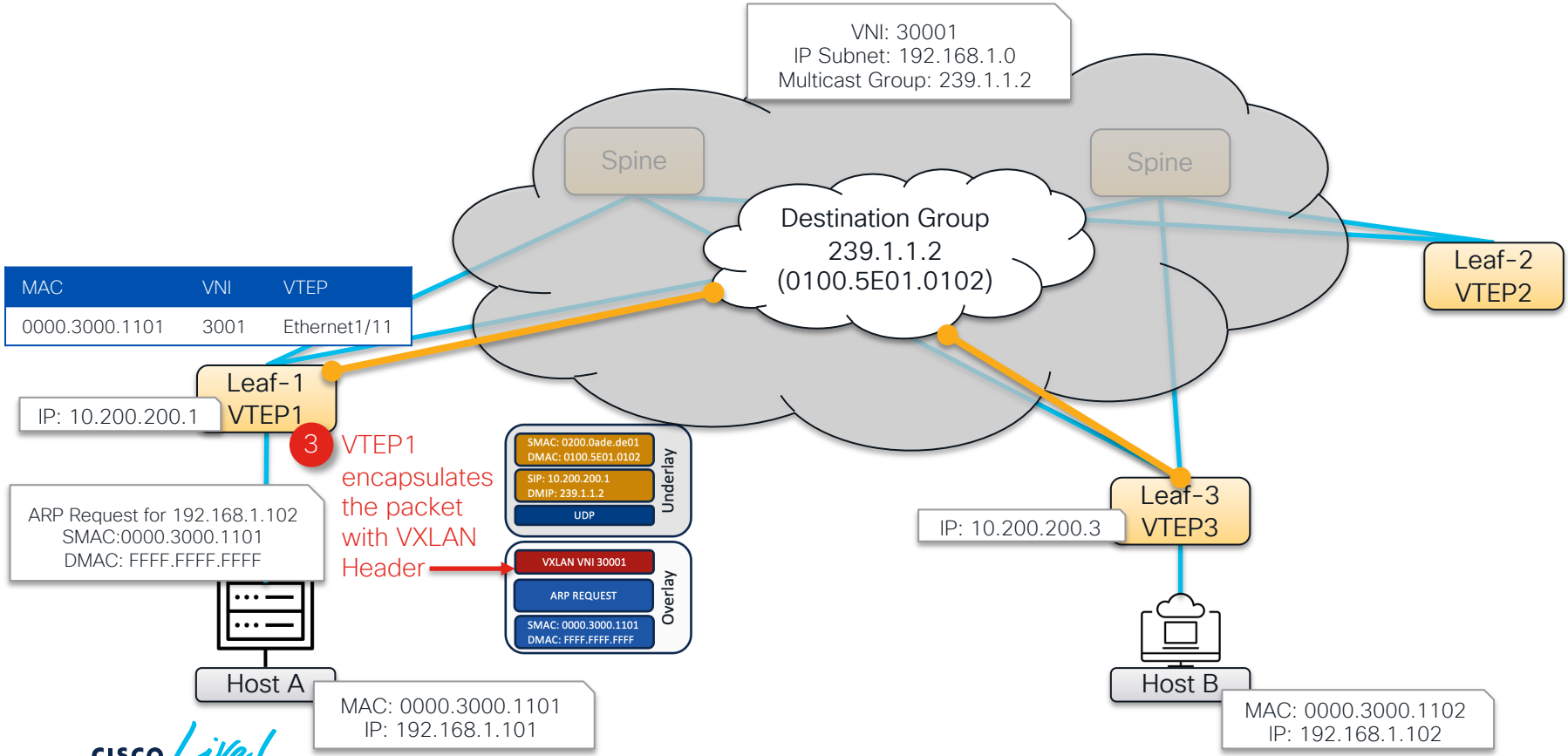
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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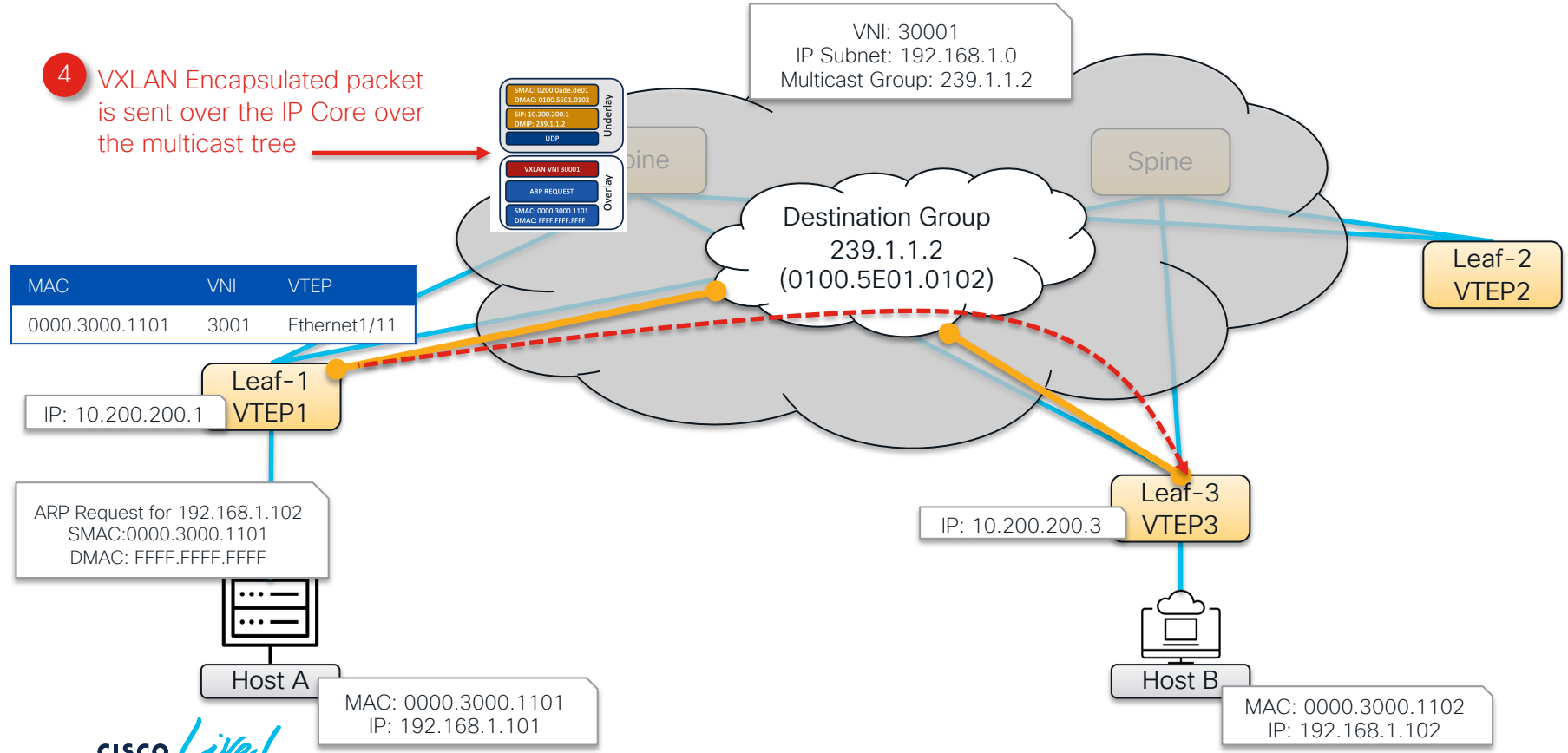
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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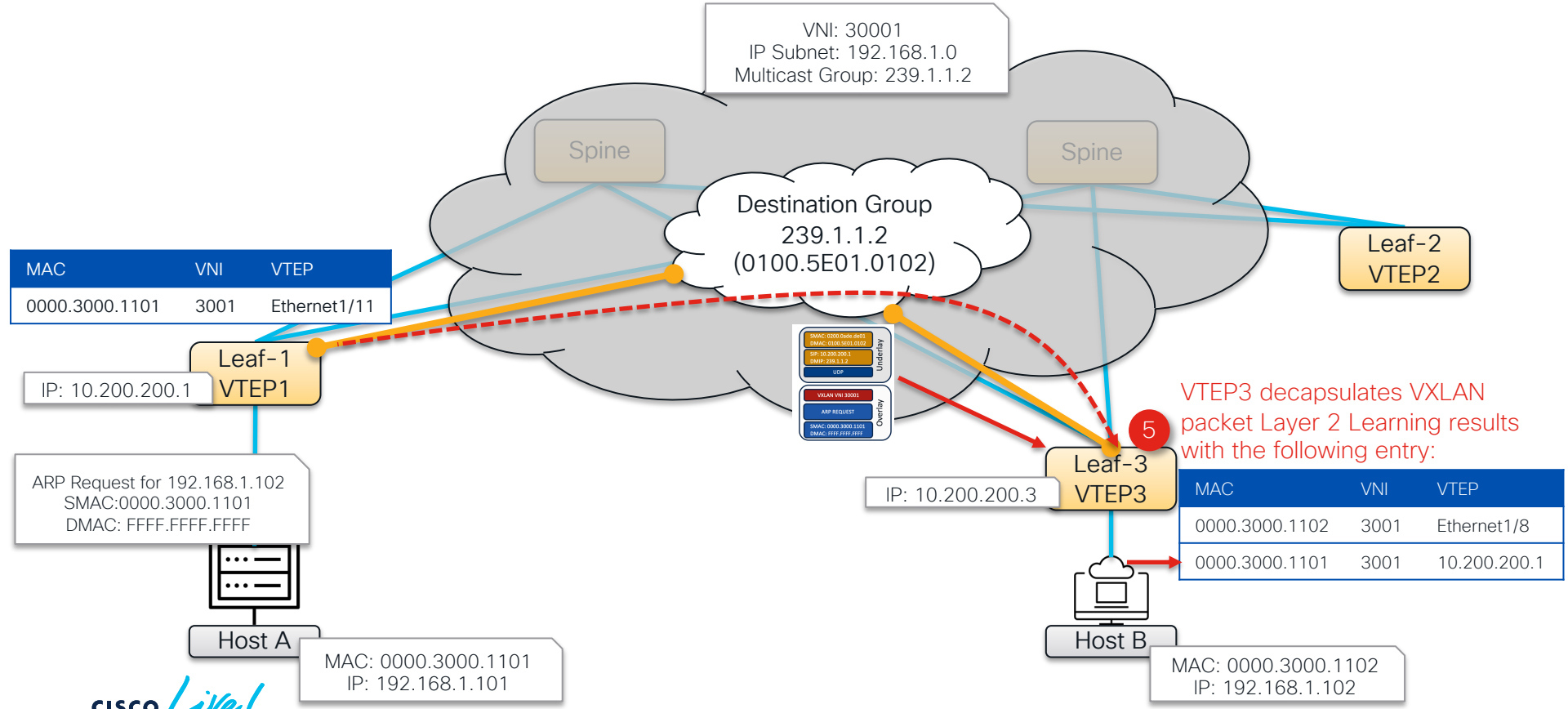
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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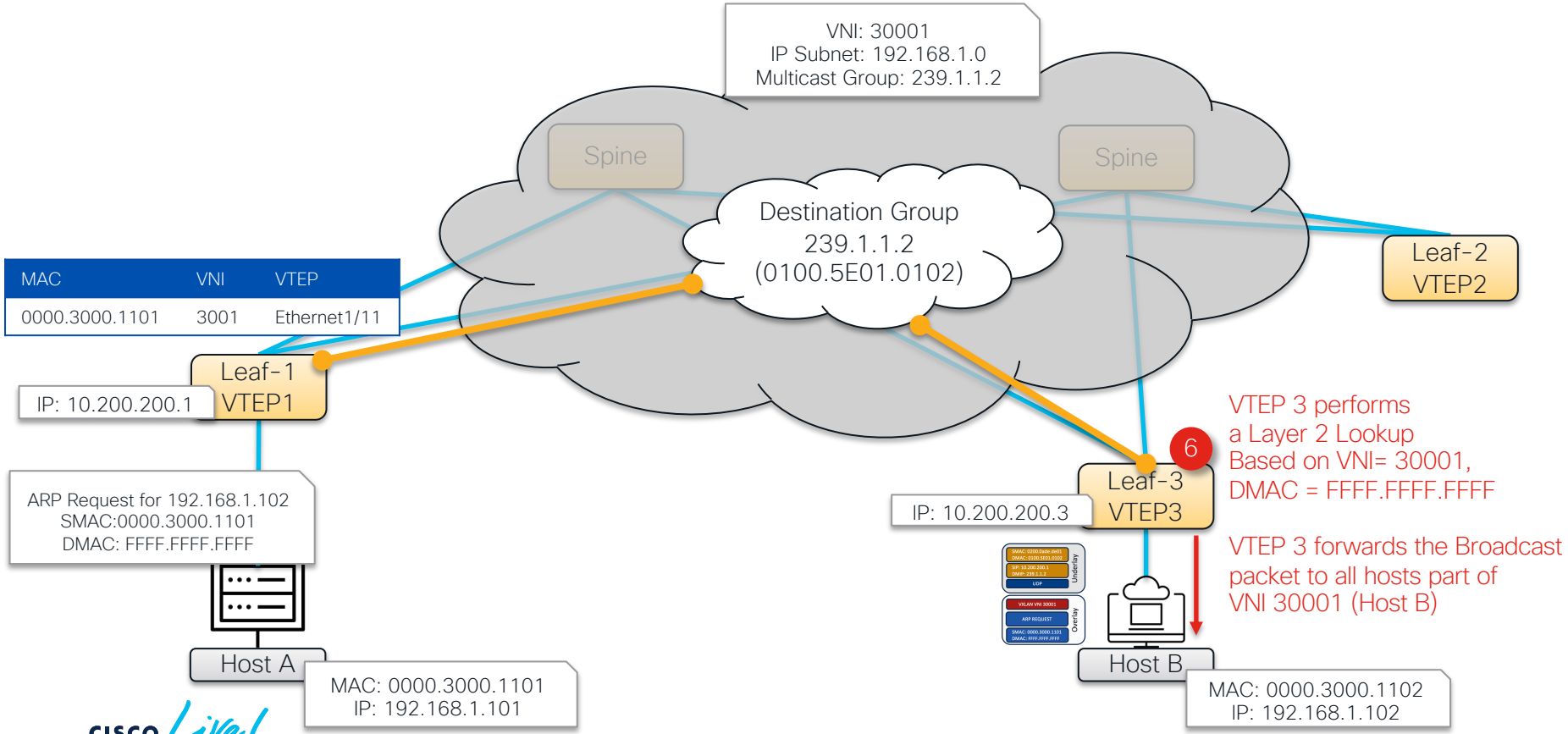
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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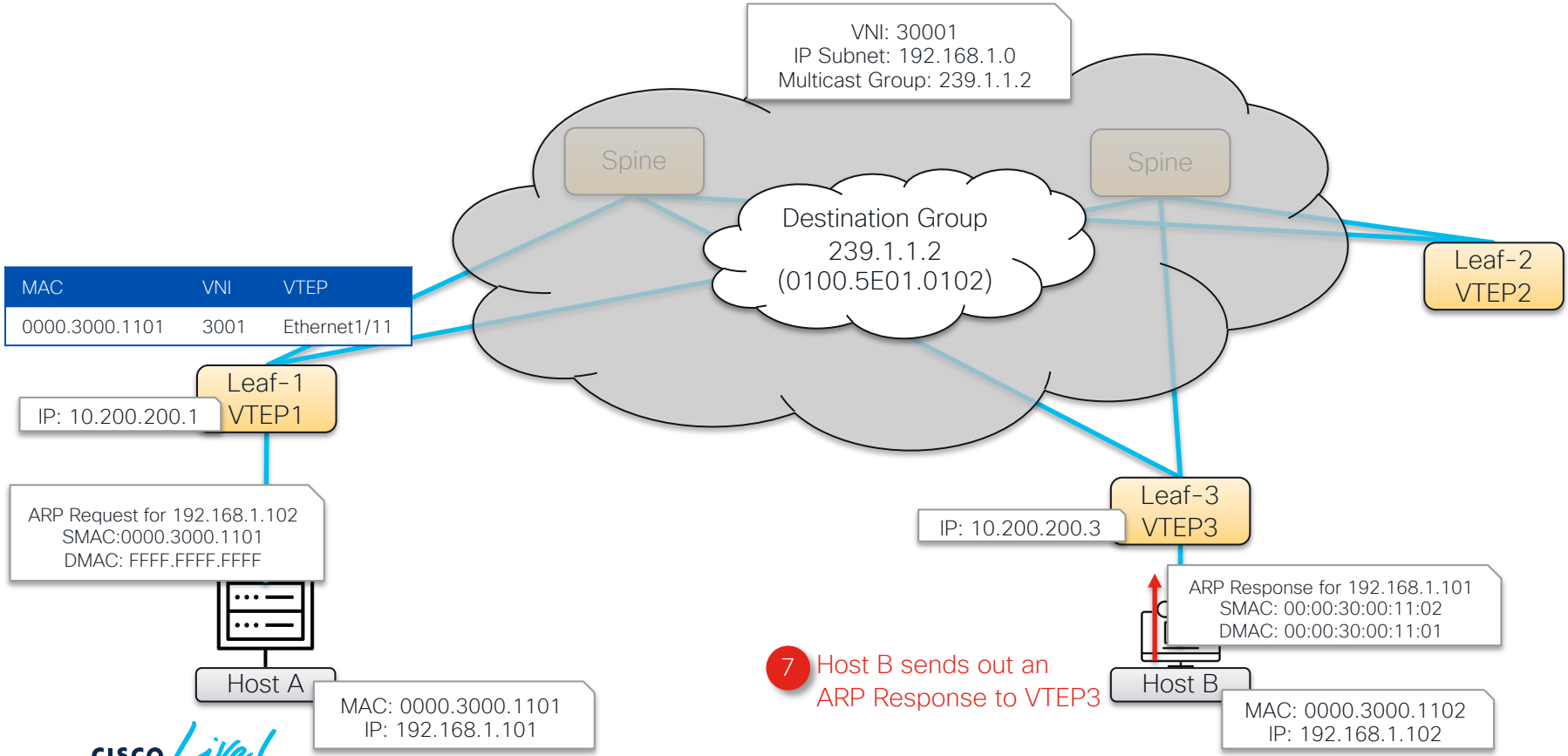
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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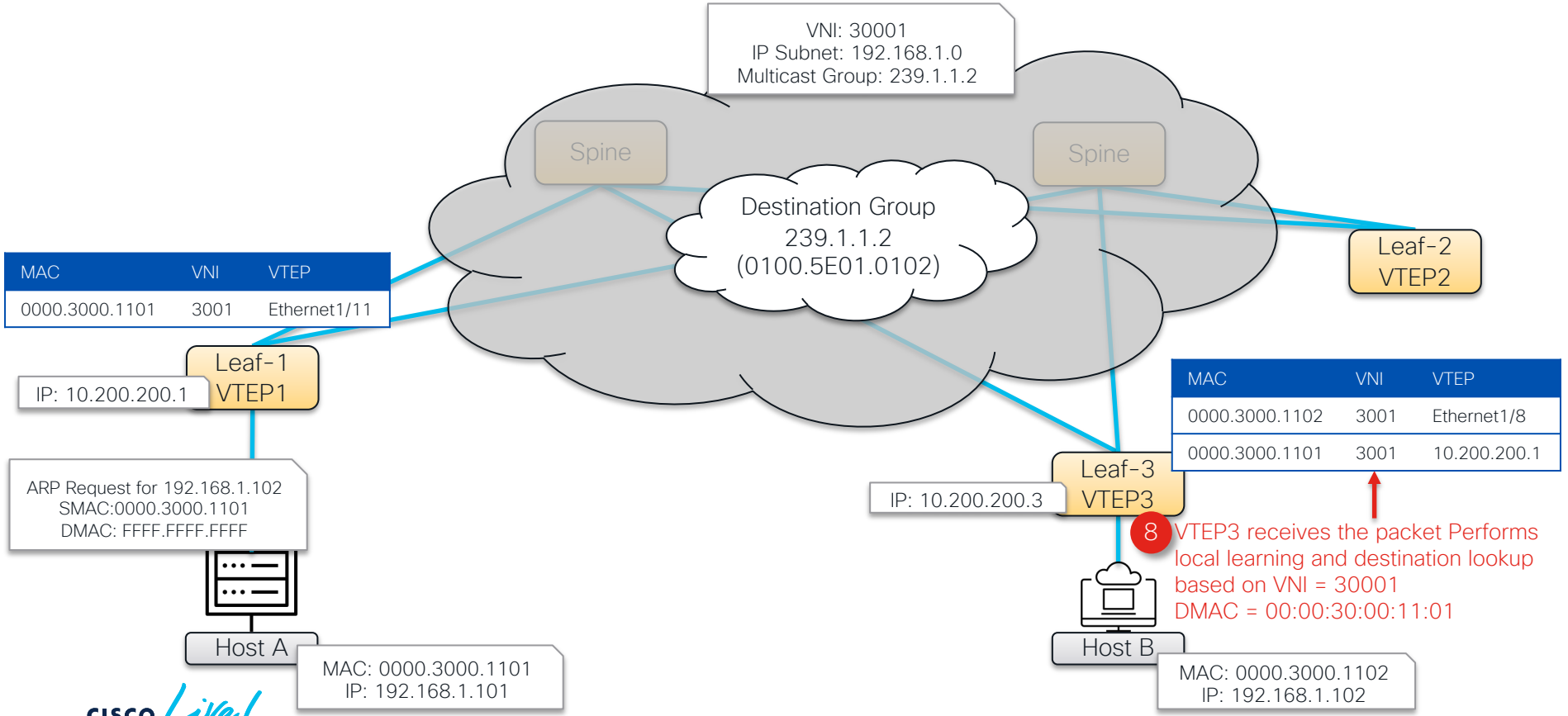
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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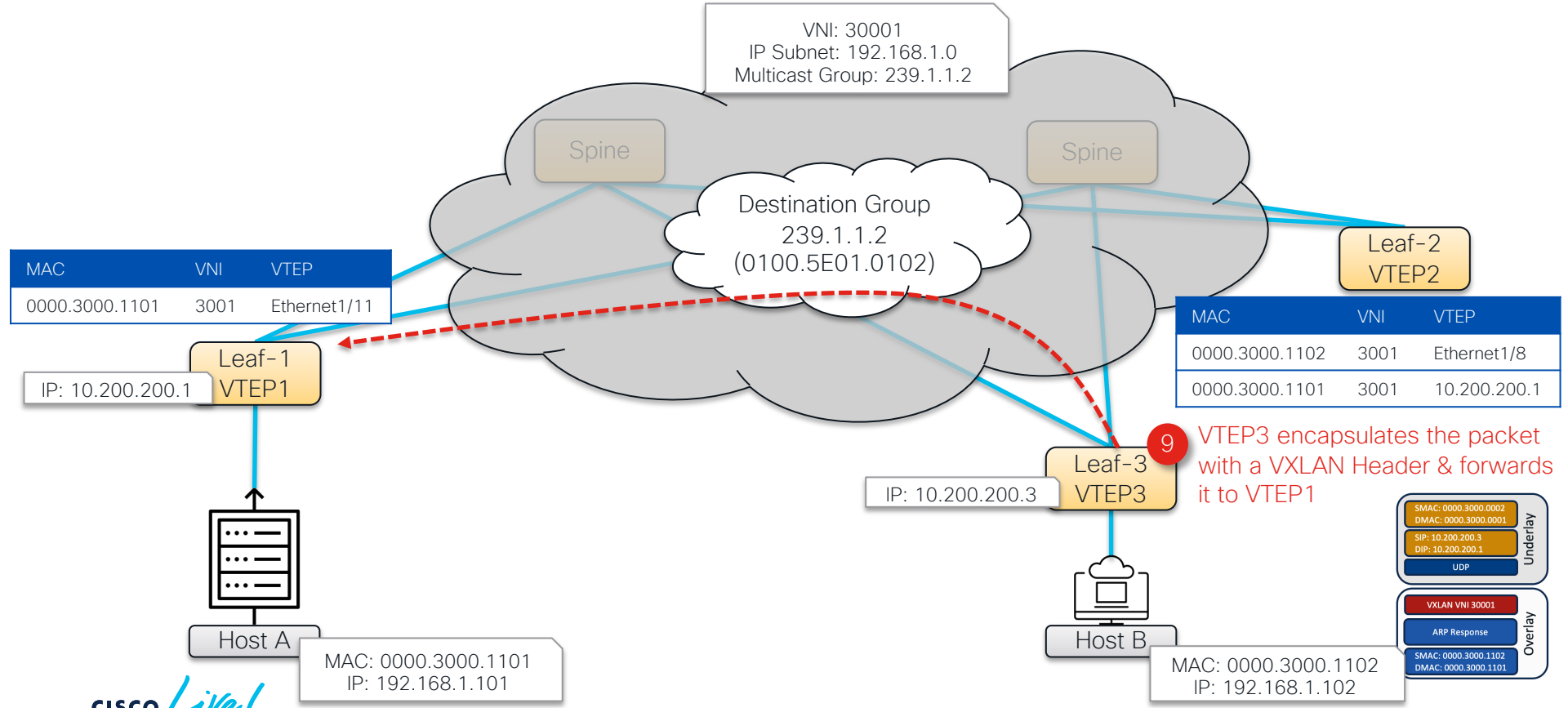
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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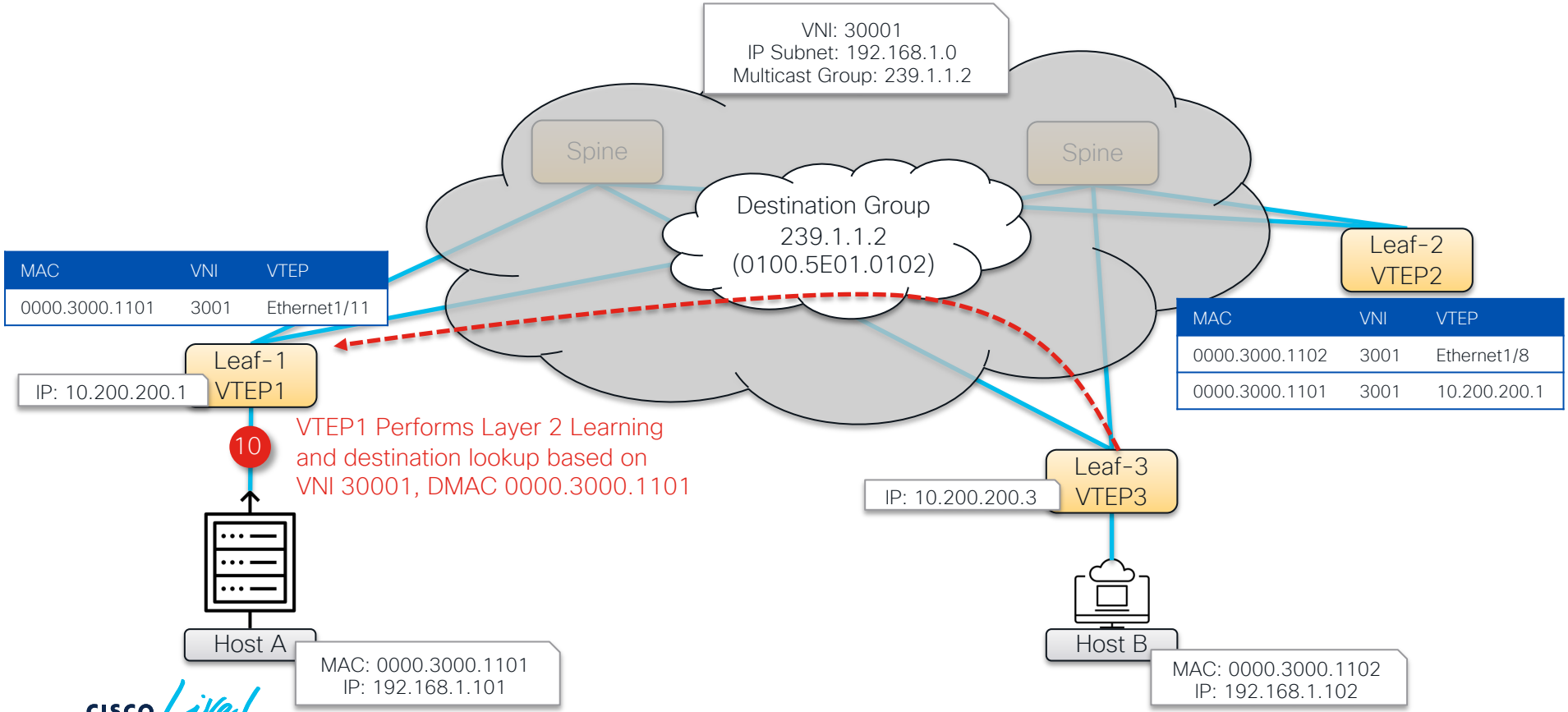
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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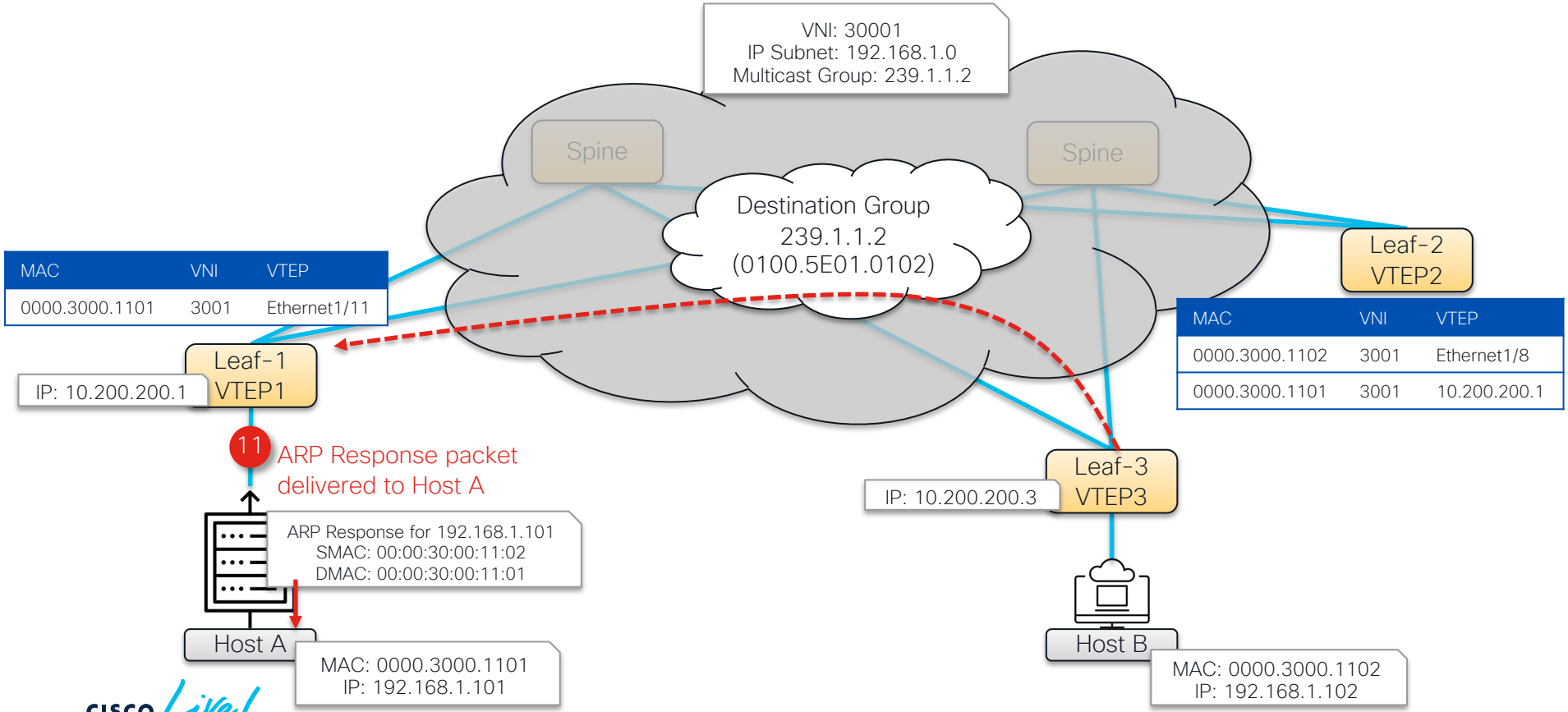
VXLAN Flood and Learn (F&L)
Host A to Host B Communication



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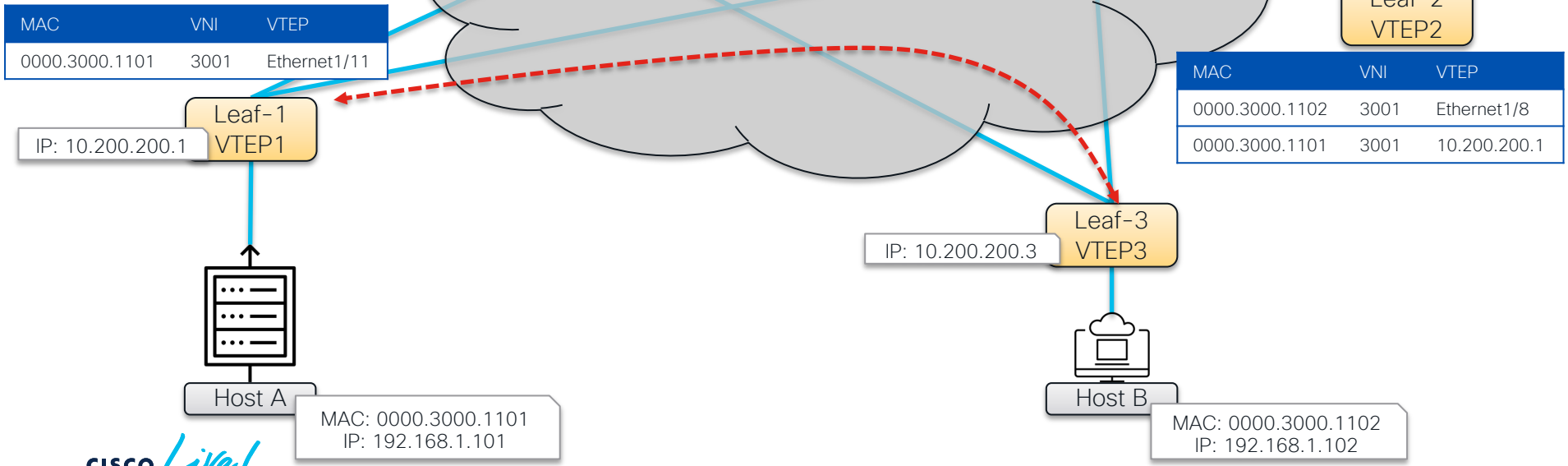
VXLAN Flood and Learn (F&L)
Host A to Host B Communication

- Host MAC Information is populated at both VTEPs (1&3)
- Host A & B know of each other's MAC-IP Binding
- Subsequent traffic between Host A & Host B is unicast over VXLAN between VTEP1 & VTEP3



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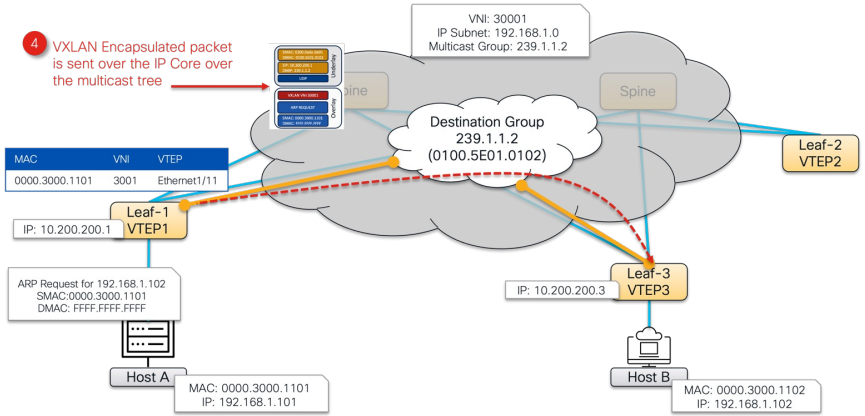
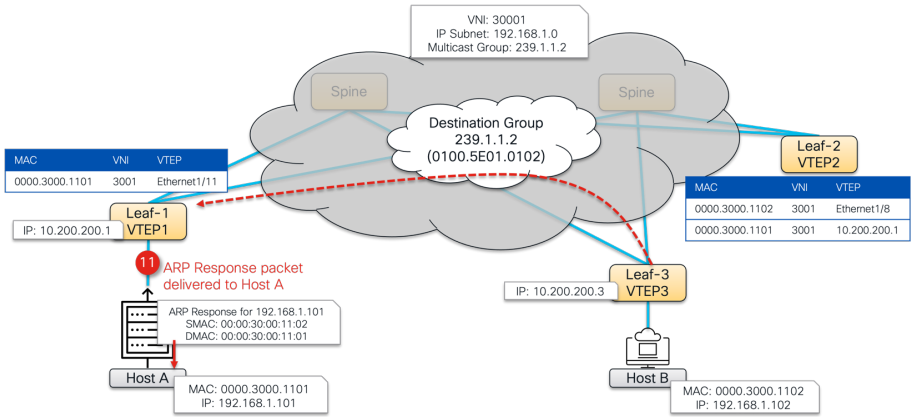
Flood & Learn Mechanism

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





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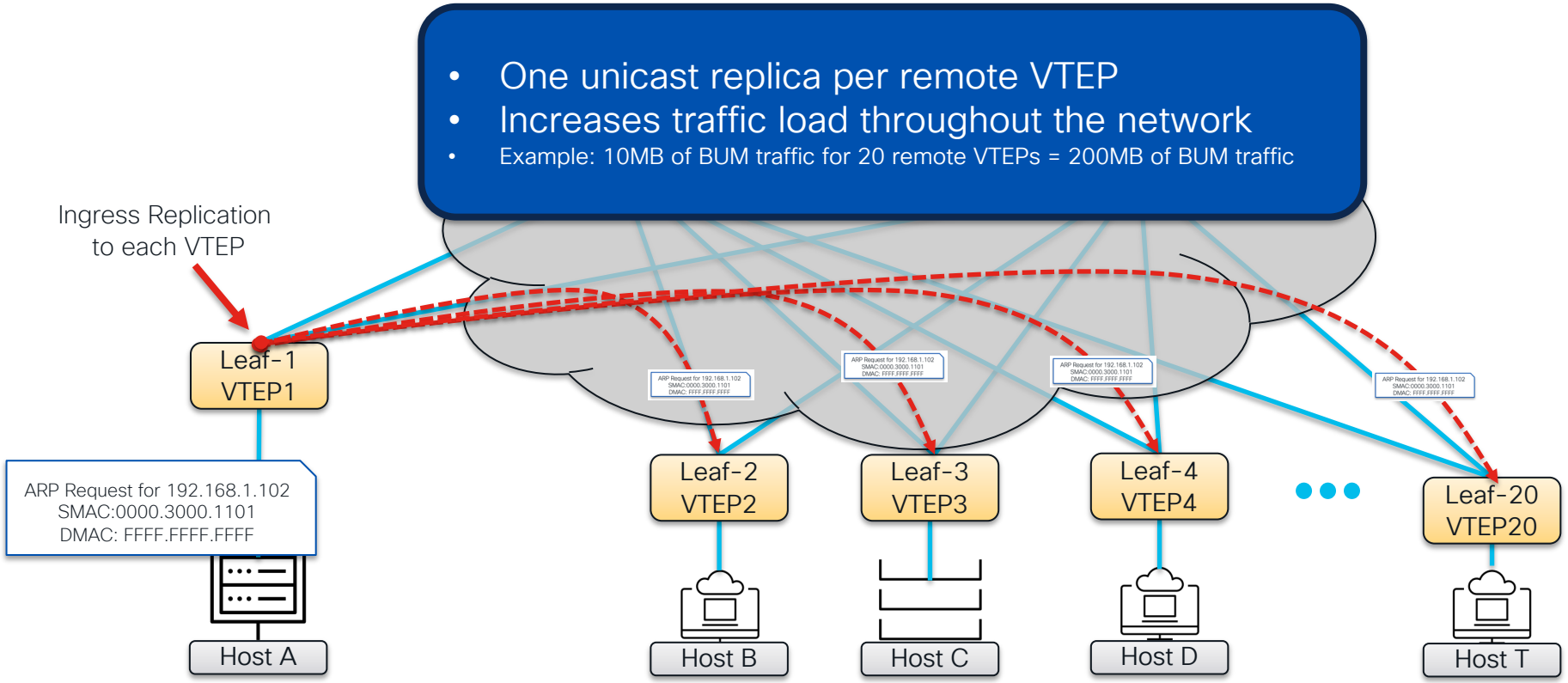
Flood & Learn Mechanism
Ingress Replication or Head-End Replication

- 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



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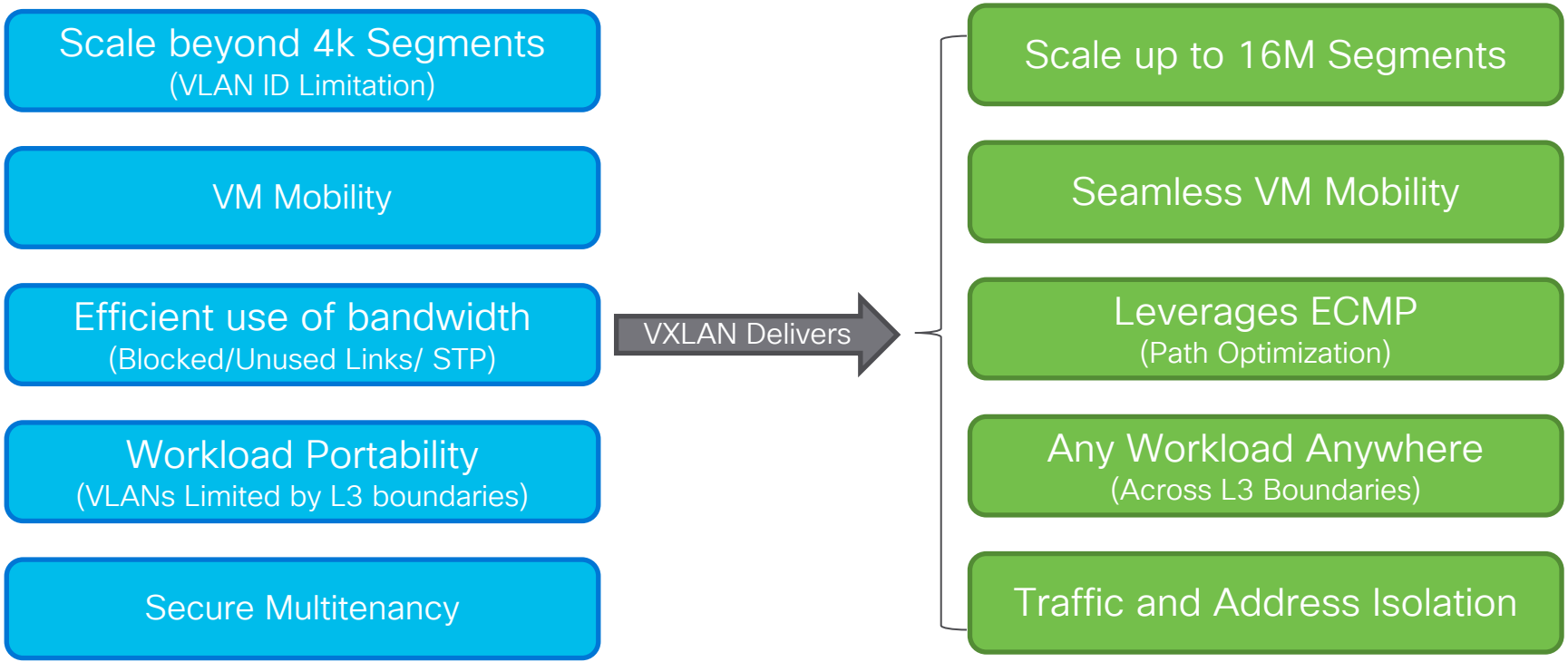
Why VXLAN? – How did we get here?



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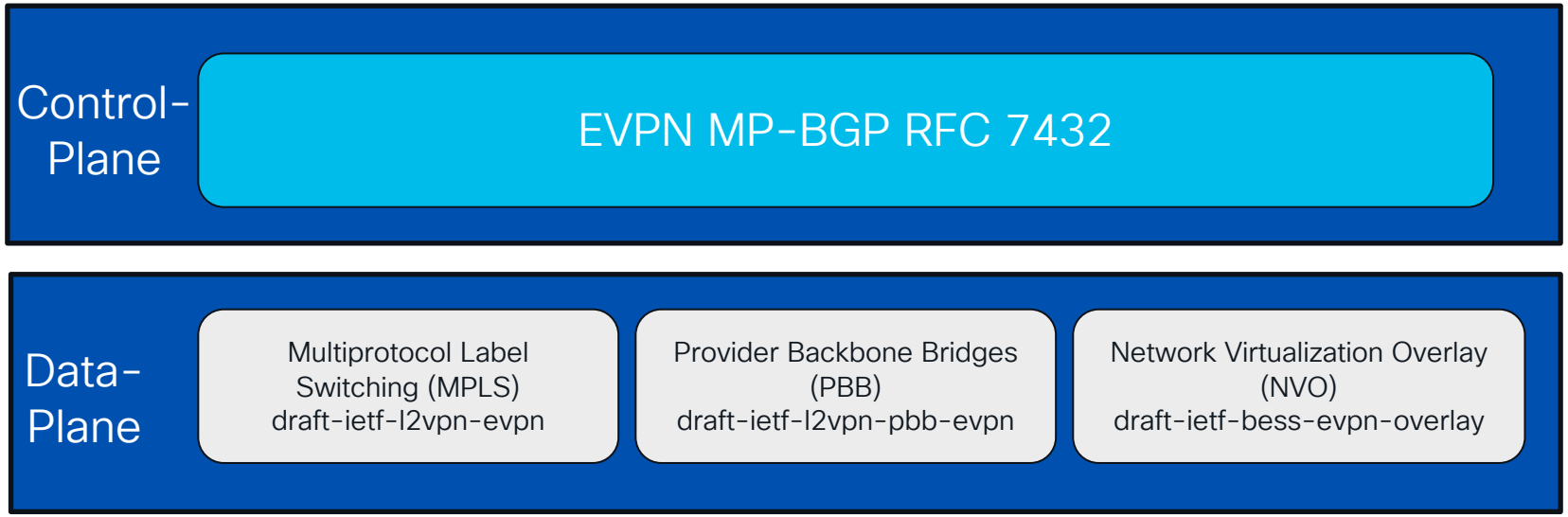
Control Plane
EVPN

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

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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

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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

*Type 6 – Selective Multicast Ethernet Tag Route
*Type 7/8 – IGMP Sync Routes

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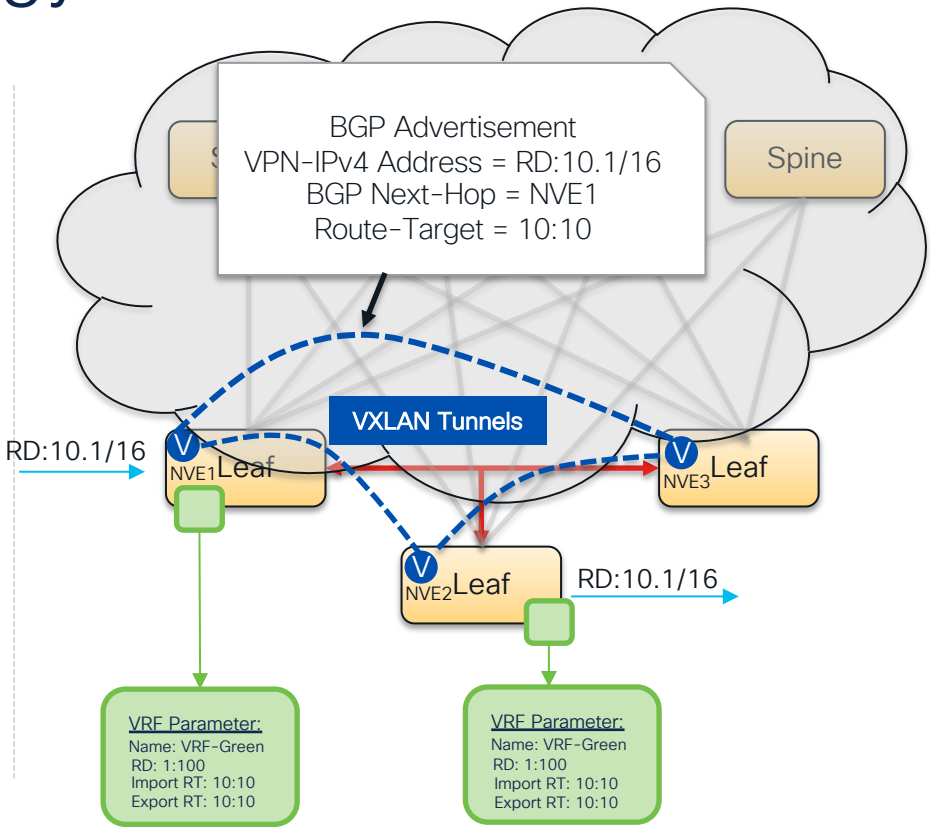
MP-BGP VPN Terminology

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



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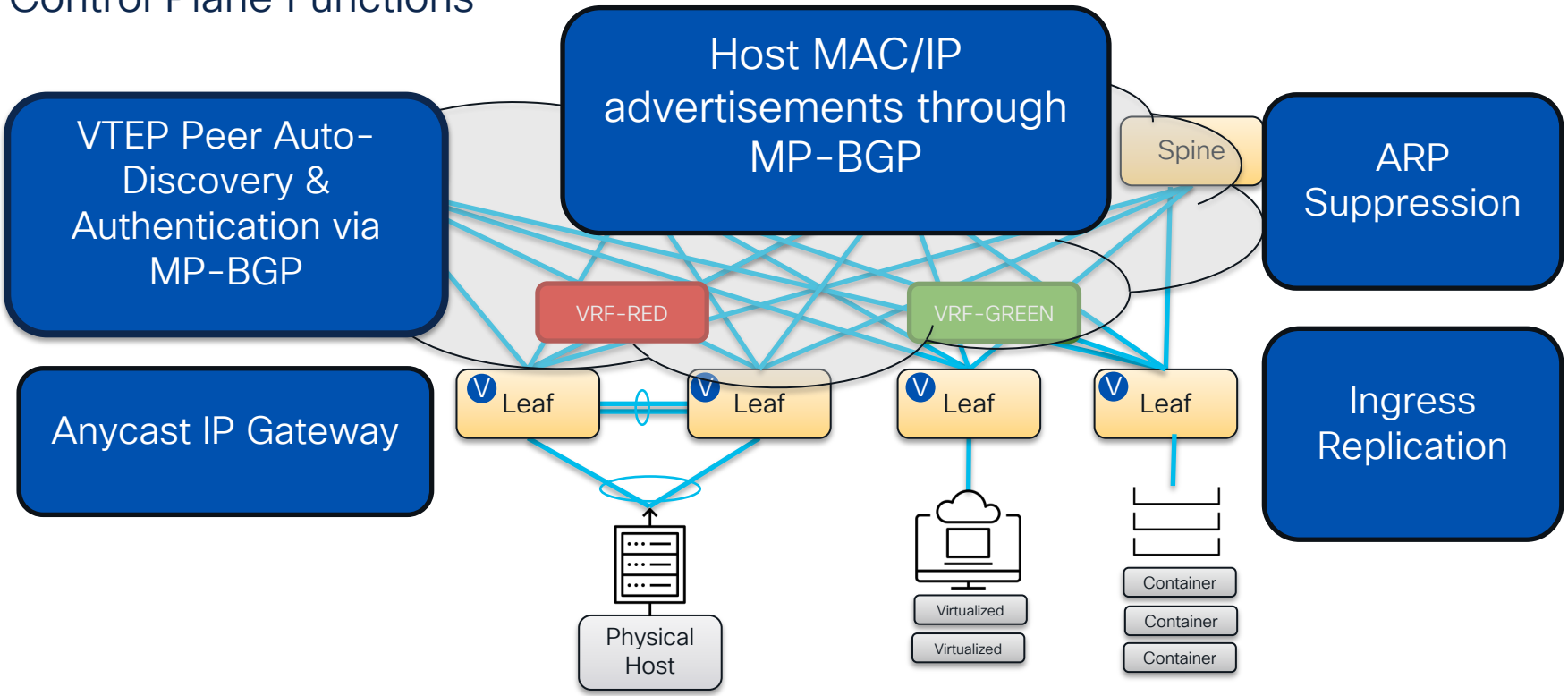
EVPN in the Data Center

Control Plane Functions



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Control-Plane Comparison

Flood&Learn (RFC7348)

- Ethernet over IP
  - No Spanning-Tree (terminates at NVE)
  - Endpoint Learning is based on Flood and Learn (it's in the name)
  - Requires Extra Work for Routing
    - FHRP for Default Gateway
    - Over-the-Top VRF-lite for Prefix Routing (or use the Underlay?!)

EVPN - Ethernet VPN (RFC8365)

- A Better Ethernet over IP
  - No Spanning-Tree (terminates at NVE)
  - Endpoint Learning is based on BGP exchange (EVPN uses BGP)
  - Provides Integrated Routing & Bridging (IRB)
    - Distributed Anycast Gateway for Default Gateway
    - Uses a Layer-3 VPN approach like MPLS L3VPN
  - And there is much more in EVPN!

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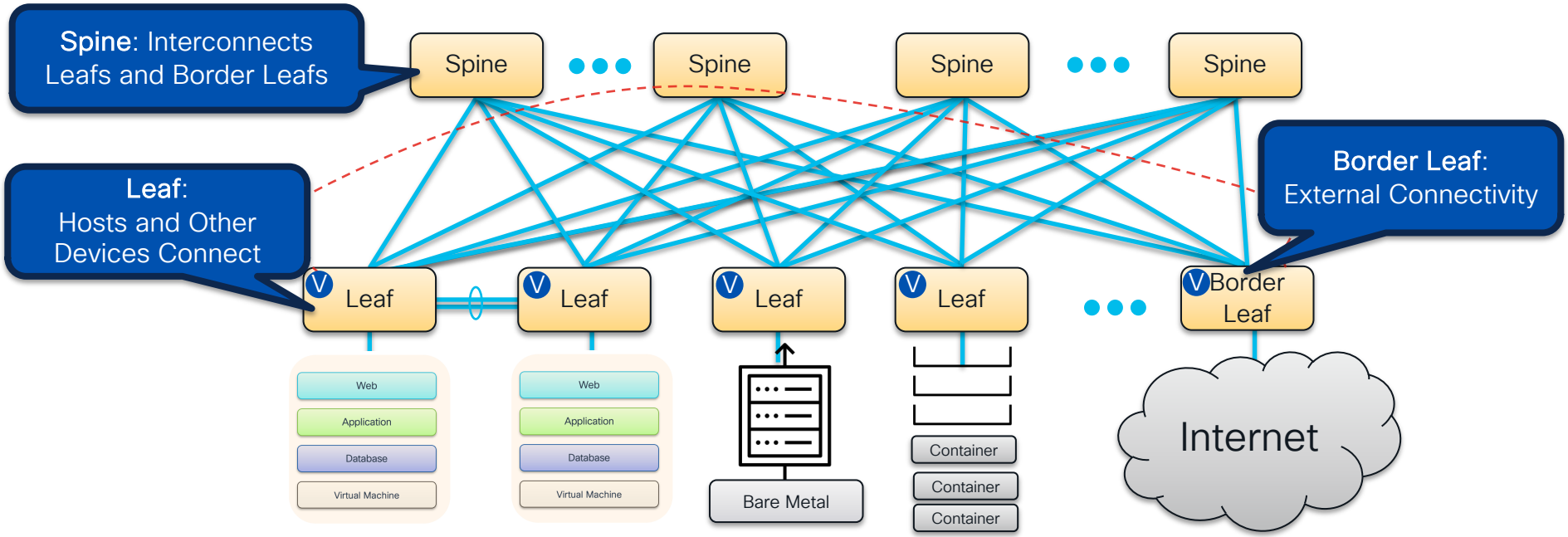
Configuring the EVPN VXLAN Fabric

VTEP Device Roles



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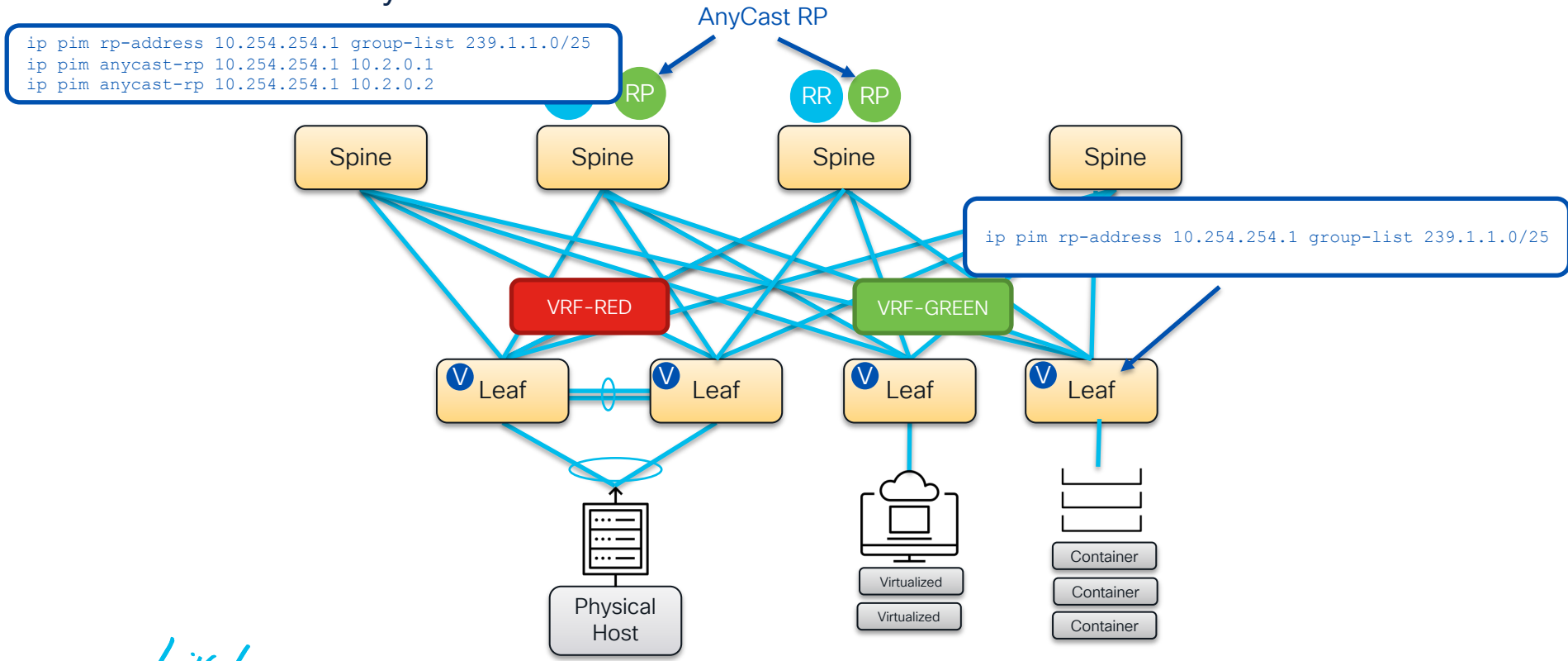
VXLAN BGP EVPN

Network Underlay



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VXLAN BGP EVPN

Network Underlay

RR Route Reflector

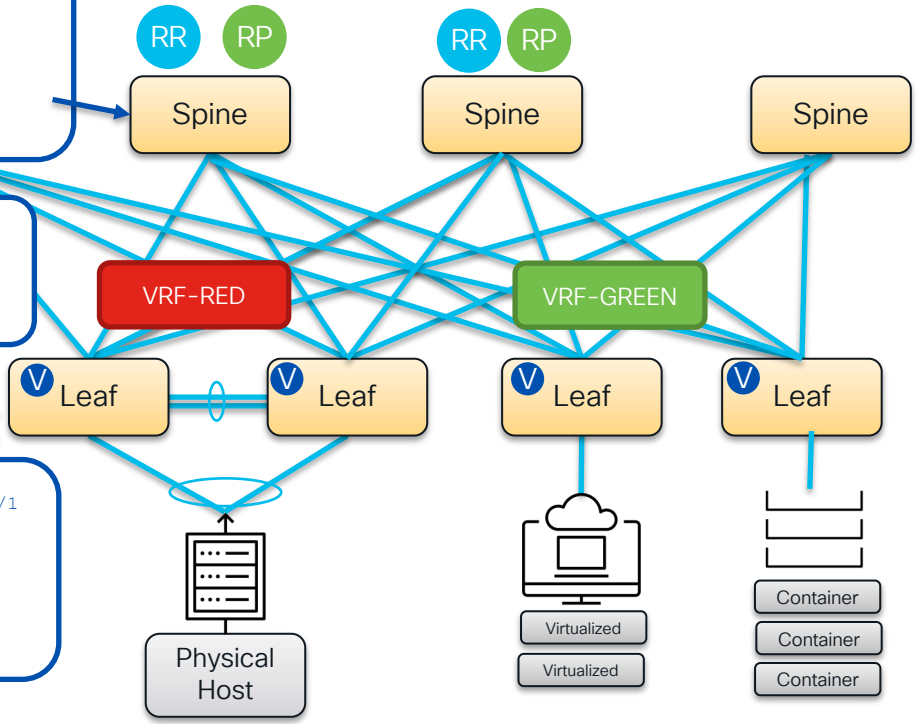
RP Rendezvous Point

```
interface Ethernet1/2
  description connected-to-leaf-1-Ethernet1/1
  no switchport
  mtu 9216
  ip address 10.4.0.5/30
  ip ospf network point-to-point
  ip router ospf UNDERLAY area 0.0.0.0
  ip pim sparse-mode
  no shutdown
```

```
interface loopback0
  description Routing loopback interface
  ip address 10.2.0.7/32
  ip router ospf UNDERLAY area 0.0.0.0
  ip pim sparse-mode
```

```
router ospf UNDERLAY
router-id 10.2.0.7
```

```
interface Ethernet1/2
  description connected-to-spine-1-Ethernet1/1
  no switchport
  mtu 9216
  ip address 10.4.0.6/30
  ip ospf network point-to-point
  ip router ospf UNDERLAY area 0.0.0.0
  ip pim sparse-mode
  no shutdown
```



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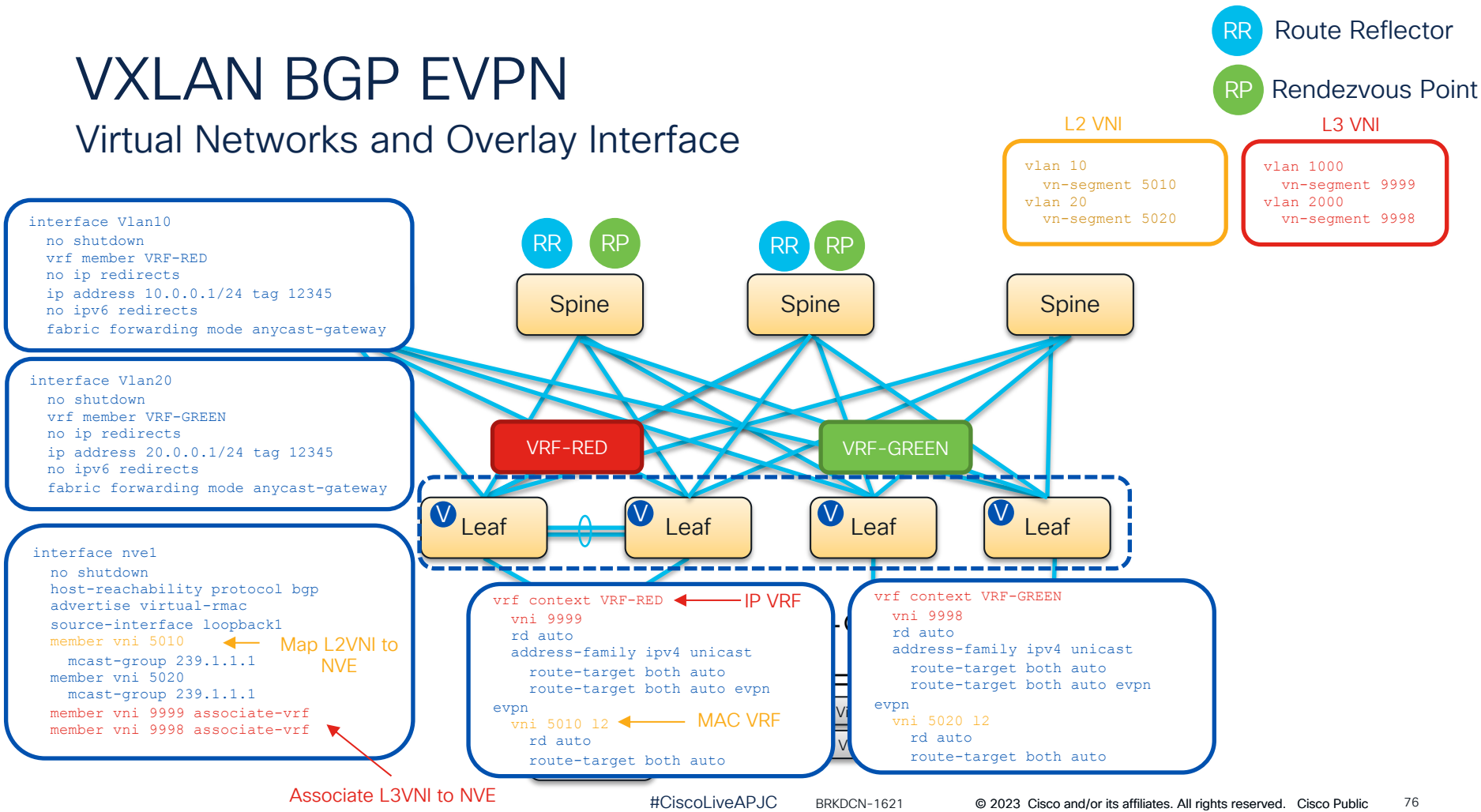
VXLAN BGP EVPN

Virtual Networks and Overlay Interface



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VXLAN BGP EVPN

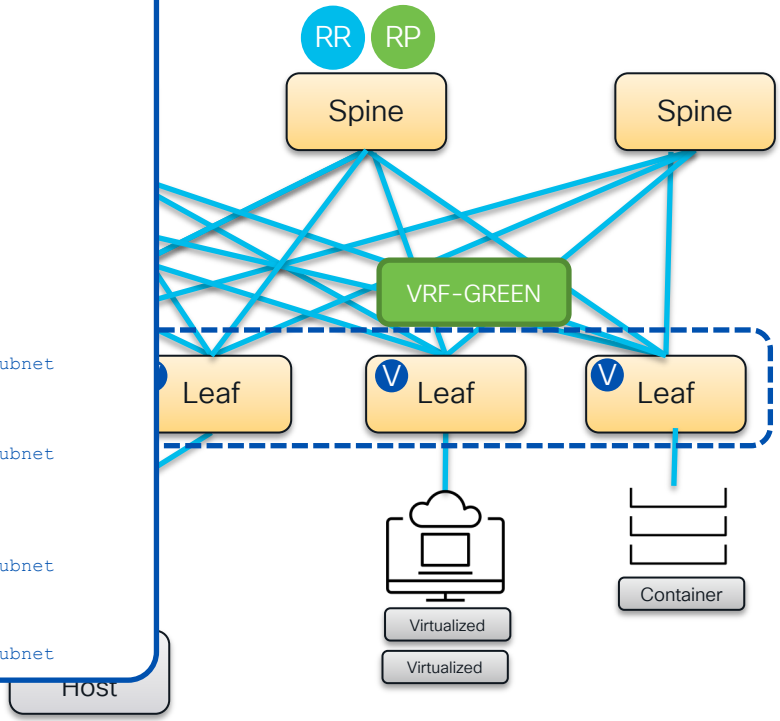
BGP on Leaf and Spine

RR Route Reflector

RP Rendezvous Point

Leaf BGP Config

```
router bgp 65010
  router-id 10.2.0.7
  address-family l2vpn evpn
    advertise-pip
  neighbor 10.2.0.1
    remote-as 65010
    update-source loopback0
    address-family l2vpn evpn
      send-community
      send-community extended
  neighbor 10.2.0.2
    remote-as 65010
    update-source loopback0
    address-family l2vpn evpn
      send-community
      send-community extended
vrf VRF-RED
    address-family ipv4 unicast
      advertise l2vpn evpn
      redistribute direct route-map fabric-rmap-redist-subnet
      maximum-paths ibgp 2
    address-family ipv6 unicast
      advertise l2vpn evpn
      redistribute direct route-map fabric-rmap-redist-subnet
      maximum-paths ibgp 2
vrf VRF-GREEN
    address-family ipv4 unicast
      advertise l2vpn evpn
      redistribute direct route-map fabric-rmap-redist-subnet
      maximum-paths ibgp 2
    address-family ipv6 unicast
      advertise l2vpn evpn
      redistribute direct route-map fabric-rmap-redist-subnet
```



Spine BGP Config

```
router bgp 65010
  router-id 10.2.0.2
  neighbor 10.2.0.3
    remote-as 65010
    update-source loopback0
    address-family l2vpn evpn
      send-community
      send-community extended
      route-reflector-client
  neighbor 10.2.0.4
    remote-as 65010
    update-source loopback0
    address-family l2vpn evpn
      send-community
      send-community extended
      route-reflector-client
  neighbor 10.2.0.5
    remote-as 65010
    update-source loopback0
    address-family l2vpn evpn
      send-community
      send-community extended
      route-reflector-client
```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VXLAN BGP EVPN

Distributed Anycast Gateway

RR Route Reflector

RP Rendezvous Point

VLAN to VNI Mapping

```
vlan 20
  vn-segment 5020
```

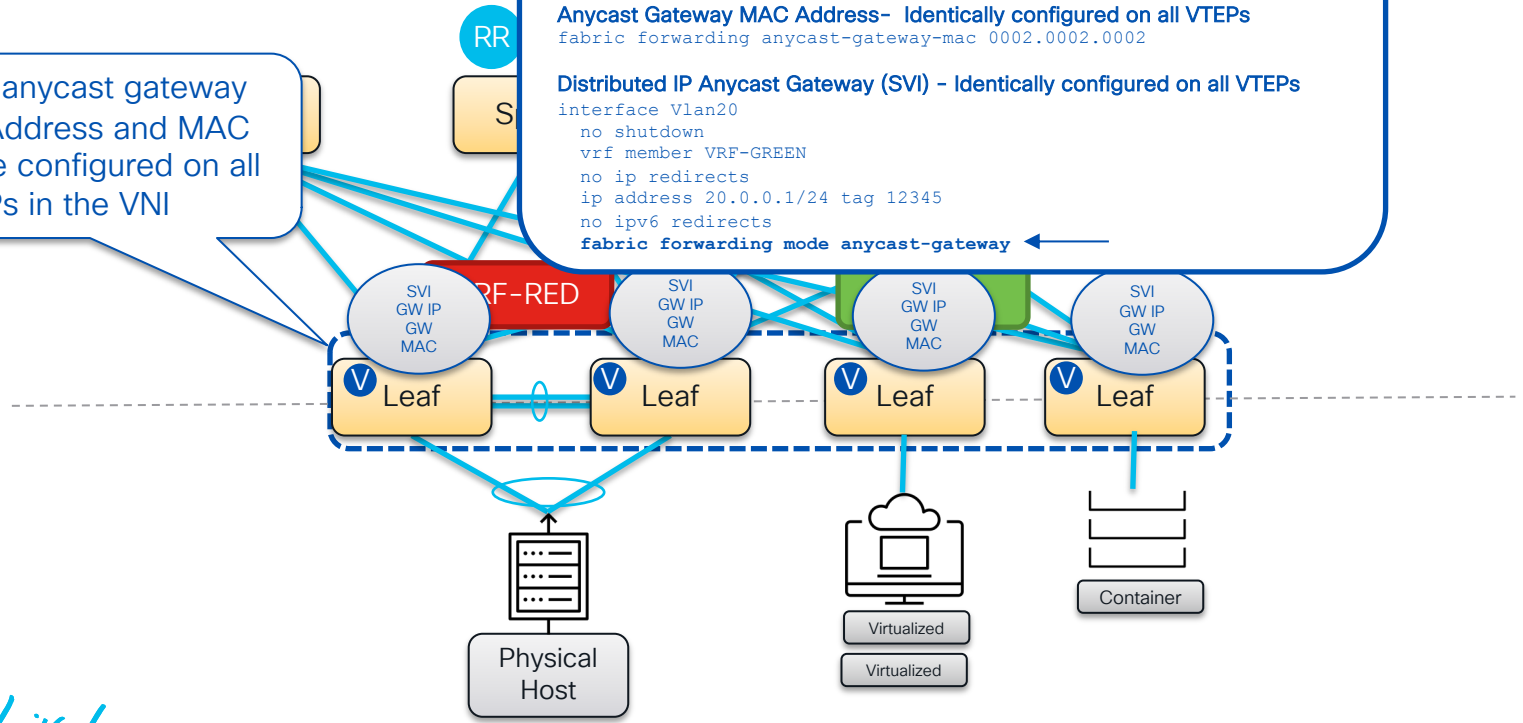
Anycast Gateway MAC Address- Identically configured on all VTEPs

```
fabric forwarding anycast-gateway-mac 0002.0002.0002
```

Distributed IP Anycast Gateway (SVI) - Identically configured on all VTEPs

```
interface Vlan20
  no shutdown
  vrf member VRF-GREEN
  no ip redirects
  ip address 20.0.0.1/24 tag 12345
  no ipv6 redirects
  fabric forwarding mode anycast-gateway
```

The same anycast gateway Virtual IP Address and MAC address are configured on all VTEPs in the VNI



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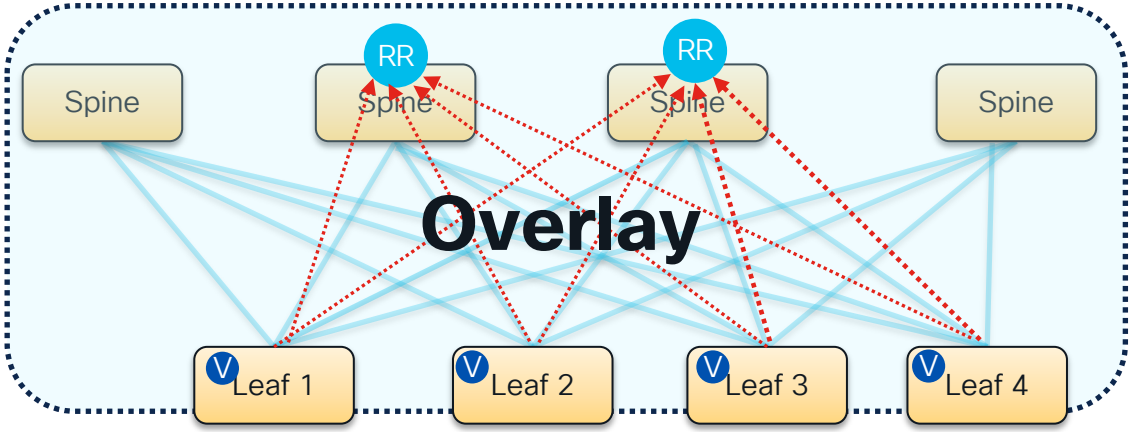
EVPN Peer and Host Discovery L2VNI

VXLAN BGP EVPN

Host and Subnet Distribution

RR Route Reflector



- Host Route Distribution decoupled from the Underlay protocol
- Use Multi-protocol-BGP (MP-BGP) on the leaf nodes to distribute internal Host/Subnet Routes and external reachability information
- Route-Reflectors (RR) deployed for scaling purposes

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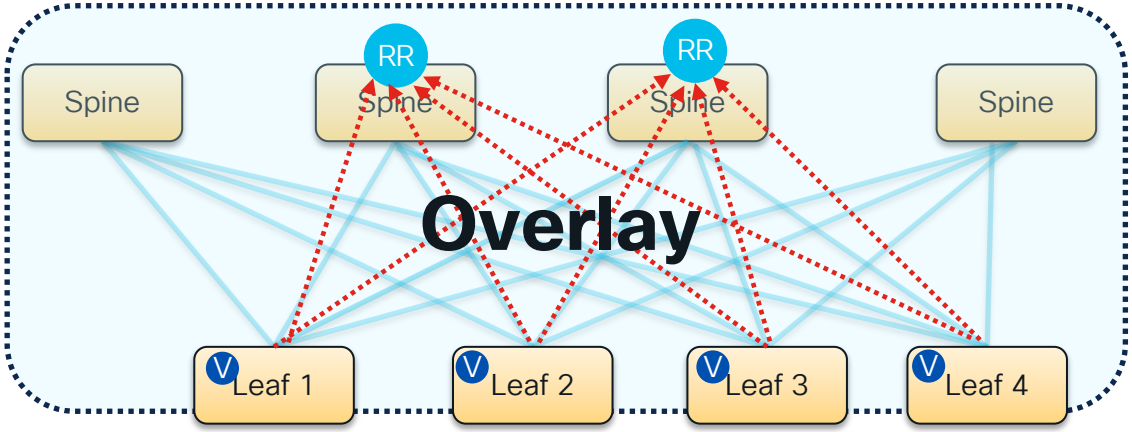
VXLAN BGP EVPN

Host and Subnet Routes

RR Route Reflector



- BGP EVPN NLRI
  (Network Layer Reachability Information)
  BGP Update Format
- Host MAC (Route Type 2)
  - MAC only, Single VNI, Single Route Target
- Host MAC + IP (Route Type 2)
  - MAC and IP, Two VNI, Two Route Targets, Router MAC
- Internal and External Subnet Prefixes (Route Type 5)
  - IP Subnet Prefix, Single VNI, Single Route Target

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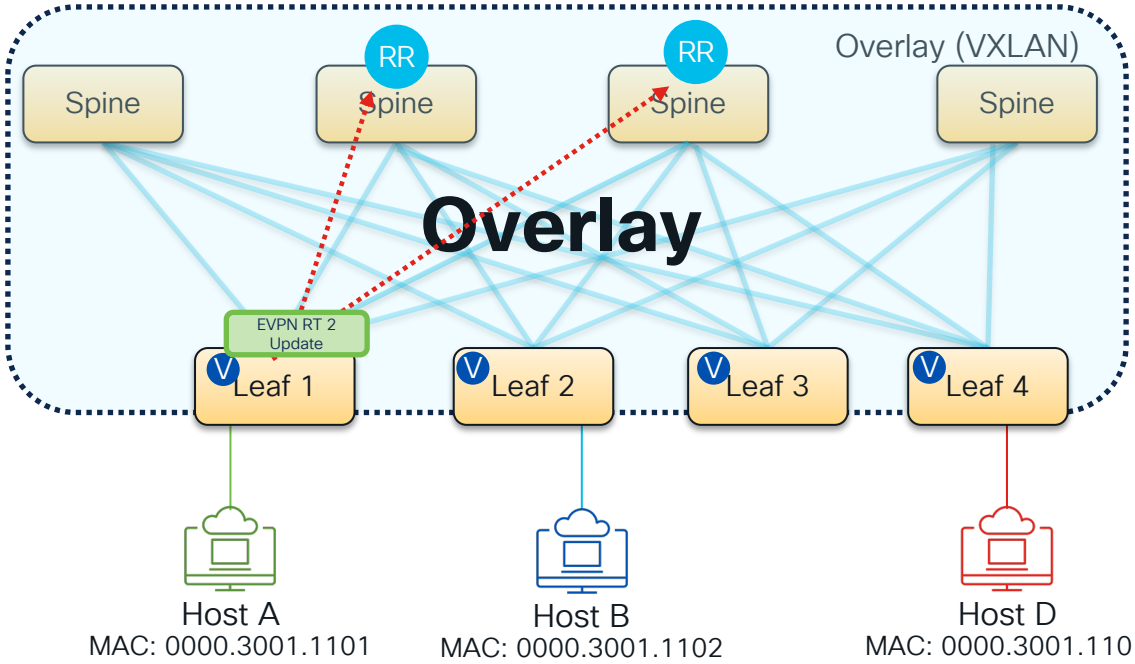
EVPN Control Plane

Host Advertisements



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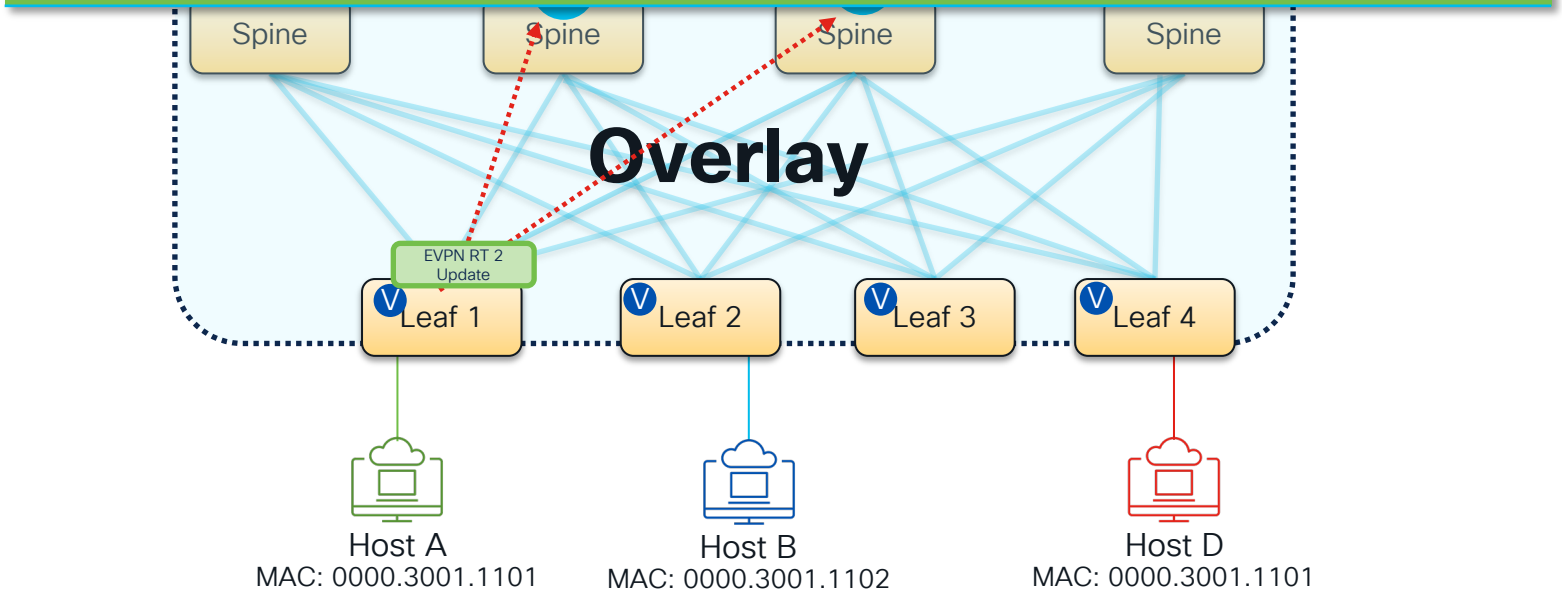
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0



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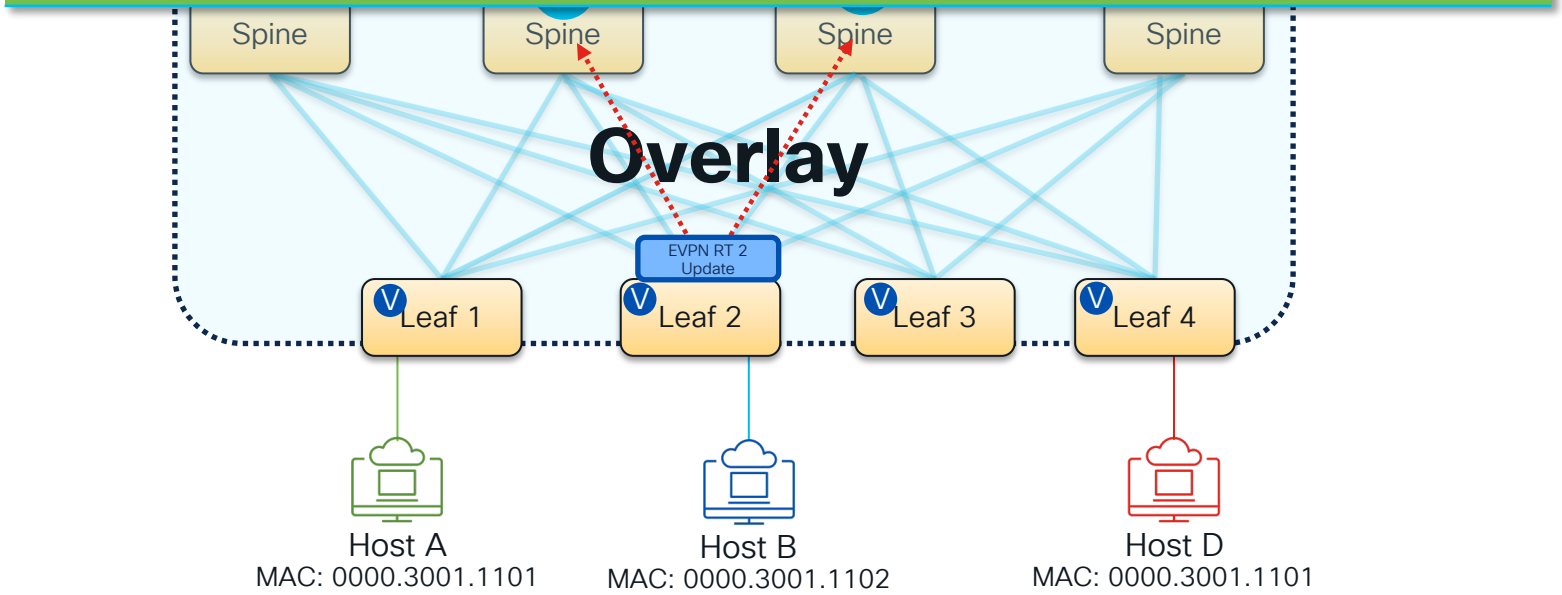
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0



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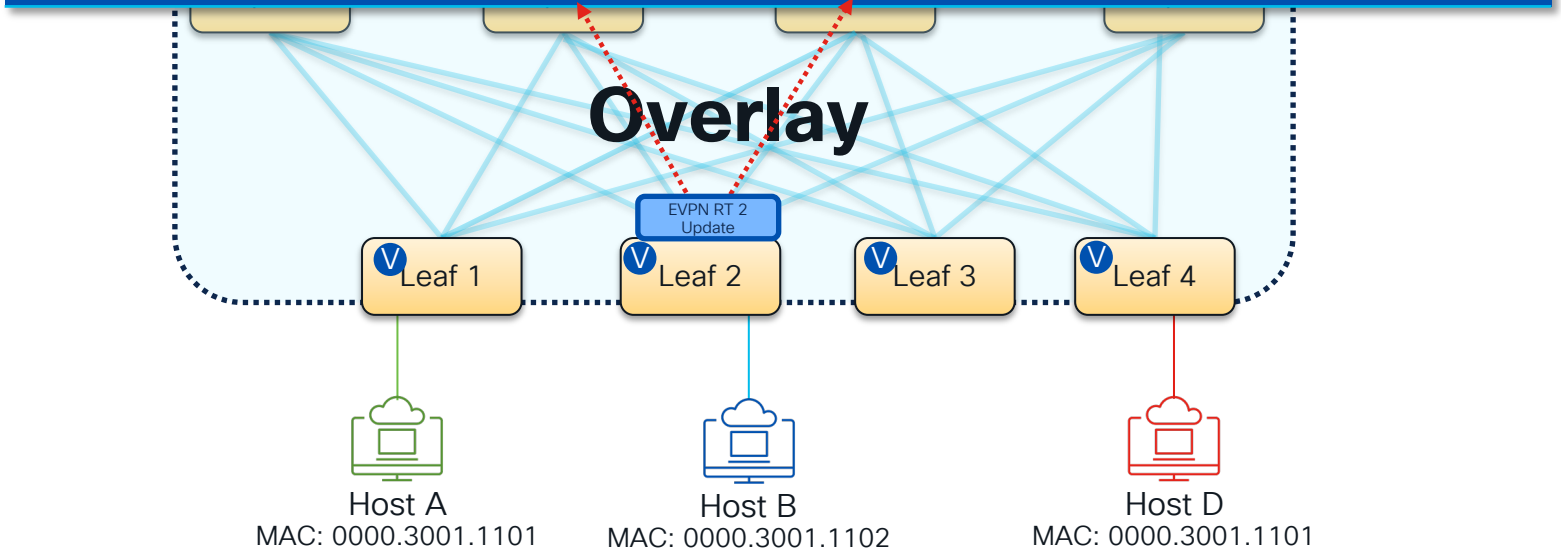
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	-	-	10.200.200.102	0



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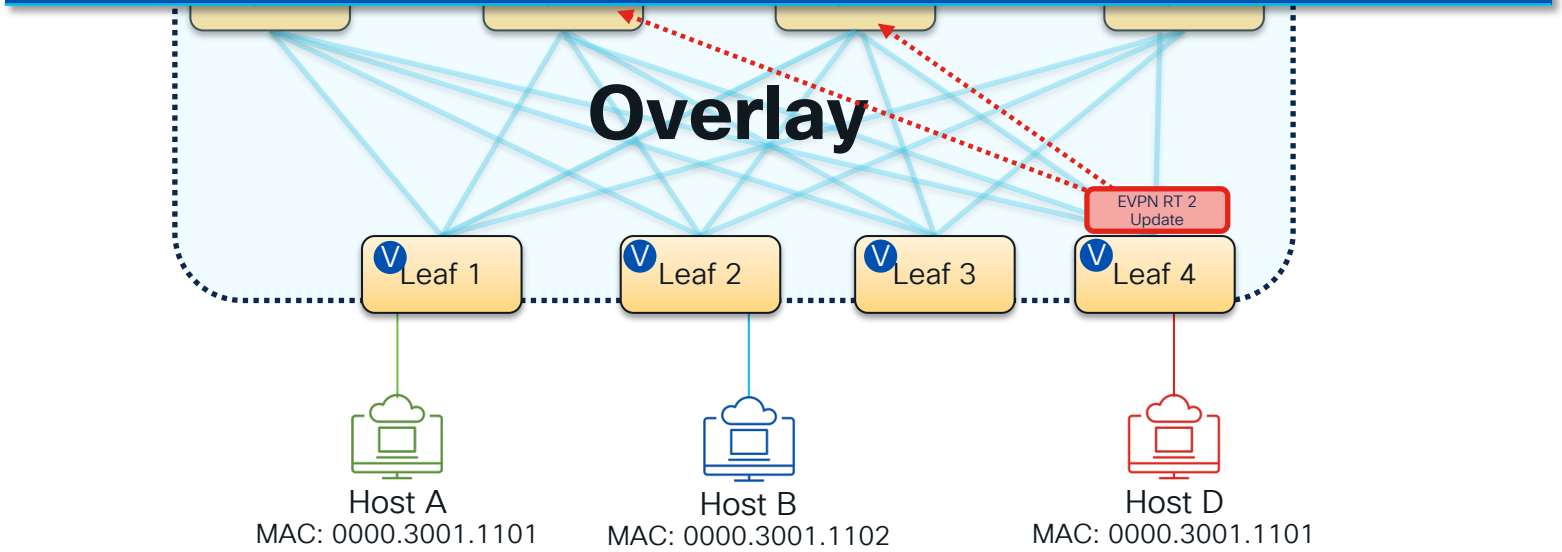
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	-	-	10.200.200.102	0



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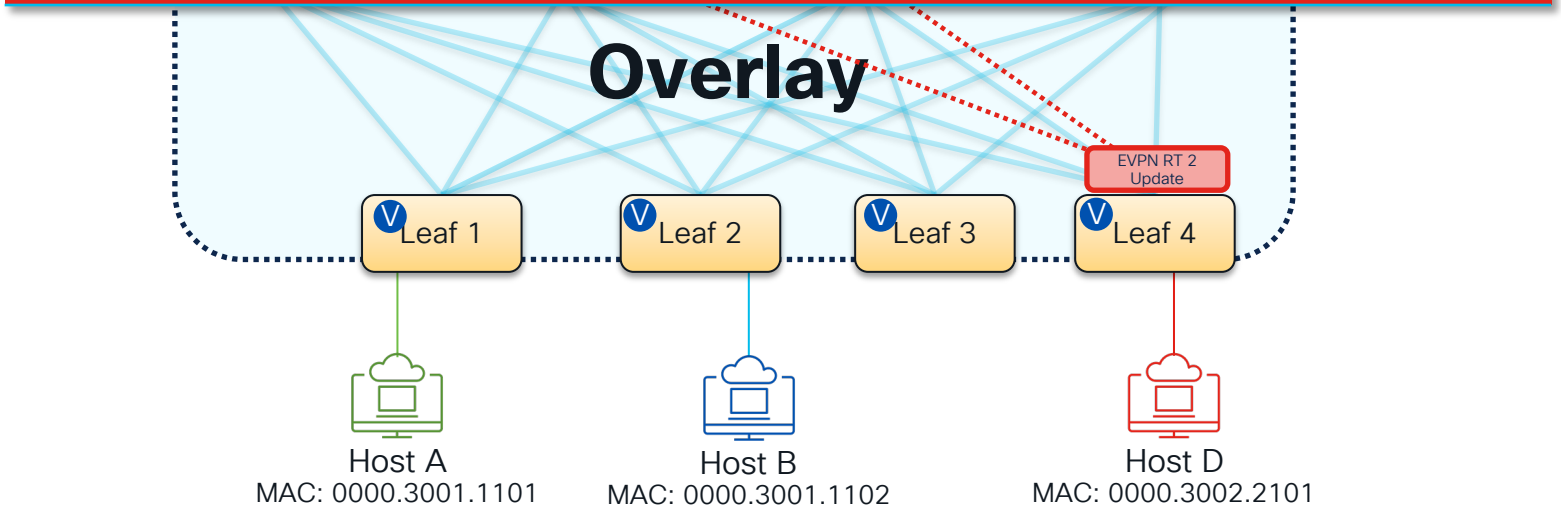
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	-	-	10.200.200.102	0
2	0000.3002.2101 / 48	3002, 65500:3001	-	-	10.200.200.104	0



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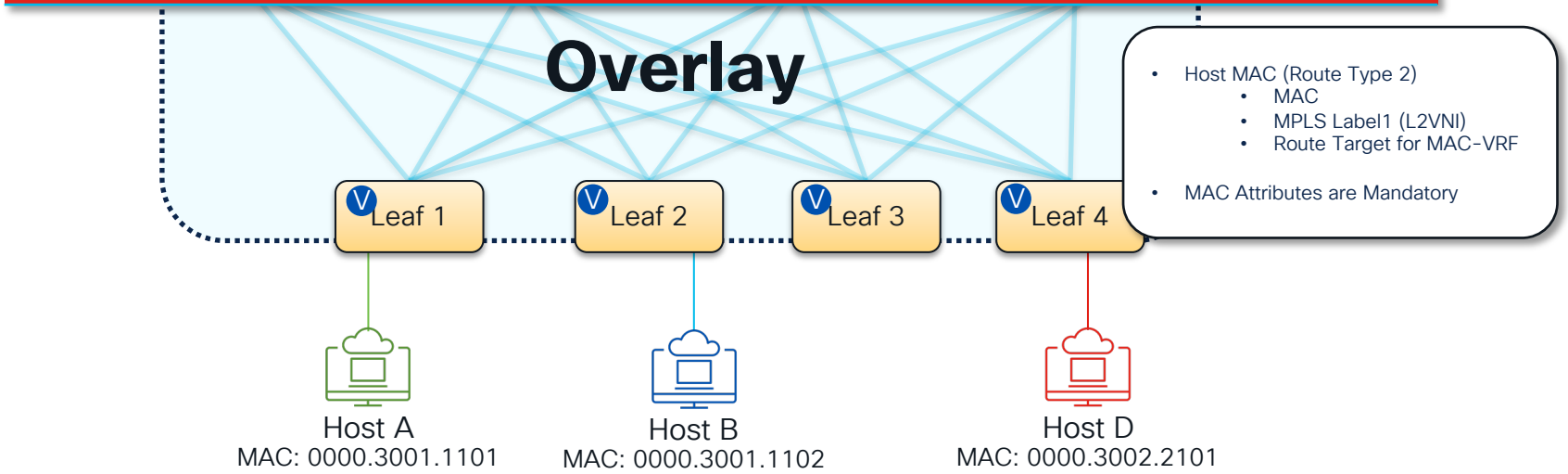
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	-	-	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	-	-	10.200.200.102	0
2	0000.3002.2101 / 48	3002, 65500:3001	-	-	10.200.200.104	0



- Host MAC (Route Type 2)
  - MAC
  - MPLS Label1 (L2VNI)
  - Route Target for MAC-VRF
- MAC Attributes are Mandatory

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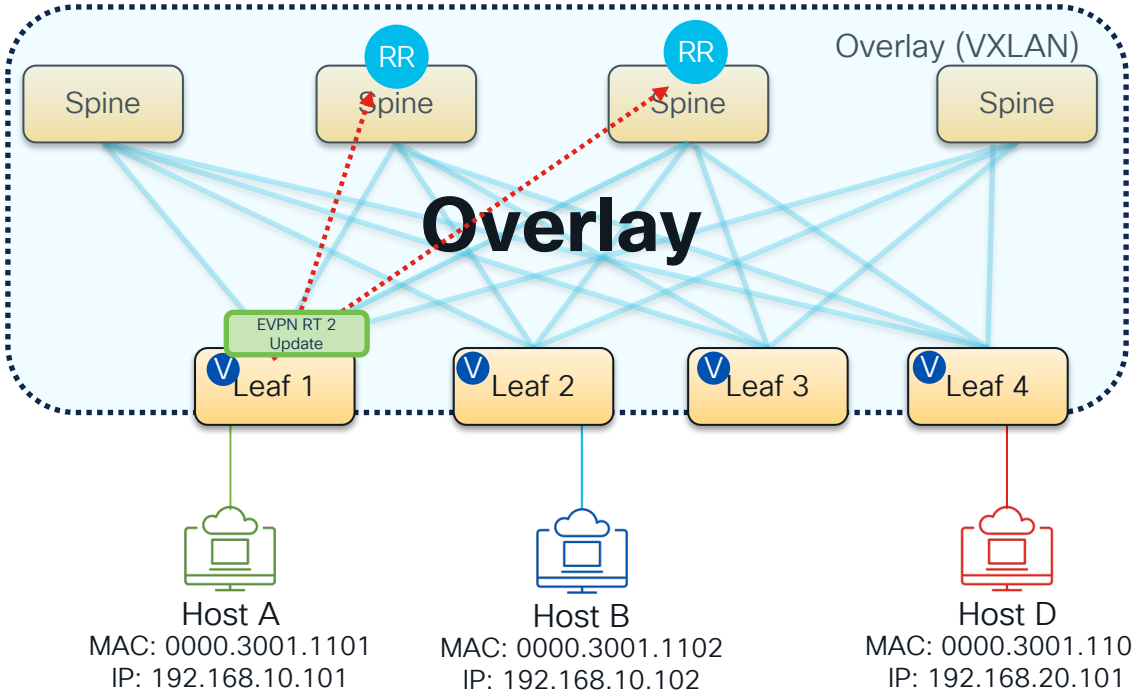
EVPN Peer and Host Discovery L3VNI

EVPN Control Plane

Host Advertisements



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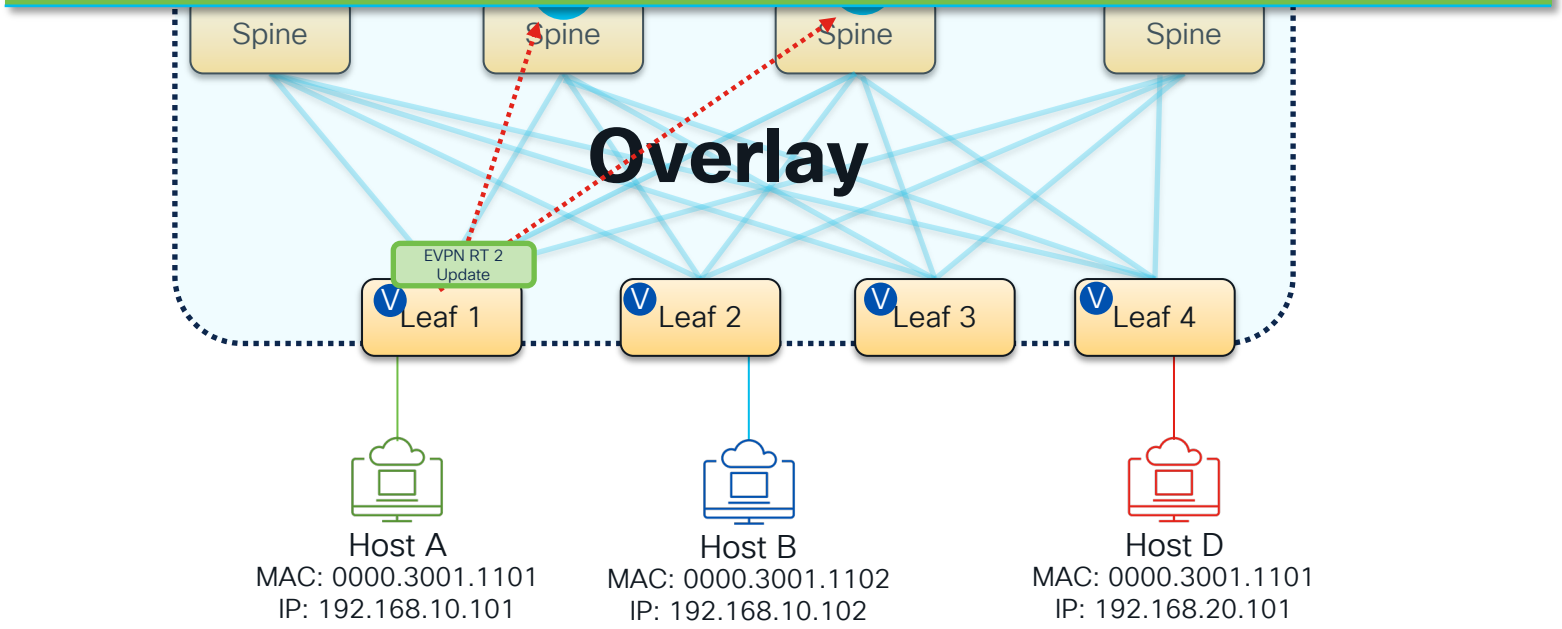
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0



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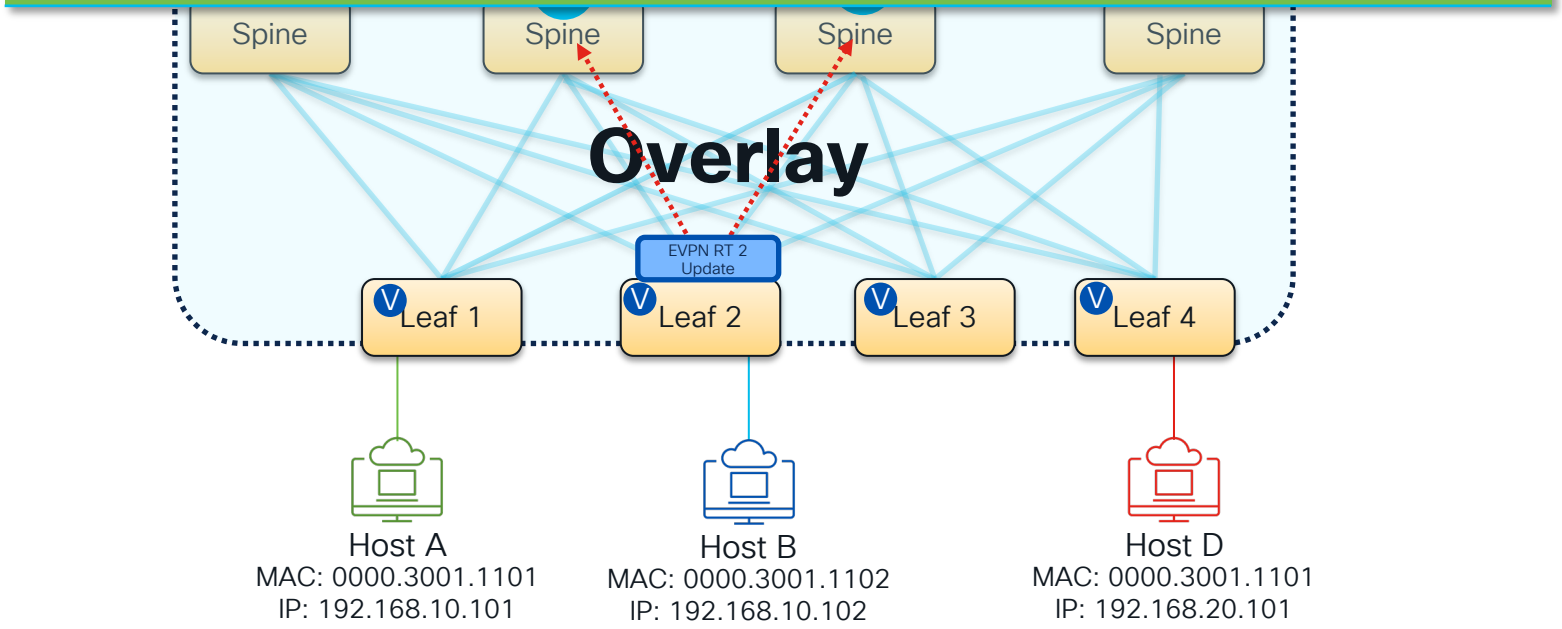
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0



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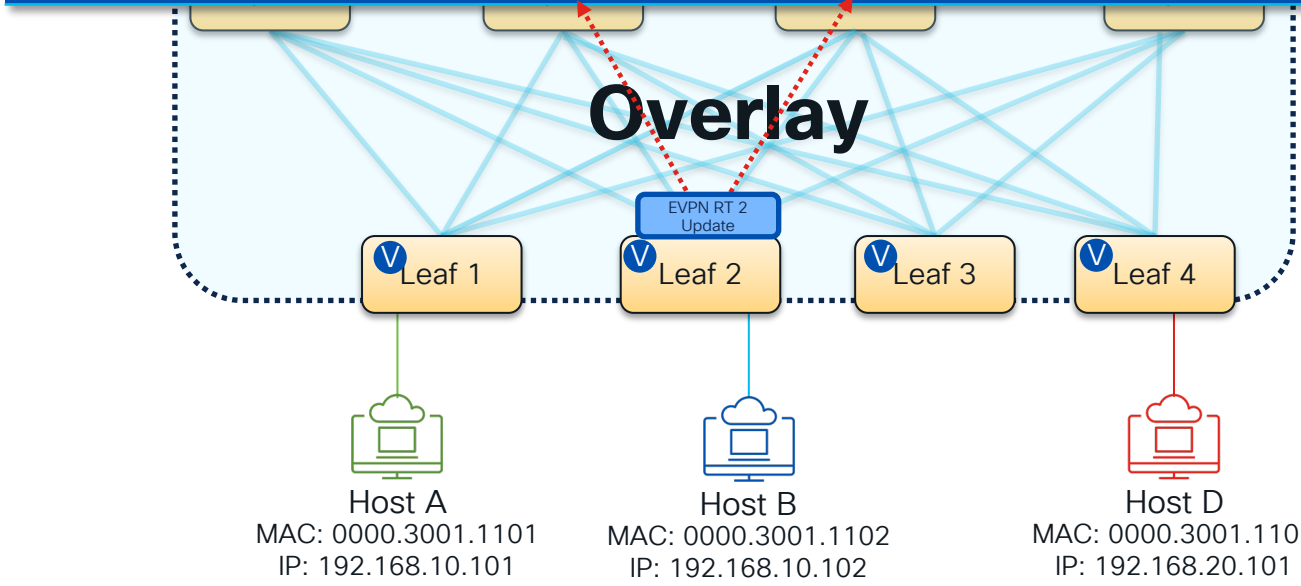
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	192.168.10.102/32	5000, 65500:5000	10.200.200.102	0



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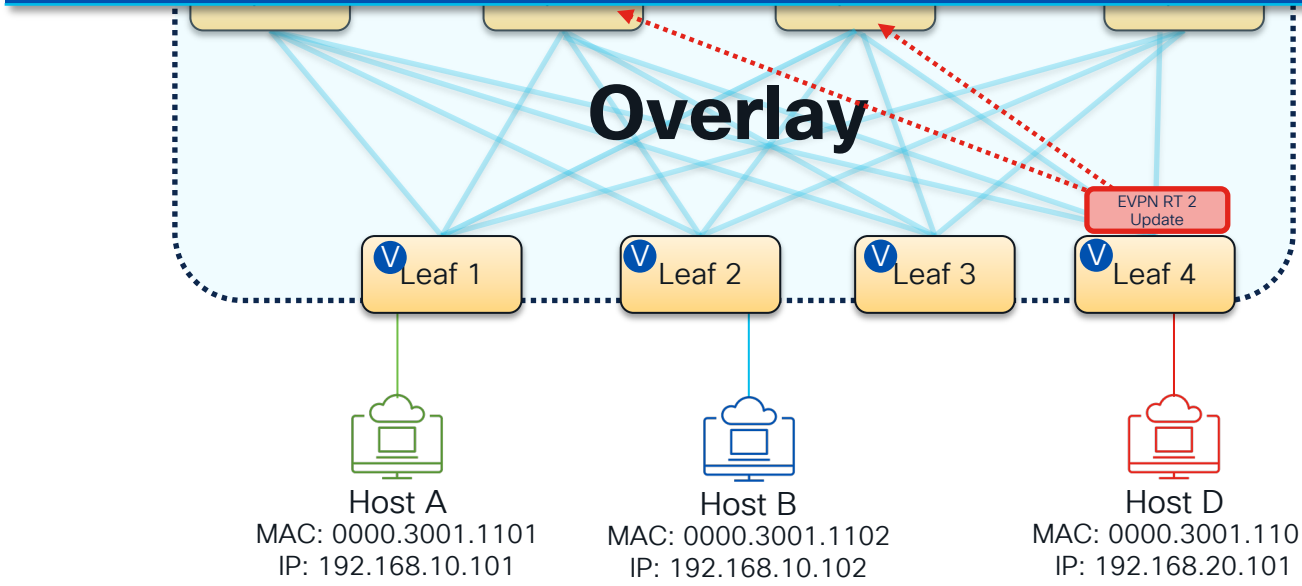
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	192.168.10.102/32	5000, 65500:5000	10.200.200.102	0



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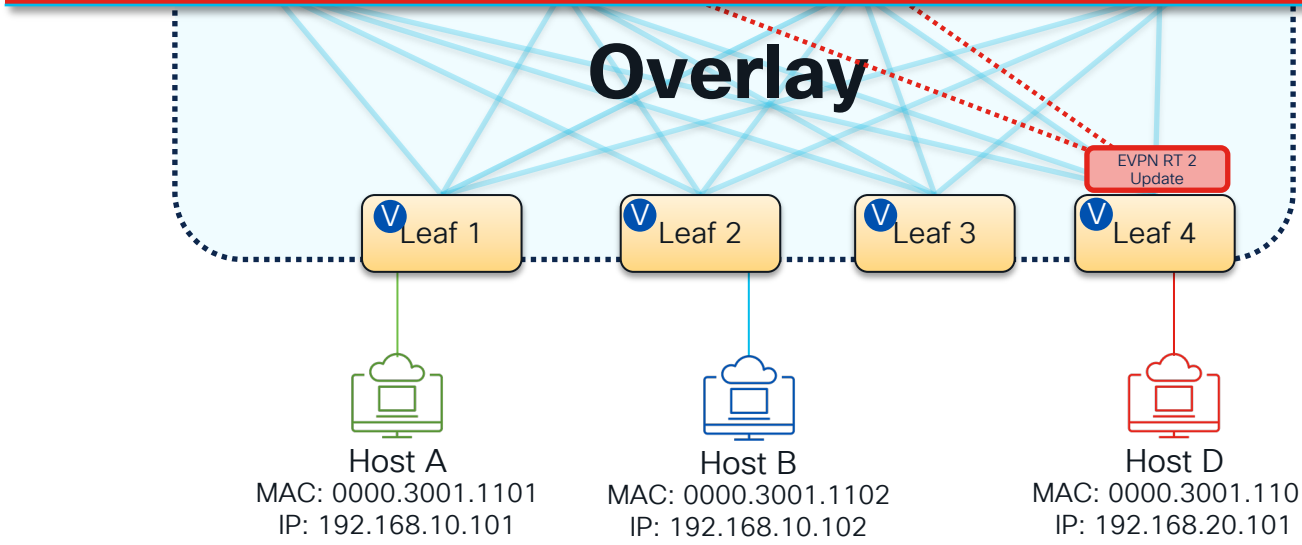
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	192.168.10.102/32	5000, 65500:5000	10.200.200.102	0
2	0000.3002.2101 / 48	3002, 65500:3001	192.168.20.101/32	5000, 65500:5000	10.200.200.104	0



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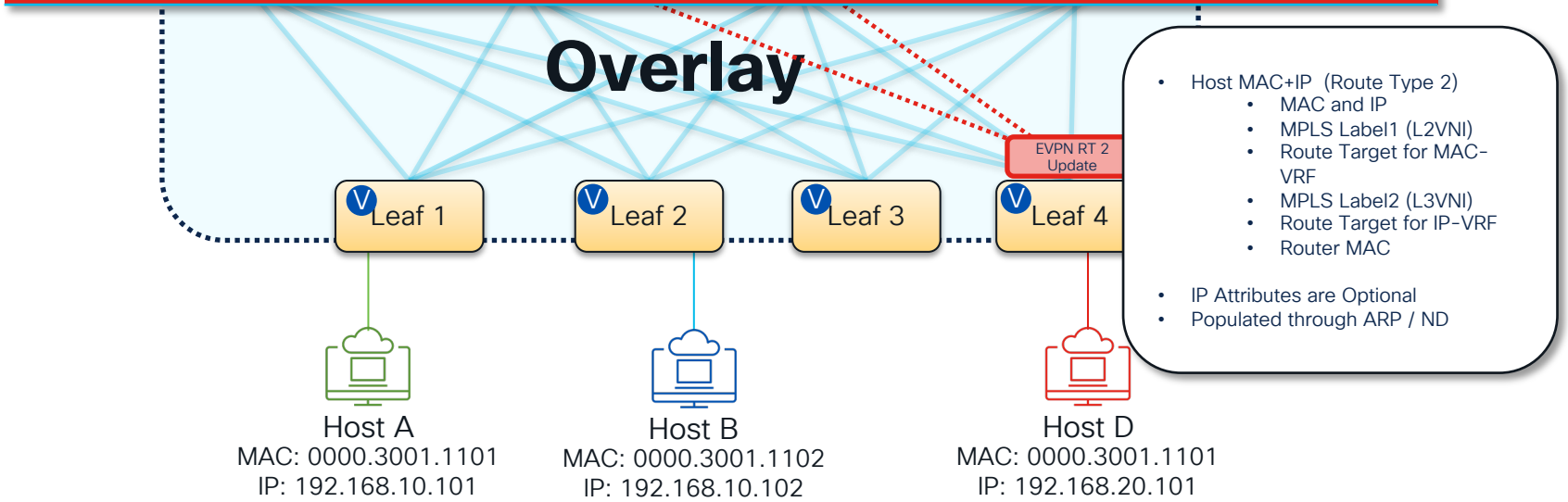
EVPN Control Plane

Host Advertisements

Type	MAC / Length	L2VNI / RT	IP / Length	L3VNI / RT	Next-Hop	Seq
2	0000.3001.1101 / 48	3001, 65500:3001	192.168.10.101/32	5000, 65500:5000	10.200.200.101	0
2	0000.3001.1102 / 48	3001, 65500:3001	192.168.10.102/32	5000, 65500:5000	10.200.200.102	0
2	0000.3002.2101 / 48	3002, 65500:3001	192.168.20.101/32	5000, 65500:5000	10.200.200.104	0



- Host MAC+IP (Route Type 2)
  - MAC and IP
  - MPLS Label1 (L2VNI)
  - Route Target for MAC-VRF
  - MPLS Label2 (L3VNI)
  - Route Target for IP-VRF
  - Router MAC
- IP Attributes are Optional
- Populated through ARP / ND

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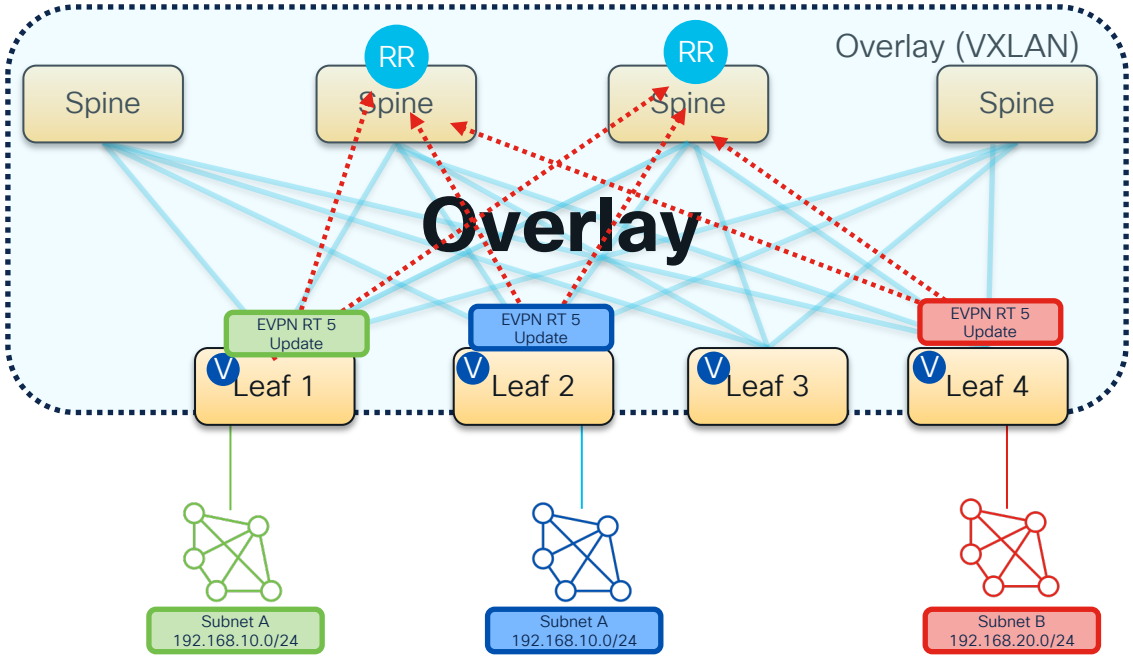
EVPN Control Plane

Subnet Advertisements



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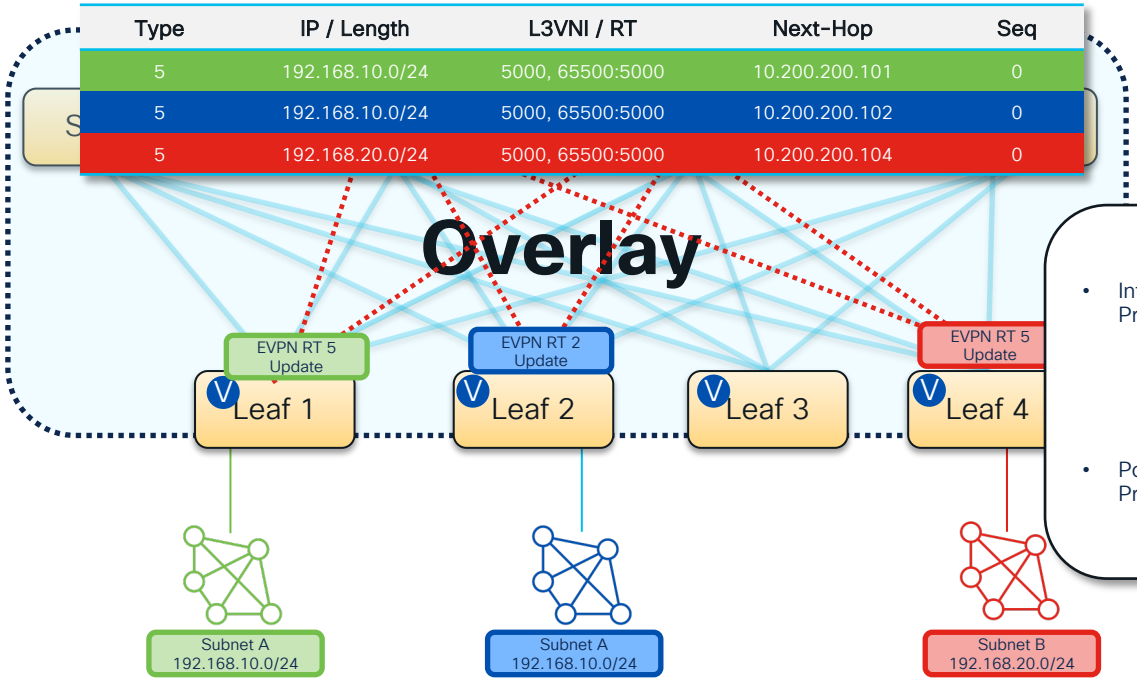
EVPN Control Plane

Subnet Advertisements



- Internal and External Subnet Prefixes (Route Type 5)
  - IP Prefix
  - MPLS Label (L3VNI)
  - Route Target for IP-VRF
  - Router MAC
- Populated through External Routing Protocol

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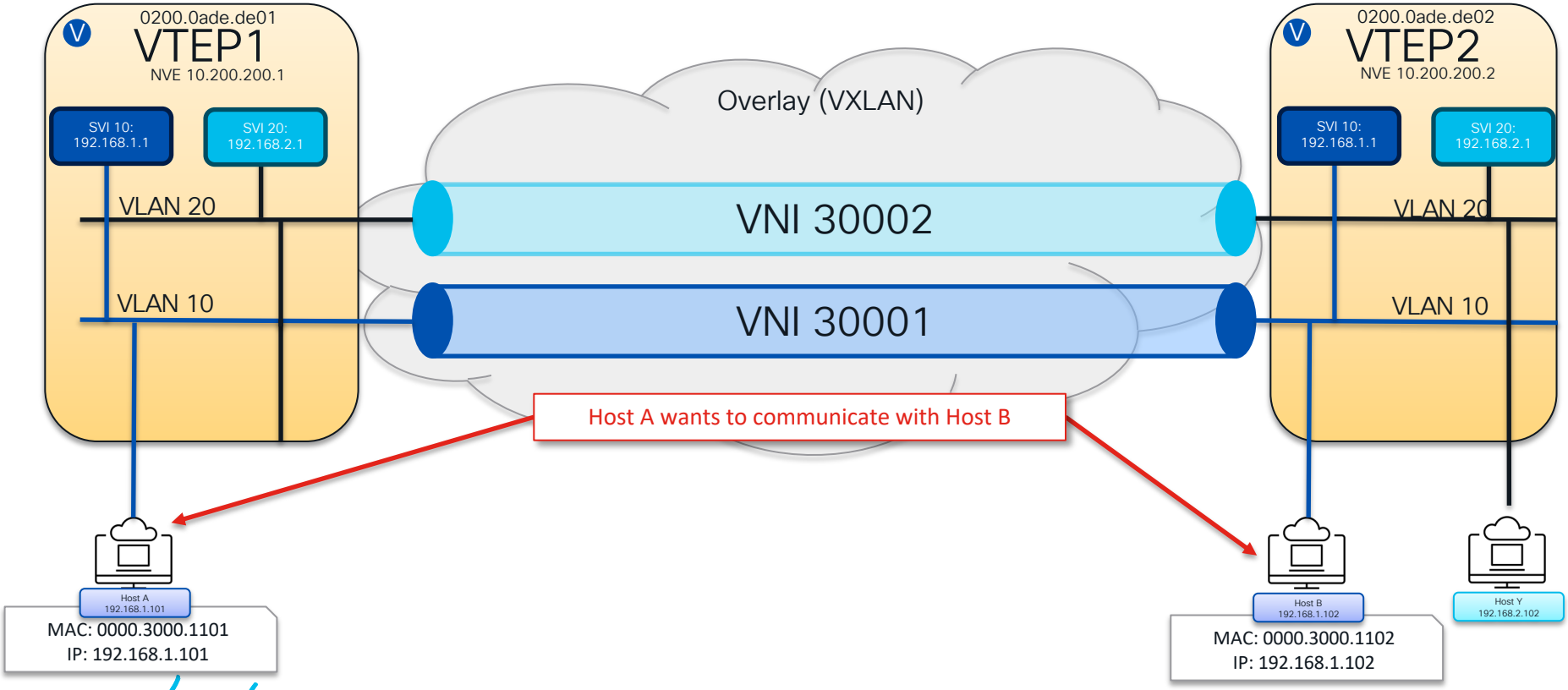
Packet Walk Host Communication in Same VLAN/VNI

Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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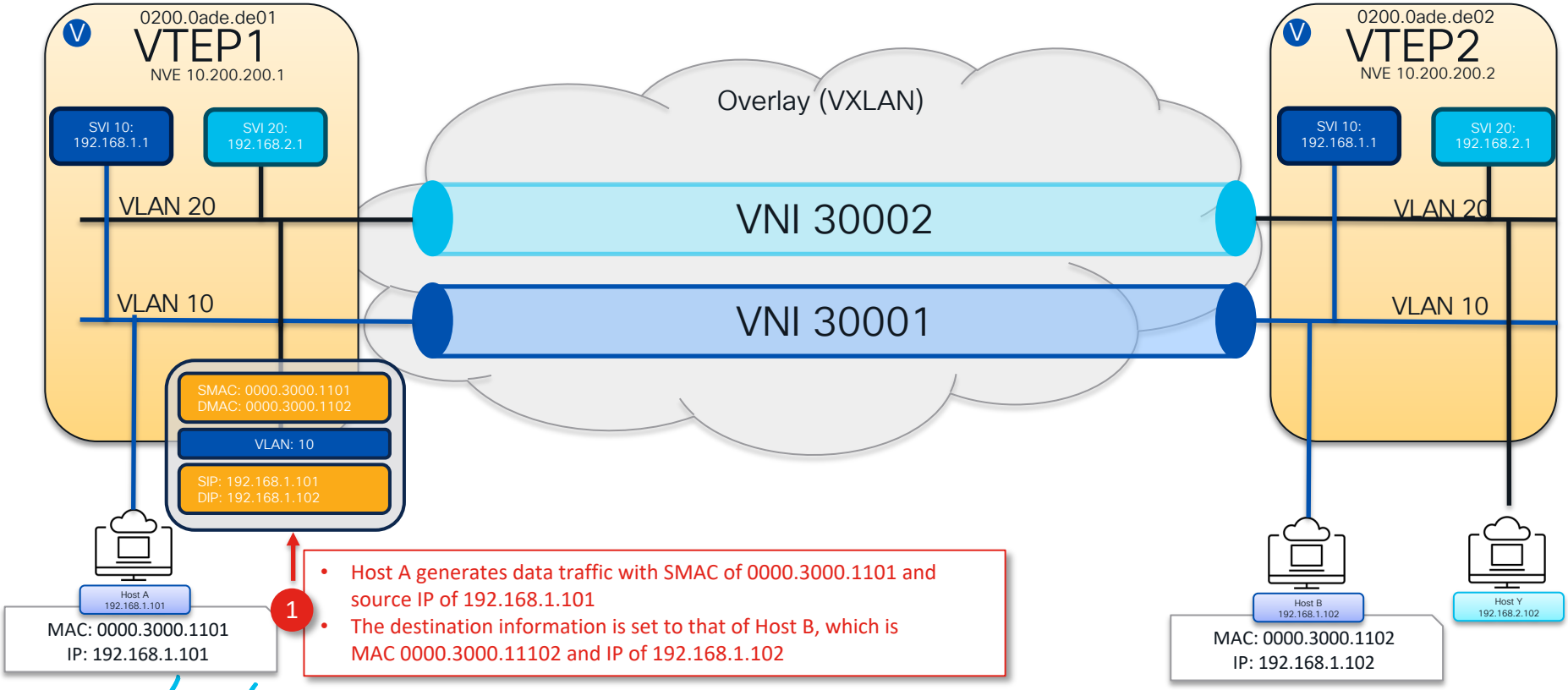
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



1

- Host A generates data traffic with SMAC of 0000.3000.1101 and source IP of 192.168.1.101
- The destination information is set to that of Host B, which is MAC 0000.3000.11102 and IP of 192.168.1.102

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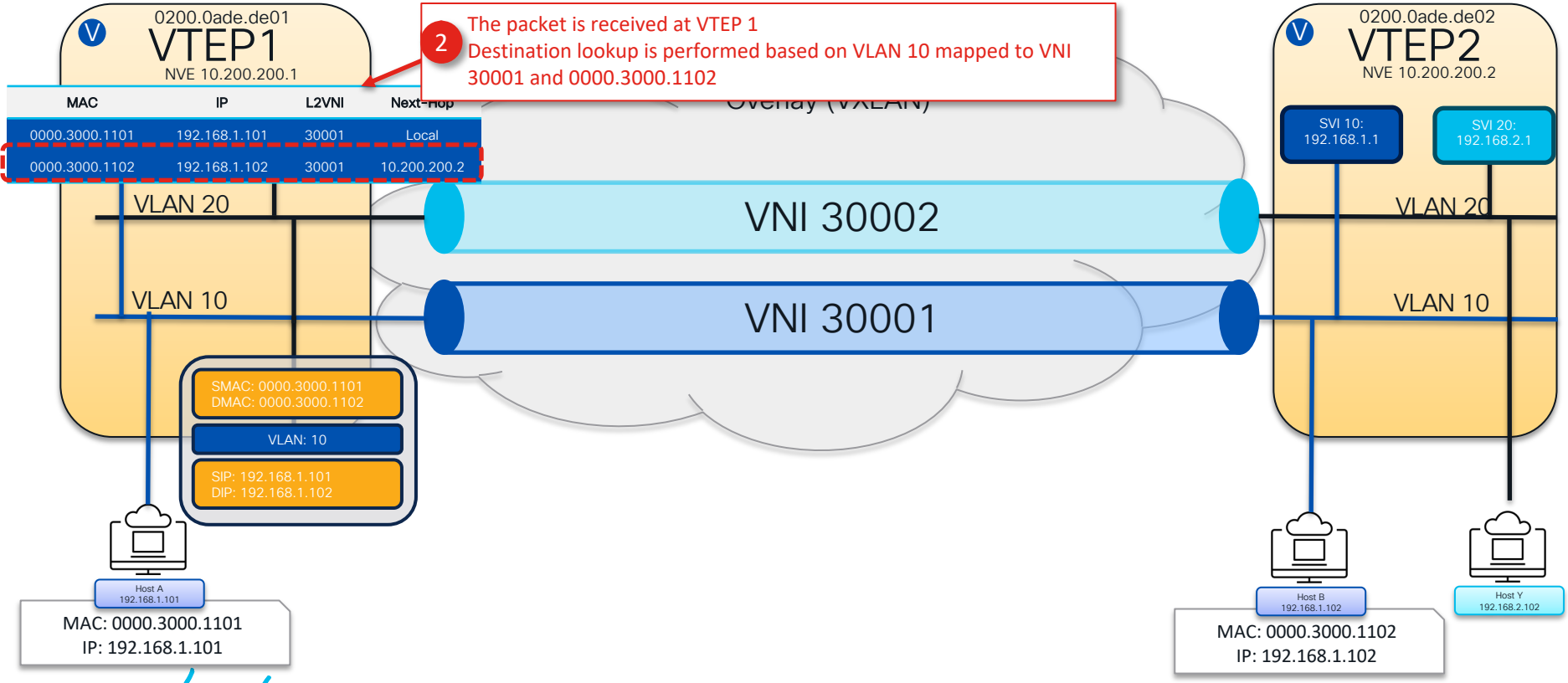
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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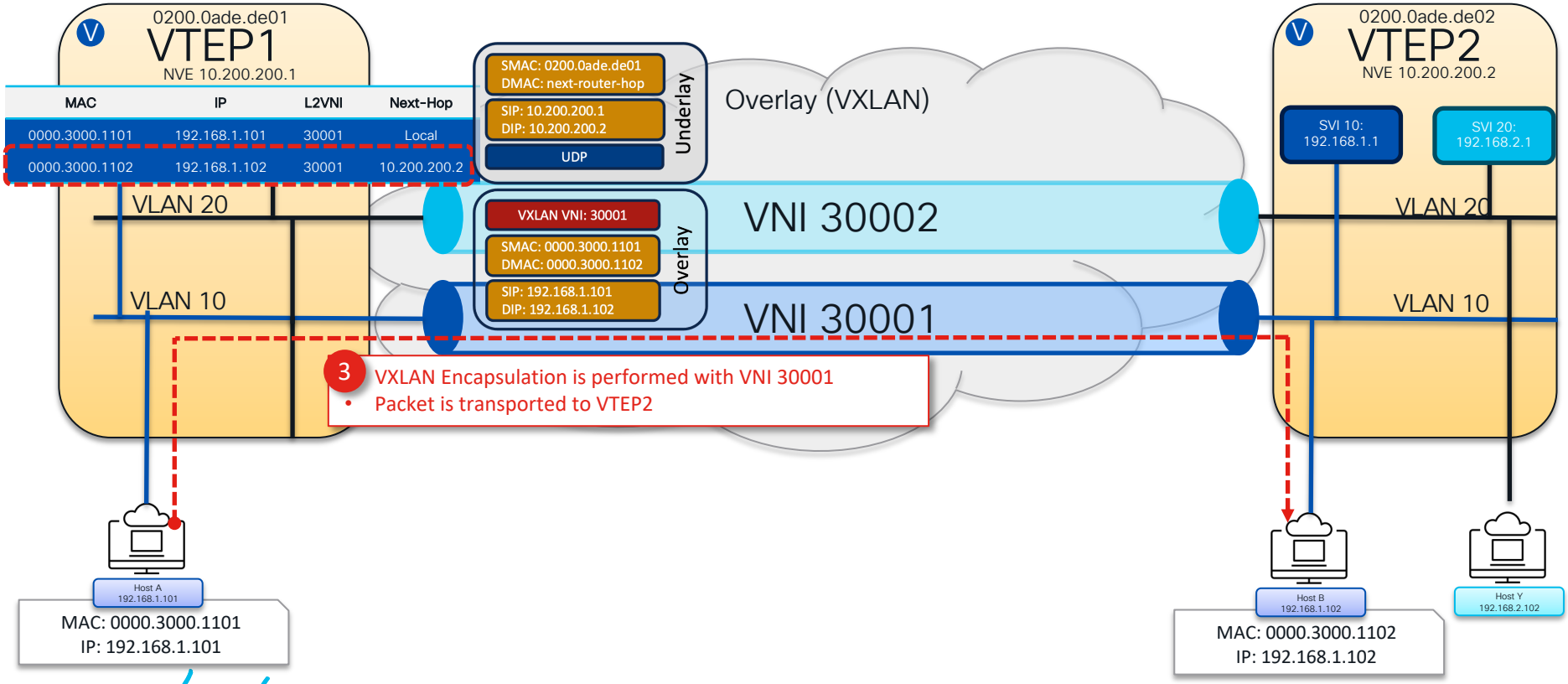
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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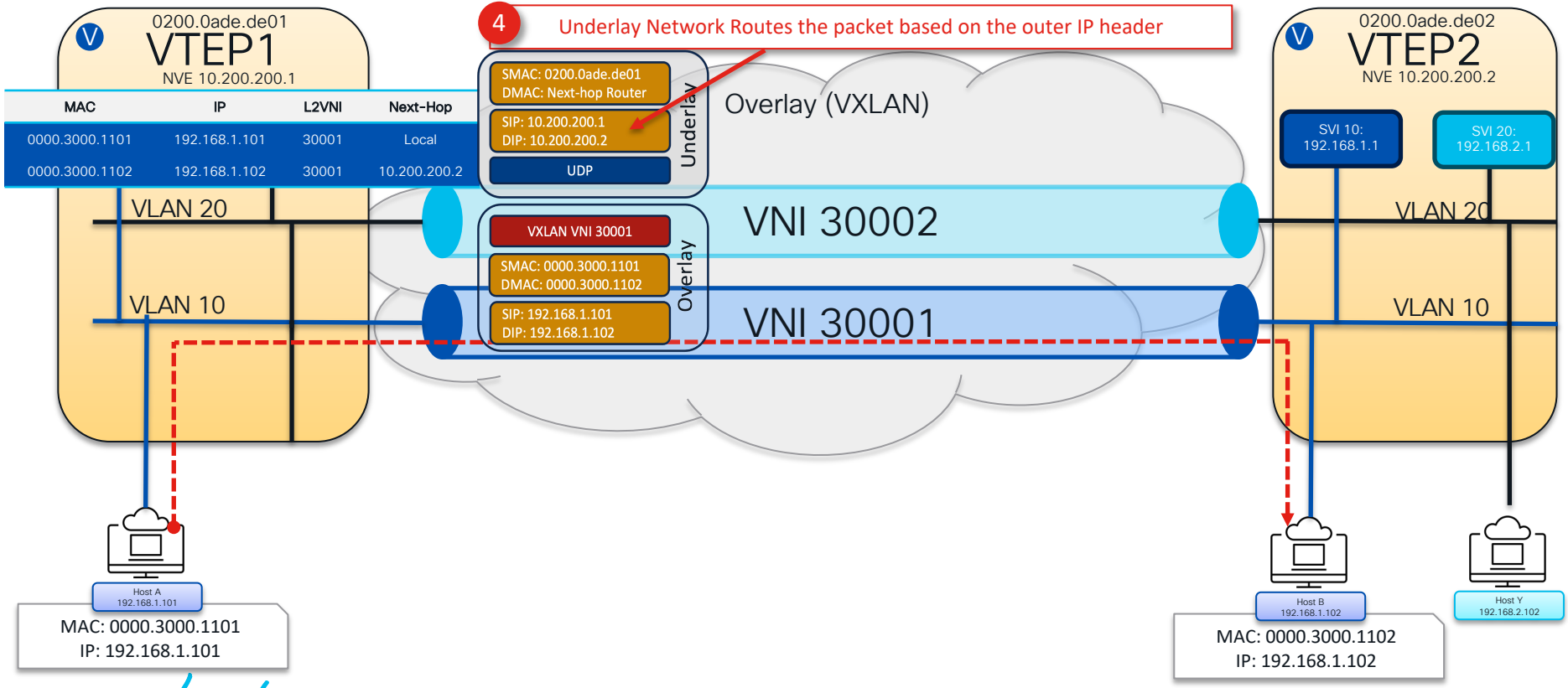
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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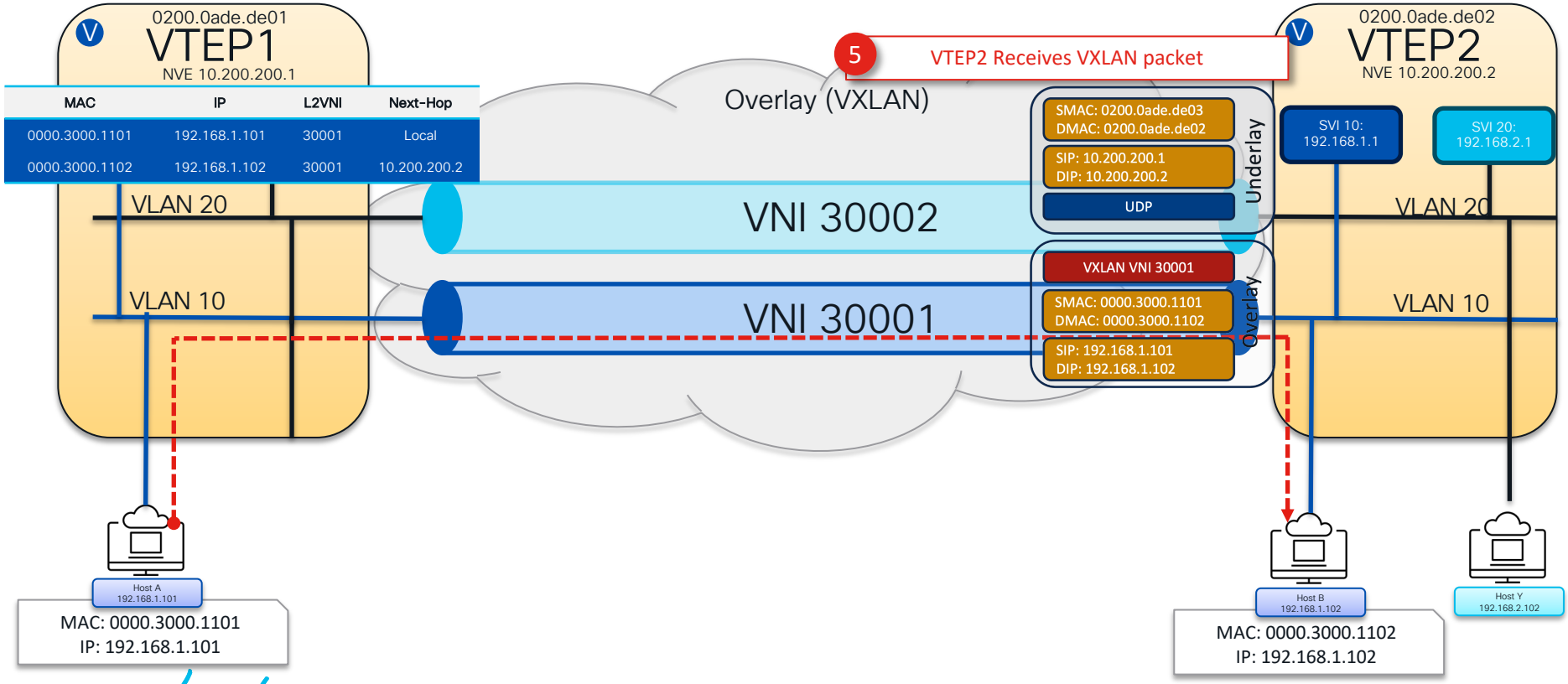
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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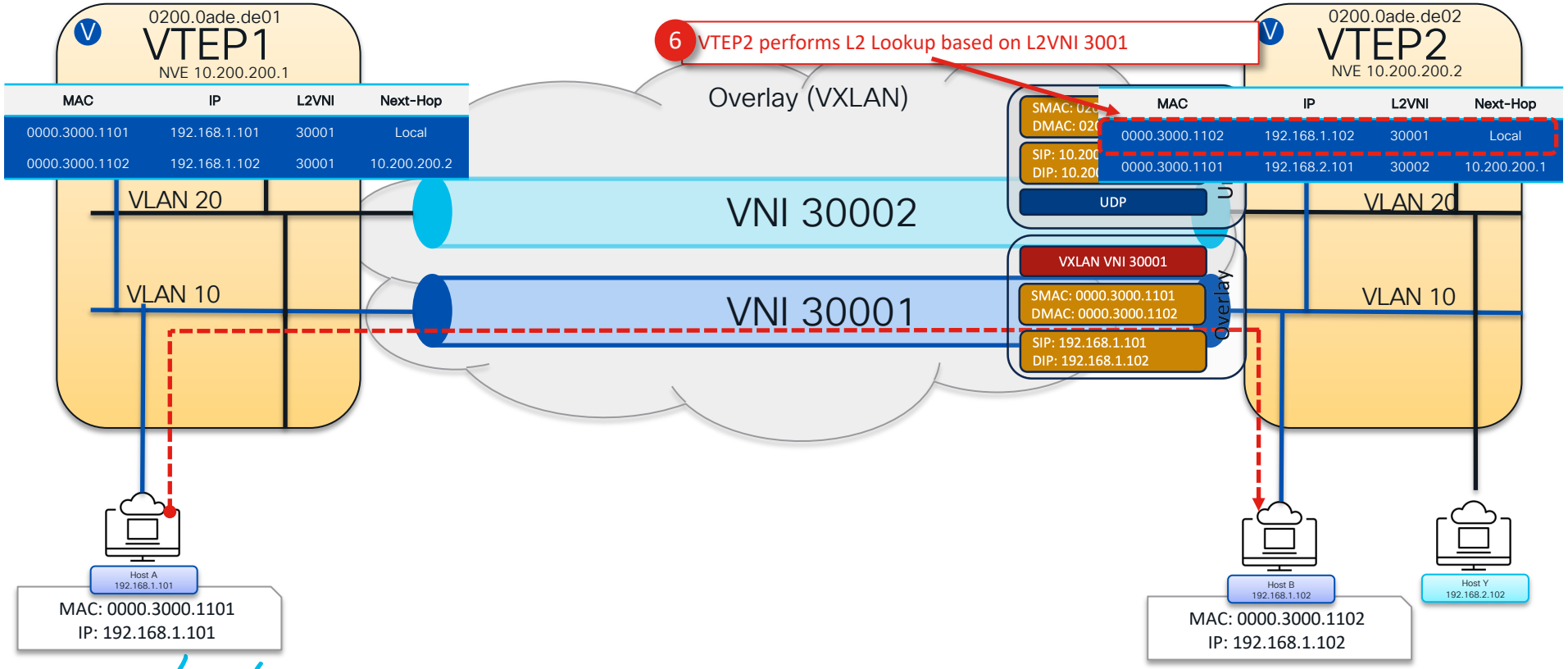
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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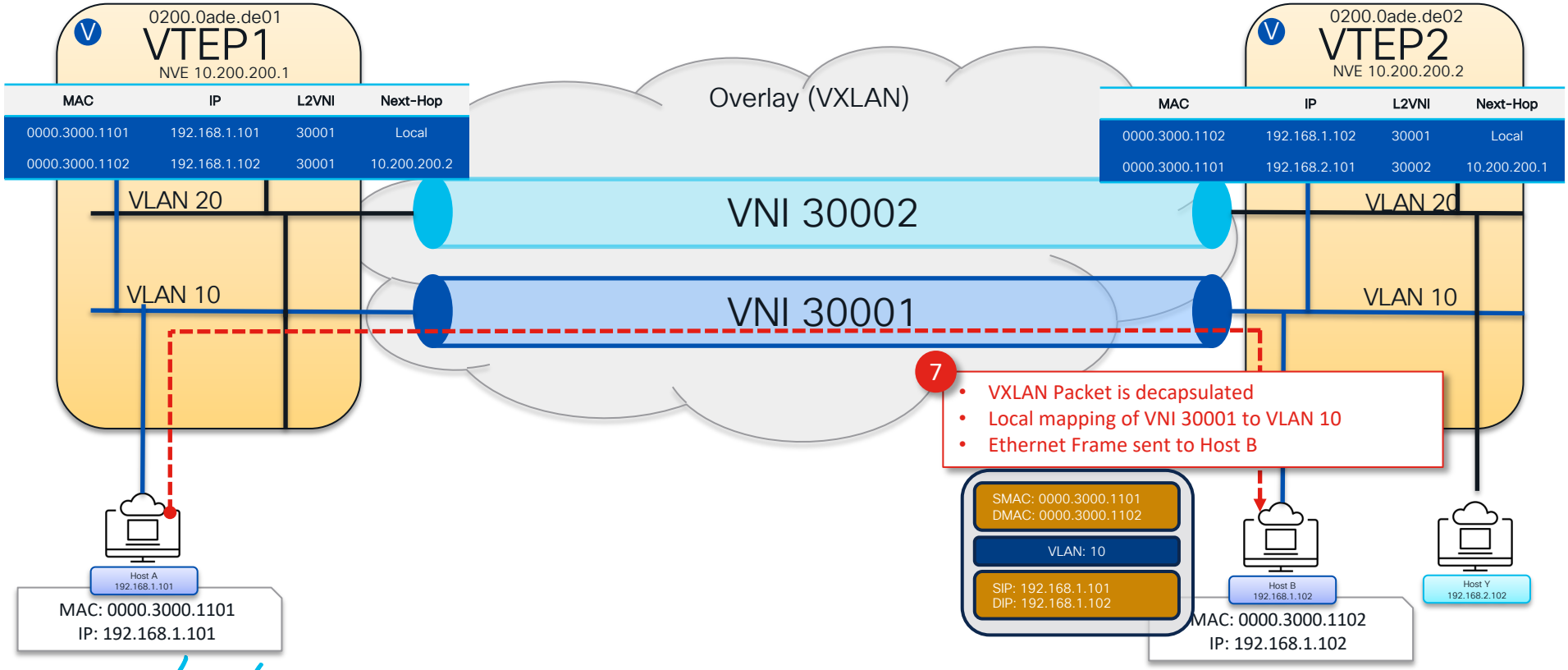
Packet Walk
Communication between hosts in the same VLAN/VNI

ARP Cache populated



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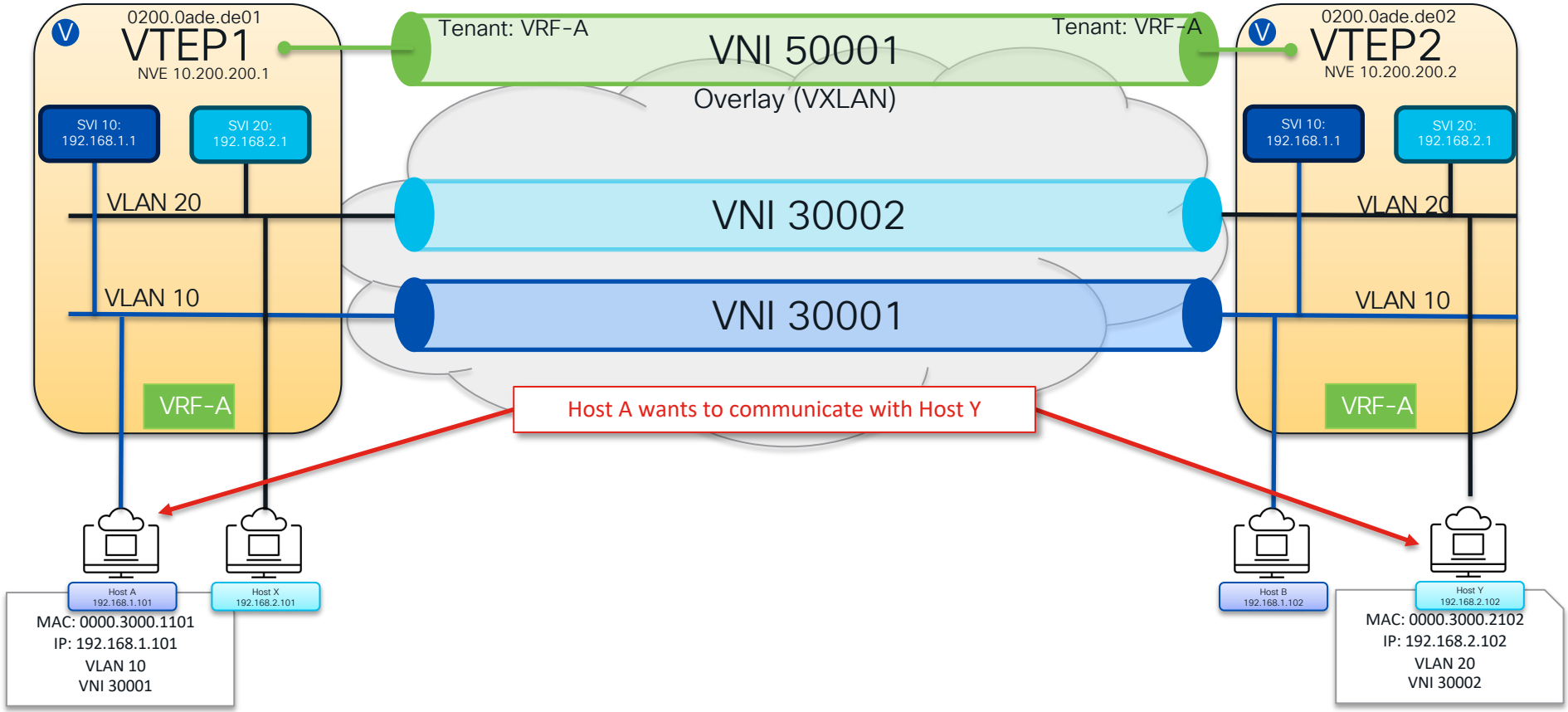
Packet Walk Host Communication in Different VLAN/VNI

Packet Walk
Communication between hosts in different VLAN/VNI (L3)



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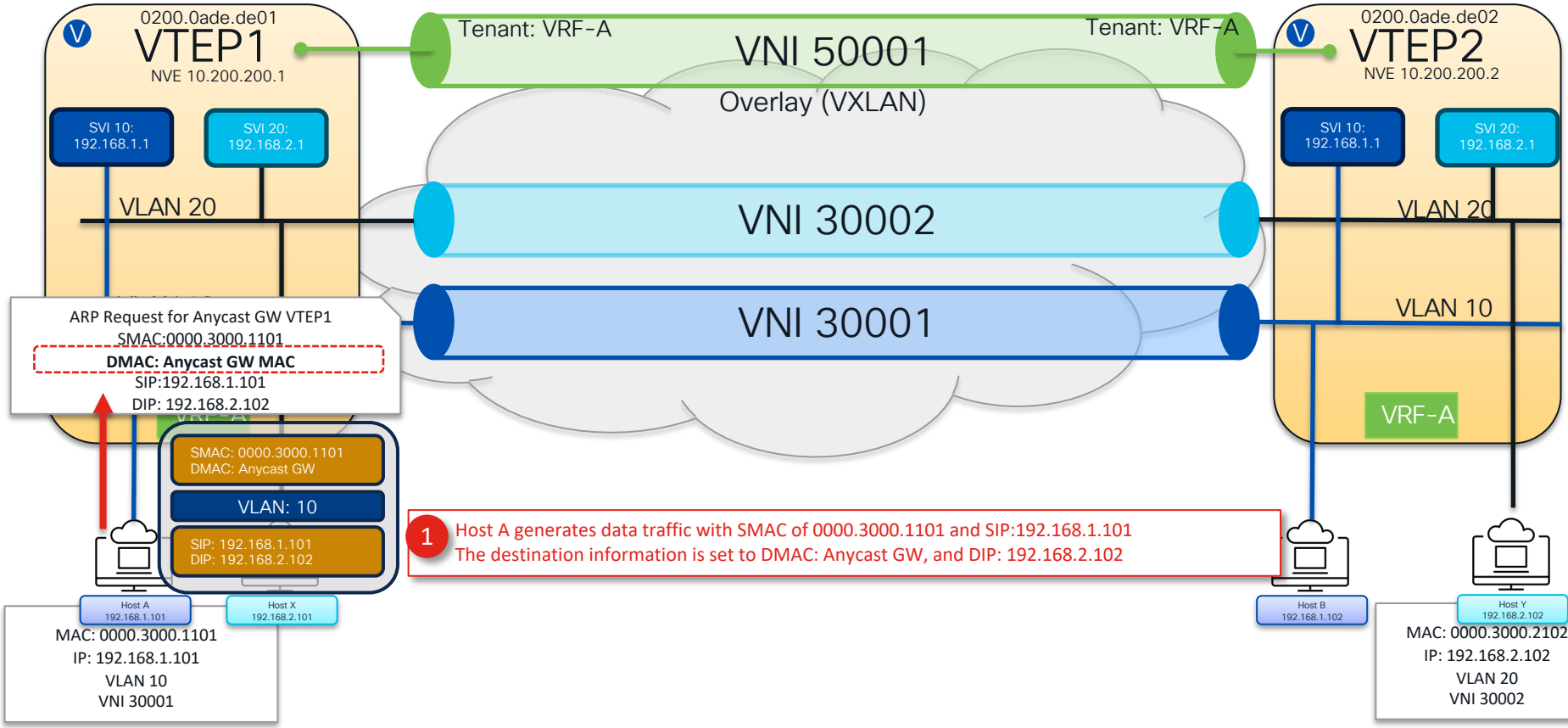
Packet Walk
Communication between hosts in different VLAN/VNI (L3)



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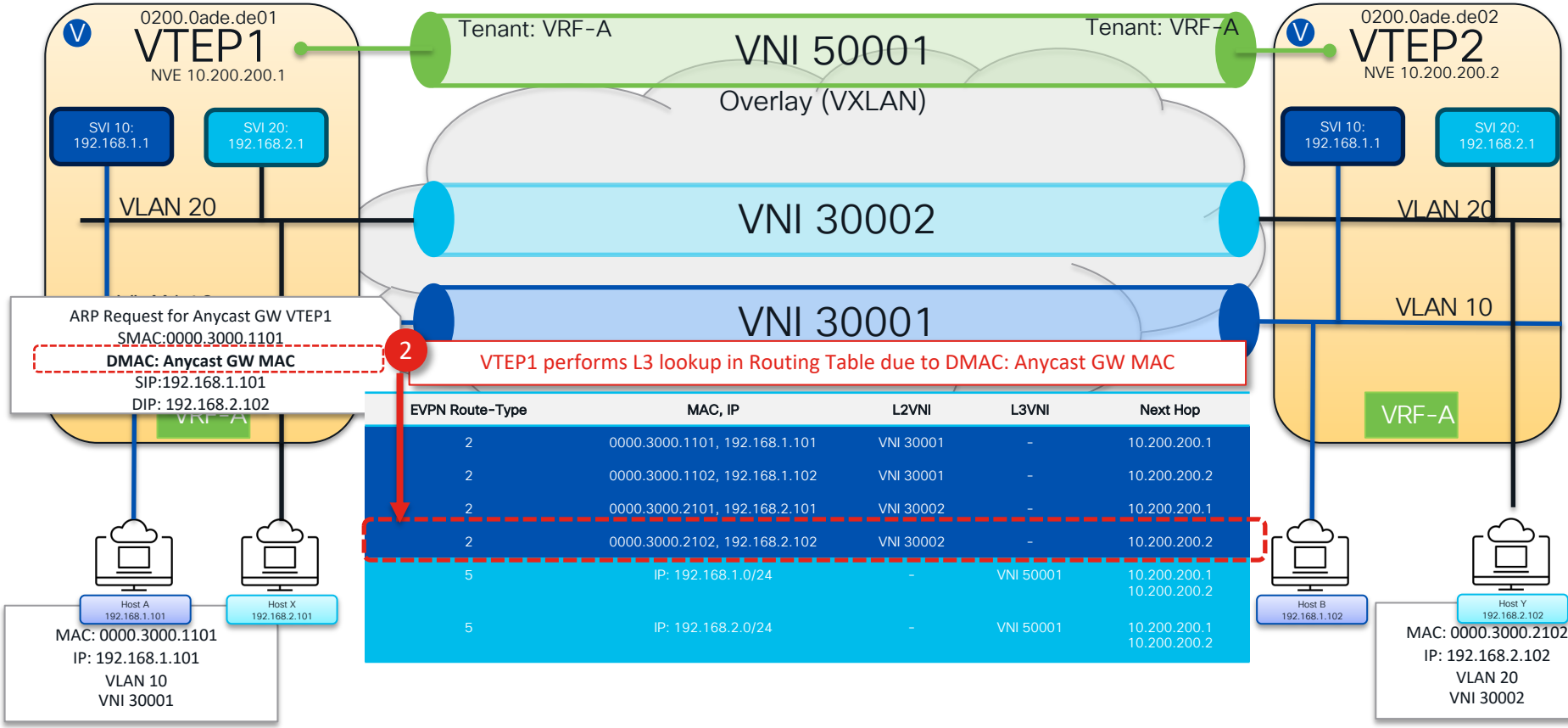
Packet Walk
Communication between hosts in different VLAN/VNI (L3)



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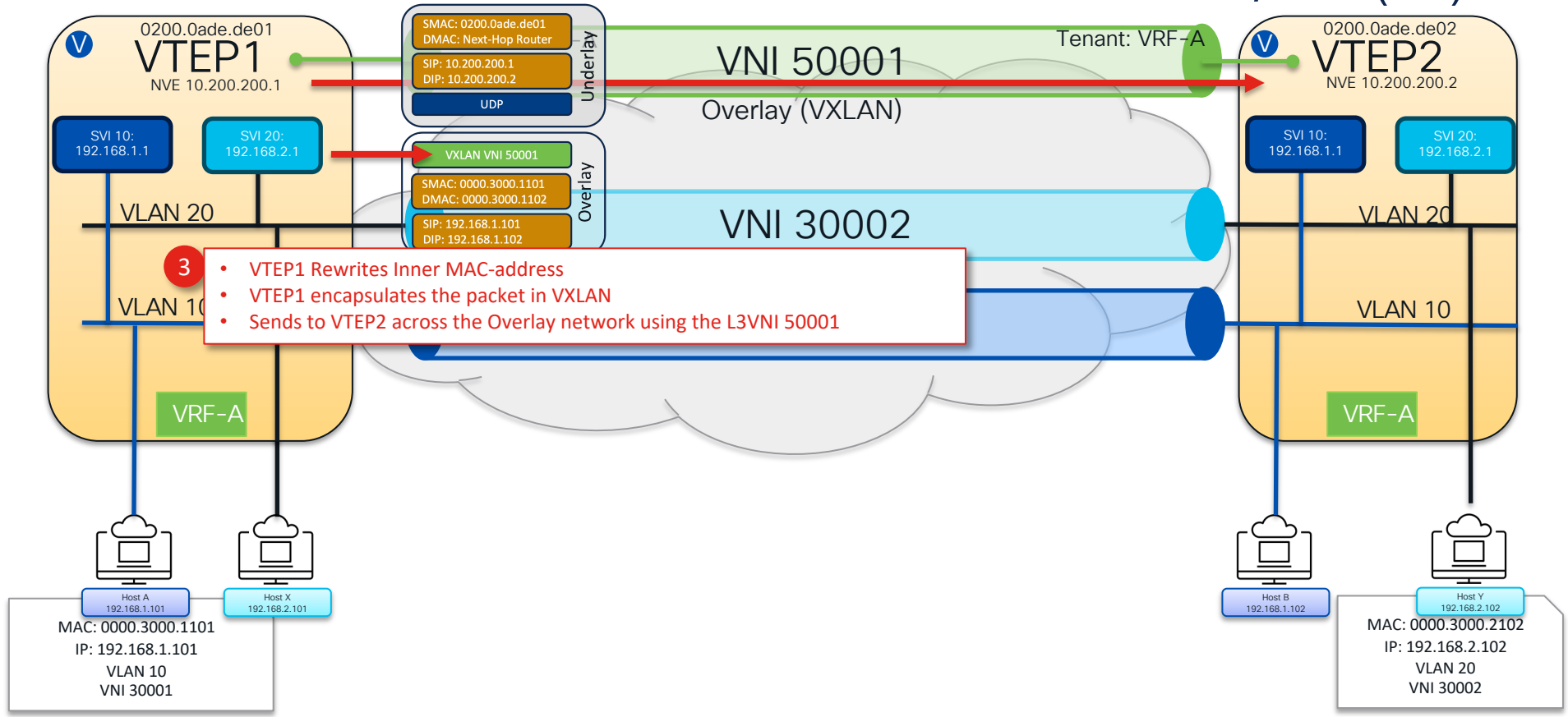
Packet Walk
Communication between hosts in different VLAN/VNI (L3)



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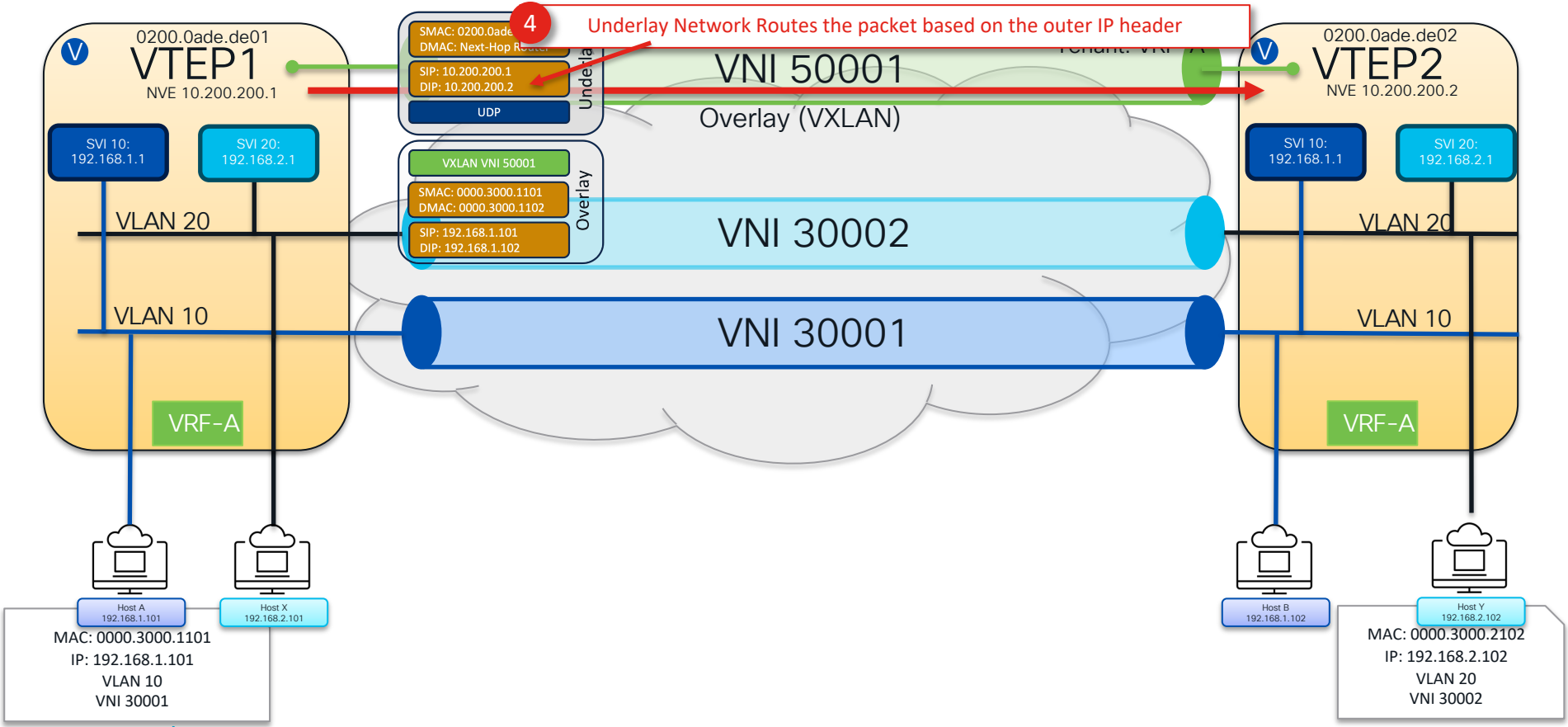
Packet Walk

Communication between hosts in different VLAN/VNI (L3)



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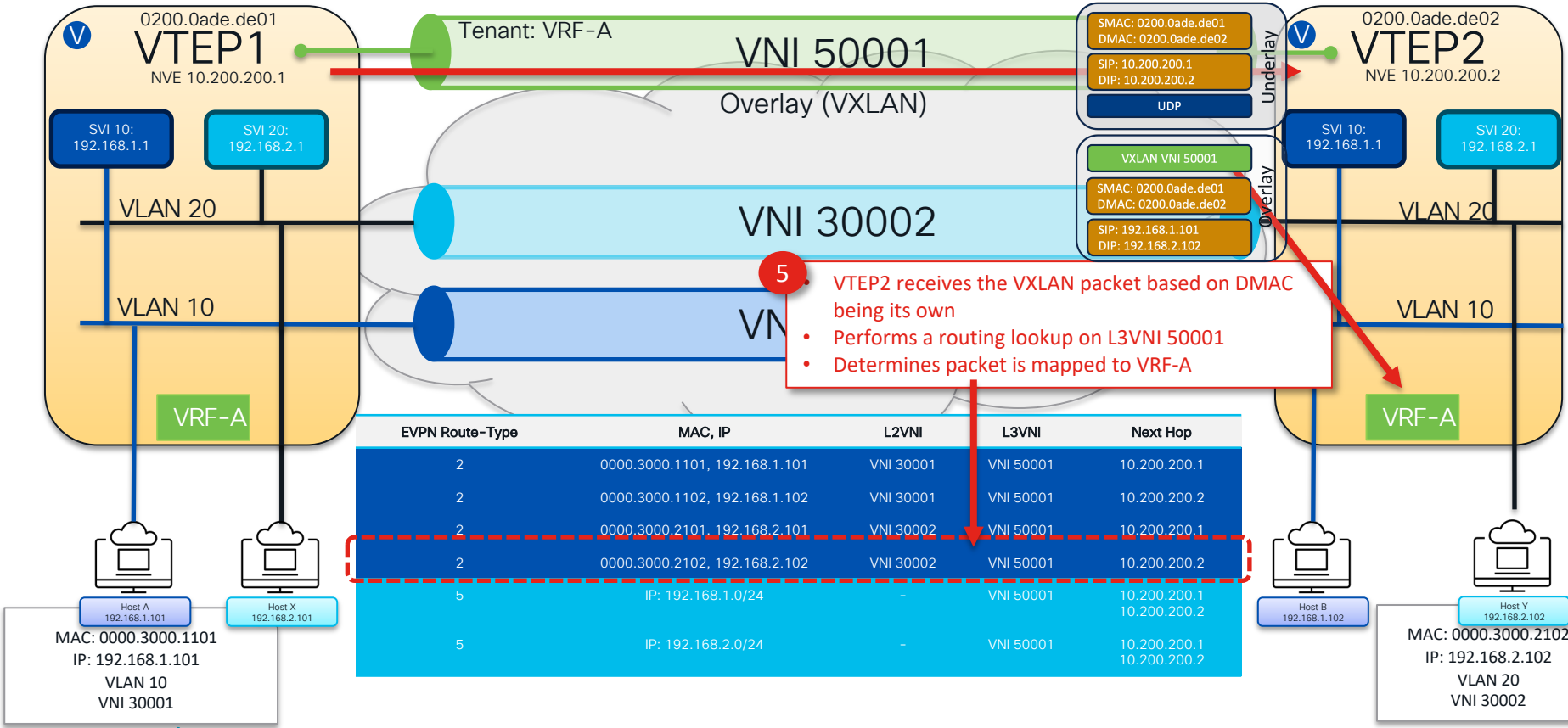
Packet Walk
Communication between hosts in different VLAN/VNI (L3)



EVPN Route-Type	MAC, IP	L2VNI	L3VNI	Next Hop
2	0000.3000.1101, 192.168.1.101	VNI 30001	VNI 50001	10.200.200.1
2	0000.3000.1102, 192.168.1.102	VNI 30001	VNI 50001	10.200.200.2
2	0000.3000.2101, 192.168.2.101	VNI 30002	VNI 50001	10.200.200.1
2	0000.3000.2102, 192.168.2.102	VNI 30002	VNI 50001	10.200.200.2
5	IP: 192.168.1.0/24	-	VNI 50001	10.200.200.1 10.200.200.2
5	IP: 192.168.2.0/24	-	VNI 50001	10.200.200.1 10.200.200.2

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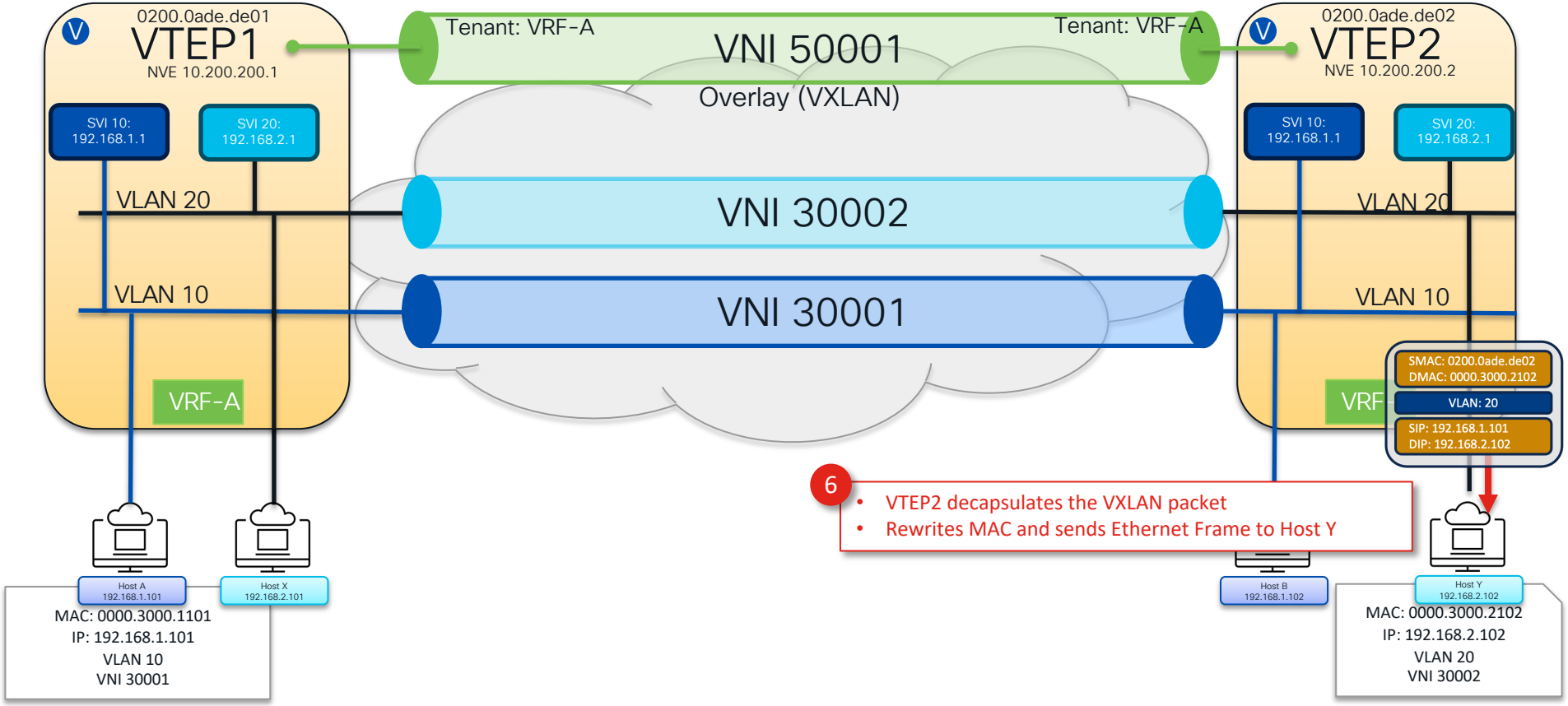
Packet Walk

Communication between hosts in different VLAN/VNI (L3)



6

- VTEP2 decapsulates the VXLAN packet
- Rewrites MAC and sends Ethernet Frame to Host Y

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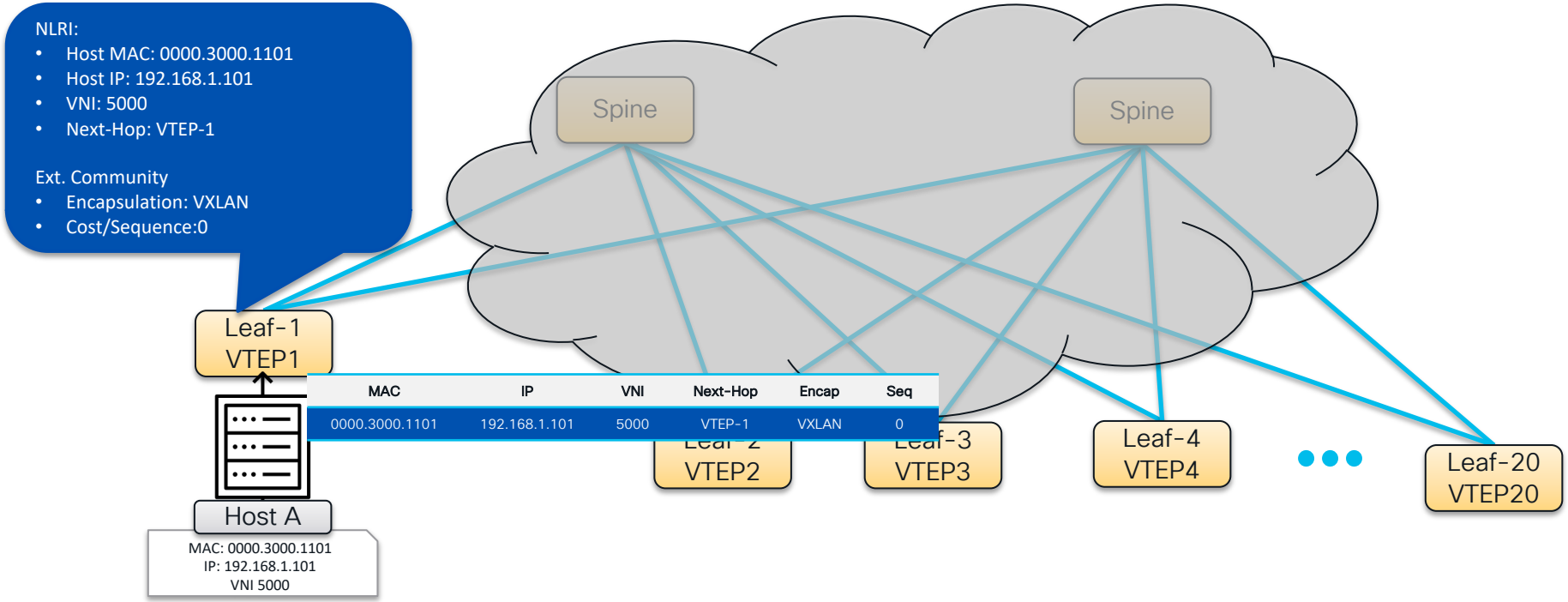
EVPN Host Mobility

EVPN Control Plane – Host Mobility



1. VTEP1 detects Host A and advertises an EVPN Route for Host A with seq#0

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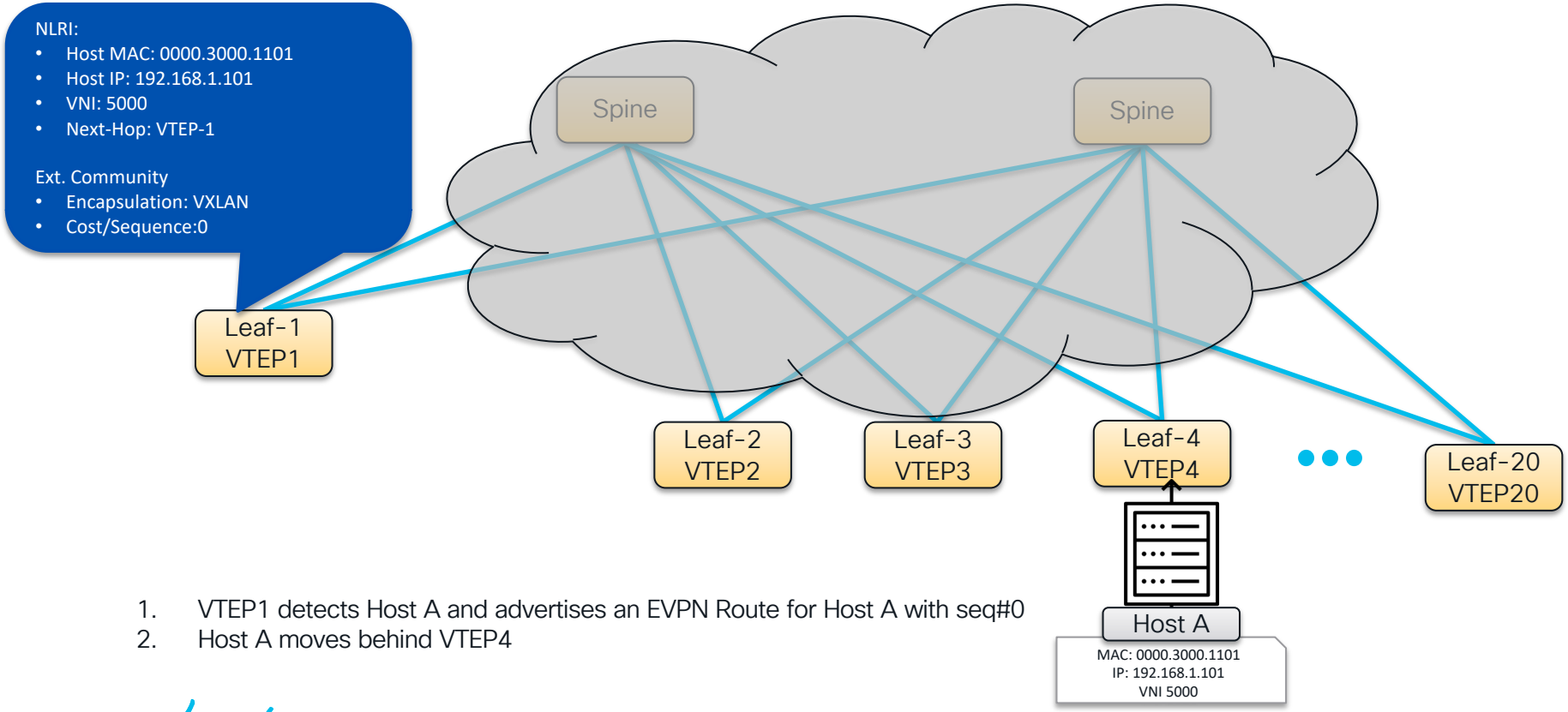
EVPN Control Plane – Host Mobility



1. VTEP1 detects Host A and advertises an EVPN Route for Host A with seq#0
2. Host A moves behind VTEP4

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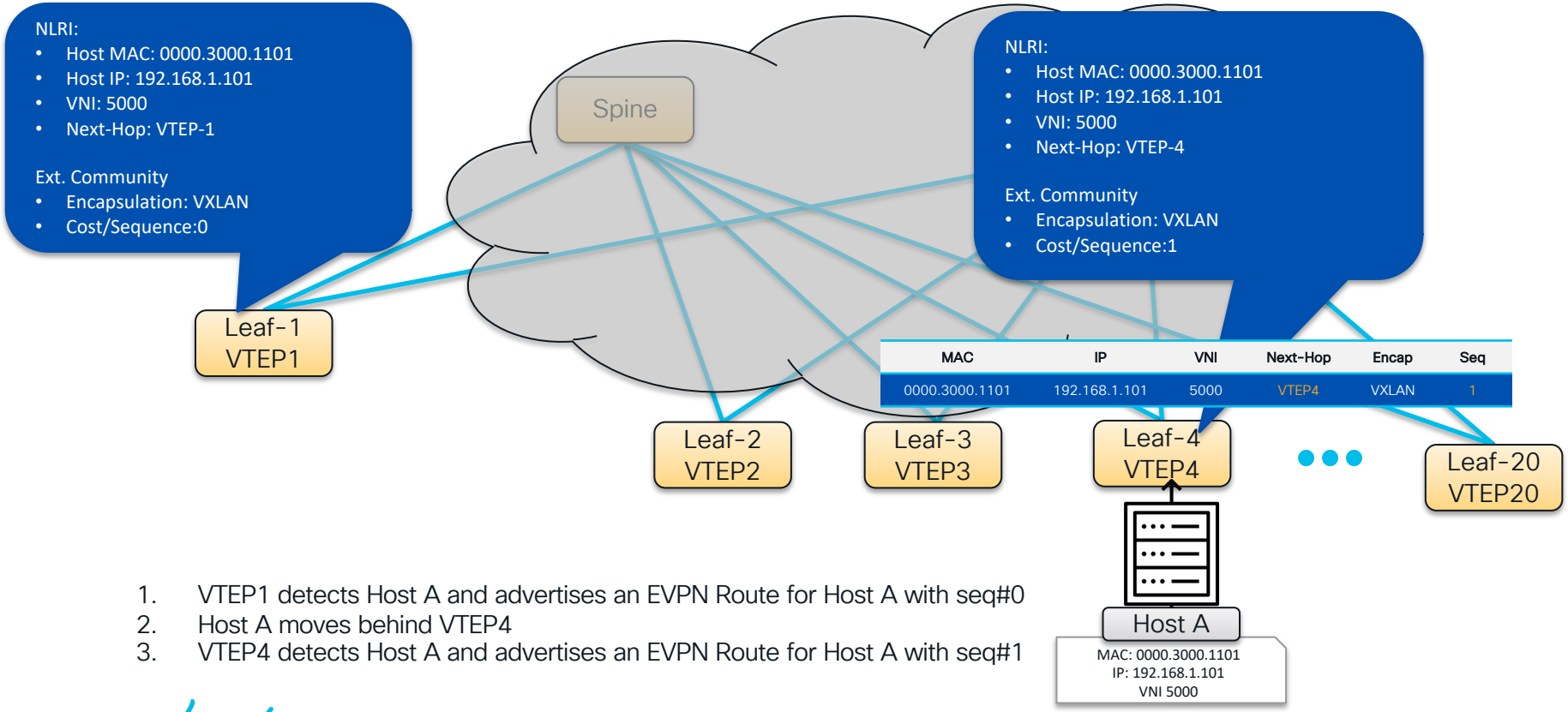
EVPN Control Plane – Host Mobility



1. VTEP1 detects Host A and advertises an EVPN Route for Host A with seq#0
2. Host A moves behind VTEP4
3. VTEP4 detects Host A and advertises an EVPN Route for Host A with seq#1

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Conclusion

Control-Plane Comparison

Flood&Learn (RFC7348)

- Ethernet over IP
  - No Spanning-Tree (terminates at NVE)
  - Endpoint Learning is based on Flood and Learn (it's in the name)
  - Requires Extra Work for Routing
    - FHRP for Default Gateway
    - Over-the-Top VRF-lite for Prefix Routing (or use the Underlay?!)

EVPN - Ethernet VPN (RFC8365)

- A Better Ethernet over IP
  - No Spanning-Tree (terminates at NVE)
  - Endpoint Learning is based on BGP exchange (EVPN uses BGP)
  - Provides Integrated Routing & Bridging (IRB)
    - Distributed Anycast Gateway for Default Gateway
    - Uses a Layer-3 VPN approach like MPLS L3VPN
  - And there is much more in EVPN!

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Conclusion

- Data Center Network Challenges and Evolution
- Virtual Private Networks and Overlay Taxonomy
- VXLAN enables scalable Data Center Networks
- BGP EVPN as a better Control-Plane
  - Provides a robust control plane enabling multi-tenancy, VM mobility, and optimizes forwarding

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Recommended Reading

- Building Data Centers with VXLAN BGP EVPN: A Cisco NX-OS Perspective
- Cisco Nexus 9000 Series NX-OS VXLAN Configuration Guide, Release 10.4(x)
- Migrating Classic Ethernet Environments to VXLAN BGP EVPN
- Migrating Cisco FabricPath Environments to VXLAN BGP EVPN White Paper
- VXLAN EVPN Multi-Site Design and Deployment White Paper
- VXLAN Design with Cisco Nexus 9300 Platform Switches
- VXLAN Network with MP-BGP EVPN Control Plane Design Guide

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Recommended CiscoLive Sessions

- VXLAN BGP EVPN Multi-Site [BRKDCN-2913]
- VXLAN EVPN: A Deep Dive into Packet Forwarding [BRKDCN-3966]
- Next Generation VXLAN Data Centre Architecture, Deployment, and Operation [TECDCN-2101]
- Architecting L4-L7 Network Services in a Multi-tenant Data Centre with VXLAN EVPN [BRKDCN-2974]
- Design, Automate, and Manage VXLAN BGP EVPN Multi-Site with NDFC [BRKDCN-2128]

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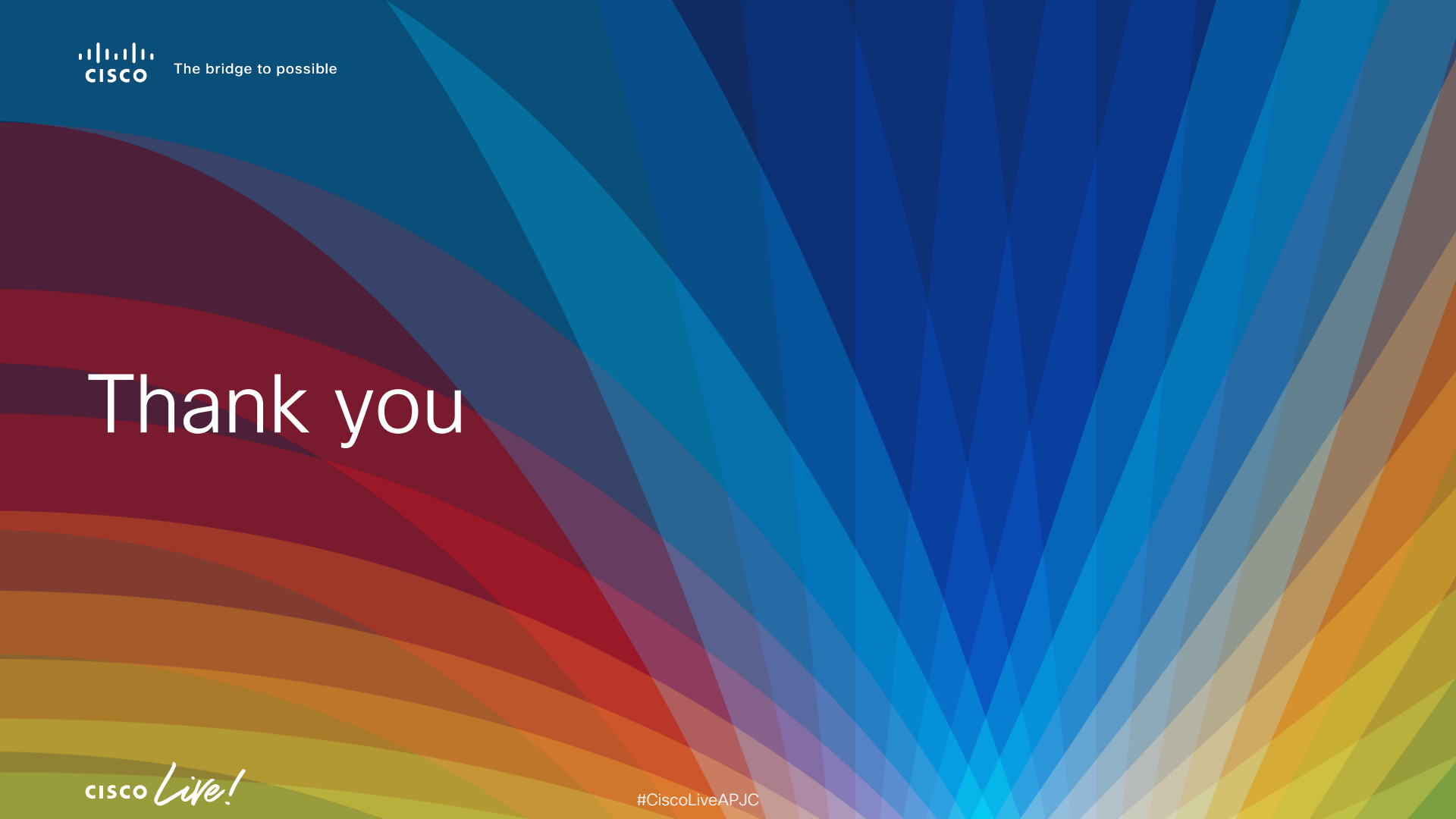
cisco
The bridge to possible
Thank you
cisco Live!
#CiscoLiveAPJC

cisco Live!

Let's go

#CiscoLiveAPJC