Cisco Nexus 7000 Series NX-OS VXLAN Configuration Guide

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CONTENTS

Preface

The preface contains the following sections:

Preface

This preface describes the audience, organization, and conventions of the Book Title. It also provides information on how to obtain related documentation.

This chapter includes the following topics:

Audience

This publication is for experienced network administrators who configure and maintain Cisco NX-OS on Cisco Nexus 7000 Series Platform switches.

Document Conventions

Note

- As part of our constant endeavor to remodel our documents to meet our customers' requirements, we have modified the manner in which we document configuration tasks. As a result of this, you may find a deviation in the style used to describe these tasks, with the newly included sections of the document following the new format.
- The Guidelines and Limitations section contains general guidelines and limitations that are applicable to all the features, and the feature-specific guidelines and limitations that are applicable only to the corresponding feature.

Command descriptions use the following conventions:

Convention	Description
bold	Bold text indicates the commands and keywords that you enter literally as shown.
Italic	Italic text indicates arguments for which the user supplies the values.

Convention	Description
[x]	Square brackets enclose an optional element (keyword or argument).
[x | y]	Square brackets enclosing keywords or arguments separated by a vertical bar indicate an optional choice.
{x | y}	Braces enclosing keywords or arguments separated by a vertical bar indicate a required choice.
[x {y | z}]	Nested set of square brackets or braces indicate optional or required choices within optional or required elements. Braces and a vertical bar within square brackets indicate a required choice within an optional element.
`variable`	Indicates a variable for which you supply values, in context where italics cannot be used.
string	A nonquoted set of characters. Do not use quotation marks around the string or the string will include the quotation marks.

Examples use the following conventions:

Convention	Description
`screen font`	Terminal sessions and information the switch displays are in screen font.
`boldface screen font`	Information you must enter is in boldface screen font.
italic screen font	Arguments for which you supply values are in italic screen font.
< >	Nonprinting characters, such as passwords, are in angle brackets.
[ ]	Default responses to system prompts are in square brackets.
!, #	An exclamation point (!) or a pound sign (#) at the beginning of a line of code indicates a comment line.

This document uses the following conventions:

Note Means *reader take note*. Notes contain helpful suggestions or references to material not covered in the manual.

Caution Means *reader be careful*. In this situation, you might do something that could result in equipment damage or loss of data.

Related Documentation

Documentation for Cisco Nexus 7000 Series Switches is available at:

- Configuration Guides

http://www.cisco.com/c/en/us/support/switches/nexus-7000-series-switches/products-installation-and-configuration-guides-list.html

- Command Reference Guides

  http://www.cisco.com/c/en/us/support/switches/nexus-7000-series-switches/products-command-reference-list.html

- Release Notes

  http://www.cisco.com/c/en/us/support/switches/nexus-7000-series-switches/products-release-notes-list.html

- Install and Upgrade Guides

  http://www.cisco.com/c/en/us/support/switches/nexus-7000-series-switches/products-installation-guides-list.html

- Licensing Guide

  http://www.cisco.com/c/en/us/support/switches/nexus-7000-series-switches/products-licensing-information-listing.html

Documentation for Cisco Nexus 7000 Series Switches and Cisco Nexus 2000 Series Fabric Extenders is available at the following URL:

http://www.cisco.com/c/en/us/support/switches/nexus-2000-series-fabric-extenders/products-installation-and-configuration-guides-list.html

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To provide technical feedback on this document, or to report an error or omission, please send your comments to nexus7k-docfeedback@cisco.com. We appreciate your feedback.

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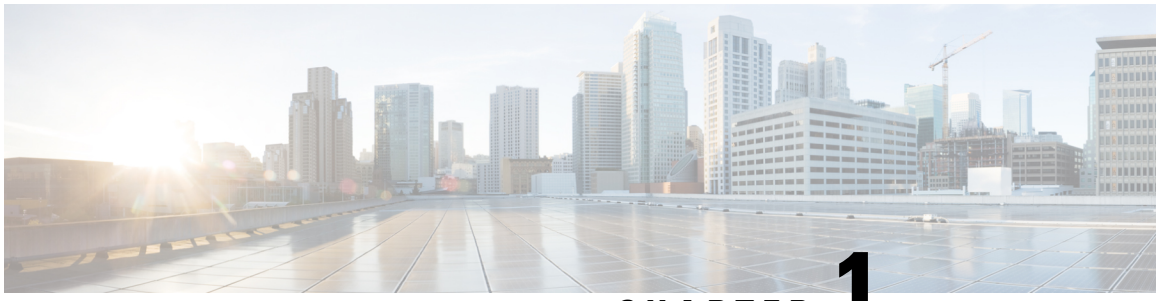
Cisco Bug Search Tool

Cisco Bug Search Tool (BST) is a web-based tool that acts as a gateway to the Cisco bug tracking system that maintains a comprehensive list of defects and vulnerabilities in Cisco products and software. BST provides you with detailed defect information about your products and software.



CHAPTER 1

New and Changed Information

This chapter provides release-specific information for each new and changed feature in the *Cisco Nexus 7000 Series NX-OS VXLAN Configuration Guide*.

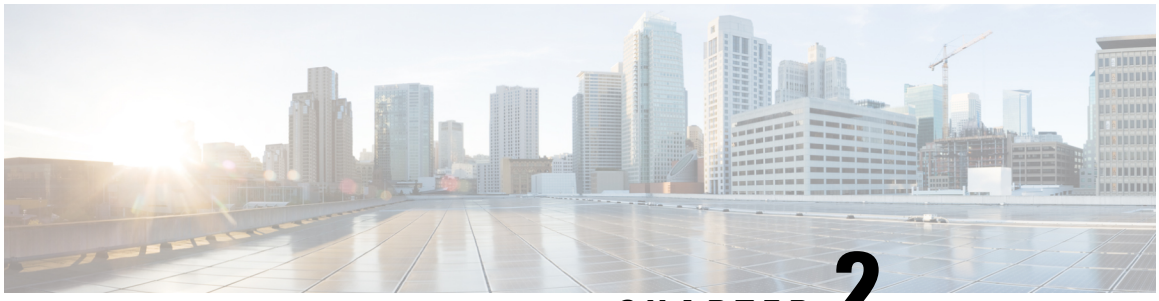
New and Changed Information

Your software release might not support all the features in this document. For the latest caveats and feature information, see the Bug Search Tool at https://tools.cisco.com/bugsearch/ and the release notes for your software release.

Table 1: New and Changed Information

Feature	Description	Changed in Release	Where Documented
Centralized VRF Route Leaking	This feature was introduced.	8.4(1)	Centralized VRF Route Leaking
Proportional Multipath for VNF	This feature was introduced.	8.3(1)	
Campus Fabric Interconnect —MPLS L3VPN	This feature was introduced.	8.2(1)	*Campus Fabric Interconnect —MPLS L3VPN* chapter
VXLAN BGP EVPN and OTV Interoperation	This feature was introduced.	8.2(1)	*VXLAN BGP EVPN and OTV Interoperation* chapter
ACI WAN Interconnect	This feature was updated. Support for this feature was extended to the M3 line card.	8.2(1)	*Configuring ACI WAN Interconnect* chapter
PBR support for the VXLAN BGP EVPN fabric	This feature was introduced.	8.2(1)	*PBR support for the VXLAN BGP EVPN fabric* chapter

Feature	Description	Changed in Release	Where Documented
Connecting LISP Disjoint RLOC Domains	This feature was introduced.	8.1(1)	*Connecting LISP Disjoint RLOC Domains*
VXLAN Flood and Learn	This feature was introduced.	7.2(0)D1(1)	Configuring VXLAN Flood and Learn
VXLAN BGP EVPN	This feature was introduced. Support for M3 modules is introduced.	7.2(0)D1(1) 7.3(0)DX(1)	Configuring VXLAN BGP EVPN
ACI WAN Interconnect	This feature was introduced.	7.3(1)D1(1)	Configuring ACI WAN Interconnect
Campus Fabric	This feature was introduced.	7.3(1)D1(1)	Campus Fabric



CHAPTER 2

Overview

This chapter contains the following sections:

Licensing Requirements

For a complete explanation of Cisco NX-OS licensing recommendations and how to obtain and apply licenses, see the *Cisco NX-OS Licensing Guide*.

VXLAN Overview

VXLAN is a MAC in IP/UDP(MAC-in-UDP) encapsulation technique with a 24-bit segment identifier in the form of a VXLAN ID. The larger VXLAN ID allows LAN segments to scale to 16 million in a cloud network. In addition, the IP/UDP encapsulation allows each LAN segment to be extended across existing Layer 3 networks making use of Layer 3 equal-cost multipath (ECMP).

Cisco Nexus 7000 switches are designed for hardware-based VXLAN function. It provides Layer 2 connectivity extension across the Layer 3 boundary and integrates between VXLAN and non-VXLAN infrastructures. This can enable virtualized and multi tenant data center designs over a shared common physical infrastructure.

VXLAN provides a way to extend Layer 2 networks across Layer 3 infrastructure using MAC-in-UDP encapsulation and tunneling. VXLAN enables flexible workload placements using the Layer 2 extension. It can also be an approach to building a multi tenant data center by decoupling tenant Layer 2 segments from the shared transport network.

When deployed as a VXLAN gateway, Cisco Nexus 7000 switches can connect VXLAN and classic VLAN segments to create a common forwarding domain so that tenant devices can reside in both environments.

VXLAN has the following benefits:

- Flexible placement of multi tenant segments throughout the data center.

It provides a way to extend Layer 2 segments over the underlying shared network infrastructure so that tenant workloads can be placed across physical pods in the data center.

- Higher scalability to address more Layer 2 segments.

  VXLAN uses a 24-bit segment ID, the VXLAN network identifier (VNID). This allows a maximum of 16 million VXLAN segments to coexist in the same administrative domain. (In comparison, traditional VLANs use a 12-bit segment ID that can support a maximum of 4096 VLANs.)

- Utilization of available network paths in the underlying infrastructure.

  VXLAN packets are transferred through the underlying network based on its Layer 3 header. It uses equal-cost multipath (ECMP) routing and link aggregation protocols to use all available paths.

There are two unicast modes in which VXLAN can run. They are Flood and Learn mode and MAC Distribution mode.

VXLAN Flood and Learn

VXLAN is MAC in IP/UDP encapsulation technique with a 24-bit segment identifier in the form of a VXLAN ID. The larger VXLAN ID allows LAN segments to scale to 16 million in a cloud network. In addition, the IP/UDP encapsulation allows each LAN segment to be extended across existing Layer 3 network. Traditionally with virtual VTEPS the only endpoints that can connect into VXLANs are physical or virtual connections. Physical servers cannot be in the VXLAN network. Routers or services that have traditional VLAN interfaces cannot be used by VXLAN-based networks.

The VXLAN flood and learn gateway feature provides solution to this problem.

VXLAN flood and learn gateway enables the following:

- Host learning on VTEPs based on flood and learn behaviour
- VTEPs join underlay IP multicast groups based on VNI ‘membership’
- If VNI exists behind VTEP, the packet flow joins the corresponding IP multicast group in underlay
- ARP (and other broadcast / unknown unicast / multicast traffic) in a given VNI flooded to all interested VTEPs
- Gateway functions centralised in VXLAN flood and learn
- Cisco Nexus 7000 / 7700 vPC pair with L2 + L3 VXLAN gateway capabilities
- vPC provides MAC state synchronization and active-active HSRP forwarding
- Redundant VTEPs share Anycast VTEP IP address in underlay
- VXLAN bridging occurs directly between VTEPs

VXLAN MAC Distribution

In VXLAN MAC Distribution mode, head-end replication is used to deliver broadcast and multicast frames to the entire network. MAC learning based on data plane activity is not performed, instead the central control

functionality of the Nexus 1000V (virtual supervisor module (VSM)) is used to keep track of all MAC addresses in the domain and send this information to the VTEPs on the system.

VXLAN Tunnel Endpoint

VXLAN uses VXLAN tunnel endpoint (VTEP) devices to map tenants' end devices to VXLAN segments and to perform VXLAN encapsulation and de-encapsulation. Each VTEP function has two interfaces: One is a switch interface on the local LAN segment to support local endpoint communication through bridging, and the other is an IP interface to the transport IP network.

The IP interface has a unique IP address that identifies the VTEP device on the transport IP network known as the infrastructure VLAN. The VTEP device uses this IP address to encapsulate Ethernet frames and transmits the encapsulated packets to the transport network through the IP interface. A VTEP device also discovers the remote VTEPs for its VXLAN segments and learns remote MAC Address-to-VTEP mappings through its IP interface.

The VXLAN segments are independent of the underlying network topology; conversely, the underlying IP network between VTEPs is independent of the VXLAN overlay. It routes the encapsulated packets based on the outer IP address header, which has the initiating VTEP as the source IP address and the terminating VTEP as the destination IP address.

Virtual Network Identifier (VNI)

In RFC 4364 L3VPNs, a 20-bit MPLS label that is assigned to a VPN route determines the forwarding behavior in the data plane for traffic following that route. These labels also serve to distinguish the packets of one VPN from another.

On the other hand, the various IP overlay encapsulations support a virtual network identifier (VNI) as part of their encapsulation format.

A VNI is a value that at a minimum can identify a specific virtual network in the data plane. It is typically a 24- bit value which can support up to 16 million individual network segments.

There are two useful requirements regarding the scope of these VNIs.

- Network-wide scoped VNIs

  Depending on the provisioning mechanism used within a network domain such as a data center, the VNI may have a network scope, where the same value is used to identify the specific Layer-3 virtual network across all network edge devices where this virtual network is instantiated. This network scope is useful in environments such as within the data center where networks can be automatically provisioned by central orchestration systems.

  Having a uniform VNI per VPN is a simple approach, while also easing network operations (i.e. troubleshooting). It also means simplifies requirements on network edge devices, both physical and virtual devices. A critical requirement for this type of approach is to have a very large amount of network identifier values given the network-wide scope.

- Locally assigned VNIs

  In an alternative approach supported as per RFC 4364, the identifier has local significance to the network edge device that advertises the route. In this case, the virtual network scale impact is determined on a per node basis, versus a network basis.

When it is locally scoped, and uses the same existing semantics of a MPLS VPN label, the same forwarding behaviors as specified in RFC 4364 can be employed. It thus allows a seamless stitching together of a VPN that spans both an IP based network overlay and a MPLS VPN.

This situation can occur for instance at the data center edge where the overlay network feeds into an MPLS VPN. In this case, the identifier may be dynamically allocated by the advertising device.

It is important to support both cases, and in doing so, ensure that the scope of the identifier be clear and the values not conflict with each other.

It should be noted that deployment scenarios for these virtual network overlays are not constrained to the examples used above to categorize the options. For example, a virtual network overlay may extend across multiple data centers.

- Global unicast table

  The overlay encapsulation can also be used to support forwarding for routes in the global or default routing table. A VNI value can be allocated for the purpose as per the options mentioned above.

VXLAN BGP EVPN Control Plane

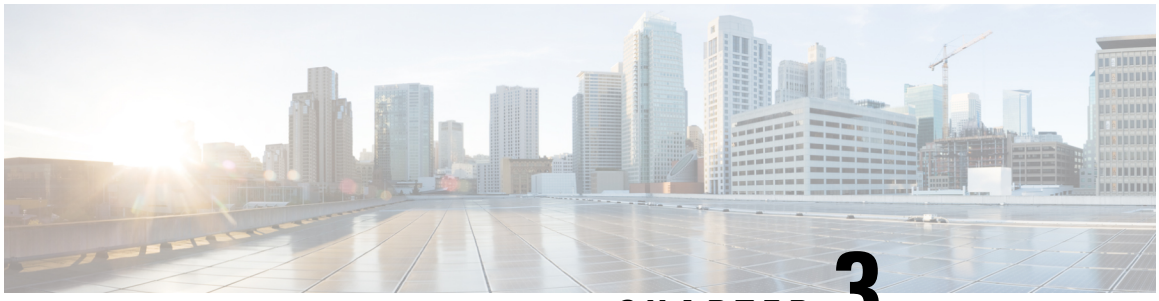
The EVPN overlay specifies adaptations to the BGP MPLS-based EVPN solution to enable it to be applied as a network virtualization overlay with VXLAN encapsulation where:

- PE node role described in BGP MPLS EVPN is equivalent to VTEP/network virtualization edge (NVE) device.
- VTEP information is distributed via BGP.
- VTEPs use control plane learning/distribution via BGP for remote MAC addresses instead of data plane learning.
- Broadcast, unknown unicast and multicast (BUM) data traffic is sent using a shared multicast tree.
- BGP route reflector (RR) is used to reduce the full mesh of BGP sessions among VTEPs to a single BGP session between a VTEP and the RR.
- Route filtering and constrained route distribution are used to ensure that the control plane traffic for a given overlay is only distributed to the VTEPs that are in that overlay instance.
- Host (MAC) mobility mechanism to ensure that all the VTEPs in the overlay instance know the specific VTEP associated with the MAC.
- Virtual network identifiers (VNIs) are globally unique within the overlay.

The EVPN overlay solution for VXLAN can also be adapted to enable it to be applied as a network virtualization overlay with VXLAN for Layer 3 traffic segmentation. The adaptations for Layer 3 VXLAN are similar to L2 VXLAN except the following:

- VTEPs use control plane learning/distribution via BGP of IP addresses (instead of MAC addresses)
- The virtual routing and forwarding instance is mapped to the VNI
- The inner destination MAC address in the VXLAN header does not belong to the host but to the receiving VTEP that does the routing of the VXLAN payload. This MAC address is distributed via BGP attribute along with EVPN routes.

Note IP hosts have an associated MAC address, coexistence of both Layer 2 VXLAN and Layer 3 VXLAN overlays are supported. Additionally, the Layer 2 VXLAN overlay will also be used to facilitate communication between non-IP based (Layer 2 only) hosts.



CHAPTER 3

Configuring VXLAN Flood and Learn

This chapter contains the following sections:

Information About VXLAN

VXLAN with vPC Overview

The vSwitch can be dually connected to the vPC via a hypervisor VLAN. The VTEP on L1 and L2 is identified by the same IP address. vPC is active/active for East-West traffic (from the physical server to the VMs behind vSwitch). It is active/standby with the elected forwarder for packets from North-South traffic.

Active/Active scheme:

- Both switches perform encapsulation and decapsulation between the VXLAN tunnel (on the access side) and the physical servers. To prevent duplicate copies, we rely on the VSL bit.
- If a packet comes in on hypervisor VLAN on a switch it is bridged to other peers via the peerlink. The decapsulated copy is prevented from going over the peer link (using reserved ftag CBL scheme). Both switches bridge locally on the hypervisor VLAN and decapsulate and bridge in the tenant VNI (the VSL bit prevents a duplicate copy from being sent to the vPC legs).
- If a packet comes into the tenant VNI from the physical server, it is bridged to the vPC peer. The VXLAN tunnel encapsulated copy is blocked from going over the peerlink using LTL+1 logic.

Active/Standby scheme:

- Since hardware does not have a mechanism to prevent both switches from sending and receiving packets to and from the North, one of the vPC peers is selected as the forwarder by PIM.

VXLAN Layer 2 Gateway

The VXLAN Layer 2 gateway bridges traffic between physical servers and VM's behind vSwitches that are in the same VNI.

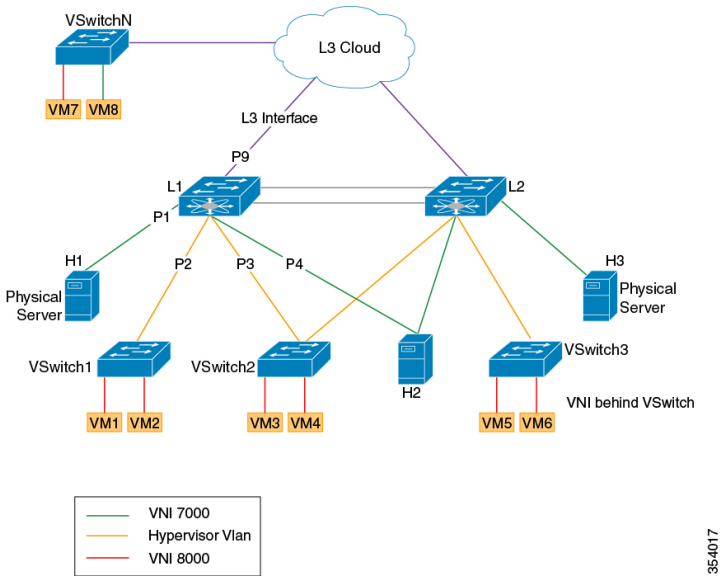
- Connectivity of vSwitches to Cisco Nexus 7000 is via a Layer 2 port through a VLAN which is called a hypervisor VLAN. One of the requirements for a VXLAN gateway is that the hypervisor VLAN should be Layer 3 enabled (SVI configured) and be a member of the core VRF.
- Traffic from the physical server is mapped to segment (VNI) using VSI configuration.
- Traffic from VMs behind vSwitches are encapsulated in VXLAN format with VNI information from the server to which it belongs. The VNI identifies the bridge-domain that both the physical server and the virtual servers are a part.
- For packets coming from vSwitches, the Layer 2 VXLAN gateway strips the VXLAN header and identifies the bridge-domain before bridging the packet to the physical server. Similarly, when physical servers talk to VM's behind vSwitches, the VXLAN header is appended with appropriate VNI information before sending it to the vSwitches.
- VXLAN uses the control multicast group for broadcast, unknown unicast and multicast (BUM) traffic. When the control multicast group is configured on the vSwitch, it sends IGMP reports to the Cisco Nexus 7000 switch on the hypervisor VLAN . This results in Layer 2 multicast state creation for the control multicast group on the hypervisor VLAN. Since the hypervisor VLAN is Layer 3 enabled on the core VRF, it triggers a PIM join and Layer 3 multicast state creation. Thus, BUM traffic is bridged to locally connected vSwitches via Layer 2 multicast bridging and to remote vSwitches behind Layer 3 cloud via Layer 3 multicast routing.

VXLAN Layer 3 Gateway

Layer 3 VXLAN gateway enables routing between different VNIs. The Cisco Nexus 7000 can be placed as a pure Layer 3 routing box, which does inter VNI routing or it can be placed along with Layer 2 VXLAN gateway functionality. To enable Layer 3 VXLAN functionality, BDI has to be configured on the tenant VNI and the tenant VRF has to be different from the core VRF.

All VMs and physical servers and VNIs belonging to the same tenants can communicate. Any packet that needs to be routed across VNIs needs to be sent to the Layer 3 gateway switch, by setting the outer IP to the Layer 3 gateway IP, and the inner DMAC to be the Layer 3 gateway MAC.

Figure 1: Layer 2 VXLAN Topology



The implications of the limited Layer 3 gateway functionality are the following:

- Since the Layer 3 gateway is centralized, there is no need to run control protocols (to advertise the host reachability information). When the Layer 3 gateway receives the packet, it looks at the Layer 3 header information to route the packet (to the destination subnet/VNI), but the actual remote switch to which the packet needs to be forwarded is resolved at the Layer 2 level, which is done via data plane learning.

Figure 2: Layer 2 Gateway Packet Header

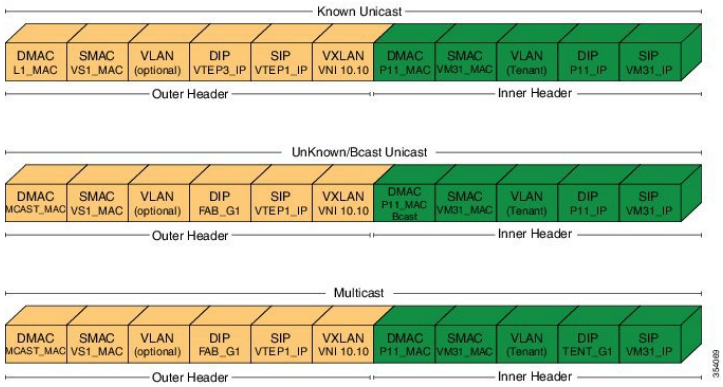


Figure 3: Layer 3 Gateway Packet Header

For example, in the above diagram the packets from VM31 (1.1.1.x) to P12 (2.2.2.x) are resolved at the Layer 3 level to go to SVI_VNI_20.20. After the routing, the destination VTEP, that is responsible for the destination host, is identified at the Layer 2 level. There are two cases to consider here:

1. If the switch that runs the Layer 3 gateway functionality does not run Layer 2 gateway functionality, that is, participates in the data plane learning, it has to flood the post-routed packet to all Layer 2 gateways through the multicast tree.
2. If the switch runs Layer 3 gateway and Layer 2 gateway functionality, the switch can resolve the destination VTEP at the Layer 2 level, and can forward the packet to the correct VTEP by itself.

Since Layer 2 gateway and Layer 3 gateway functionalities are tightly integrated from the configuration perspective (Layer 3 gateway is achieved by configuring the BDIs for bridge-domains corresponding to the VNIs), case (1) will not be applicable in the Cisco Nexus 7000, and only case (2) is supported.

Since there is a centralized Layer 3 gateway, any multicast packet that needs to be routed across multiple VNIs, will be have to be replicated multiple times (one for each VNI).

In the above example, if P12 is interested in traffic initiated by VM31, the Layer 3 gateway will have to send two copies of the packet (one for VNI 20.20, and, one for VNI 30.30).

Also, note that routing between VNI and Layer 3 interfaces can be supported only for those interfaces that are local to the Layer 3 gateway, assuming those local Layer 3 interfaces are configured in the same tenant VRF as the VNI. One possible solution would be to have a separate Layer 3 connection between those leaf switches and spine (Layer 3 gateway) switch, configure them all in tenant VRF, run OSPF (or IS-IS) for that tenant VRF, and run PIM to draw multicast traffic along the tree.

Guidelines and Limitations for VXLAN

VXLAN has the following guidelines and limitations:

- VxLAN and Fabric Path features cannot be enabled on the same VDC.
- 4 VTEP interfaces per VDC are supported. The total number of remote VTEPs is 1K per VDC.

- 1K VNIs are allowed per VDC.
- 1k BDIs are allowed per system.
- Bidir in underlay is not supported on vPC VXLAN Gateways.
- In VXLAN vPC deployments with F3 modules, the vPC peer-link should be on an isolated ASIC instance from the Layer 3 core ports. After changing the peer-link ports to an isolated ASIC instance, ensure that you reload the switch.
- In a VXLAN vPC deployment with F3 modules and connected FEX devices, unknown unicast traffic from a remote source to the vPC switch pair may result in duplicate traffic if the MAC address is known to the vPC switches. Both vPC switches will receive a copy of the packet and forward it to the receiver behind FEX.
- In a VXLAN vPC deployment with F3 modules, known unicast traffic from a remote source to the vPC switch pair may result in loss of traffic if the MAC address is no longer known to the vPC switches.
- The number of IPv4 unicast routes supported is 64K shared with multicast routes.
- Number of IPv4 Multicast Groups is 32K due to software limitation.
- Maximum number of MAC addresses learned (local MACs and remote MACs) is 64K per F3 ASIC. (F3 MAC table size is 64K).
- VXLAN with IGMP snooping on VTEP tunnel interface is supported. You can configure **ip igmp snooping disable-nve-static-router-port** globally or per vlan to learn snooping states dynamically.
- VXLAN with Ingress replication using control plane is not supported.
- You can send Layer 3 end-to-end traffic with a maximum packet size of 9192 between VSI ports in different VNI segments.
- Layer 3 traffic will be dropped if the MTU packet size is greater than 9192.
- Inner VLAN class of service (CoS) needs to be propagated from ingress to egress in VXLAN. At the encap side, CoS value will be copied to outer differentiated services code point (DSCP) and on the decap side DSCP QOS will be copied back to egress VLAN COS.
- vPC peer-link can carry both global VLAN and bridge-domains that are having VXLAN enabled.
- MLD snooping on bridge-domain with VXLAN is not supported.
- ACL and QoS on a VTEP tunnel are not supported.
- Layer 3 VXLAN gateways are supported.
- PVLAN with VXLAN is not supported.
- Extending VLAN/VNI with OTV, VPLS, NV-GRE, and Layer 2 LISP when VXLAN is enabled is not supported due to hardware restrictions in the F3 ASIC.
- Extending Layer 2 MPLS network directly with VXLAN is not supported. Layer 2 MPLS has to be terminated and connected as a CE port for VXLAN extension due to forwarding restrictions.
- Interop with IPGRE is not supported.
- Interop with Layer 3 LISP is not supported.
- F3 SPAN feature does not support spanning L3 egress multicast packets.

- Netflow is not supported on VTEP interface.
- Netflow on VXLAN-enabled bridge domains is not supported.
- FEX ports are not supported as edge ports for VXLAN enabled bridge-domains.
- Extending global VLANs using VXLAN is not supported.
- BPDUs are not sent over the VTEP tunnel.
- Layer 3 Multicast - SSM in the core is not supported.
- MIB/XML support for VXLAN related changes is not supported.
- VXLAN encapsulation of an outer header with an IPv6 header is not supported.
- In VXLAN vPC Setup, RP should be configured on L3 core network. Direct connectivity between L2 gateway and vPC L3 gateway without L3 core in between is not supported.
- Any Source Multicast (ASM) is supported. Bidirectional PIM is supported on a single, non-vPC leaf switch.
- Physical port vPC for Vn-segment Service Instance (VSI) is not supported.
- The following Interface NVE counters are supported.
  - Unicast and Multicast packets and bytes transmitted
  - Unicast and Multicast packets and bytes received
- SPAN is not supported for NVE tunnel interfaces.
- Equal cost multipath (ECMP) on the core is based on inner packet (DMAC, SMAC) combination.
- Maximum 64 MST instances are supported.
- MST scale limit is 300K logical ports on unidimensional setup.
- When vPC peer-link flap, Mac addresses will be flushed for orphan and vPC ports. End point needs to re-ARP.
- 32 VSI encapsulation profiles are supported per interface.
- SSM is not supported
- Bi-Dir multicast mode is not supported for vPC
- IGMP Snooping Layer2 Multicast Mac lookup mode is not supported.
- IPv6 for Multicast is not supported.
- Hypervisor VLANs can be configured using regular VLAN and trunk or access port configurations.
- vPC peer-link can carry both global VLANs and bridge-domains that are VXLAN enabled.

Considerations for VXLAN Deployment

- A loopback address is required when using the **source-interface config** command. The loopback address represents the local VTEP IP.

- For the Network Virtualization Endpoint (NVE) source loop back address, secondary address should be same on both the vPC peers and the primary address should be different.
- To establish IP multicast routing in the core, IP multicast configuration, PIM configuration, and RP configuration is required.
- VTEP to VTEP unicast reachability can be configured through any IGP protocol.

vPC Considerations for VXLAN Deployment

- Bind NVE to a loopback address that is separate from other loopback addresses that are required by Layer 3 protocols. A best practice is to use a dedicated loopback address for VXLAN.
- The loopback address used by NVE needs to be configured to have a primary IP address and a secondary IP address.
- The secondary IP address is used for all VXLAN traffic that includes multicast and unicast encapsulated traffic.
- vPC peers must have identical configurations as listed below:
  - Consistent Bridge-domain to VNI mapping.
  - Consistent NVE binding to the same loopback interface.
  - The same secondary IP address must be confgured on both the switches. However, each vPC peer switch should have a unique primary IP address assigned to it.
  - Consistent NVE interface to VNI mapping.
  - Consistent VNI to group mapping.
- For multicast, the vPC node that receives the (S, G) join from the RP (rendezvous point) becomes the DF (designated forwarder). On the DF node, encap routes are installed for multicast.

  Decap routes are installed based on the election of a decapper from between the VPC primary node and the VPC secondary node. The winner of the decap election is the node with the least cost to the RP or the source. However, if the cost to the RP is the same for both nodes, the VPC primary node is elected.

  The winner of the decap election has the decap mroute installed. The other node does not have a decap route installed.
- On a VPC device, BUM traffic (broadcast, unknown-unicast, and multicast traffic) from hosts is replicated on the vPC peer-link. A copy is made of every native packet and each native packet is sent across the vPC peer-link to service orphan-ports connected to the peer VPC switch.

  To prevent traffic loops in VXLAN networks, native packets ingressing the vPC peer-link cannot be sent to an uplink. However, if the peer switch is the encapper, the copied packet traverses the vPC peer-link and is sent to the uplink.

  In a VXLAN vPC deployment with peer switch, encapsulation profile, and bridge domain configurations, the vPC secondary peer switch does not generate or process BPDUs for bridge domains.
- When vPC peer-link is shut, the loopback primary address is used as the source IP address for encapsulation by both vPC switches.

Note Orphans connected to the VPC secondary will experience loss of traffic for the period that the vPC peer-link is shut. This is similar to Layer 2 orphans in a VPC secondary of a traditional VPC setup.

- When vPC peer-link is no-shut, the NVE loopback secondary address is used.
- For VPC, the loopback interface has 2 IP addresses: the primary IP address and the secondary IP address.

  The primary IP address is unique and is used by Layer 3 protocols.

  The secondary IP address on loopback is necessary because the interface NVE uses it for the VTEP IP address. The secondary IP address must be same on both vPC peers.
- The VPC peer-gateway feature must be enabled on both peers. As a best practice, use peer-switch, peer gateway, ip arp sync, ipv6 nd sync configurations for improved convergence in VPC topologies.

  The following is an example (best practice) of a VPC configuration:

```
switch# sh ru vpc

version 6.1(2)I3(1)
feature vpc
vpc domain 2
  peer-switch
  peer-keepalive destination 172.29.206.65 source 172.29.206.64
  peer-gateway
  ipv6 nd synchronize
  ip arp synchronize
```

- On a VPC pair, shutting down NVE or NVE loopback on one of the VPC nodes is not a supported configuration. This means that traffic fail over on one-side NVE shut or one-side loopback shut is not supported.
- Redundant anycast RPs configured in the network for multicast load-balancing and RP redundancy are supported on VPC VTEP topologies.
- The following are the examples of SVI with PIM enabled:

```
switch# show run interface BDI3

interface BDI3
  description special_svi_over_mct
  no shutdown
  ip address 30.2.1.1/30
  ip pim sparse-mode


switch# show run interface BDI3

interface BDI3
 description special_svi_over_vPC peer-link no shutdown
 ipv6 address FE80::290:27FF:FE8C:B709
 ip pim sparse-mode
```

Note The SVI must be configured on both VPC peers and requires PIM to be enabled.

- As a best practice when changing the secondary IP address of an anycast VPC VTEP, the NVE interfaces on both the VPC primary and the VPC secondary should be shut before the IP changes are made.
- For a VXLAN vPC deployment, you should configure the **switchport trunk native vlan tag exclude control** command on the interface port channel configured as the vPC peer-link.

Network Considerations for VXLAN Deployments

- MTU Size in the Transport Network

  Due to the MAC-to-UDP encapsulation, VXLAN introduces 50-byte overhead to the original frames. Therefore, the maximum transmission unit (MTU) in the transport network needs to be increased by 50 bytes. If the overlays use a 1500-byte MTU, the transport network needs to be configured to accommodate 1550-byte packets at a minimum. Jumbo-frame support in the transport network is required if the overlay applications tend to use larger frame sizes than 1500 bytes.

- ECMP and LACP Hashing Algorithms in the Transport Network

  As described in a previous section, Cisco Nexus 7000 Series Switches introduce a level of entropy in the source UDP port for ECMP and LACP hashing in the transport network. As a way to augment this implementation, the transport network uses an ECMP or LACP hashing algorithm that takes the UDP source port as an input for hashing, which achieves the best load-sharing results for VXLAN encapsulated traffic.

- Multicast Group Scaling

  The VXLAN implementation on Cisco Nexus 7000 Series Switches uses multicast tunnels for broadcast, unknown unicast, and multicast traffic forwarding. Ideally, one VXLAN segment mapping to one IP multicast group is the way to provide the optimal multicast forwarding. It is possible, however, to have multiple VXLAN segments share a single IP multicast group in the core network. VXLAN can support up to 16 million logical Layer 2 segments, using the 24-bit VNID field in the header. With one-to-one mapping between VXLAN segments and IP multicast groups, an increase in the number of VXLAN segments causes a parallel increase in the required multicast address space and the amount of forwarding states on the core network devices. At some point, multicast scalability in the transport network can become a concern. In this case, mapping multiple VXLAN segments to a single multicast group can help conserve multicast control plane resources on the core devices and achieve the desired VXLAN scalability. However, this mapping comes at the cost of suboptimal multicast forwarding. Packets forwarded to the multicast group for one tenant are now sent to the VTEPs of other tenants that are sharing the same multicast group. This causes inefficient utilization of multicast data plane resources. Therefore, this solution is a trade-off between control plane scalability and data plane efficiency.

  Despite the suboptimal multicast replication and forwarding, having multiple-tenant VXLAN networks to share a multicast group does not bring any implications to the Layer 2 isolation between the tenant networks. After receiving an encapsulated packet from the multicast group, a VTEP checks and validates the VNID in the VXLAN header of the packet. The VTEP discards the packet if the VNID is unknown to it. Only when the VNID matches one of the VTEP's local VXLAN VNIDs, does it forward the packet to that VXLAN segment. Other tenant networks will not receive the packet. Thus, the segregation between VXLAN segments is not compromised.

- Spanning Tree Protocol (STP) domain

  Ensure that the root of an STP domain local to the VXLAN fabric is a VTEP, or placed within the fabric. The STP root should not be outside the VXLAN fabric (below the VTEPs) since it will lead to Layer 2 loops.

Considerations for the core VRF

The following are considerations for the configuration of the core VRF:

- On the VTEP device:
  - Enable and configure IP multicast.
  - Create and configure a loopback interface with a /32 IP address.
  - Enable IP multicast on the loopback interface.
  - Advertise the loopback interface/32 addresses through the routing protocol that runs in the transport network.
  - Enable IP multicast on the uplink outgoing physical interface.
- Throughout the transport network:
  - Enable and configure IP multicast.

ISSU Support

The following are the ISSU support details for VXLAN flood and learn deployment:

- Cisco Nexus 7000 Series switches running Cisco NX-OS Release 6.2.10 or 6.2.12.
- F2E, M2, and F3 modules.
- Virtual Device Context (VDC) Types:
  - F3 Only
  - F3 & F2, F3 & M2

Supported ISSU Steps:

1. Upgrade ISSU to Cisco NX-OS Release 7.2(0)D1(1).
2. For F3 Only VDC, configure default interface for all L2/L3 interfaces.
3. Reload F3 Only VDC or the switch.
4. Enable “feature nve” in F3 Only VDC.
5. Configure VXLAN - VSI/NVE.

Configuring VXLAN

Enabling VXLANs

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	[**no**] **feature nv overlay**	Enables the VXLAN feature.
Step 3	[**no**] **feature vni**	Configures the global mode for all VXLAN bridge domains.
Step 4	[**no**] **vni** [*range*]	Defines the VNI range.
Step 5	(Optional) **copy running-config startup-config**	Saves the change persistently through reboots and restarts by copying the running configuration to the startup configuration.

Example

```
switch# configure terminal
switch(config)# feature nv overlay
switch(config)# feature vni
switch(config)# vni 7000
switch(config)# copy running-config startup-config
```

Configuring VNI Service Instances

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**encapsulation profile vni** *vsi-range*	Encapsulates traffic in the virtual network.
Step 3	**dot1q** *var* **vni** *vnid*ı	Defines the matching criteria to map Q-in-Q ingress frames.
Step 4	**interface** *var*	Enters interface configuration mode.
Step 5	**service instance** *num* **vni**	Creates a service instance.
Step 6	**no shut down**	Enables the service instance on this interface.
Step 7	**encapsulation profile** *vsi-range*	Encapsulates traffic in the virtual network.

Example

The following example shows how to configure VNI service instances:

```
config t
       encapsulation profile vni vsi_100_to_7000
            dot1q 100 vni 7000
  interface e1/1
      service instance 1 vni
      no shut down
      encapsulation profile vsi_100_to_7000
```

Mapping VLAN to VNI

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**system bridge-domain** *ID*	Identify the bridge domain IDs that are available for bridge-domain configuration.
Step 3	**bridge-domain** *vlan-ID*	Enables bridging to map VLAN to VXLAN VNI.
Step 4	**member vni** *number*	Maps VXLAN to a bridge domain.

Example

The following example shows how to map an encapsulation profile to a VNI:

```
switch# configure terminal
switch(config)# system bridge-domain 100-500
switch(config)# bridge-domain 100
switch(config)# member vni 7000
```

Creating an VTEP and NVE Interface

An NVE interface is the overlay interface that terminates VXLAN tunnels.

There is a one-on-one mapping between NVE interface configuration and the source interface. Source interface used under a NVE cannot be reused.

You can create and configure an NVE (overlay) interface with the following:

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.

	Command or Action	Purpose
Step 2	**interface nve** *x*	Creates a VXLAN overlay interface that terminates VXLAN tunnels. **Note** Only 4 NVE interfaces are allowed on the switch. Range is from 1 to 4.
Step 3	**source-interface loopback** *src-if*	The source interface must be a loopback interface that is configured on the switch with a valid /32 IP address. This /32 IP address must be known by the transient devices in the transport network and the remote VTEPs. This is accomplished by advertising it through a dynamic routing protocol in the transport network.
Step 4	**member vni** *vni* [**mcast-group** *mcast-ip*]	Associate VXLAN VNIs (Virtual Network Identifiers) with the NVE interface.
Step 5	**exit**	Exits interface configuration mode.
Step 6	**interface loopback** *if-number*	Creates a loopback interface.
Step 7	**ip address** *address*	Assigns an ip address to the configured interface.
Step 8	**vrf member core**	Creates a vrf member core in the interface.

Example

The following example shows how to create a VTEP / NVE interface:

```
switch# configure terminal
switch(config)# interface nve 1
switch(config-if)# source-interface loopback 10
switch(config-if)# member vni 7000 mcast-group 225.1.1.1
switch(config-if)# member vni 8000 mcast-group 226.1.1.1

switch# configure terminal
switch(config)# interface loopback 10
switch(config-if)# ip address 10.1.1.1/32
switch(config-if)# vrf member core
```

Configuring vPC Peer-link

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**interface** *var*	Enters interface configuration mode.

	Command or Action	Purpose
Step 3	**switchport**	Sets the interface type to be a Layer 2 host port.
Step 4	**switchport mode trunk**	Sets the interface as a Layer 2 trunk port.
Step 5	**switchport trunk native vlan tag exclude control**	Enables native VLAN tagging on a trunk port, while ensuring that the control packets on the native VLAN are untagged. **Note** For trunk ports, by default data and control packets are untagged. The **switchport trunk native vlan tag** command form ensures that control and data packets of the native VLAN are tagged.
Step 6	**spanning-tree port type network**	Configures the interface that connects to a Layer 2 switch or bridge as a network spanning tree port.
Step 7	**vpc peer-link**	Configures the port channel as a vPC peer-link.

Example

The following example shows how to configure vPC peer-link:

```
switch# configure terminal
switch(config)# interface port-channel10
switch(config-if)# switchport
switch(config-if)# switchport mode trunk
switch(config-if)# switchport trunk native vlan tag exclude control
switch(config-if)# spanning-tree port type network
switch(config-if)# vpc peer-link
```

Configuring L3 Interface on VXLAN Tunnel/Hypervisor VLAN

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**interface** *var*	Enters interface configuration mode.
Step 3	**ip address** *address*	Configures the IP address on the interface.
Step 4	**vrf member core**	Creates a vrf member core in the interface.

Example

The following example shows how to configure L3 interface on VXLAN tunnel/hypervisor VLAN:

```
switch# configure terminal
switch(config)# interface vlan 300
switch(config-if)# ip address 11.1.1.1/24
switch(config-if)# vrf member core
```

Configuring L3 Interface for IP Cloud Connectivity

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**interface** *var*	Enters interface configuration mode.
Step 3	**no switchport**	Disables the switchport.
Step 4	**ip address** *address*	Configures the IP address on the interface.
Step 5	**vrf member core**	Creates a vrf member core in the interface.

Example

The following example shows how to configure L3 interface for IP cloud connectivity:

```
switch# configure terminal
switch(config)# interface e7/1
switch(config-if)# no switchport
switch(config-if)# ip address 11.1.1.1/24
switch(config-if)# vrf member core
```

Configuring L3 Interface on Tenant Bridge-Domains/VNIs in L3 Gateway

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**feature interface-vlan**	Enables the creation of BDI interfaces.
Step 3	**interface bridge-domain** *number*	Enters interface configuration mode.
Step 4	**ip address** *address*	Configures the IP address on the interface.
Step 5	**vrf member** *tenant*	Configures the VRF member.

	Command or Action	Purpose
Step 6	**hsrp** *var*	Creates an HSRP group and enters HSRP configuration mode.
Step 7	**ip address** *address*	Configures the virtual IP address for the HSRP group and enables the group. Repeat steps 1-5 to configure another bridge-domain interface and HSRP.

Example

The following example shows how to configure L3 interface on tenant bridge-domains/VNIs in L3 gateway:

```
feature interface-vlan
interface bridge-domain 100
     ip address 50.1.1.2/24
     vrf member tenant
     hsrp 50
         ip address 50.1.1.1


feature interface-vlan
interface bridge-domain 200
    ip address 60.1.1.2/24
    vrf member tenant
     hsrp 60
     ip address 60.1.1.1
```

Disabling VXLANs

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters configuration mode.
Step 2	**no feature vni**	Disables the global mode for all VXLAN bridge domains
Step 3	**no feature nv overlay**	Disables the VXLAN feature.
Step 4	**no bridge-domain**	Disables bridging to map VLAN.
Step 5	**no member vni**	Dissociates VXLAN VNIs from the NVE interface.
Step 6	**no vni**	Removes the VXLAN segment ID to which the VLAN is mapped.

	Command or Action	Purpose
Step 7	(Optional) **copy running-config startup-config**	Saves the change persistently through reboots and restarts by copying the running configuration to the startup configuration.

Verifying the VXLAN Configuration

To display the VXLAN configuration information, enter one of the following commands:

Command	Purpose
show tech-support vxlan	Displays related VXLAN tech-support information.
show logging level nve	Displays logging level.
show tech-support nve	Displays related NVE tech-support information.
show run interface nve *x*	Displays NVE overlay interface configuration.
show nve interface nve *x*	Displays NVE overlay interface status.
show interface nve *x*	Displays all the counters of an NVE interface.
show nve peers	Displays NVE peer status.
show bridge-domain	Displays the bridge domain information.
show run vni	Displays the VXLAN VNI configuration.
show interface nve counters	Displays the NVE counters in an interface.
show interface bdi	Displays the configuration summary of the corresponding BDI.
show vni x	Displays the list of all VNIs
show ip mroute	Displays information about mroute entries in the mroute table.
show nve VXLAN-params	Displays VXLAN parameters, such as VXLAN destination or UDP port.
show nve internal platform interface nve 1 detail	Displays NVE overlay internal detailed information.
show nve vxlan-params	Displays VXLAN parameters, such as VXLAN destination or UDP port.

Configuration Examples

Example of VXLAN Flood and Learn Configuration

The following example shows the VXLAN Flood and Learn configuration.

VTEP-1:

```
feature pim
system bridge-domain 50,75
feature nv overlay
feature interface-vlan

feature vni
vni 30000
vni 50000

ip route 10.10.10.2/32 Ethernet10/1 10.1.1.2
ip pim rp-address 10.1.1.1 group-list 209.165.0.0/4

bridge-domain 50
bridge-domain 75

encapsulation profile vni VSI_50_TO_5000
  dot1q 50  vni 5000
encapsulation profile vni VSI_75_TO_7500
    dot1q 75  vni 7500
bridge-domain 50
  member vni 5000
bridge-domain 75
  member vni 7500

interface nve1
  no shutdown
  source-interface loopback10
  member vni 5000 mcast-group 209.165.1.1
  member vni 7500 mcast-group 209.165.1.1

interface Bdi50
   no shutdown
   ip address 10.50.50.50/24

interface Bdi75
   no shutdown
   ip address 10.75.75.75/24

interface Ethernet7/17
  no switchport
  no shutdown
  service instance 1 vni
    no shutdown
    encapsulation profile VSI_50_TO_5000  default
  service instance 2 vni
    no shutdown
    encapsulation profile VSI_75_TO_7500 default

interface Ethernet10/1
  no switchport
  ip address 10.1.1.1/30
```

```
  ip pim sparse-mode
  no shutdown

interface loopback10
  ip address 10.10.10.1/32
  ip pim sparse-mode
```

Note The internal interface on the VTEP is configured as a layer-3 port. However, there is no IP assigned to it. It is also important to note that the BD value defined on the VTEP does not have to match the VLAN ID on the device from which you are sending the traffic. However, the dot1q to VNI mapping defined in the encapsulation profile, which is called under the service instance on the internal interface, must match the VLAN ID on the device from which you are sending the traffic.

VTEP-2:

```
feature pim
system bridge-domain 50,75
feature nv overlay
feature interface-vlan

feature vni
vni 32000
vni 52000

ip route 10.10.10.1/32 Ethernet10/7 10.1.1.1
ip pim rp-address 10.1.1.1 group-list 209.165.0.0/4

bridge-domain 50
bridge-domain 75

encapsulation profile vni VSI_50_TO_5000
  dot1q 50  vni 5000
encapsulation profile vni VSI_75_TO_7500
    dot1q 75  vni 7500
bridge-domain 50
  member vni 5000
bridge-domain 75
  member vni 7500

interface nve1
  no shutdown
  source-interface loopback10
  member vni 5000 mcast-group 209.165.1.1
  member vni 7500 mcast-group 209.165.1.1

interface Bdi50
 no shutdown
 ip address 10.50.50.51/24

interface Bdi75
 no shutdown
 ip address 10.75.75.76/24

interface Ethernet7/30
  no switchport
  no shutdown
  service instance 1 vni
    no shutdown
    encapsulation profile VSI_50_TO_5000  default
```

```
  service instance 2 vni
    no shutdown
    encapsulation profile VSI_75_TO_7500 default

interface Ethernet10/7
  no switchport
  ip address 10.1.1.2/30
  ip pim sparse-mode
  no shutdown

interface loopback10
  ip address 10.10.10.2/32
  ip pim sparse-mode
```

Example of Verifying VXLAN Flood and Learn Configuration

The following example shows the VXLAN Flood and Learn configuration verification.

VTEP-1:

```
VTEP-1# show nve vni
Codes: CP - Control Plane        DP - Data Plane
       UC - Unconfigured         SA - Suppress ARP

Interface VNI      Multicast-group   State Mode Type [BD/VRF]      Flags
--------- -------- ----------------- ----- ---- ------------------ -----
nve1      5000     209.165.1.1         Up    DP   L2 [50]
nve1      7500     192.168.1.1         Up    DP   L2 [75]

VTEP-1# show running-config interface nve 1

interface nve1
  no shutdown
  source-interface loopback10
  member vni 5000 mcast-group 209.165.1.1
  member vni 7500 mcast-group 192.168.1.1

VTEP-1# show service instance vni detail

VSI: VSI-Ethernet7/17.1
If-index: 0x35310001
Admin Status: Up
Oper Status: Up
Auto-configuration Mode: No
encapsulation profile vni VSI_50_TO_5000
  dot1q 50 vni 5000
Dot1q   VNI     BD
------------------
50      5000    50

VSI: VSI-Ethernet7/17.2
If-index: 0x35310002
Admin Status: Up
Oper Status: Up
Auto-configuration Mode: No
encapsulation profile vni TEST
  dot1q 100 vni 7500
Dot1q   VNI     BD
------------------
100     7500    75

VTEP-1# show bridge-domain
```

```
Bridge-domain 50  (2 ports in all)
Name:: Bridge-Domain50
 Administrative State: UP               Operational State: UP
        VSI-Eth7/17.1
        vni5000
        nve1

Bridge-domain 75  (2 ports in all)
Name:: Bridge-Domain75
 Administrative State: UP               Operational State: UP
        VSI-Eth7/17.2
        vni7500
        nve1

VTEP-1# show mac address-table dynamic
 Note: MAC table entries displayed are getting read from software.
 Use the 'hardware-age' keyword to get information related to 'Age'

 Legend:
        * - primary entry, G - Gateway MAC, (R) - Routed MAC, O - Overlay MAC
        age - seconds since last seen,+ - primary entry using vPC Peer-Link, E -
 EVPN entry
        (T) - True, (F) - False ,  ~~~ - use 'hardware-age' keyword to retrieve
age info
  VLAN/BD   MAC Address      Type      age     Secure NTFY Ports/SWID.SSID.LID
---------+-----------------+--------+---------+------+----+------------------
* 50       547f.eeec.af43    dynamic     ~~~      F    F  nve1/10.10.10.2
* 50       547f.eeec.af44    dynamic     ~~~      F    F  VSI-Eth7/17.1
* 50       547f.eeec.af45    dynamic     ~~~      F    F  nve1/10.10.10.2
* 75       547f.eeec.af44    dynamic     ~~~      F    F  VSI-Eth7/17.2
* 75       547f.eeec.af45    dynamic     ~~~      F    F  nve1/10.10.10.2

VTEP-1# show ip mroute detail
IP Multicast Routing Table for VRF "default"

Total number of routes: 7
Total number of (*,G) routes: 2
Total number of (S,G) routes: 4
Total number of (*,G-prefix) routes: 1

(*, 209.165.1.1/32), uptime: 19:51:28, nve(1) ip(0) pim(1)
  Data Created: No
  VXLAN Flags
    VXLAN Encap
  Stats: 0/0 [Packets/Bytes], 0.000   bps
  Incoming interface: Ethernet10/1, RPF nbr: 1.1.1.1
  Outgoing interface list: (count: 2)
    Ethernet10/1, uptime: 19:51:09, pim, (RPF)
    nve1, uptime: 19:51:28, nve

(10.10.10.1/32, 209.165.1.1/32), uptime: 19:51:28, nve(0) mrib(0) ip(0) pim(1)
  Data Created: No
  Received Register stop
  VXLAN Flags
    VXLAN Encap
  Stats: 19/2274 [Packets/Bytes], 0.000   bps
  Incoming interface: loopback10, RPF nbr: 10.10.10.1, internal
  Outgoing interface list: (count: 1)
    Ethernet10/1, uptime: 19:51:09, pim

(10.10.10.2/32, 209.165.1.1/32), uptime: 18:10:06, pim(1) mrib(1) ip(0)
  Data Created: Yes
  VXLAN Flags
```

```
    VXLAN Decap
  Stats: 9/846 [Packets/Bytes], 0.000   bps
  Incoming interface: Ethernet10/1, RPF nbr: 1.1.1.2, internal
  Outgoing interface list: (count: 2)
    Ethernet10/1, uptime: 01:00:32, pim, (RPF)
    nve1, uptime: 18:10:06, mrib

(*, 209.165.1.1/32), uptime: 12:52:13, nve(1) ip(0) pim(1)
  Data Created: No
  VXLAN Flags
    VXLAN Encap
  Stats: 0/0 [Packets/Bytes], 0.000   bps
  Incoming interface: Ethernet10/1, RPF nbr: 1.1.1.1
  Outgoing interface list: (count: 2)
    Ethernet10/1, uptime: 12:51:52, pim, (RPF)
    nve1, uptime: 12:52:13, nve

(10.10.10.1/32, 209.165.1.1/32), uptime: 12:52:13, nve(0) mrib(0) ip(0) pim(1)
  Data Created: No
  Received Register stop
  VXLAN Flags
    VXLAN Encap
  Stats: 300/39850 [Packets/Bytes], 0.000   bps
  Incoming interface: loopback10, RPF nbr: 10.10.10.1, internal
  Outgoing interface list: (count: 1)
    Ethernet10/1, uptime: 12:51:52, pim

(10.10.10.2/32, 209.165.1.1/32), uptime: 12:51:34, pim(1) mrib(1) ip(0)
  Data Created: Yes
  VXLAN Flags
    VXLAN Decap
  Stats: 22/1928 [Packets/Bytes], 0.000   bps
  Incoming interface: Ethernet10/1, RPF nbr: 1.1.1.2, internal
  Outgoing interface list: (count: 2)
    Ethernet10/1, uptime: 00:52:14, pim, (RPF)
    nve1, uptime: 12:51:34, mrib

(*, 209.166.0.0/8), uptime: 20:56:33, pim(0) ip(0)
  Data Created: No
  Stats: 0/0 [Packets/Bytes], 0.000   bps
  Incoming interface: Null, RPF nbr: 0.0.0.0
  Outgoing interface list: (count: 0)

VTEP-1# show ip arp

Flags: * - Adjacencies learnt on non-active FHRP router
       + - Adjacencies synced via CFSoE
       # - Adjacencies Throttled for Glean
       D - Static Adjacencies attached to down interface

IP ARP Table for context default
Total number of entries: 4
Address         Age       MAC Address     Interface
10.50.50.1      00:11:32  547f.eeec.af44  Bdi50
10.50.50.2      00:11:14  547f.eeec.af44  Bdi50
10.75.75.1      00:10:45  547f.eeec.af44  Bdi75
10.75.75.2      00:15:04  547f.eeec.af45  Bdi75
10.1.1.2        00:05:39  547f.eeec.af43  Ethernet10/1

VTEP-1# show ip route
IP Route Table for VRF "default"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
```

```
'%<string>' in via output denotes VRF <string>

10.1.1.0/30, ubest/mbest: 1/0, attached
    *via 10.1.1.1, Eth10/1, [0/0], 20:25:13, direct
1.1.1.1/32, ubest/mbest: 1/0, attached
    *via 10.1.1.1, Eth10/1, [0/0], 20:25:13, local
10.10.10.1/32, ubest/mbest: 2/0, attached
    *via 10.10.10.1, Lo10, [0/0], 20:25:45, local
    *via 10.10.10.1, Lo10, [0/0], 20:25:45, direct
10.10.10.2/32, ubest/mbest: 1/0
    *via 10.1.1.2, Eth10/1, [1/0], 20:23:42, static
10.50.50.0/24, ubest/mbest: 1/0, attached
    *via 10.50.50.50, Bdi50, [0/0], 01:18:47, direct
10.50.50.50/32, ubest/mbest: 1/0, attached
    *via 10.50.50.50, Bdi50, [0/0], 01:18:47, local
10.75.75.0/24, ubest/mbest: 1/0, attached
    *via 10.75.75.75, Bdi75, [0/0], 01:10:05, direct
10.75.75.75/32, ubest/mbest: 1/0, attached
    *via 10.75.75.75, Bdi75, [0/0], 01:10:05, local
```

VTEP-2:

```
VTEP-2# show nve vni
Codes: CP - Control Plane        DP - Data Plane
       UC - Unconfigured         SA - Suppress ARP

Interface VNI      Multicast-group   State Mode Type [BD/VRF]      Flags
--------- -------- ----------------- ----- ---- ------------------ -----
nve1      5000     209.166.1.1         Up    DP   L2 [50]
nve1      7500     192.168.1.1         Up    DP   L2 [75]

VTEP-2# show running-config interface nve 1

interface nve1
  no shutdown
  source-interface loopback10
  member vni 5000 mcast-group 209.166.1.1
  member vni 7500 mcast-group 192.168.1.1

VTEP-2# show service instance vni detail

VSI: VSI-Ethernet7/30.1
If-index: 0x3531d001
Admin Status: Up
Oper Status: Up
Auto-configuration Mode: No
encapsulation profile vni VSI_50_TO_5000
  dot1q 50 vni 5000
Dot1q   VNI     BD
------------------
50      5000    50

VSI: VSI-Ethernet7/30.2
If-index: 0x3531d002
Admin Status: Up
Oper Status: Up
Auto-configuration Mode: No
encapsulation profile vni TEST
  dot1q 100 vni 7500
Dot1q   VNI     BD
------------------
100     7500    75

VTEP-2# show bridge-domain
```

```
Bridge-domain 50  (2 ports in all)
Name:: Bridge-Domain50
 Administrative State: UP              Operational State: UP
        vni5000
        VSI-Eth7/30.1
        nve1

Bridge-domain 75  (2 ports in all)
Name:: Bridge-Domain75
 Administrative State: UP              Operational State: UP
        vni7500
        VSI-Eth7/30.2
        nve1

VTEP-2# show mac address-table dynamic
 Note: MAC table entries displayed are getting read from software.
 Use the 'hardware-age' keyword to get information related to 'Age'

 Legend:
        * - primary entry, G - Gateway MAC, (R) - Routed MAC, O - Overlay MAC
        age - seconds since last seen,+ - primary entry using vPC Peer-Link, E -
 EVPN entry
        (T) - True, (F) - False ,  ~~~ - use 'hardware-age' keyword to retrieve
age info
  VLAN/BD   MAC Address      Type      age     Secure NTFY Ports/SWID.SSID.LID
---------+-----------------+--------+---------+------+----+------------------
* 50       547f.eeec.af44    dynamic     ~~~      F    F  nve1/10.10.10.1
* 50       547f.eeec.af45    dynamic     ~~~      F    F  VSI-Eth7/30.1
* 75       547f.eeec.af45    dynamic     ~~~      F    F  VSI-Eth7/30.2
* 75       547f.eeec.af48    dynamic     ~~~      F    F  nve1/10.10.10.1

VTEP-2# show ip mroute detail
IP Multicast Routing Table for VRF "default"

Total number of routes: 5
Total number of (*,G) routes: 2
Total number of (S,G) routes: 2
Total number of (*,G-prefix) routes: 1

(*, 209.165.1.1/32), uptime: 19:56:19, nve(1) ip(0) pim(0)
  Data Created: No
  VXLAN Flags
    VXLAN Encap
  Stats: 8/748 [Packets/Bytes], 0.000   bps
  Incoming interface: Ethernet10/7, RPF nbr: 1.1.1.1
  Outgoing interface list: (count: 1)
    nve1, uptime: 19:56:19, nve

(10.10.10.2/32, 209.165.1.1/32), uptime: 19:56:19, nve(0) mrib(0) pim(1) ip(0)
  Data Created: No
  Received Register stop
  VXLAN Flags
    VXLAN Encap
  Stats: 9/834 [Packets/Bytes], 0.000   bps
  Incoming interface: loopback10, RPF nbr: 10.10.10.2
  Outgoing interface list: (count: 1)
    Ethernet10/7, uptime: 18:15:17, pim

(*, 209.165.1.1/32), uptime: 12:57:03, nve(1) ip(0) pim(0)
  Data Created: No
  VXLAN Flags
    VXLAN Encap
  Stats: 10/864 [Packets/Bytes], 0.000   bps
```

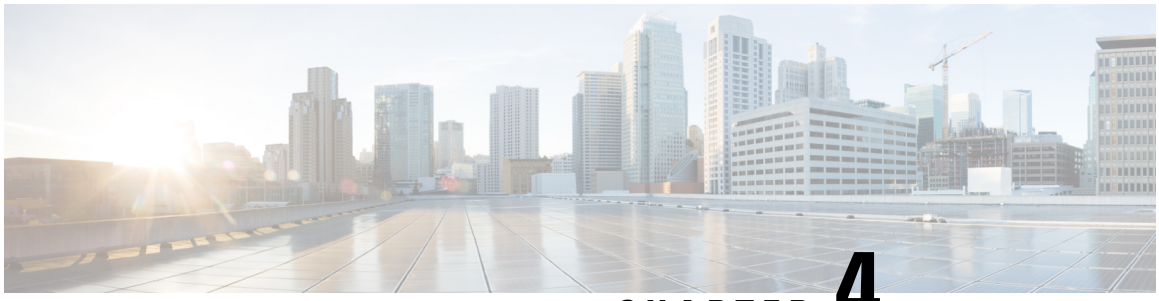
```
  Incoming interface: Ethernet10/7, RPF nbr: 1.1.1.1
  Outgoing interface list: (count: 1)
    nve1, uptime: 12:57:03, nve

(10.10.10.2/32, 209.165.1.1/32), uptime: 12:57:03, nve(0) mrib(0) ip(0) pim(1)
  Data Created: No
  Received Register stop
  VXLAN Flags
    VXLAN Encap
  Stats: 30/2648 [Packets/Bytes], 0.000   bps
  Incoming interface: loopback10, RPF nbr: 10.10.10.2
  Outgoing interface list: (count: 1)
    Ethernet10/7, uptime: 12:56:45, pim

(*, 209.167.0.0/8), uptime: 18:20:36, pim(0) ip(0)
  Data Created: No
  Stats: 0/0 [Packets/Bytes], 0.000   bps
  Incoming interface: Null, RPF nbr: 0.0.0.0
  Outgoing interface list: (count: 0)

VTEP-2# show ip arp

Flags: * - Adjacencies learnt on non-active FHRP router
       + - Adjacencies synced via CFSoE
       # - Adjacencies Throttled for Glean
       D - Static Adjacencies attached to down interface

IP ARP Table for context default
Total number of entries: 4
Address         Age       MAC Address     Interface
10.50.50.1      00:11:30  547f.eeec.af44  Bdi50
10.50.50.2      00:17:07  547f.eeec.af45  Bdi50
10.75.75.1      00:04:14  547f.eeec.af45  Bdi75
10.75.75.2      00:03:24  547f.eeec.af45  Bdi75
10.1.1.1        00:10:52  547f.eeec.af48  Ethernet10/7

VTEP-2# show ip route
IP Route Table for VRF "default"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>

10.1.1.0/30, ubest/mbest: 1/0, attached
    *via 10.1.1.2, Eth10/7, [0/0], 20:30:24, direct
10.1.1.2/32, ubest/mbest: 1/0, attached
    *via 10.1.1.2, Eth10/7, [0/0], 20:30:24, local
10.10.10.1/32, ubest/mbest: 1/0
    *via 10.1.1.1, Eth10/7, [1/0], 20:29:48, static
10.10.10.2/32, ubest/mbest: 2/0, attached
    *via 10.10.10.2, Lo10, [0/0], 20:29:39, local
    *via 10.10.10.2, Lo10, [0/0], 20:29:39, direct
10.50.50.0/24, ubest/mbest: 1/0, attached
    *via 10.50.50.51, Bdi50, [0/0], 01:22:50, direct
10.50.50.51/32, ubest/mbest: 1/0, attached
    *via 10.50.50.51, Bdi50, [0/0], 01:22:50, local
10.75.75.0/24, ubest/mbest: 1/0, attached
    *via 10.75.75.76, Bdi75, [0/0], 01:14:50, direct
10.75.75.76/32, ubest/mbest: 1/0, attached
    *via 10.75.75.76, Bdi75, [0/0], 01:14:50, local
```

Feature History for VXLAN Flood and Learn

This table lists the release history for this feature.

Table 2: Feature History for VXLAN Flood and Learn

Feature Name	Releases	Feature Information	
VXLAN Flood and Learn	7.2(0)D1(1)	This feature was introduced.	



CHAPTER 4

Configuring VXLAN BGP EVPN

This chapter contains the following sections:

Information About VXLAN BGP EVPN

Introducing IP Fabric Overlays (VXLAN)

Motivation for an overlay

An overlay is a dynamic tunnel that transports frames between two endpoints. In a switch-based overlay, the architecture provides flexibility for spine switches and leaf switches.

- Spine switch table sizes do *not* increase proportionately when end hosts (physical servers and VMs) are added to the leaf switches.
- The number of networks/tenants that can be supported in the cluster can be increased by just adding more leaf switches.

How this is achieved is explained in detail later.

Note For easier reference, some common references are explained below:

- *End host* or *server* refers to a physical or virtual workload that is attached to a ToR switch.
- A *ToR* switch is also referred as a *leaf* switch. Since the VTEP functionality is implemented on the ToRs, a VTEP refers to a ToR or leaf switch enabled with the VTEP function. Note that the VTEP functionality is enabled on all leaf switches in the VXLAN fabric and on border leaf/spine switches.

VXLAN as the overlay technology

VXLAN is a MAC in IP/UDP overlay that allows layer 2 segments to be stretched across an IP core. All the benefits of layer 3 topologies are thereby available with VXLAN including the popular layer-3 ECMP feature for efficient traffic spread across multiple available paths. The encapsulation and decapsulation of VXLAN headers is handled by a functionality embedded in VXLAN Tunnel End Points (VTEPs). VTEPs themselves could be implemented in software or a hardware form-factor.

VXLAN natively operates on a flood and learn mechanism where BU (Broadcast, Unknown Unicast) traffic in a given VXLAN network is sent over the IP core to every VTEP that has membership in that network. There are two ways to send such traffic: (1) Using IP multicast (2) Using Ingress Replication or Head-end Replication. The receiving VTEPs will decapsulate the packet, and based on the inner frame perform layer-2 MAC learning. The inner SMAC is learnt against the outer Source IP Address (SIP) corresponding to the source VTEP. In this way, reverse traffic can be unicasted toward the previously learnt end host.

Other motivations include:

1. *Scalability* — VXLAN provides Layer-2 connectivity that allows the infrastructure that can scale to 16 million tenant networks. It overcomes the 4094-segment limitation of VLANs. This is necessary to address today's multi-tenant cloud requirements.
2. *Flexibility*— VXLAN allows workloads to be placed anywhere, along with the traffic separation required in a multi-tenant environment. The traffic separation is done using network segmentation (segment IDs or virtual network identifiers [VNIs]).

   Workloads for a tenant can be distributed across different physical devices (since workloads are added as the need arises, into available server space) but the workloads are identified by the same layer 2 or layer 3 VNI as the case may be.
3. *Mobility*— You can move VMs from one data center location to another without updating spine switch tables. This is because entities within the same tenant network in a VXLAN/EVPN fabric setup retain the same segment ID, regardless of their location.

Overlay example:

The example below shows why spine switch table sizes are not increased due to VXLAN fabric overlay, making them lean.

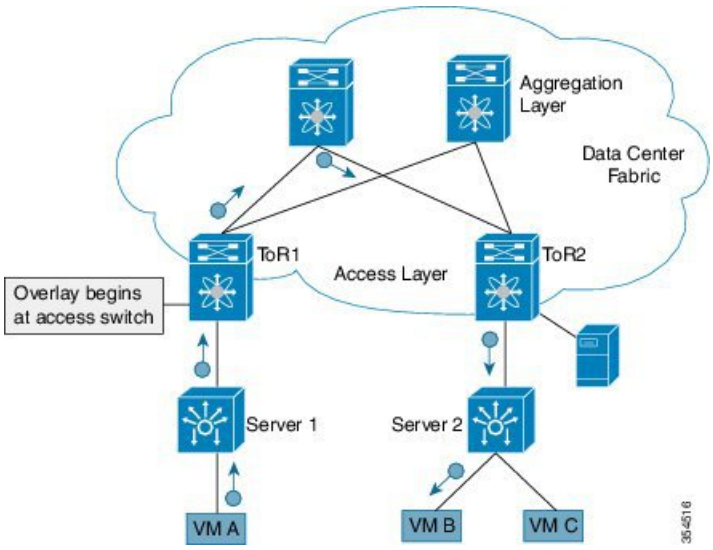
VM A sends a message to VM B (they both belong to the same tenant network and have the same segment VNI). ToR1 recognizes that the source end host corresponds to segment x, searches and identifies that the target end host (VM B) belongs to segment x too, and that VM B is attached to ToR2. Note that typically the communication between VM A and VM B belonging to the same subnet would first entail ARP resolution.

ToR1 encapsulates the frame in a VXLAN packet, and sends it in the direction of ToR2.

The devices in the path between ToR1 to ToR2 are not aware of the original frame and route/switch the packet to ToR2.

ToR2 decapsulates the VXLAN packet addressed to it. It does a lookup on the inner frame. Through its end host database, ToR2 recognizes that VM B is attached to it and belongs to segment x, forwards the original frame to VM B.

Figure 4: VXLAN Overlay



- VXLAN semantics are in operation from ToR1 to ToR2 through the encapsulation and decapsulation at source and destination VTEPs, respectively. The *overlay* operation ensures that the original frame/packet content is not exposed to the underlying IP network.
- The IP network that sends packets from ToR1 to ToR 2 based on the outer packet source and destination address forms the *underlay* operation. As per design, none of the spine switches need to learn the addresses of end hosts below the ToRs. So, learning of hundreds of thousands of end host IP addresses by the spine switches is avoided.

Learning of (hundreds of thousands of) end host IP and MAC addresses

One of the biggest limitations of VXLAN flood and learn is the inherent flooding that is required ensuring that learning happens at the VTEPs. In a traditional deployment, a layer-2 segment is represented with a VLAN that comprises a broadcast domain, which also scopes BU traffic. With VXLAN, now the layer-2 segment spans a much larger boundary across an IP core where floods are translated to IP multicast (or HER). Consequently, the flood-n-learn based scheme presents serious scale challenges especially as the number of end hosts go up. This is addressed via learning using a control-plane for distribution of end host addresses. The control plane of choice is MP-BGP EVPN. By implementing MP-BGP EVPN with VXLAN, the following is made possible:

- End hosts' information is available to the attached ToR via First Hop Protocols such as ARP/ND/DHCP etc., when a new bare-metal server or VM is attached.
- End host to ToR mapping information for each ToR is shared with every other ToR using BGP via a route reflector.
- Specifically, within BGP, the EVPN address family is employed to carry MAC *and* IP address information of the end hosts along with other information such as the network and tenant (aka VRF) to which they belong. This allows optimal forwarding of both layer-2 and layer-3 traffic within the fabric.
- VMs belonging to the same tenant might be many hops apart (though assigned with the same segment ID/VNI), and there might be frequent movement and addition of end hosts. When a new VM comes up or is moved between ToRs, the information is instantly updated into BGP by the detecting ToR thereby ensuring that the updated reachability information is also known to every other ToR.

- In order to accurately route/switch packets between end hosts in the data center, each participating ToR in a VXLAN cluster must be aware of the end hosts attached to it and also the end hosts attached to other ToRs, in real time.

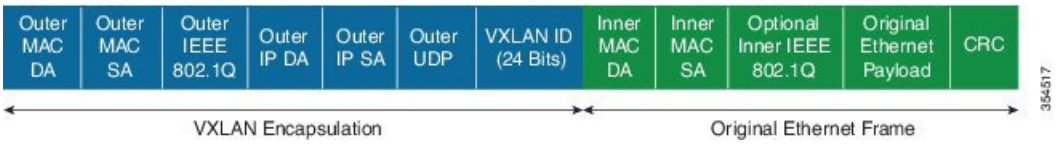
VXLAN-EVPN fabric— The overlay protocol is VXLAN and BGP uses EVPN as the address family for communicating end host MAC and IP addresses, so the fabric is referred thus.

Realizing Layer-2 and Layer-3 Multi-Tenancy

Using segment IDs or VNIs for multi tenancy in the VXLAN fabric

Typically, when a tenant is created, it is assigned a unique VNI referred to as the layer-3 VNI or the layer 3 segment ID. This serves as a unique identifier for tenant layer-3 context also referred to as the tenant VRF. For each network created within the tenant, a unique identifier is assigned which is referred to as the layer-2 VNI or layer-2 segment-id. The VNIs all come from the same 2^24 – 1 pool represented by the 24-bit VNI identifier carried in the VXLAN header.

Figure 5: VXLAN Packet Format

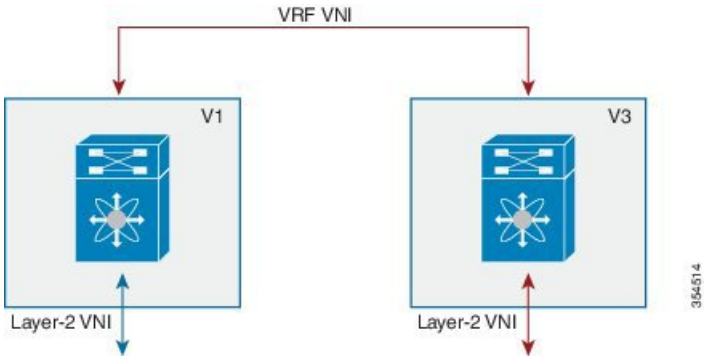


Some Segment ID/VNI pointers are given below:

- If a new VM or physical server for this tenant is added to the data center, it is associated with the *same layer-3 VNI*, regardless of the physical location. In addition, if it is part of a given tenant network, it is assigned the same layer-2 VNI that identifies that network.
- By confining server and end host identification of a specific tenant to a unique VNI (or few unique VNIs), segmentation and security are ensured.
- By ensuring that the VNI-to-end host mapping information on each ToR is updated and shared through the route reflector, the latest information is available through the VXLAN setup.
- Routing at the ToR/access layer facilitates a more scalable design, contains network failures, and enables transparent mobility.

Traffic between servers in the same tenant network that is confined to the same subnet is bridged. In this case, the VTEPs stamp the layer-2 VNI in the VXLAN header when the communication is between servers that are below different ToRs. The forwarding lookup is based on (L2-VNI, DMAC). For communications between servers that are part of the same tenant but belong to different networks, routing is employed. In this case, the layer-3 VNI is carried in the VXLAN header when communication is between servers below different ToRs. This approach is referred to as the symmetric IRB (Integrated Routing and Bridging) approach, the symmetry comes from the fact that VXLAN encapsulated routed traffic in the fabric from source to destination and vice-versa will carry the same layer-3 VNI. This is shown in the figure below.

Figure 6: Inter Tenant Traffic Flow Using VRF VNI



In the above scenario, traffic from a server (with layer-2 VNI *x*) on VTEP V1 is sent to a server (with layer-2 VNI *y*) on VTEP V2. Since the VNIs are different, the layer-3 VNI (unique to the VRF) is used for communication over VXLAN between the servers.

Fabric Overlay Control-Plane (MP-BGP EVPN)

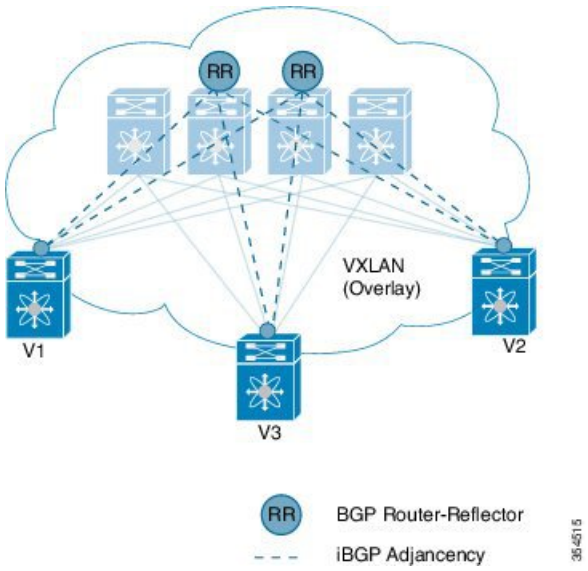
The main reasons for using BGP EVPN as the overlay control plane are:

- *Standards based*—The overlay (VXLAN) and the control plane (BGP) are standards based.
- *Implement control-plane MAC learning* so that VMs/servers for each tenant have a unique identity across the fabric.

  In a VXLAN-EVPN based fabric, MAC learning occurs via the control plane [through multi-protocol (MP) BGP] instead of the data plane.

  When a new end host is attached to a VTEP (aka ToR), the VTEP advertises the MAC and IP address of the end host to a route reflector which in turn advertises it to the other VTEPs through MP-BGP (as shown in the image below). Since MP-BGP enables isolation of groups of interacting agents, VMs/servers that belong to the same tenant are logically isolated from other tenants.

Figure 7: End Host IP + MAC Address Distribution in a VXLAN Setup



The reasons for using BGP EVPN continues below:

- *Reduce flooding*
  - Since the number of end hosts attached to VTEPs in a data center is huge, a mechanism is required to reduce flooding for discovery of end host location and resolution information. This is achieved via MAC/IP binding information distribution.
  - MAC address distribution eliminates (or reduces) unknown unicast flooding because MAC addresses are prepopulated.
  - MAC to IP *binding* information helps in local ARP suppression.
- *Distributed Anycast Gateway*
  - For a given subnet, the same default gateway with the same IP and MAC address is realized simultaneously on appropriate ToR switches thereby ensuring the default gateway for the end hosts is always at its closest point aka its directly attached switch.
  - This ensures that routed traffic is also optimally forwarded within the fabric without going through any tromboning.
- *VM Mobility Support*
  - The control plane supports transparent VM mobility and quickly updates reachability information to avoid hair-pinning of east-west traffic.
  - The distributed anycast gateway also aids in supporting transparent VM mobility since post VM move, the ARP cache entry for the default gateway is still valid.
- *Efficient bandwidth utilization and resiliency with Active-Active multipathing*

  VXLAN is supported with virtual PortChannel (vPC). This allows resiliency in connectivity for servers attached to access switches with efficient utilization of available bandwidth. VXLAN with vPC is also

supported for access to aggregation (leaf switch to spine switch) connectivity, promoting a highly available fabric.

- *Secure VTEPs*

  In a VXLAN-EVPN fabric, traffic is only accepted from VTEPs whose information is learnt via the BGP-EVPN control plane. Any VXLAN encapsulated traffic received from a VTEP that is not known via the control plane will be dropped. In this way, this presents a secure fabric where traffic will only be forwarded between VTEPs validated by the control plane. This is a major security hole in data-plane based VXLAN flood-n-learn environments where a rogue VTEP has the potential of bringing down the overlay network.

- *BGP specific motivations*
  - *Increased flexibility*— EVPN address family carries both Layer-2 and Layer-3 reachability information. So, you can build bridged overlays or routed overlays. While bridged overlays are simpler to deploy, routed overlays are easier to scale out.
  - *Increased security*— BGP authentication and security constructs provide more secure multi-tenancy.
  - *Improved convergence time*— BGP being a hard-state protocol is inherently non-chatty and only provides updates when there is a change. This greatly improves convergence time when network failures occur.
  - *BGP Policies*— Rich BGP policy constructs provide policy-based export and import of reachability information. It is possible to constrain route updates where they are not needed thereby realizing a more scalable fabric.
  - *Advantages of route reflectors*— Increases scalability and reduces the need for a full mesh (coverage) of BGP sessions.

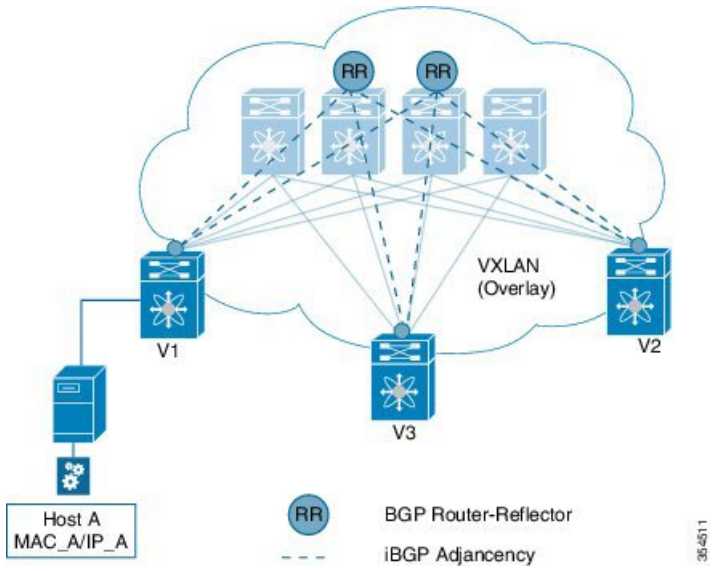
    A route reflector in an MP-BGP EVPN control plane acts as a central point for BGP sessions between VTEPs. Instead of each VTEP peering with every other VTEP, the VTEPs peer with a spine device designated as a route reflector. For redundancy purposes, an additional route reflector is designated.

End Host and Subnet Route Distribution

Some pointers about end host MAC and IP route distribution in a VXLAN EVPN fabric are given below:

- When a new end host is attached to a VTEP (say *Host A* in the below scenario), the VTEP V1 learns the end host's MAC and IP address. MP-BGP on the VTEP nodes enables advertising of the addresses (IP + MAC) to the route reflector.

Figure 8: New End Host Attaches to a VTEP



- MP-BGP also distributes subnet routes and external reachability information between VTEPs. When VTEPs obtain end host routes of remote end hosts attached to other VTEPs, they install the routes in their RIB and FIB.

Note that the end host route distribution is decoupled from the underlay protocol.

End host communication within a VNI and across VNIs

As we know, in a VXLAN EVPN fabric a unique Layer-2 VNI is designated to each tenant network.

Recall, when two end hosts sharing the same layer-2 VNI communicate with each other, the traffic is bridged, and confined to a subnet. When two end hosts in different layer-2 VNIs communicate with each other, the traffic is routed and moves between subnets.

Furthermore, an end host retains its address and tenant association when it moves to another VTEP.

One tenant network, one Layer-2 VNI, and one default gateway IP and MAC address

Since end hosts in a tenant network might be attached to different VTEPs, the VTEPs are made to share a common gateway IP and MAC address for intra-tenant communication.

If an end host moves to a different VTEP, the gateway information remains the same and reachability information is available in the BGP control plane.

Distributed IP anycast gateway

The gateway is referred as a *distributed IP anycast gateway*, since the gateway is distributed across all relevant VTEPs.

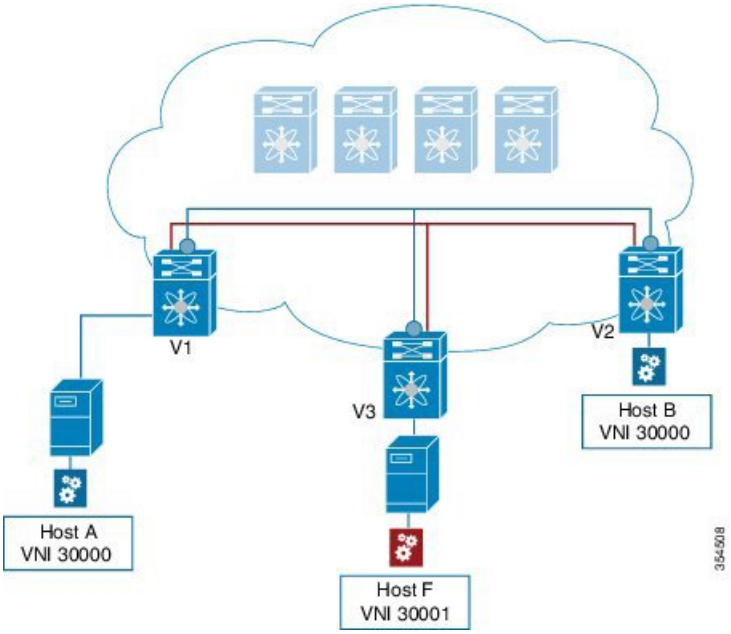
The gateway provides routing and bridging capabilities, and the mechanism is referred as *Integrated Routing and Bridging* (IRB).

The distributed anycast gateway for routing is completely stateless and does not require the exchange of protocol signalization for election or failover decision.

All VTEPs host active default gateways for their respective configured subnets and First Hop Routing Protocols (FHRP) such as HSRP, VRRP etc. are not needed.

A sample distributed gateway for a setup is given below:

Figure 9: Distributed Gateway



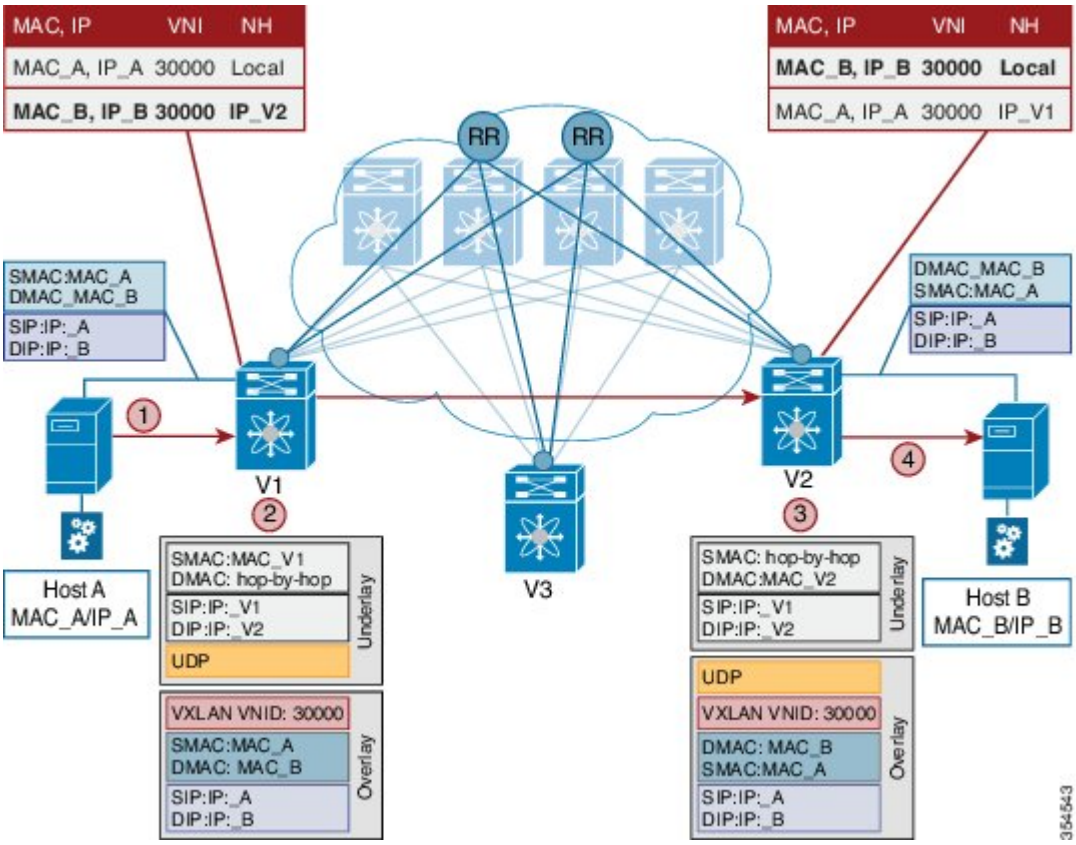
Blue tenant network's configuration

Similar configuration needs to be implemented on the leaf switch V1 and all other switches containing the blue tenant network's end hosts. Configuration details are provided in BGP EVPN and Overlay Configuration chapter. Similar configuration needs to be implemented for red tenant too.

After the configurations, end host traffic within a VNI (say 30000) is bridged, and traffic between tenant networks is routed. The routing takes place through a Layer-3 VNI (say 50000) typically having a one-on-one association with a VRF instance.

Forwarding between servers within a Layer-2 VNI

Figure 10: Packet Forwarding (Bridge)



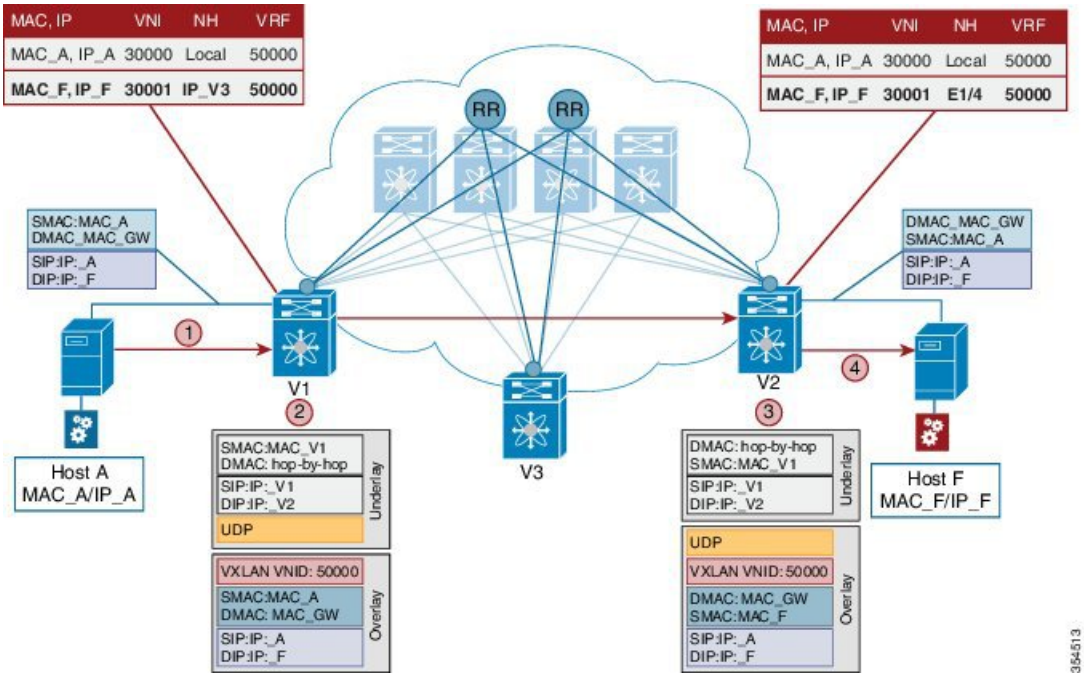
The VNI of the source end host, *Host A*, and the target end host, *Host B*, is 30000.

- Host A sends traffic to the directly attached VTEP V1.
- V1 performs a lookup based on the destination MAC address in the packet header (For communication that is bridged, the target end host's MAC address is updated in the DMAC field).
- VTEP V1 bridges the packets and sends it toward VTEP V2 with a VXLAN header stamped with the Layer 2 VNI 30000.
- VTEP V2 receives the packets, and post decapsulation, lookup, bridges them to Host B.

Packet forwarding between servers belonging to different Layer-2 VNIs

In the below example, the source and target end hosts (Host A and Host F) belong to different Layer-2 virtual networks (with VNIs 30000 and 30001). So, the traffic flow is between subnets, and hence routed. The VRF VNI 50000 is used to route the traffic

Figure 11: Packet Forwarding (Route)



A high level overview of the flow is given below:

1. Host A sends traffic to its default gateway (post ARP resolution) which is configured on the directly attached VTEP V1.
2. V1 performs a FIB lookup based on the destination IP address in the packet header.
3. VTEP V1 routes the packets and sends it toward VTEP V2 with a VXLAN header stamped with the VRF (Layer 3) VNI 50000.
4. VTEP V2 receives the packets, and post decapsulation, routing lookup, and rewrite, sends them to Host F.

Routing at the VTEP - A high level view

Mandatory configurations

1. A VLAN is configured for each segment - sending segment, VRF segment and receiving segment.
2. BGP and EVPN configurations ensure redistribution of this information across the VXLAN setup.

Real time behavior

The source VTEP receives traffic and takes the routing decision. It then stamps the packet with the associated VRF VNI while sending traffic to the destination VTEP, which in turn forwards traffic to the destination server

Communication between a VXLAN overlay and an external network

The data center interconnect (DCI) functionality is implemented on the border device (leaf or spine) of the VXLAN EVPN network. Depending on the type of hand-off to the outside network such as MPLS, LISP,

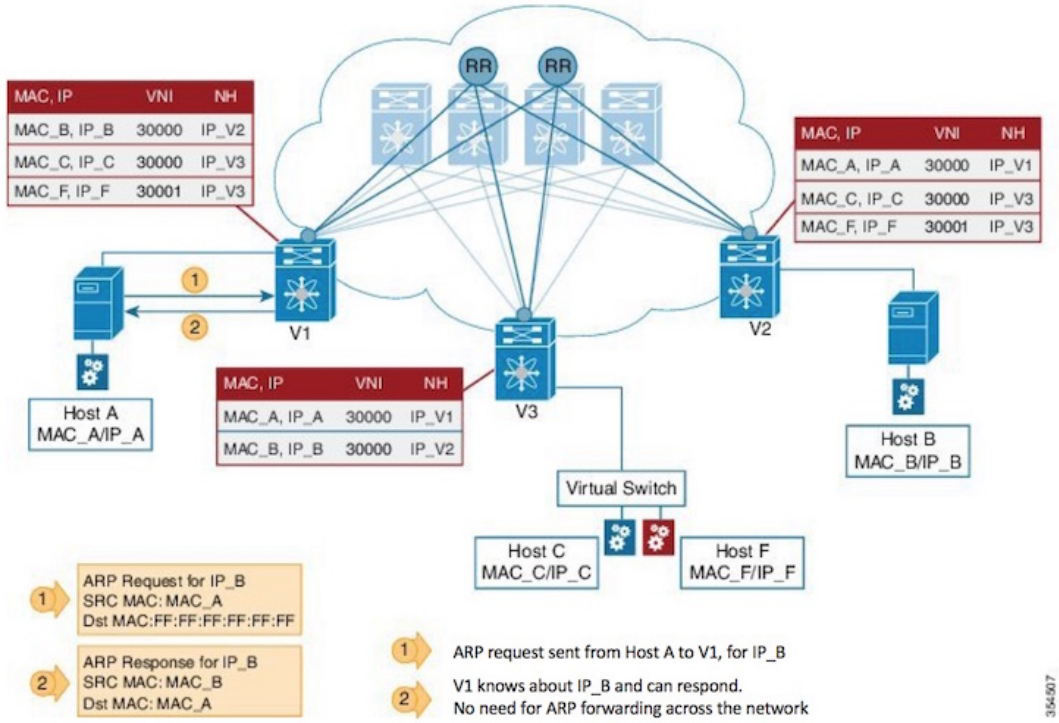
layer-2, and so on, appropriate DCI configuration is required on the border device(s) and the connecting edge device(s) of the outside network.

ARP Suppression

The following section illustrates ARP suppression functionality at VTEP V1 (Refer the *ARP Suppression* image, given below). ARP suppression is an enhanced function configured under the layer-2 VNI (using the **suppress-arp** command). Essentially, the IP-MACs learnt locally via ARP as well as those learnt over BGP-EVPN are stored in a local ARP suppression cache at each ToR. ARP request sent from the end host is trapped at the source ToR. A lookup is performed in the ARP suppression cache with the destination IP as the key. If there is a HIT, then the ToR proxies on behalf of the destination with the destination MAC. This is the case depicted in the below image.

In case the lookup results in a MISS, when the destination is unknown or a silent end host, the ToR re-injects the ARP request received from the requesting end host and broadcasts it within the layer-2 VNI. This entails sending the ARP request out locally over the server facing ports as well as sending a VXLAN encapsulated packet with the layer-2 VNI over the IP core. The VXLAN encapsulated packet will be decapsulated by every receiving VTEP that has membership within the same layer-2 VNI. These receiving VTEPs will then forward the inner ARP frame toward the server facing ports. Assuming that the destination is alive, the ARP request will reach the destination, which in turn will send out an ARP response toward the sender. The ARP response is trapped by the receiving ToR, even though ARP response is a unicast packet directed to the source VM, since the ARP-suppression feature is enabled. The ToR will learn about the destination IP/MAC and in turn advertise it over BGP-EVPN to all the other ToRs. In addition, the ToR will reinject the ARP response packet into the network (VXLAN-encapsulate it toward the IP core since original requestor was remote) so that it will reach the original requestor.

Figure 12: ARP Suppression



Unknown unicast (packet) suppression

Typically, an unknown unicast scenario arises when an end host has resolved the ARP but the MAC address of the end host is not available/updated in the switch.

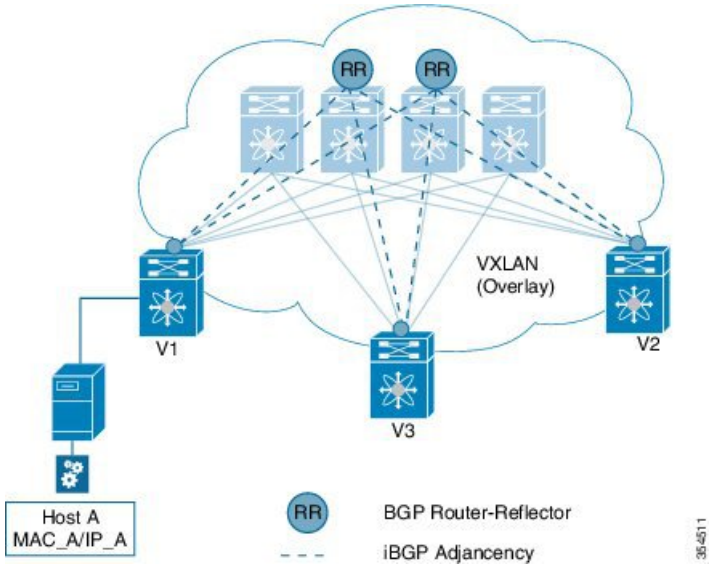
Unknown unicast traffic from an end host is by default flooded in the VLAN. It is possible to avoid the flooding of this traffic to the overlay network without affecting the flooding of this traffic on local host/sever ports attached to the ToR switch. Use the **suppress-unknown-unicast** command to do the same.

The *suppress unknown unicast* function is supported on ToRs/VTEPs in a VXLAN EVPN fabric. This function allows flooding of traffic within the attached switch by including local host/server ports attached to the ToR switch in the output interface index flood list (OIFL) and excluding overlay Layer-3 ports in the hardware.

Performing End Host Detection, Deletion and Move

End host detection by a VTEP device

Figure 13: End Host Detection



When a new end host (*Host A*) is attached to VTEP V1, the following actions occur:

1. VTEP V1 learns Host A's MAC and IP address (MAC_A and IP_A).
2. V1 advertises MAC_A and IP_A to the other VTEPs V2 and V3 through the route reflector.
3. The choice of encapsulation (VXLAN) is also advertised.

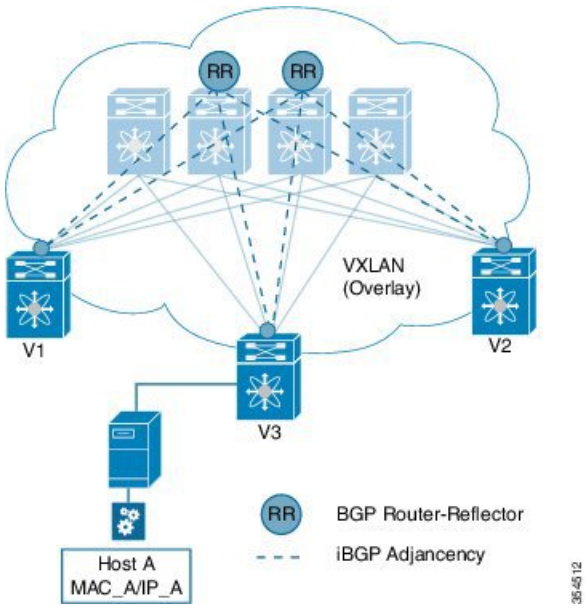
A sample depiction of Host A related information:

Figure 14: Host A - Address Distribution Parameters

MAC, IP	VNI (L2)	VNI (L2)	NH	Encap	Seq
MAC_A, IP_A	30000	50000	IP_V1	3:VXLAN	0

354510

Figure 15: Host move from V1 to V3



If Host A moves from VTEP V1 to V3, the following actions occur:

1. V3 detects Host A and advertises it with Sequence 1 (updating the previous instance of the sequence, *0*). The next hop IP address is reassigned to that of VTEP 3.

   Figure 16: Host A – Updated Parameters

MAC, IP	VNI (L2)	VNI (L2)	NH	Encap	Seq
MAC_A, IP_A	30000	50000	**IP_V3**	3:VXLAN	**1**

364509

2. VTEP V1 detects a more recent route and withdraws its advertisement.

Mobility in a vPC scenario

In a vPC scenario where 2 ToR switches are vPC peers, whether the end host is attached to an orphan port or has a dual homed connection, the VIP address is advertised in the control plane and data plane, and the VIP address is carried in the (outer) source IP address field of the VXLAN packet.

Note VIP is a common, virtual VTEP IP address that is used for (unicast and multi destination) communication to and from the two switches in the vPC setup. The VIP address represents the two switches in the vPC setup, and is designated as the next hop address (for end hosts in the vPC domain) for reachability purposes.

Pinging from a vPC switch—If you ping from switch A in a vPC setup (comprising of switches A and B) to a connected device or a remote end host, the common, virtual IP address (VIP) is considered the source IP address, and a successful response to the ping will be sent either to A, or to B. If the response is sent to B, then A (the sender) will not receive it.

As a workaround, create a loopback interface with a unique IP address for each vPC switch, and use the loopback IP address as the source for pinging attached devices or end hosts. Also leak the unique address between the vPC pair to ensure that the (ICMP) response is routed back to the sending vPC switch.

Also, you can use the VXLAN OAM functionality as a workaround.

Multi-Destination Traffic

Refer to the table below to know the multicast protocol(s) for your Cisco Nexus switches support::

If you are using this Nexus switch:	*Use this option for BUM traffic*
Cisco Nexus 7000 and 7700/F3 Series	PIM ASM/SSM or PIM BiDir

Guidelines and Limitations for VXLAN BGP EVPN

VXLAN BGP EVPN has the following guidelines and limitations:

- In the VXLAN Fabric, for L3 flows TTL is decremented for the inner packet on the egress VTEP after routing. Traceroute command done from a host connected to VXLAN Fabric to another host part of fabric displays smaller IP address from incoming VRF's context from Egress VTEP.
- Only spine role is supported in Cisco NX-OS Release 7.2(0)D1(1).
- VXLAN and Fabric Path features cannot be enabled on the same VDC for F3 and M3 modules.
- VXLAN BGP EVPN is supported on M3 series modules from Cisco NX-OS Release 7.3(0)DX(1) onwards.
- Following are not supported for VxLAN BGP EVPN in VDCs having M3 modules:
  - LISP handoff is not supported.
  - Hosts connected behind FEX is not supported.
- Ensure that the root of a Spanning Tree Protocol (STP) domain local to the VXLAN fabric is a VTEP, or placed within the fabric. The STP root should not be outside the VXLAN fabric (below the VTEPs) since it will lead to Layer 2 loops.
- In VXLAN vPC deployments with F3 modules, the vPC peer-link should be on an isolated ASIC instance from the Layer 3 core ports. After changing the peer-link ports to an isolated ASIC instance, ensure that you reload the switch.
- In a VXLAN vPC deployment with F3 modules and connected FEX devices, unknown unicast traffic from a remote source to the vPC switch pair may result in duplicate traffic if the MAC address is known to the vPC switches. Both vPC switches will receive a copy of the packet and forward it to the receiver behind FEX.
- In a VXLAN vPC deployment with F3 modules, known unicast traffic from a remote source to the vPC switch pair may result in loss of traffic if the MAC address is no longer known to the vPC switch pair.
- In a VXLAN vPC deployment with peer switch, encapsulation profile, and bridge domain configurations, the vPC secondary peer switch does not generate or process BPDUs for bridge domains.

- If the vPC feature is enabled on a non-vPC (standalone) switch, the NVE source loopback interface will be in *shutdown* state after an upgrade. To restore the interface to *up* state, remove the vPC feature using the **no feature vpc** command in global configuration mode, as shown below.

  ```
  switch(config)# no feature vpc
  ```

- ARP suppression is only supported for a VNI if the VTEP hosts the First-Hop Gateway (Distributed Anycast Gateway) for this VNI. The VTEP and the SVI for this VLAN have to be properly configured for the distributed anycast gateway operation, for example, global anycast gateway MAC address is configured and anycast gateway feature with the virtual IP address is on the SVI.

The following table lists the VXLAN feature support matrix.

Feature	Cisco NX-OS Release 7.2(0)D1(1)	Cisco NX-OS Release 7.3(0)D1(1) (F3 Modules)	Cisco NX-OS Release 7.3(0)DX(1) (F3 Modules)	Cisco NX-OS Release 7.3(0)DX(1) (M3 Modules)	Cisco NX-OS Release 8.0(1) (M3 Modules)
IPv4/v6 unicast L3GW	Supported	Supported	Supported	Supported	Supported
LISP Hand-off	Supported	Supported	Supported	Not Supported	Not Supported
IPv4/V6 unicast L2GW	Not Supported	Supported	Supported	Not Supported	Supported
vPC Support	Not Supported	Supported	Supported	Not Supported	Supported
IPv4/v6 multicast L2GW	Not Supported	Supported	Supported	Not Supported	Supported
RP on vPC complex	Not Supported	Supported	Supported	Not Supported	Supported
MPLS (L3VPN) Handoff	Not Supported	Supported	Supported	Not Supported	Supported
PIM Bidir underlay	Not Supported	Supported	Supported	Not Supported	Supported
FEX	Not Supported	Supported	Supported	Not Supported	Not Supported
vPC FEX (A-A/S/T)	Not Supported	Supported	Not Supported S/T - supported	Not Supported	Not Supported
Auto Config	Not Supported	Supported	Supported	Not Supported	Not Supported
ARP Suppression	Not Supported	Supported	Supported	Not Supported	Supported

Configuring VXLAN BGP EVPN

BGP EVPN and Overlay Configuration

The following BGP, EVPN and overlay configurations are required for the Cisco Nexus 7000 Series and 7700 Series switches with F3 and M3 modules:

1. Initial configuration - Install the network virtualization overlay, BGP, and EVPN features on the VTEPs.
2. Layer 2 VNI configurations for tenant networks within a tenant.

   (This configuration is applicable only to F3 modules).
3. Layer 3 VNI configurations for a tenant.

Note Though configuration examples are mainly IPv4, IPv6 addresses are also supported in the VXLAN EVPN fabric.

Cisco NX-OS Release 7.2(0)D1(1) supported only the border spine functionality. Cisco NX-OS Release 7.3(0)DX(1) supports the Cisco Nexus 7000 leaf functionality for F3 modules.

Initial configuration

(config) #

```
install feature-set fabric
feature-set fabric
feature fabric forwarding
feature interface-vlan
feature ospf
OR
feature isis
```

Attention You can use either OSPF or IS-IS as the underlay routing protocol.

Note The **install feature-set fabric** command should only be used in the admin VDC. When using a VDC, ensure the VDC is of type F3 or M3, for EVPN. A sample configuration is given below:

(config) #

```
vdc test
    limit-resource module-type f3
```

You should not configure F3 and M3 modules at the same time on the leaf switch VTEP for the 7.3(x) release, since it will alter the way BPDUs are generated and tagged, causing STP issues with the downstream network.

(config) #

```
feature nv overlay
feature bgp
feature vni
nv overlay evpn
```

Configure the anycast gateway MAC address

(config) #

```
fabric forwarding anycast-gateway-mac 0202.0002.0002
```

Configure BGP L2VPN EVPN address family

(config) #

```
router bgp 100
   neighbor 10.1.1.53 remote-as 100
     address-family ipv4 unicast
     address-family l2vpn evpn
        send-community extended
```

Layer 2 VNI configurations for a tenant network

Note This configuration is applicable only to F3 modules.

Create a bridge domain and associate the Layer 2 VNI with it

(config) #

```
vni 30000
system bridge-domain 200-210
bridge-domain 200
   member vni 30000
```

While the **system bridge-domain** command identifies the bridge domain IDs, the **bridge-domain** command configures the specified bridge domain(s).

Associate a VLAN (or dot1q tag) with the Layer 2 VNI:

(config) #

```
encapsulation profile vni cisco
  dot1q 50 vni 30000
```

Associate the encapsulation profile with the server facing interface

(config) #

```
interface Ethernet 1/12
```

```
   no shutdown
   no switchport
   service instance 1 vni
   encapsulation profile cisco default
      no shutdown
```

Create a loopback interface and assign an IP address to it

(config) #

```
interface loopback 0
   ip address 10.1.1.54/32
```

Associate the Layer 2 VNI to the overlay and configure multicast group membership

(config) #

```
interface nve 1
   no shutdown
   source-interface loopback0
   host-reachability protocol bgp
   member vni 30000
      mcast-group 224.1.33.3
```

Enable EVPN and associate the Layer 2 VNI to it

Enable route distinguisher and route target functions for the Layer 2 VNI

(config) #

```
evpn
  vni 30000 l2
    rd auto
    route-target import auto
    route-target export auto
```

Note that with the Cisco Nexus 7000 Series switches, a VNI is associated with a bridge-domain (1:1). Refer to the respective configuration guide for more information on bridge-domains. The combination of the **router BGP** command (configured earlier) and the **evpn** command ensures that BGP EVPN is configured to advertise 'MAC address + associated host route (optional)' of servers attached to the VTEP, for the specified Layer 2 VNI. The MAC+IP routes for the hosts are advertised into BGP-EVPN for hosts belonging to layer 2 VNI 30000.

Layer 3 VNI configurations for a tenant

Associate the VRF VNI to the customer VRF

Enable VRF route distinguisher and VRF route target functions for the Layer 3 VNI

(config) #

```
vrf context coke
   vni 50000
   rd auto
   address-family ipv4 unicast
```

```
      route-target both auto evpn
```

In the above example, the option *both* is used to import and export routes associated with the Layer 3 VNI 50000. Specifically, the layer-3 routes will be advertised with route-target 100:50000 where 100 is the BGP Autonomous system number and 50000 is the layer-3 VNI.

Associate the VRF VNI to a bridge-domain and associate a BDI to the customer VRF

(config) #

```
system bridge-domain add 2200
vni 50000
bridge-domain 2200
  member vni 50000

interface bdi2200
  vrf member coke
  ip forward
  no ip redirects
  no shutdown
```

While the **system bridge-domain** command identifies the bridge domain IDs, the **bridge-domain** command configures the specified bridge domain(s).

Add the Layer 3 VRF VNI to the overlay network and enable BGP reachability

(config) #

```
interface nve 1
   host-reachability protocol bgp
   member vni 50000 associate-vrf
```

Configure BGP, associate the customer VRF to BGP and enable L2VPN EVPN route distribution

(config) #

```
router bgp 100
   vrf coke
      address-family ipv4 unicast
         advertise l2vpn evpn
```

Enable host/server facing BDI (and associate it to a VRF) for Layer 3 connectivity on the distributed anycast gateway

(config) #

```
interface bdi200
   vrf member coke
   ip address 10.1.1.1/24
   fabric forwarding mode anycast-gateway
   no shutdown
```

VXLAN BGP EVPN Verification

For verification of MAC routes, refer these commands:

The following is sample output to verify that end host MAC addresses (local and remote) are added to the MAC address table:

```
switch# show mac address-table dynamic

Note: MAC table entries displayed are getting read from software.
 Use the 'hardware-age' keyword to get information related to 'Age'

 Legend:
        * - primary entry, G - Gateway MAC, (R) - Routed MAC, O - Overlay MAC
        age - seconds since last seen,+ - primary entry using vPC Peer-Link, E -
 EVPN entry
        (T) - True, (F) - False ,  ~~~ - use 'hardware-age' keyword to retrieve
age info

VLAN/BD   MAC Address      Type      age     Secure NTFY Ports/SWID.SSID.LID
---------+-----------------+--------+---------+------+----+------------------

* 200      2010.0000.0010    dynamic   270      F    F   Eth100/1/1
* 200      2010.0000.0011    dynamic   0        F    F   nve1/10.1.1.56
* 200      2010.0000.0012    dynamic   0        F    F   nve1/10.1.1.74
* 200      2010.0000.0013    dynamic   0        F    F   nve1/10.1.1.56
* 200      8080.c800.0038    dynamic   0        F    F   nve1/10.1.1.74
* 1        24e9.b392.316b    dynamic   1190     F    F   Eth100/1/1
```

The following is sample output for viewing MAC addresses of end hosts across all EVPN instances (EVIs) pertaining to the switch:

```
switch# show l2route evpn mac all

Topology    Mac Address    Prod   Next Hop (s)
----------- -------------- ------ ---------------
200         2010.0000.0010 Local  Eth100/1/1
200         2010.0000.0011 BGP    10.1.1.56
200         2010.0000.0012 BGP    10.1.1.74
200         2010.0000.0013 BGP    10.1.1.56
200         8080.c800.0038 BGP    10.1.1.74
2200        002a.6ab2.0181 VXLAN  10.1.1.56
2200        8c60.4f14.2efc VXLAN  10.1.1.74
```

The following sample output displays BGP routing table information for the L2VPN EVPN address family. It includes route distinguisher and next hop information.

```
switch # show bgp l2vpn evpn

BGP routing table information for VRF default, address family L2VPN EVPN
BGP table version is 198, local router ID is 10.1.1.54
Status: s-suppressed, x-deleted, S-stale, d-dampened, h-history, *-valid, >-best
Path type: i-internal, e-external, c-confed, l-local, a-aggregate, r-redist, I-injected
Origin codes: i - IGP, e - EGP, ? - incomplete, | - multipath, & - backup

   Network            Next Hop            Metric     LocPrf     Weight Path

Route Distinguisher: 10.1.1.54:32967    (L2VNI 30000)
*>l[2]:[0]:[0]:[48]:[2010.0000.0010]:[0]:[0.0.0.0]/216
                      10.1.1.54                              100      32768 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0011]:[0]:[0.0.0.0]/216
                      10.1.1.56                              100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0012]:[0]:[0.0.0.0]/216
                      10.1.1.74                              100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0013]:[0]:[0.0.0.0]/216
                      10.1.1.56                              100          0 i
*>i[2]:[0]:[0]:[48]:[8080.c800.0038]:[0]:[0.0.0.0]/216
```

```
                      10.1.1.74                           100          0 i
*>l[2]:[0]:[0]:[48]:[2010.0000.0010]:[32]:[209.165.202.139]/272
                      10.1.1.54                           100      32768 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0011]:[32]:[209.165.202.140]/272
                      10.1.1.56                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0012]:[32]:[209.165.202.141]/272
                      10.1.1.74                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0013]:[32]:[209.165.202.142]/272
                      10.1.1.56                           100          0 i
*>i[2]:[0]:[0]:[48]:[8080.c800.0038]:[32]:[209.165.202.143]/272
                      10.1.1.74                           100          0 i

Route Distinguisher: 10.1.1.56:3
*>i[5]:[0]:[0]:[24]:[209.165.202.130]:[0.0.0.0]/224
                      10.1.1.56               0           100          0 ?

Route Distinguisher: 10.1.1.56:32967
*>i[2]:[0]:[0]:[48]:[2010.0000.0011]:[0]:[0.0.0.0]/216
                      10.1.1.56                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0013]:[0]:[0.0.0.0]/216
                      10.1.1.56                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0011]:[32]:[209.165.202.140]/272
                      10.1.1.56                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0013]:[32]:[209.165.202.142]/272
                      10.1.1.56                           100          0 i

Route Distinguisher: 10.1.1.74:32967
*>i[2]:[0]:[0]:[48]:[2010.0000.0012]:[0]:[0.0.0.0]/216
                      10.1.1.74                           100          0 i
*>i[2]:[0]:[0]:[48]:[8080.c800.0038]:[0]:[0.0.0.0]/216
                      10.1.1.74                           100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0012]:[32]:[209.165.202.141]/272
                      10.1.1.74                           100          0 i
*>i[2]:[0]:[0]:[48]:[8080.c800.0038]:[32]:[209.165.202.143]/272
                      10.1.1.74                           100          0 i
```

The following sample output displays peer VTEP device information.

```
switch # show nve peers

Interface Peer-IP    State LearnType Uptime   Router-Mac
--------- ---------------  ----- --------- -------- -----------------
nve1      10.1.1.56         Up    CP        1d12h    002a.6ab2.0181
nve1      10.1.1.74         Up    CP        1d12h    8c60.4f14.2efc
```

For IP host and prefix routes verification, refer these commands:

The following sample output displays tenant (VRF) information

```
switch # show ip arp vrf coke

Flags: * - Adjacencies learnt on non-active FHRP router
       + - Adjacencies synced via CFSoE
       # - Adjacencies Throttled for Glean
       D - Static Adjacencies attached to down interface

IP ARP Table for context coke
Total number of entries: 1
Address               Age       MAC Address       Interface
209.165.202.144  00:18:23       2010.0000.0010    Bdi200
```

The following sample output displays tenant (VRF) information

```
switch # show ip route vrf coke

IP Route Table for VRF "coke"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>

10.1.1.0/24, ubest/mbest: 1/0, attached
    *via 10.1.1.1, Bdi10, [0/0], 1d12h, direct
10.1.1.1/32, ubest/mbest: 1/0, attached
    *via 10.1.1.1, Bdi10, [0/0], 1d12h, local
209.165.202.130/27, ubest/mbest: 1/0, attached
    *via 209.165.202.129, Bdi200, [0/0], 1d12h, direct, tag 12345,
209.165.202.129/32, ubest/mbest: 1/0, attached
    *via 209.165.202.129, Bdi200, [0/0], 1d12h, local, tag 12345,
209.165.202.139/32, ubest/mbest: 1/0, attached
    *via 209.165.202.139, Bdi200, [190/0], 1d12h, hmm
209.165.202.140 /32, ubest/mbest: 1/0
    *via 10.1.1.56%default, [200/0], 1d12h, bgp-100, internal, tag 100,  (mpls-vpn)segid
50000 tunnel: 16843064 encap: 1
```

The following sample output displays MAC - IP address binding for all attached and remote end hosts (learned through the BGP EVPN control plane).

```
switch # show l2route evpn mac-ip all

Topology ID Mac Address    Prod     Host IP                                 Next Hop(s)
----------- -------------- ---- --------------------------------------- --------
200         2010.0000.0010 HMM      209.165.202.139    N/A

200         2010.0000.0011 BGP      209.165.202.140    10.1.1.56

200         2010.0000.0012 BGP      209.165.202.141    10.1.1.74

200         2010.0000.0013 BGP      209.165.202.142    10.1.1.56

200         8080.c800.0038 BGP      209.165.202.143    10.1.1.74
```

The following sample output displays BGP routing table information for Layer-3 VNIs.

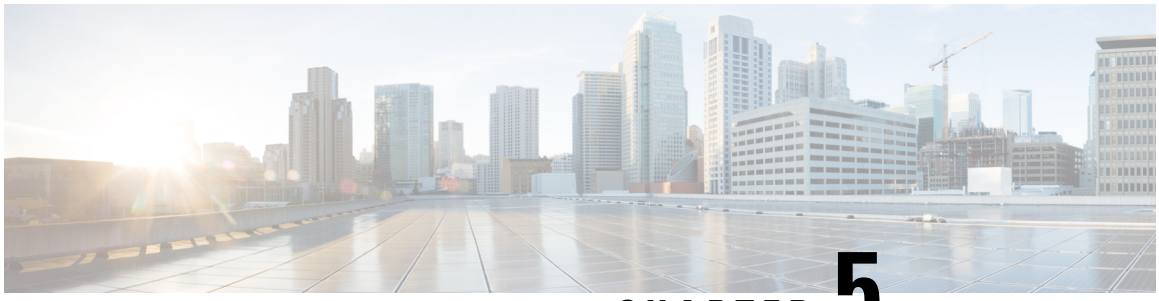
```
switch # show bgp l2vpn evpn

Route Distinguisher: 10.1.1.54:3    (L3VNI 50000)
*>i[2]:[0]:[0]:[48]:[2010.0000.0011]:[32]:[209.165.202.144]/272
                      10.1.1.56                          100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0012]:[32]:[209.165.202.141]/272
                      10.1.1.74                          100          0 i
*>i[2]:[0]:[0]:[48]:[2010.0000.0013]:[32]:[209.165.202.143]/272
                      10.1.1.56                          100          0 i
*>l[5]:[0]:[0]:[24]:[209.165.202.130]:[0.0.0.0]/224
                      10.1.1.54                0         100      32768 ?
* i                   10.1.1.56                0         100          0 ?
```

Feature History for VXLAN BGP EVPN

This table lists the release history for this feature.

Table 3: Feature History for VXLAN BGP EVPN

Feature Name	Releases	Feature Information	
VXLAN BGP EVPN	7.2(0)D1(1) 7.3(0)DX(1)	This feature was introduced. Support for M3 modules is introduced.	



CHAPTER 5

Configuring ACI WAN Interconnect

This chapter contains the following sections:

VXLAN EVPN - MPLS L3VPN for ACI Fabric

Prerequisites for Configuring ACI WAN Interconnect

- A Cisco Nexus 7000 Series switch with an F3/F4/M3 line card.

Feature History for ACI WAN Interconnect

This table lists the release history for this feature.

Table 4: Feature History for ACI WAN Interconnect

Feature Name	Releases	Feature Information
ACI WAN Interconnect	7.3(1)D1(1)	This feature was introduced for the F3 line card. Support for MPLS L3VPN as a mechanism or transport outside the ACI fabric was introduced for the F3 line card. **Note** VRF-Lite and LISP technologies are not supported for this release.
	8.1(1)	Support for the VRF IP routing (or VRF-Lite) was introduced for the F3 line card.
	8.2(1)	Support for this feature was extended to the M3 line card. Support for VRF-Lite and MPLS L3VPN was introduced for the M3 line card, in addition to the existing support for the F3 line card. Support for LISP as a mechanism or transport outside the ACI fabric was introduced for the F3 and M3 line cards.
	8.4(1)	Support for VRF-Lite and MPLS L3VPN was introduced for the F4 line card.

Overview of VXLAN EVPN - MPLS L3VPN for ACI Fabric

ACI WAN Interconnect is a multi-platform, multi-OS architecture used to interconnect multi-tenant ACI data center fabrics to the external Layer 3 domain (north-south communication). For interconnecting ACI networks (a solution traditionally referred to as Data Center Interconnect – DCI) the ACI Multi-Pod and ACI Multi-Site architecture are instead available, as discussed in more detail in the two papers below:

https://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/application-centric-infrastructure/white-paper-c11-737855.html

https://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/application-centric-infrastructure/white-paper-c11-739609.html

Note

Note: the ACI WAN Interconnect architecture is often referred to with the acronym "GOLF", so the two terms will be used interchangeably in the rest of this paper. The WAN Edge routers establishing MP-BGP EVPN control plane adjacencies and VXLAN data-plane communication with the ACI fabric will also frequently referred to as "GOLF routers".

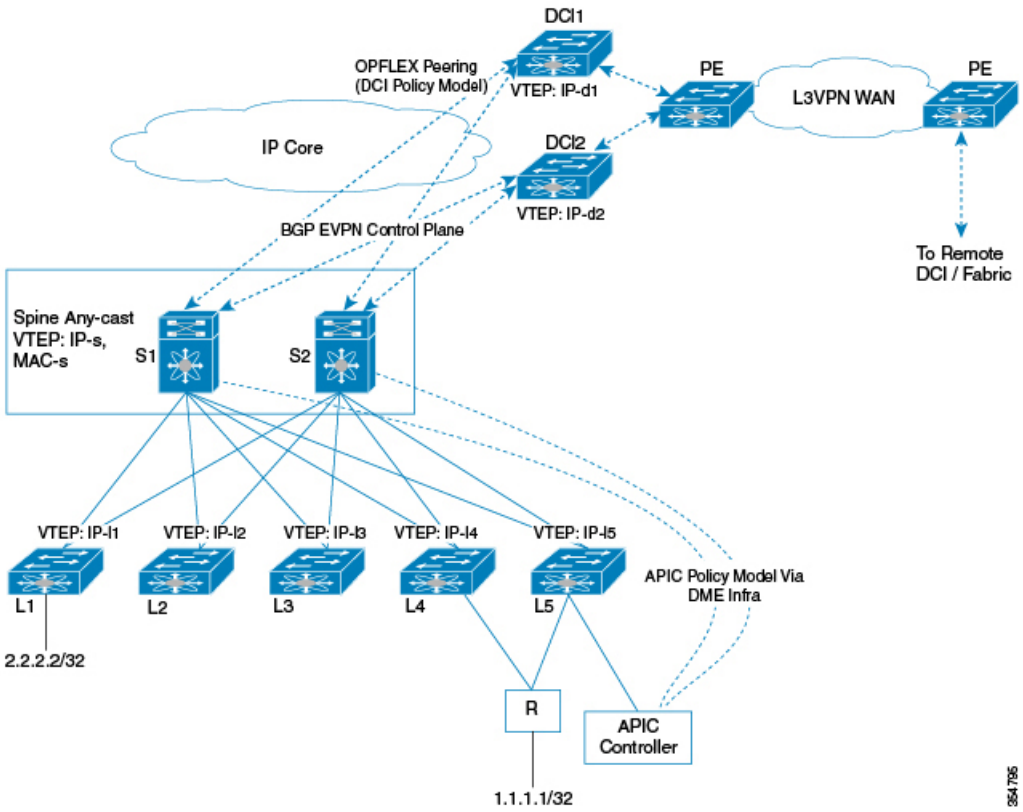
The Cisco Application Centric Infrastructure (ACI) allows application requirements to define the network. This architecture simplifies, optimizes, and accelerates the entire application deployment life cycle.

The ACI fabric include switches with the APIC to run in the leaf/spine ACI fabric mode. These switches form a "fat-tree" network by connecting each leaf node to each spine node; all other devices connect to the leaf nodes. The APIC manages the ACI fabric. The recommended minimum configuration for the APIC is a cluster of three replicated hosts. The APIC fabric management functions do not operate in the data path of the fabric.

- For more details on ACI, refer to Cisco Application Centric Infrastructure Fundamentals guide and Cisco ACI Basic Configuration Guide.

The ACI data center fabric can be connected across Layer 3 boundaries (to external sites and back) using MPLS L3VPN, VRF IP Routing (VRF Lite), or LISP as the mechanism of transport outside the ACI fabric.

Figure 17: ACI Fabric & L3VPN Hand-off



The MPLS L3VPN hand off scenario is explained below.

- BGP-EVPN peering from DCI gateways to two spines in a POD.
- Spines advertise host OR prefix routes for hosts directly behind a leaf, with the Spine Any-cast IP VTEP (IP-s) as the next-hop. These are mostly public BD subnets advertised to outside world.
- Spines can relay a transit route advertised by ACI leafs with leaf VTEPs as next-hops to be used as ECMP paths.
- North-to-South traffic tunneled from DCI to Spine any-cast IP (can land on any of the Spines) or the ECMP is tunneled directly to advertise ACI-leaf VTEPs.
- North-to-South traffic tunneled to Spine will get routed on spine-to-leaf based on /32 lookup.
- Routes advertised from DCI to Spine will get reflected to leaves with the DCI VTEP as the next-hop.
- South-to-North traffic will get routed on the leaves, and ECMP is tunneled directly to the two DCIs.
- Downstream assigned per-VRF VNIDs are advertised by DCI and ACI VTEPs.
- DCI tenant configuration object model are pushed from APIC to Spine to DCI via the OpFlex framework.
- Spines advertise public BD subnet host or prefix routes for hosts directly behind a leaf, with the Spine Any-cast IP VTEP (IP-s) as the next-hop.
- Physical and underlay L3 connectivity between the DCIs and Spines can be via an infrastructure IP network in between or via direct layer 3 sub-interfaces.

Note Adding or deleting ‘route-target’ on APIC removes VRF from the switch. You need to wait for VRF to be added or deleted completely as it takes time for addition or deletion. Make sure VRF is out of delete hold down before adding a new VRF.

Note If the incoming traffic on the PE device is getting transmitted over VXLAN fabric on the same device (as the incoming traffic is MPLS) QoS behavior or value for the outgoing packet is derived based on the EXP of the incoming traffic. Further QoS processing will be based on the EXP. This will decide the DSCP value in the outgoing VXLAN packet. In such scenario, the inner and the outer headers of the VXLAN encapsulation packet will have different DSCP values. This can result in a different/unexpected QoS treatment for the traffic in VXLAN fabric.

In such cases, it is recommended that you configure the below simple ingress QoS policy on the MPLS interface. This will enable the system to perform QoS processing based on incoming DSCP as against the incoming EXP of the packet. An example is provided below:

```
table-map
  default copy

policy-map type qos
class class-default
set dscp dscp table

interface
mpls ip
mtu 9150
service-policy type qos input
no shutdown
```

Spine – DCI Connectivity

ACI Spines is directly connected or connected via an inter-POD network router to DCI gateways. Underlay connectivity being direct or via an intermediate router does not have any bearing on the DCI gateway functions.

Spine – DCI BGP EVPN Session

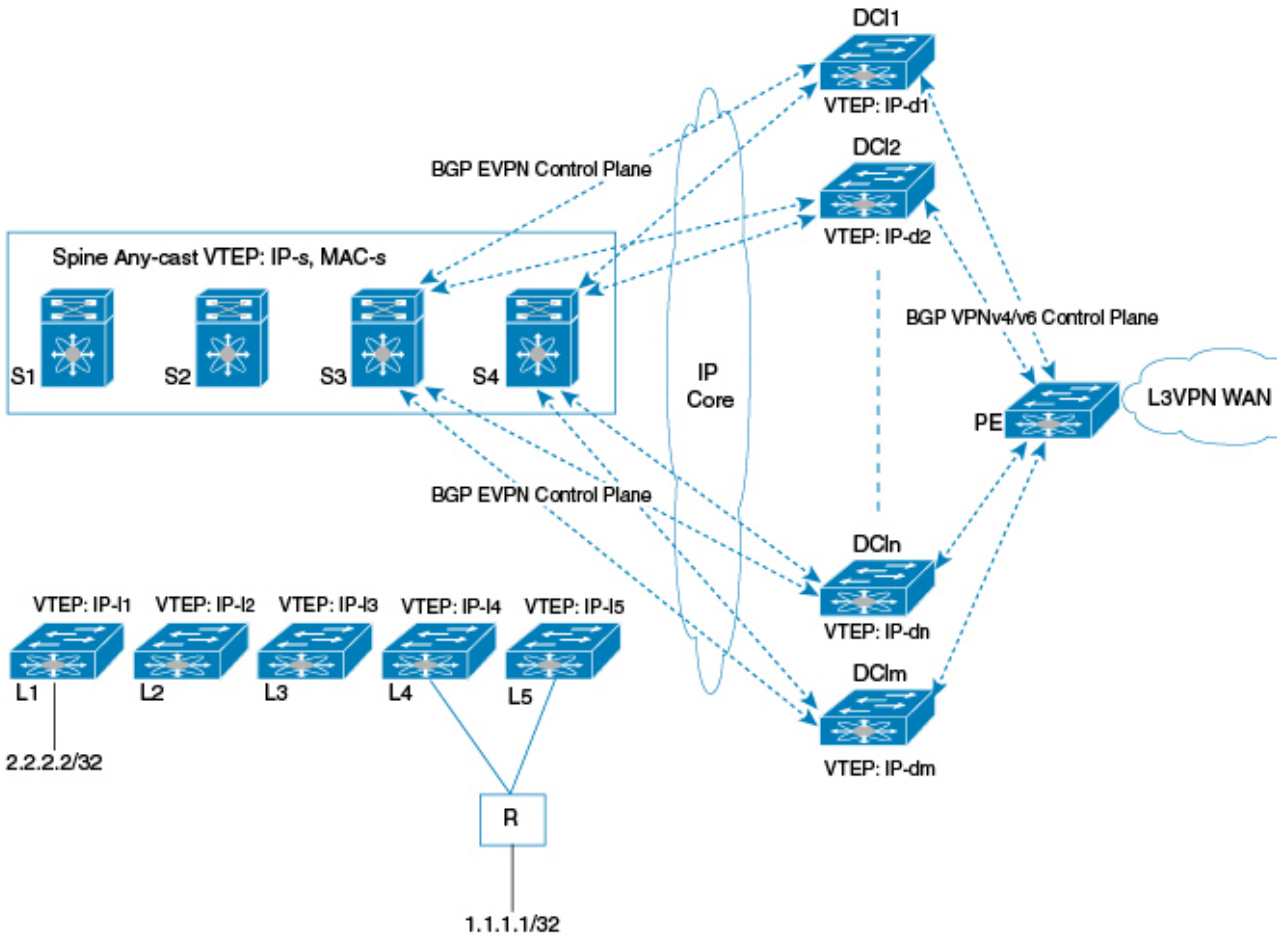
BGP session between the Spine and DCI gateway can be eBGP or iBGP. eBGP is the commonly used topology.

The MPLS-L3VPN hand-off for ACI fabric can be deployed using one of the following topologies:

- Single POD with multiple DCI gateways
- Multi-POD with shared DCI gateway
- Multi-POD with Separate DCI gateway

Single POD With Multiple DCI Gateways

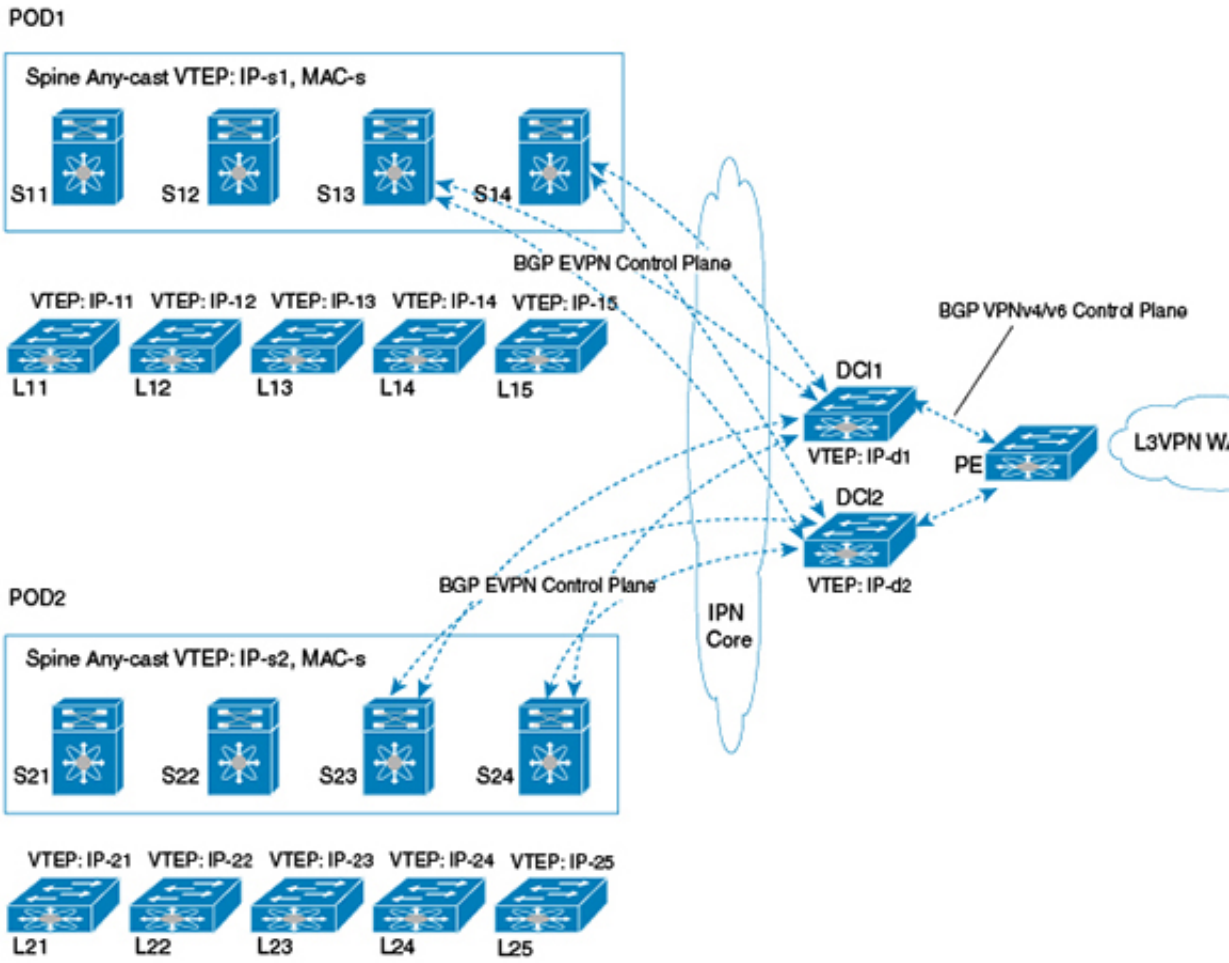
Figure 18: Single POD with Multiple DCI Gateways



This topology is used if VRF scale within the single POD is more that the VRF scale supported on a single DCI gateway. A set of VRFs are imported and advertised on one DCI pair, while another set of VRFs could be present on another DCI pair. Fabric spines advertise all routes to all DCI pairs, but only configured VRF routes are imported and advertised towards L3VPN PE on the respective DCIs.

Multi-POD With Shared DCI Gateways

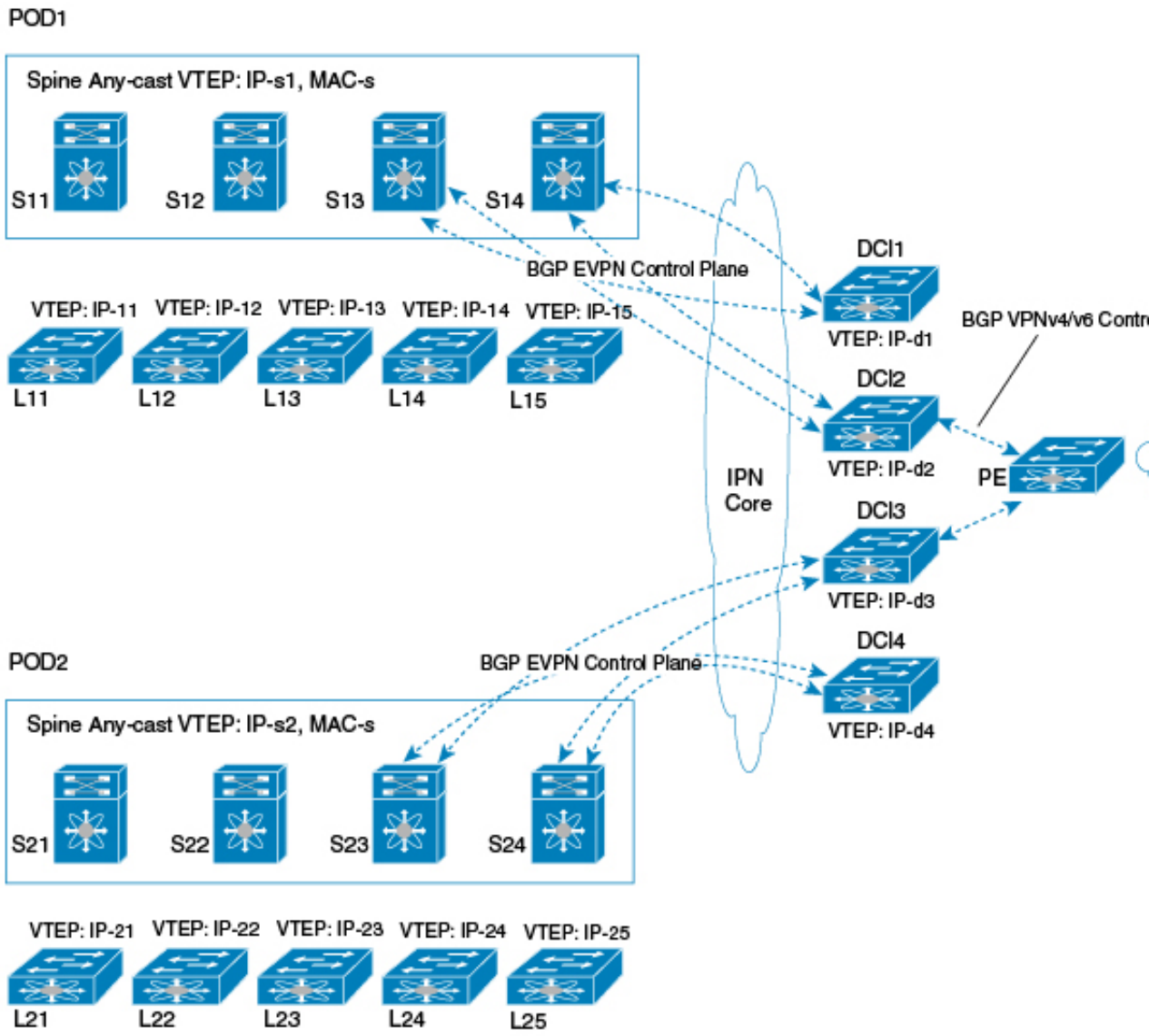
Figure 19: Multi-POD with Shared DCI Gateway



In this topology multiple PODs share the same DCI gateway. The DCI pair imports and advertises VRF routes from multiple POD spines. DCI pair has underlay connectivity to multiple PODs over an inter-POD network underlay.

Multi-POD With Separate DCI Gateways

Figure 20: Multi-POD with Separate DCI Gateways



This is a regular multi-POD topology where separate PODs use dedicated DCI gateways.

Configuration for VXLAN EVPN - MPLS L3VPN for ACI Fabric using OpFlex is described in the following section.

OpFlex DCI Auto-Configuration

Cisco OpFlex is a southbound protocol in a software-defined network (SDN) designed to facilitate the communications between the SDN Controller and the infrastructure (switches and routers). The goal is to

create a standard that enables policies to be applied across physical and virtual switches/routers in a multi-user environment.

For more details on OpFlex refer to OpFlex: An Open Policy Protocol White Paper.

To enable automation of fabric facing tenant configuration on the DCI, DCI interfaces with the fabric as an external Policy Element (PE) that talks to ACI fabric spine acting as a proxy-Policy Repository (PR) for DCI specific policy information. An OpFlex policy framework is used between the spines and the DCIs to distribute this DCI policy model from the fabric to the DCI gateways. DCI uses this policy information pushed from the spine to auto generate fabric facing per-tenant configuration.

ACI spine in turn derives this DCI object model from the concrete object model (object store) populated on the Spine through the ACI DME infrastructure. APIC controller (via DME infra) pushes a logical model that results in a resolved concrete model on the Spine Policy Element. Spine gleans specific attributes required to instantiate the ACI WAN Interconnect DCI service for individual tenants from this resolved concrete model and populates a per-DCI object-model that is distributed to individual DCIs via the OpFlex framework. Spine essentially acts a proxy on behalf of the fabric to push per-tenant DCI policies to the DCI that acts as an external policy element to the fabric.

Note that this PR – PE contract between the fabric and the DCI is limited to fabric facing per-tenant provisioning and not a contract for management functions in general. All remaining configuration, including WAN facing configuration, as well as all other management, operational aspects on the DCI will continue to work independent of this PR – PE contract with the fabric, via existing mechanisms.

Interconnect Policy Provisioning (IPP)

Interconnect Policy Provisioning (IPP) enables automation of fabric facing per-tenant provisioning on the DCI gateway.

The IPP utilizes OpFlex to push policies from ACI fabric to the DCI gateway. Using these policy attributes, HMM auto-config is triggered to apply the profile along with the attributes to provision the required fabric-facing configurations.

OpFlex Peering and Multi-POD

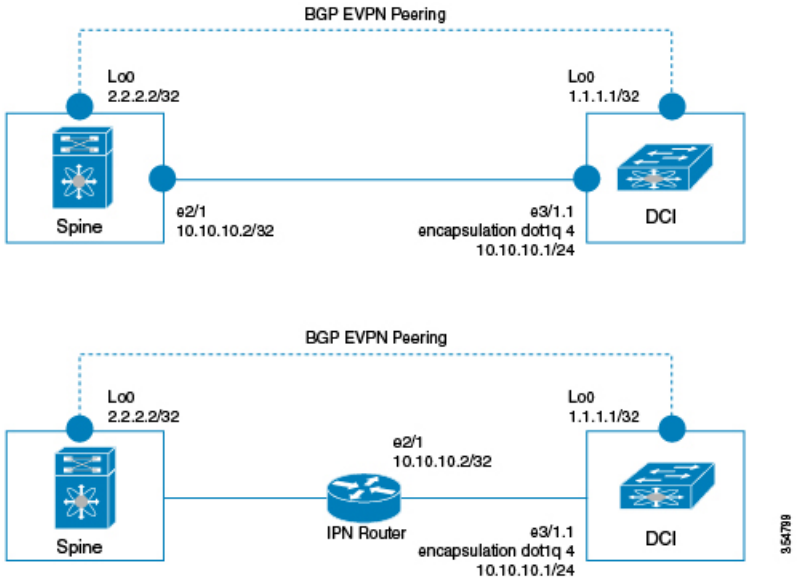
In a multi-POD topology, where the same DCI pair peers with multiple PODs, each POD would be configured as a separate fabric ID and would result in a separate OpFlex framework to be instantiated with the respective spine peers in that fabric that would result in OpFlex sessions to the spine peers within each POD.

Each OpFlex framework translates to a separate managed object database that is populated as a result of policy information distributed from respective spines.

In a scenario where the same L3 domain is spread across the two PODs, DCI can receive updates for the same VRF from multiple OpFlex frameworks, possibly with different RTs. DCI handles this multiple update scenario by appending the route targets for the POD if the fabric facing local VRF configuration has already been instantiated.

DCI Auto-Configuration Scenario

Figure 21: DCI Auto-Configuration



DCI could have the following scenarios:

- Underlay L3 connectivity to the spine via an Inter-POD-Network router in a multi-POD topology
- Directly connected to the spine

Spine — IPN Router — DCI (multi-pod topology)

DCI would be part of an external subnet that is reachable via an inter-pod network/router and not part of the infra subnet (that is administered via APIC). External subnets are administered outside of APIC and would have the IP addresses administered manually.

Spine — DCI (DCI directly connected to multiple spines)

A separate subnet is allocated for all DCIs to be on, and this subnet is not administered via APIC/DHCP. DCI and spine interface IP addresses on this subnet are administered manually.

Essentially, in both topologies, DCI underlay interface that carries OpFlex/ BGP control plane/VXLAN data plane traffic is assumed to be not on the infra subnet that requires IP address to be obtained via DHCP. L3 reachability to ACI VTEPs, BGP peers, and OpFlex proxy on the ACI infra subnet is through the underlay routing to/from this external DCI subnet.

The following sections describe the OpFlex configuration steps.

1) One time configuration (as described below) for the following is done manually:

- DCI underlay connectivity
- Routing
- BGP-EVPN peering to the spines
- BGP-IPVPN peering to the WAN PE

```
# enable features
install feature-set mpls
install feature-set fabric
```

```
feature-set mpls
feature-set fabric
feature fabric forwarding
fabric forwarding switch-role dci-node border
nv overlay evpn
feature bgp
feature interface-vlan
feature nv overlay
feature vni
feature ospf
feature ipp
feature mpls l3vpn
feature mpls ldp


#BGP Fabric and WAN Peering
router bgp 65000
  address-family l2vpn evpn
    allow-vni-in-ethertag
  ! EVPN Neighbor
  neighbor 2.2.2.1 remote-as 75000
    address-family l2vpn evpn
      import vpn unicast reoriginate
  ! WAN Peering
  neighbor 11.11.11.1 remote-as 65000
    update-source loopback 0
    address-family vpnv4 unicast
      import l2vpn evpn reoriginate
```

Note The **allow-vni-in-ethertag** configuration allows EVPN Route Type 2 routes to be received from the ACI spine devices.

```
# DCI TEP IP
interface loopback0
  ipv4 address 1.1.1.1/32

# underlay fabric facing L3 interface
interface e3/1
  ipv4 address 10.10.10.1/24

# VXLAN local TEP
interface NVE 1
  source-interface loopback0
  host-reachability protocol bgp
  unknown-peer-forwarding enable
  vxlan udp port 48879

# underlay routing
router ospf
  area 0
    interface loopback0
    interface e3/1

# DCIs learn reachability to all ACI TEP IPs via OSPF or ISIS
router ospf 100
  router-id 40.0.0.9
  area 0.0.0.100 nssa
# Configuring a peer in downstream (vni) mode
interface nve 1
```

```
[no] vni assignment downstream [all]
        Peer-ip <ip address 1>
        Peer-ip <ip address 2>
     …….
     Peer-ip <ip address 3>

# Changing the default forwarding behavior

interface nve <nve-int-number>
 [no] unknown-peer-forwarding enable
```

2) Configuring profile templates

The following config-profile templates are manually configured so that IPP can leverage HMM auto-config functionality to instantiate the profiles for the VRF tenant.

```
# MPLS L3VPN hand-off common profile
configure profile vrf-common-mpls-l3vpn-dc-edge
  vrf context $vrfName
    vni $include_vrfSegmentId
    rd auto
    address-family ipv4 unicast
      route-target import $include_client_import_ipv4_bgpRT_1 evpn
      route-target export $include_client_export_ipv4_bgpRT_1 evpn
      route-target import $include_client_import_ipv4_bgpRT_2 evpn
      route-target export $include_client_export_ipv4_bgpRT_2 evpn
      route-target import $include_client_import_ipv4_bgpRT_3 evpn
      route-target export $include_client_export_ipv4_bgpRT_3 evpn
      route-target import $include_client_import_ipv4_bgpRT_4 evpn
      route-target export $include_client_export_ipv4_bgpRT_4 evpn
      route-target import $include_client_import_ipv4_bgpRT_5 evpn
      route-target export $include_client_export_ipv4_bgpRT_5 evpn
      route-target import $include_client_import_ipv4_bgpRT_6 evpn
      route-target export $include_client_export_ipv4_bgpRT_6 evpn
      route-target import $include_client_import_ipv4_bgpRT_7 evpn
      route-target export $include_client_export_ipv4_bgpRT_7 evpn
      route-target import $include_client_import_ipv4_bgpRT_8 evpn
      route-target export $include_client_export_ipv4_bgpRT_8 evpn
    address-family ipv6 unicast
      route-target import $include_client_import_ipv6_bgpRT_1 evpn
      route-target export $include_client_export_ipv6_bgpRT_1 evpn
      route-target import $include_client_import_ipv6_bgpRT_2 evpn
      route-target export $include_client_export_ipv6_bgpRT_2 evpn
      route-target import $include_client_import_ipv6_bgpRT_3 evpn
      route-target export $include_client_export_ipv6_bgpRT_3 evpn
      route-target import $include_client_import_ipv6_bgpRT_4 evpn
      route-target export $include_client_export_ipv6_bgpRT_4 evpn
      route-target import $include_client_import_ipv6_bgpRT_5 evpn
      route-target export $include_client_export_ipv6_bgpRT_5 evpn
      route-target import $include_client_import_ipv6_bgpRT_6 evpn
      route-target export $include_client_export_ipv6_bgpRT_6 evpn
      route-target import $include_client_import_ipv6_bgpRT_7 evpn
      route-target export $include_client_export_ipv6_bgpRT_7 evpn
      route-target import $include_client_import_ipv6_bgpRT_8 evpn
      route-target export $include_client_export_ipv6_bgpRT_8 evpn*
  router bgp $asn
    vrf $vrfName
      address-family ipv4 unicast
        advertise l2vpn evpn
        label-allocation-mode per-vrf
      address-family ipv6 unicast
        advertise l2vpn evpn
        label-allocation-mode per-vrf
  interface nve $nveId
```

```
    member vni $include_vrfSegmentId associate-vrf
configure terminal
```

Note * If the core-facing WAN uses the same RT value, add the following route-targets to simplify the manual configuration.

```
      route-target import $include_client_import_ipv4_bgpRT_1
      route-target export $include_client_export_ipv4_bgpRT_1
      route-target import $include_client_import_ipv4_bgpRT_2
      route-target export $include_client_export_ipv4_bgpRT_2
      …….
```

```
# MPLS L3VPN Universal profile
configure profile defaultNetworkMplsL3vpnDcProfile
  ipp tenant $vrfName $client_id
  include profile any
end


# MT Full VRF tenant profile
configure profile vrf-tenant-profile
  vni $vrfSegmentId
  bridge-domain $bridgeDomainId
    member vni $vrfSegmentId
  interface bdi $bridgeDomainId
    vrf member $vrfName
    ip forward
    no ip redirects
    ipv6 forward
    no ipv6 redirects
    no shutdown
end
```

3) Instantiating an OpFlex framework to an ACI fabric is manually configured as follows:

```
# Enable IPP feature
feature ipp

# Add ipp owned global configuration
ipp
  profile-map profile defaultNetworkMplsL3vpnDcProfile include-profile
vrf-common-mpls-l3vpn-dc-edge
  local-vtep nve 1
  bgp-as 100
  identity 11.1.1.1

# Configure to allocate bridge-domain assignments
system bridge-domain 100-3000
system fabric bridge-domain 2000-3000

# Add fabric forwarding configuration for the auto-config
feature-set fabric
feature fabric forwarding

# 'border' enables bgp evpn to work
fabric forwarding switch-role dci-node border

# timers are used to cleanup and remove recovered configurations
fabric database timer cleanup 5
fabric database timer recovery 15

# DCI Setup infra connectivity to OpFlex (interfaces are fabric facing)
```

```
interface e3/1.1
  no shutdown
  encapsulation dot1q 4
  ip address 10.1.1.1/24
  ip ospf network point-to-point
  ip router ospf 100 area 0.0.0.100

# Add IPP owned per ACI/OpFlex instance configuration
ipp
 fabric 1
    opflex-peer 10.2.2.2 8009
    ssl encrypted
  fabric 2
    opflex-peer 10.2.3.2 8009
    ssl encrypted
```

Note Default port for connecting to the OpFlex proxy server on the spine is 8009.

4) Per-tenant configuration

In a scenario, where the DCI is connected to multiple ACI PODs, and has an OpFlex framework to each POD, spines in each POD will send a tenant policy update with the BGP RT value used by that POD. DCI will add each RT as an import/export RT for the tenant VRF in question.

Following per-tenant configuration will be auto-generated on receiving fabric tenant ADD event for the first time:

```
vrf context cust1
  vni 10000
  rd auto
  address-family ipv4 unicast
    route-target import 1000:1000 evpn
    route-target export 1000:1000 evpn
  address-family ipv6 unicast
    route-target import 1000:1000 evpn
    route-target export 1000:1000 evpn

router bgp 65000
  vrf cust1
    address-family ipv4 unicast
      advertise l2vpn evpn
    address-family ipv6 unicast
      advertise l2vpn evpn

interface nve 1
  member vni 10000 associate-vrf

vni 10000
bridge-domain 100
  member vni 10000
interface bdi 100
  vrf member cust1
  ip forward
  no ip redirects
  ipv6 forward
  no ipv6 redirects
  no shutdown

ipp tenant cust1 1
```

Show and Debug Command Examples

The following examples list the show and debug commands that are used in IPP configuration.

```
switch# show ipp internal ?
  event-history  Show various event logs of IPP
  mem-stats       Dynamic memory stats
  pss                  Internal IPP pss info
  work-info       Internal IPP worker thread info
```

```
switch# show ipp internal debug
IPP Debug information
Debug Flags                    : Off
Debug-filters                  : Off
```

```
switch# show ipp internal event-history ?
  errors    Show error logs of IPP
  events    Show IPP process events
  ha        Show IPP process HA events
  msgs      Show various message logs of IPP
  opflex    Show IPP process opflex events
  periodic  Show IPP process periodic events
  trace     Show processing logs of IPP
```

```
switch# show ipp internal event-history ha
Process Event logs of IPP
2016 May 27 17:06:50.843014 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-13:coke-13
 from PSS
2016 May 27 17:06:50.842880 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:48.606305 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-10:coke-10
 from PSS
2016 May 27 17:06:48.606168 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:47.245350 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-72:coke-72
 from PSS
2016 May 27 17:06:47.245169 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:46.377087 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-63:coke-63
 from PSS
2016 May 27 17:06:46.376936 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:45.699181 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-28:coke-28
 from PSS
2016 May 27 17:06:45.698969 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:45.008724 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-45:coke-45
 from PSS
2016 May 27 17:06:45.008545 ipp [6452]: [6492]: Updating tenant in PSS TLVU
2016 May 27 17:06:44.413233 ipp [6452]: [6492]: Updated tenant instance 1 rd coke-19:coke-19
 from PSS
2016 May 27 17:06:44.413075 ipp [6452]: [6492]: Updating tenant in PSS TLVU
.....
```

```
switch# show ipp internal event-history events
Process Event logs of IPP
2016 May 27 17:08:16.457294 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-99
218 command
2016 May 27 17:08:15.105985 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-98
235 command
2016 May 27 17:08:14.370121 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-97
216 command
2016 May 27 17:08:13.133061 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-96
198 command
2016 May 27 17:08:12.331485 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-95
201 command
2016 May 27 17:08:11.052111 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-94
209 command
```

```
2016 May 27 17:08:10.341556 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-93
173 command
2016 May 27 17:08:09.061573 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-92
184 command
2016 May 27 17:08:08.376121 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-91
255 command
2016 May 27 17:08:07.183026 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-90
260 command
2016 May 27 17:08:06.483588 ipp [6452]: [6495]: Unconfig ipp tenant dci_coke-9 2
……
```

```
switch# show ipp internal event-history msgs
Msg events for IPP Process
1) Event:E_DEBUG, length:45, at 581444 usecs after Mon May 30 11:34:23 2016
    [100] [19461]: nvdb: transient thread created

2) Event:E_DEBUG, length:82, at 579664 usecs after Mon May 30 11:34:23 2016
    [100] [6495]: comp-mts-rx opc - from sap 19164 cmd ipp_show_internal_event_h
ist_cmd
3) Event:E_DEBUG, length:49, at 882139 usecs after Mon May 30 11:33:45 2016
    [100] [19410]: nvdb: terminate transaction failed
……
```

```
switch# show ipp internal event-history opflex
Process opflex logs of IPP
2016 May 30 11:05:46.967301 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-72/GbpRoutingDomain/coke-72/
2016 May 30 11:05:46.967242 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-63/GbpRoutingDomain/coke-63/
2016 May 30 11:05:46.967165 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-28/GbpRoutingDomain/coke-28/
2016 May 30 11:05:46.716185 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-45/GbpRoutingDomain/coke-45/
2016 May 30 11:05:46.715810 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-19/GbpRoutingDomain/coke-19/
2016 May 30 11:05:46.715754 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-90/GbpRoutingDomain/coke-90/
2016 May 30 11:05:46.715696 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-73/GbpRoutingDomain/coke-73/
2016 May 30 11:05:46.715639 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-82/GbpRoutingDomain/coke-82/
2016 May 30 11:05:46.715580 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-55/GbpRoutingDomain/coke-55/
2016 May 30 11:05:46.715214 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
Resolving policy /PolicyUniverse/PolicySpace/coke-29/GbpRoutingDomain/coke-29/
2016 May 30 11:05:46.715153 ipp [6452]: [4710]: Processor.cpp:261:resolveObj():
……..
```

```
switch# show ipp internal event-history periodic
Process periodic event logs of IPP
2016 May 27 17:05:28.931685 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.927410 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.924043 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.383726 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.380290 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.376599 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.373088 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.368292 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.364850 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.361421 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.357986 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.354585 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.351387 ipp [6452]: [6493]: IPP Worker thread in progress
2016 May 27 17:05:28.347969 ipp [6452]: [6493]: IPP Worker thread in progress
```

```
2016 May 27 17:05:28.343087 ipp [6452]: [6493]: IPP Worker thread in progress
……..

switch# show ipp internal event-history trace
Trace logs of IPP
2016 May 30 01:07:32.962911 ipp [6452]: [6492]: sysmgr consumed mts[2558] messag
e MTS_OPC_SYSMGR_PSS_SHRINK, drop
2016 May 30 01:07:32.962893 ipp [6452]: [6492]: sysmgr processing mts[2558] mess
age MTS_OPC_SYSMGR_PSS_SHRINK
2016 May 28 01:07:29.561840 ipp [6452]: [6492]: sysmgr consumed mts[2558] messag
e MTS_OPC_SYSMGR_PSS_SHRINK, drop
2016 May 28 01:07:29.561818 ipp [6452]: [6492]: sysmgr processing mts[2558] mess
age MTS_OPC_SYSMGR_PSS_SHRINK
2016 May 27 17:06:50.843023 ipp [6452]: [6492]: Done processing MTS[250880] mess
age MTS_OPC_HMM dropped
……..

switch# show ipp internal mem-stats
Mem stats for IPP Process
Num blocks     User size     Total size    Library
--------------------------------------------------------------------------------
     304            155244        162128  ipp
     332             64567         70336  ld-2.15.so
     120              5712          8504  libc-2.15.so
       3                60           120  libdl-2.15.so
       1                 8            24  librt-2.15.so
   22877           1053813       1533896  libstdc++.so.6.0.16
      28              2294          2872  libvlan_mgr.so.0.0.0
      12              2860          3144  libsviifdb.so.0.0.0
       1               408           432  libltlmap.so.0.0.0
       9               576           792  libindxobj.so.0.0.0
     230              6472         11072  libast_db.so.0.0.0
     116              2304          4648  libavl.so.0.0.0
       4              8256          8352  libxos_lpss.so.0.0.0
      14              2604          2928  libfsrv.so.0.0.0
    3544            148784        193384  libcrypto.so.1.0.0
      99              6702          8728  libsdb.so.0.0.0
     358             11340         18544  libglib-2.0.so.0.3200.3
       2                80           128  libstartup-config.so.0.0.0
      32            151948        152648  libsdwrap.so.0.0.0
     162              5952          9296  libfsrv_client.so.0.0.0
       1               256           280  libcmd.so.0.0.0
      94              6195          8280  libcli_common.so.0.0.0
      28             31332         31960  librsw.so.0.0.0
       5             41120         41232  libtcp_clt.so.0.0.0
       3               152           216  libutils.so.0.0.0
      88             24520         26680  libpss.so.0.0.0
       3               528           600  libmts.so.0.0.0
       9              1800          2016  libsysmgr.so.0.0.0
       2             65804         65848  libopflex.so.0.0.0
       2               512           560  libuv.so.0.0.0
     689             34556         51008  libmtrack.so.0.0.0


 Grand totals:
        29172 Blocks
        1836759 User Bytes
        2420656 Total Bytes


switch# show ipp internal pss
-------------------------------
```

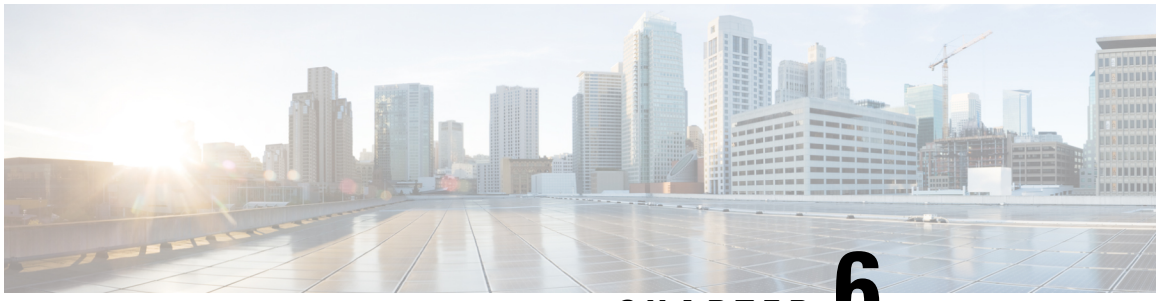
```
PSS Data
------------------------------

IPP_PSS_KEY_INIT_STATE
    Server state       : 1
IPP_PSS_KEY_GENINFO
    Global tenant id   : 365
IPP_PSS_KEY_TENANT
    Fabric id              : 1
    Fabric vrf name        : coke-1:coke-1
    Vrf name               : dci_coke-1
    Tenant id              : 289
    Hmm hostid             : 289
    V4 RT (import/export)  : 1:1/1:1
    V6 RT (import/export)  : 1:1/1:1
    Flags                  : 0x0
IPP_PSS_KEY_TENANT
    Fabric id              : 1
    Fabric vrf name        : coke-10:coke-10
    Vrf name               : dci_coke-10
    Tenant id              : 266
    Hmm hostid             : 266
    V4 RT (import/export)  : 1:10/1:10
    V6 RT (import/export)  : 1:10/1:10
    Flags                  : 0x0
IPP_PSS_KEY_TENANT
    Fabric id              : 1
    Fabric vrf name        : coke-100:coke-100
    Vrf name               : dci_coke-100
    Tenant id              : 346
    Hmm hostid             : 346
    V4 RT (import/export)  : 1:100/1:100
    V6 RT (import/export)  : 1:100/1:100
    Flags                  : 0x0
IPP_PSS_KEY_TENANT
    Fabric id              : 1
    Fabric vrf name        : coke-11:coke-11
    Vrf name               : dci_coke-11
    Tenant id              : 351
    Hmm hostid             : 351
    V4 RT (import/export)  : 1:11/1:11
    V6 RT (import/export)  : 1:11/1:11
    Flags                  : 0x0
.....
```

```
switch# show ipp internal vrf-db
   1: Vrf: dci_coke-1
        0: RT v4:(1:1,1:1) v6:(1:1,1:1)
           Host Id: 289, # tenants: 1
             Tenant Id: 289
   2: Vrf: dci_coke-10
        0: RT v4:(1:10,1:10) v6:(1:10,1:10)
           Host Id: 266, # tenants: 1
             Tenant Id: 266
   3: Vrf: dci_coke-100
        0: RT v4:(1:100,1:100) v6:(1:100,1:100)
           Host Id: 346, # tenants: 1
             Tenant Id: 346
   4: Vrf: dci_coke-11
        0: RT v4:(1:11,1:11) v6:(1:11,1:11)
           Host Id: 351, # tenants: 1
             Tenant Id: 351
   5: Vrf: dci_coke-12
```

```
        0: RT v4:(1:12,1:12) v6:(1:12,1:12)
           Host Id: 281, # tenants: 1
             Tenant Id: 281
   6: Vrf: dci_coke-13
        0: RT v4:(1:13,1:13) v6:(1:13,1:13)
           Host Id: 275, # tenants: 1
             Tenant Id: 275
   7: Vrf: dci_coke-14
        0: RT v4:(1:14,1:14) v6:(1:14,1:14)
           Host Id: 305, # tenants: 1
             Tenant Id: 305
……….
switch# show ipp internal work-info
IPP Worker information

Work in Progress                        : False
Update queue size                       : 0
#Worker walk                            : 354
#Timedout work                          : 0
#Work done                              : 365
#Signal worker thread                   : 365


switch# show ipp fabric
Global info:
  config-profile defaultNetworkMplsL3vpnDcProfile
  include-config-profile vrf-common-mpls-l3vpn-dc-edge
  local-vtep nve 1
  bgp-as 100
  identity 1.1.1.1

Fabric 1 (Healthy)
  opflex-peer 20.4.11.1:8009 (Connected and ready)
  ssl encrypted

  Tenant Policies
     1: Fabric Vrf: coke-1:coke-1, Vrf: dci_coke-1
        RT v4:(1:1,1:1) v6:(1:1,1:1)
        Id 289, HostId: 289
        flags 0x0
     2: Fabric Vrf: coke-10:coke-10, Vrf: dci_coke-10
        RT v4:(1:10,1:10) v6:(1:10,1:10)
        Id 266, HostId: 266
        flags 0x0
     3: Fabric Vrf: coke-100:coke-100, Vrf: dci_coke-100
        RT v4:(1:100,1:100) v6:(1:100,1:100)
        Id 346, HostId: 346
        flags 0x0
……..
switch# show tech-support ipp
`show running-config ipp`

!Command: show running-config ipp
!Time: Wed Jun  1 08:37:18 2016

version 7.3(0)DX(1)
feature ipp

ipp
  profile-map profile defaultNetworkMplsL3vpnDcProfile include-profile vrf-commo
n-mpls-l3vpn-dc-edge
  local-vtep nve 1
  bgp-as 100
```

```
  identity 1.1.1.1
  fabric 1
    opflex-peer 20.4.11.1 8009
    ssl encrypted
ipp tenant dci_coke-1 289
ipp tenant dci_coke-10 266
ipp tenant dci_coke-100 346
ipp tenant dci_coke-11 351
ipp tenant dci_coke-12 281
ipp tenant dci_coke-13 275
ipp tenant dci_coke-14 305
ipp tenant dci_coke-15 292
ipp tenant dci_coke-16 339
ipp tenant dci_coke-17 323
ipp tenant dci_coke-18 330
ipp tenant dci_coke-19 361
ipp tenant dci_coke-2 310
ipp tenant dci_coke-20 350
ipp tenant dci_coke-21 283
ipp tenant dci_coke-22 272
ipp tenant dci_coke-23 299
ipp tenant dci_coke-24 294
ipp tenant dci_coke-25 337
ipp tenant dci_coke-26 326
ipp tenant dci_coke-27 334
ipp tenant dci_coke-28 363
ipp tenant dci_coke-29 356
ipp tenant dci_coke-3 343
ipp tenant dci_coke-30 277
ipp tenant dci_coke-31 307
ipp tenant dci_coke-32 293
ipp tenant dci_coke-33 341
ipp tenant dci_coke-34 321
ipp tenant dci_coke-35 329
ipp tenant dci_coke-36 269
ipp tenant dci_coke-37 352
ipp tenant dci_coke-38 285
.............
```

```
switch# debug ipp ?
  all         All debugs
  cli         CLI command processing debugs
  event     IPP events
  ha          HA related debugs
  hmm       IPP HMM api debug
  opflex    IPP opflex debugs
  periodic IPP events periodic
```



CHAPTER 6

Campus Fabric

This chapter contains the following sections:

Campus Fabric

Overview of Campus Fabric

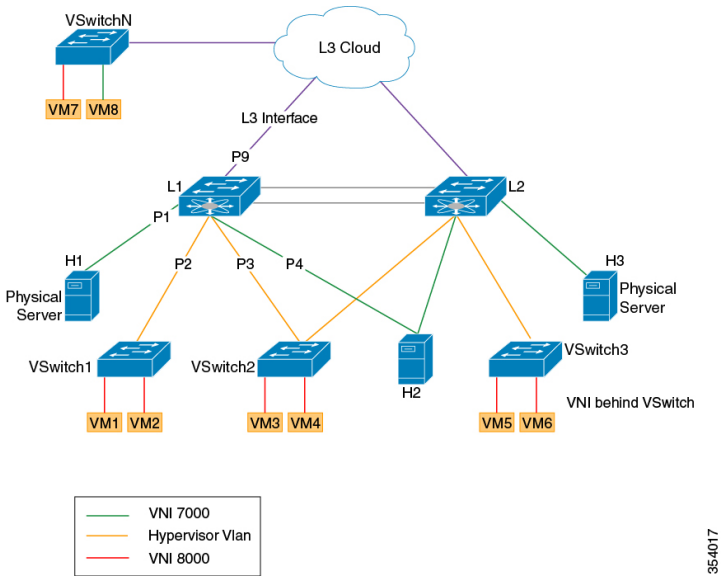
The Campus Fabric feature provides the basic infrastructure for building virtual networks based on policy-based segmentation constructs. Fabric overlay provides services such as host mobility and enhanced security, which are in addition to normal switching and routing capabilities.

This feature enables a LISP-based Control Plane for VXLAN Fabric. This feature is supported only on the M3 module. The Cisco Nexus 7700 Series with M3 Module acts as a fabric border which connects traditional Layer 3 networks or different fabric domains to the local fabric domain, and translates reachability and policy information from one domain to another. However inter-fabric connectivity on a same switch is not supported.

Cisco Nexus 7700 is positioned as a fabric border node in the Campus Fabric architecture.

Note IPv6 unicast traffic is not supported for the LISP VRF leak feature on Software-Defined Access fabrics since Cisco Catalyst 3000 Series switches do not support IPv6 traffic for extranets.

Figure 22: Campus Fabric Architecture



The key elements of the Campus fabric architecture are explained below.

Campus Fabric : The Campus Fabric is an instance of a "Network Fabric". A Network Fabric describes a network topology where data traffic is passed through interconnecting switches, while providing the abstraction of a single Layer-2 and/or Layer-3 device. This provides seamless connectivity, independent of physical topology, with policy application and enforcement at the edges of the fabric. Enterprise fabric uses IP overlay, which makes the network appear like a single virtual router/switch without the use of clustering technologies. This logical view is independent of the control plane used to distribute information to the distributed routers or switches.

Fabric Edge Node : Fabric edge nodes are responsible for admitting, encapsulating/decapsulating and forwarding traffic to and from endpoints connected to the fabric edge. Fabric edge nodes lie at the perimeter of the fabric and are the first points for attachment of the policy. It is to be noted that the endpoints need not be directly attached to the fabric edge node. They could be indirectly attached to a fabric edge node via an intermediate Layer-2 network that lies outside the fabric domain.

Traditional Layer-2 networks, wireless access points or end-hosts are connected to Fabric Edge nodes.

Fabric Intermediate Node: Fabric intermediate nodes provide the Layer-3 underlay transport service to fabric traffic. These nodes are pure layer-3 forwarders that connect the Fabric Edge and Fabric Border nodes.

In addition, Fabric intermediate nodes may be capable of inspecting the fabric metadata and could apply policies based on the fabric metadata (not mandatory). However, typically, all policy enforcement is at the Fabric Edge and Border nodes.

Fabric Border Node : Fabric border nodes connect traditional Layer-3 networks or different fabric domains to the Campus Fabric domain.

If there are multiple Fabric domains, the Fabric border nodes connect a fabric domain to one or more fabric domains, which could be of the same or different type. Fabric border nodes are responsible for translation of context from one fabric domain to another. When the encapsulation is the same across different fabric domains, the translation of fabric context is generally 1:1. The Fabric Border Node is also the device where the fabric control planes of two domains exchange reachability and policy information.

APIC-EM Controller : This is the SDN controller developed by the Enterprise Networking Group. This controller serves both Brownfield and Greenfield deployments. Campus Fabric service will be developed on the APIC-EM controller. This service will drive the management and orchestration of the Campus Fabric, as well as the provision of policies for attached users and devices.

Fabric Header: Fabric header is the VXLAN header which carries the segment ID(VNI) and user group(SGT). SGT is encoded in the reserved bits of the VXLAN header.

Cisco Catalyst 3000 is positioned as the fabric edge and Cisco Nexus 7700 is positioned as the fabric border in this architecture. LISP is the control plane in the campus fabric architecture and it programs the VXLAN routes. LISP is enhanced to support VXLAN routes for Campus Fabric architecture.

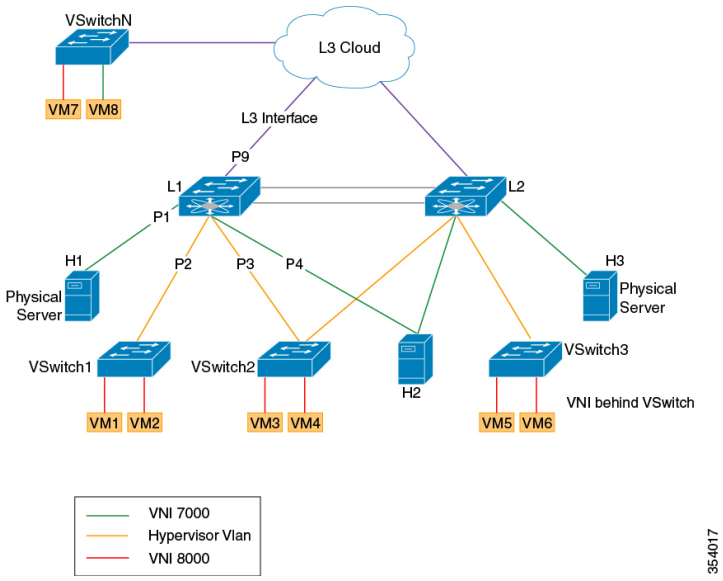
The following features are supported on Cisco Nexus 7700:

- LISP control plane pushing VXLAN routes
- VXLAN L3GW (VRF-lite Hand-off)
- Optimal Tenant L3 Multicast (ASM/Bidir/SSM) based on LISP Multicast (Ingress Replication over unicast core)
- IS-IS as underlay
- TTL propagation

VXLAN Encapsulation for Layer-3 LISP Configuration

This section summarizes only the steps that are used for configuring LISP for a hand-off from VXLAN on the border spine or border leaf switch.

Figure 23: Overall Topology of Campus Fabric




```
feature-set fabric
hostname PxTR1

feature telnet
feature bgp
feature pim
feature isis
```

```
feature lisp
feature interface-vlan
system bridge-domain 100
feature nv overlay
feature vni
vni 5000

vlan 1
bridge-domain 100

route-map LISP-RMAP permit 10
bridge-domain 100

/* UNDERLAY VRF*/
vrf context core
  description "UNDERLAY VRF"
  ipv6 lisp itr-etr
  ip lisp itr-etr
  ipv6 lisp itr map-resolver 9.9.9.9
  ip lisp itr map-resolver 9.9.9.9
  ip lisp etr map-server 9.9.9.9 key 3 a97b0defe7b8ff70
  ip lisp multicast
  lisp encapsulation vxlan

/*  OVERLAY VRF */
vrf context vrf5000
  description "OVERLAY VRF "
  vni 5000
  ip pim rp-address 200.1.2.1 group-list 225.0.0.0/24
  ip lisp proxy-itr 10.1.1.1
  ip lisp proxy-etr
  lisp instance-id 5000
  ip lisp locator-vrf core
  ip lisp map-cache 100.0.1.0/24 map-request
  ip lisp multicast
  lisp encapsulation vxlan
  address-family ipv4 unicast
    route-target import 3:3
    route-target export 1:1

bridge-domain 100
  member vni 5000

interface Bdi100
  description "BDI in OVERLAY vrf"
  no shutdown
  vrf member vrf5000
  no ip redirects
  ip forward
  ip pim sparse-mode

interface nve1
  no shutdown
  source-interface loopback0
  host-reachability protocol lisp
  member vni 5000 associate-vrf

interface Ethernet1/5
  description PxTR1 to SPINE1 link(UNDERLAY VRF)
  vrf member core
  ip address 10.1.1.1/24
  isis circuit-type level-1-2
  ip router isis 100
  ip pim sparse-mode
```

```
  no shutdown

interface Ethernet5/1
  no shutdown

interface Ethernet5/1.1
  description PxTR1 to CORE vrf vrf5000(OVERLAY VRF)
  encapsulation dot1q 2
  vrf member vrf5000
  ip address 80.1.1.1/24
  ip pim sparse-mode
  no shutdown

interface loopback0
  description "Source Locator loopback"
  vrf member core
  ip address 1.1.1.1/32
  isis circuit-type level-1-2
  ip router isis 100
  ip pim sparse-mode

interface loopback100
  Description "OVERLAY VRF loopback"
  vrf member vrf5000
  ip address 111.1.1.1/32
  ip pim sparse-mode

/*  IGP on the  UNDERLAY VRF */
router isis 100
  net 49.0001.1111.1111.1111.00
  vrf core
    net 49.0001.1111.1111.1111.00
  vrf vrf5000

/* BGP neighbor towards the CORE */

router bgp 100
  description "
  router-id 12.12.12.13
  vrf vrf5000
    address-family ipv4 unicast
      redistribute lisp route-map LISP-RMAP
      redistribute direct route-map LISP-RMAP
    neighbor 80.1.1.2 remote-as 100
      Description "BGP neigbor to the CORE Router"
      address-family ipv4 unicast
      address-family ipv6 unicast
```

SGT Propagation, Termination, and Generation

The security group tag (SGT) allows the network to enforce the access control policy by enabling the endpoint device to act upon the SGT to filter traffic.

At the ingress point, traffic from the source is tagged with an SGT containing the security group number of the source entity. The SGT is propagated with the traffic across the domain. At the egress point, an egress device uses the source SGT and the security group number of the destination entity to determine which access policy to apply from the security group access control lists (SGACL) policy matrix.

The least significant 16 bits in the reserved field of the VXLAN header is used to carry the SGT information.

For traffic ingressing the site from internet a mechanism is needed to classify the packets as internet packets and drive SGT based on the classification. This SGT is used in the reserved field of the VXLAN header during VXLAN encapsulation.

For traffic egressing the site the SGT field should be used from the reserved field during VXLAN decapsulation and policy enforcement can be done based on the sg tag. This is where M3 module acts as a PETR. This is enabled using the**ip lisp sgt** command.

Multicast Head-end Replication

Head-end replication for LISP multicast over a unicast core is supported on M3 modules.

Head-end replication accomplishes the need of a multicast transport for Overlay Transport Virtualization (OTV) control plane communications. Multicast transport is used to let a single OTV update or packets to reach all other OTV devices using a specific multicast group address across domains.

LISP Multicast configuration on an ETR or ITR is covered in the "VXLAN Encapsulation for Layer-3 LISP Configuration" section described above.

TTL Propagation

TTL (Time-to-Live) is a setting for each DNS record that specifies how long a resolver should cache the DNS query before the query expires and a new query needs to be made.

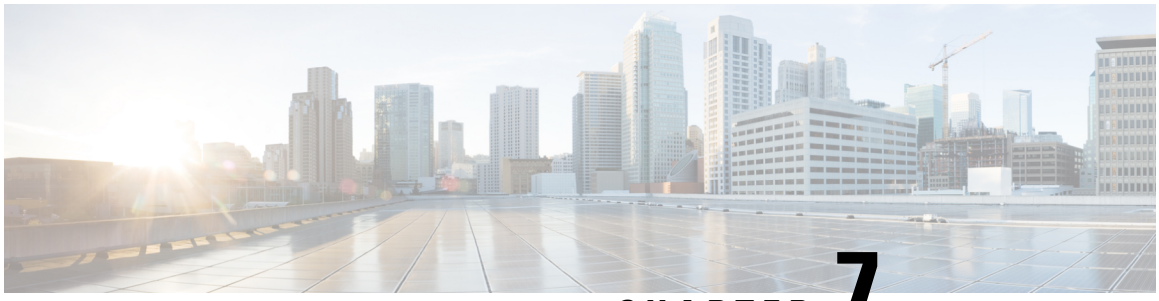
TTL propagation from the inner header to the outer header during VXLAN encapsulation is done based on a CLI. On enabling this CLI, the TTL propagation will be disabled from the inner header to the outer header during encapsulation. This is enabled using the **lisp disable-ttl-propagate** command.

Feature History for Campus Fabric

This table lists the release history for this feature.

Table 5: Feature History for Campus Fabric

Feature Name	Releases	Feature Information	
Campus Fabric	7.3(1)D1(1)	This feature was introduced.	



CHAPTER 7

Campus Fabric Interconnect - MPLS L3VPN

This feature explains a sample Software-Defined Access (SD-Access) network topology comprising two Locator/ID Separation Protocol (LISP) control plane-Virtual eXtensible Local Area Network (VXLAN) data plane based campus fabrics connected through Multiprotocol Label Switching (MPLS) L3VPN. The focus of the feature is the role of the Cisco Nexus 7000/7700 Series border leaf switch which sends end host traffic from the fabric to an end host in a remote fabric over MPLS (through the MPLS core).

Note IPv6 unicast traffic is not supported for the LISP VRF leak feature on Software-Defined Access fabrics since Cisco Catalyst 3000 Series switches do not support IPv6 traffic for extranets.

This chapter contains the following sections:

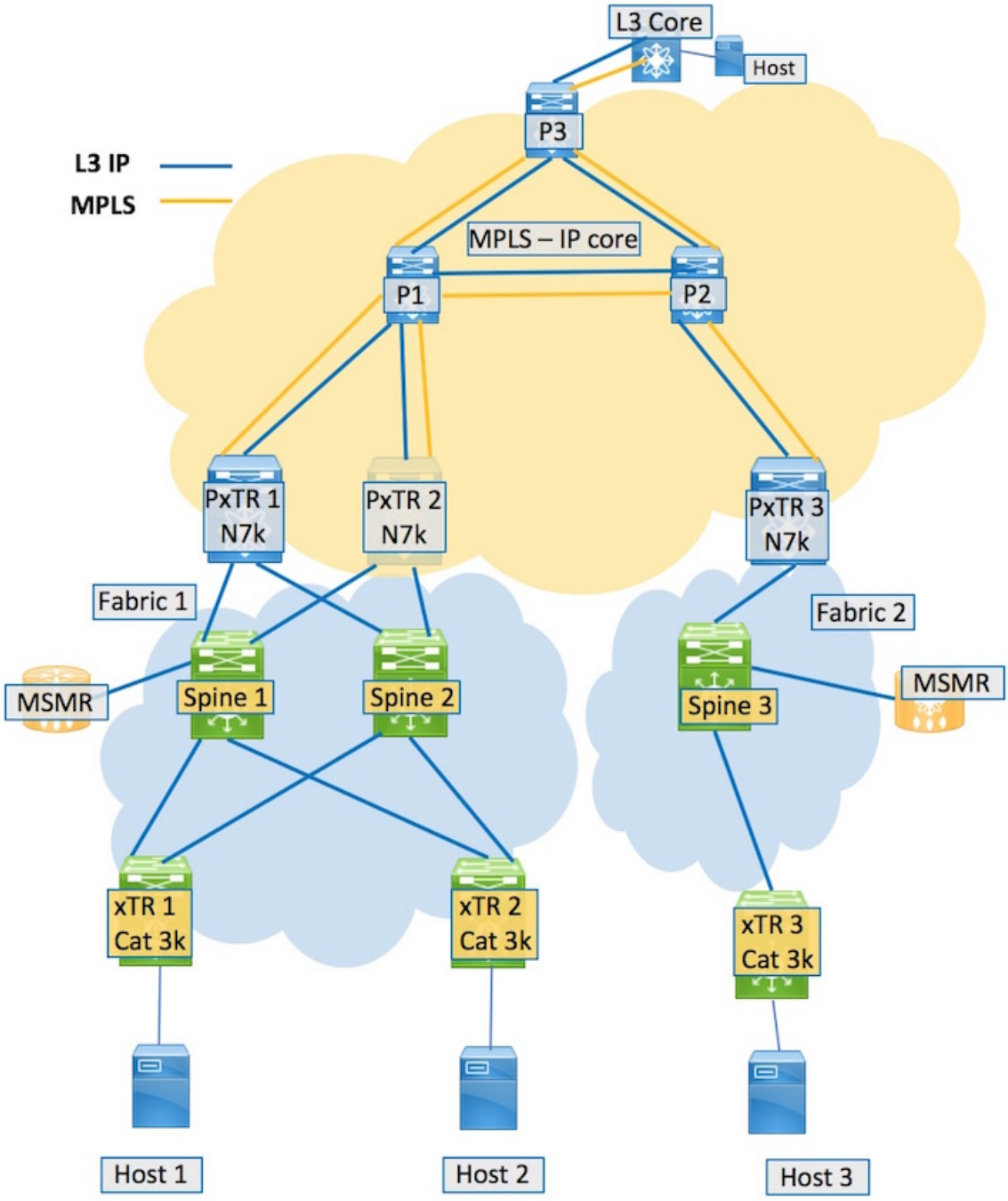
Prerequisites of Campus Fabric Interconnect—MPLS L3VPN

- A Nexus 7000 or 7700 Series switch with an M3 line card.
- Conceptual and configuration knowledge about VXLAN-with-LISP campus fabrics, since the focus of this feature is the fabric interconnect function.
- Functioning campus fabrics wherein the LISP, VXLAN and other required configurations are enabled. See the "Campus Fabric" chapter for more information.

Information About Campus Fabric Interconnect—MPLS L3VPN

Sample topology and traffic flow between two campus fabrics connected through MPLS L3VPN:

Figure 24: Sample topology - Campus Fabric Interconnect—MPLS L3VPN



Fabric 1 and Fabric 2 are two campus fabrics. PxTR 1 and PxTR 2 are Cisco Nexus 7000/7700 Series switches that perform the role of border switches in Fabric 1. PxTR 2 is the fabric border switch in Fabric 2. MPLS configurations are enabled on the PxTR switches such that Fabric 1 and Fabric 2 are connected through MPLS L3VPN between PxTR 1/PxTR 2 and PxTR 3.

Campus Fabric Architecture—Fabric 1

End hosts are attached to Cisco Catalyst switches xTR 1 and xTR 2 which perform the role of LISP xTRs. The LISP control plane extends from the xTRs to PxTR 1 and PxTR 2. Spine1 and Spine 2 are Layer-3 switches used for routing in the underlay, through an interior gateway protocol (IGP) such as Open Shortest Path First (OSPF). Spine 1 is connected to the Map-Server/Map-Resolver (MSMR).

For the overlay, VXLAN is implemented on the xTRs and the PxTRs, and they also perform the role of VXLAN Virtual Tunnel End Points (VTEPs).

The LISP (control plane) and the VXLAN (data plane) overlays begin and terminate between the xTRs and PxTRs.

Traffic Flow Between Fabrics—Campus Fabric Interconnect

PxTR1 and PxTR2 perform the provider edge (PE) function, and are connected to the provider switch P1 in the MPLS/IP core. MPLS L3VPN is implemented on the PxTRs for traffic flow across the fabrics. If Host 1 in Fabric 1 sends traffic to Host 3 in Fabric 2, then this is a sample flow:

- Traffic from Host1 reaches a PxTR, the fabric border switch, since the destination end host is located in a remote site. The PxTR VXLAN decapsulates the packets and sends it towards P1 through MPLS.

Note The **redistribute lisp route-map** command ensures that the LISP map-cache routes are redistributed into Multiprotocol Border Gateway Protocol (MP-BGP).

- P1 sends the traffic through the MPLS/IP core to the Provider switch P2 which is connected to the fabric border switch of Fabric 2, PxTR 3. P2 forwards the MPLS traffic to PxTR3.

Note The assumption is that MPLS L3VPN is implemented on the receiving switch and the LISP control plane and VXLAN data planes are converged/updated.

- PxTR3 receives the traffic, removes the MPLS label, and does appropriate lookups as regards to the destination end host. Then, PxTR3 VXLAN encapsulates the packets towards xTR3, since Host 3 is attached to it.
- xTR 3 receives the traffic, VXLAN decapsulates the packets and sends the original packets (sent by Host 1) to Host 3.

How to Configure Campus Fabric Interconnect—MPLS L3VPN

Note

- Type the **switch# configure terminal** command to enter global configuration mode **(config)#**
- Since the focus of this feature is the fabric interconnect function, ensure that the campus fabric is functional, and LISP, VXLAN and other configurations are enabled.
- The example is for PxTR 1 configurations. However, configurations have to be implemented on PxTR 1, PxTR 2, and PxTR 3 for traffic flow across fabrics.

Feature Set Configuration

Configure MPLS L3VPN, BGP, LDP, LISP and VXLAN features:

```
PxTR 1(config)# feature-set mpls
                feature-set fabric
                feature bgp
                feature lisp
                feature mpls l3vpn
                feature mpls ldp
                feature nv overlay
                feature vni
```

- Some configurations, such as LISP and VXLAN features, are already enabled for campus fabric configuration. They are noted here for completeness.

Campus Fabric Configuration

Step 1 Configure VXLAN related commands

Create a bridge domain and associate the corresponding Layer 3 VNI:

```
PxTR 1(config)#  vni 6000
                 system bridge-domain 300
                 bridge-domain 300
                    member vni 6000
```

Add the Layer 3 virtual routing and forwarding (VRF) VNI to the VXLAN overlay network and enable LISP reachability:

```
PxTR 1(config)# interface nve1
                  no shutdown
                  host-reachability protocol lisp
                  source-interface loopback0
                  member vni 6000 associate-vrf
```

Step 2 Configure LISP related commands

Configure LISP parameters and route distinguisher and route target functions for the *vrf6000* VRF:

```
PxTR 1(config)# vrf context vrf6000
                  vni 6000
                  ip lisp proxy-itr 192.0.2.1
                  ip lisp proxy-etr
                  lisp instance-id 6000
                  ip lisp locator-vrf fab0
                  ip lisp map-cache 198.51.0.0/16 map-request
                  lisp encapsulation vxlan
                  rd 6000:6000
                  address-family ipv4 unicast
                     route-target import 6000:6000
                     route-target export 6000:6000
```

The **ip lisp map-cache** command creates a static map-cache entry for reachability to remote Endpoint Identifiers (EIDs).

Step 3 Configure fabric facing BDI

Associate a BDI to the *vrf6000* VRF:

```
PxTR 1(config)# interface Bdi300
                  no shutdown
                  vrf member vrf6000
                  no ip redirects
                  ip forward
```

Campus Fabric Interconnect Configuration

Step 1 Configure MPLS commands on the WAN facing interface:

```
PxTR 1(config)# interface Ethernet1/35.1
                  mpls ip
                  description connect_P1_mpls
                  encapsulation dot1q 162
                  ip address 203.0.113.1/30
                  ip router ospf 299 area 0.0.0.0
                  no shutdown
```

- After enabling the corresponding interface on P1, an MPLS link is established between PxTR 1 (the PE switch) and P1 (the Provider switch) .

```
PxTR 1(config)# mpls ldp configuration
                  router-id Lo299 force
```

- The configurations enable the specified loopback interface's IP address as the Label Distribution Protocol (LDP) router ID.

Step 2 Configure BGP for traffic flow between the fabric border (PE) switch PxTR 1 and the Provider switch P1:

```
PxTR 1(config)# router bgp 100
                  router-id 209.165.201.1
```

```
            address-family ipv4 unicast
```

- The IPv4 address family and router ID configurations are enabled.

```
neighbor 209.165.200.225 remote-as 5000
         update-source loopback299
         ebgp-multihop 10
         address-family vpnv4 unicast
            send-community extended
            exit
         address-family ipv4 unicast
```

- BGP neighbor/peer VPNv4 and IPv4 address family configurations are enabled.

```
vrf vrf6000
          address-family ipv4 unicast
             redistribute lisp route-map LISP-RMAP
             aggregate-address 198.51.0.0/16 summary-only
             label-allocation-mode per-vrf
```

- The **redistribute lisp route-map** command redistributes the LISP map-cache routes into MP-BGP.
- Aggregate routes within the vrf6000 VRF are enabled to be distributed to the BGP neighbor.

Note The configurations are relevant to PxTR 1. Similarly, enable the campus fabric interconnect function on PxTR 2 and PxTR 3.

Verifying Campus Fabric Interconnect—MPLS L3VPN

You can verify MPLS configurations on a fabric border switch with these verification commands:

Verifying MPLS LDP Configuration

In the following example, you can verify MPLS LDP configuration:

```
PxTR1# show mpls ldp discovery

Local LDP Identifier:
    209.165.201.1:0
    Discovery Sources:
    Interfaces:
        Ethernet2/20.1 (ldp): xmit/recv
        LDP Id: 203.0.113.1:0
```

Verifying MPLS LDP Neighbor Configuration

In the following example, you can verify MPLS LDP neighbor configuration:

```
PxTR1# show mpls ldp neighbor
```

```
Peer LDP Ident: 203.0.113.1:0; Local LDP Ident 209.165.201.1:0
    TCP connection: 203.0.113.1.646 - 209.165.201.1.63118
    State: Oper; Msgs sent/rcvd: 69/71; Downstream
    Up time: 00:53:49
    LDP discovery sources:
      Ethernet2/20.1, Src IP addr: 192.0.2.250
    Addresses bound to peer LDP Ident:
      203.0.113.1   172.16.0.1   192.0.2.250  203.0.113.10
```

Verifying MPLS Label Switching VRF Information

In the following example, you can verify MPLS label switching VRF information:

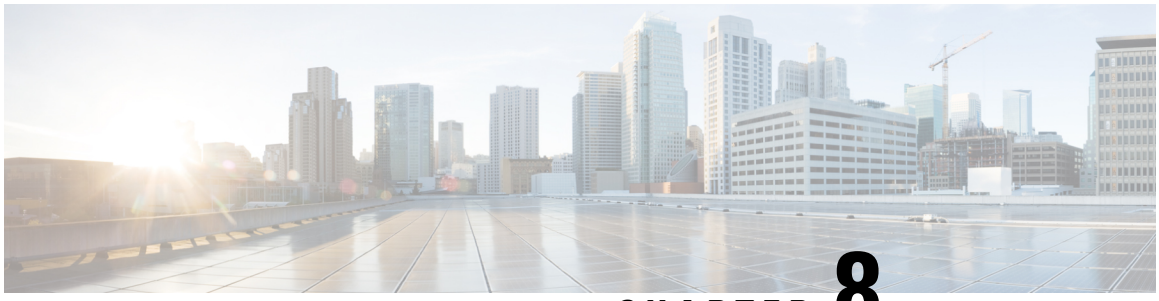
```
PxTR1# show mpls switching vrf vrf6000

Legend:
(P)=Protected, (F)=FRR active, (*)=more labels in stack.

In-Label   VRF
IPv4 Aggregate Labels
31         vrf6000
```

Feature History for Campus Fabric Interconnect—MPLS L3VPN

This table lists the release history for this feature.

Table 6: Feature History for Campus Fabric Interconnect—MPLS L3VPN

Feature Name	Release	Feature Information	
Feature History for Campus Fabric Interconnect—MPLS L3VPN	8.2(1)	This feature was introduced. This feature explains how to enable traffic flow across two campus fabrics through MPLS L3VPN. No new commands were introduced for this feature.	



CHAPTER 8

LISP Support for Disjointed RLOC Domains

This chapter contains the following sections:

LISP Support for Disjointed RLOC Domains

Overview of LISP Support for Disjointed RLOC Domains

Locator/ID Separation Protocol (LISP) implements a *level of indirection* that enables a new IP routing architecture. LISP separates IP addresses into two address spaces, Endpoint Identifiers (EIDs), which are assigned to end hosts, and Routing Locators (RLOCs), which are assigned to devices that make up the global routing system.

This feature enables communication between LISP sites that are connected to different RLOC spaces and have no connectivity to each other.

Prerequisites for LISP Support for Disjointed RLOC Domains

- You understand how LISP works, including infrastructure, workflow, roles and functions.

Information About LISP Support for Disjointed RLOC Domains

The fundamental principle of any network is that routing and reachability should exist between all devices that make up the total network system. There are many network systems, public and private, for which internetwork connectivity is not directly available.

- A Multiprotocol Label Switching (MPLS) IPv4 VPN from service provider A and an MPLS IPv4 VPN from service provider B, with different scopes, 10.1.0.0/16 and 10.2.0.0/16.
- An MPLS IPv4 VPN from service provider A and IPv4 internet.

When some sites within a network connect to one routing domain and other sites connect to another routing domain, a gateway function must be provided to facilitate connectivity between these disjointed routing domains. In traditional routing architectures, providing connectivity between disjointed routing domains can be quite complex. The inherent property of LISP, which separates IP addresses into two address spaces, gives it the ability to connect disjointed RLOC domains through simplified configuration mechanisms. The key components are new control plane configuration options on the LISP Map-Server, and the Re-encapsulating

Tunnel Router (RTR) function, which provides data plane connectivity between disjointed locator spaces. The components and the workflow are explained.

LISP Map-Server

When a LISP site registers with the Map-Server, it provides RLOC information. Ensure that all relevant RLOCs are registered with the Map-Server. Map-Server configurations are required to enable connectivity across RLOC spaces.

Note A device with IOS XE software is used for the role of Map-Server. For more information, see *IP Routing: LISP Configuration Guide, Cisco IOS XE Release 3S*.

LISP RTR

An RTR provides data plane communications support for LISP to LISP traffic between LISP sites that do not share common locator space. Functionally, an RTR takes in LISP encapsulated packets from an Ingress Tunnel Router (ITR) in one locator scope, decapsulates them, checks the map-cache, and then re-encapsulates them to an Egress Tunnel Router (ETR) in another locator scope. The following are important considerations for an RTR:

- RTR should have RLOCs in all locator scopes that are being joined.
- An RTR sends Map-Request messages to populate its map-cache. As a Map-Request message contains an ITR RLOC field that is populated with one or more entries corresponding to the locators of the device sending the Map-Request message, locator set configuration is required on the RTR to define its locators. This enables the Map-Server to correctly receive Map-Request messages from the RTR to assess locator scope connectivity.
- Since an RTR performs functions similar to a Proxy Ingress Tunnel Router (PITR) and Proxy Egress Tunnel Router (PETR), the PITR and PETR features must be enabled on the RTR.

Note Cisco Nexus 7000 Series device is used for the PxTR (a device performing PITR and PETR functions) and RTR functions.

Workflow of LISP Support for Disjointed RLOC Domains

For connecting disjointed RLOC domains in topology:

- Specified prefixes form the EID space in site A and site B.
- Ingress and Egress tunnel routers (referred as xTRs) represent the LISP site routers. xTR 1 and xTR 2 in site A have RLOC connectivity to one locator space, and the xTR in site B has RLOC connectivity to a different locator space.
- The RTR (PxTR 1, PxTR 2) is the LISP data plane device that enables communication between end hosts in the two sites, across locator spaces.
- Two virtual routing and forwarding (VRF) instances are created on the RTRs, one for the underlay (VRF *core*), and one for the overlay (VRF *vrf5000*).

Note Map-Servers and RTRs can be connected to eight locator scopes or address spaces.

An end host connected to xTR 1 in site A sends traffic to an end host attached to the xTR in site B. Since the source and destination RLOCs are from different RLOC spaces, PxTR 1 performs the role of RTR to transport traffic across the RLOC spaces. The detailed workflow:

1. xTR 1 (acting as an ITR) receives traffic from an attached end host, and sends a Map-Request for the destination EID (198.51.100.10), to the Map-Server (denoted by the IP address 192.0.2.9/32).
2. The Map-Server responds with a proxy reply containing the configured RTR locators (with IP addresses 192.0.2.1 and 203.0.113.15). The Map-Server does because the ITR-RLOC in the Map-Request from xTR 1 contains the RLOC from site A.
3. xTR 1 populates its map-cache with locator information (that is, PxTR 1 and PxTR 2 RLOCs) for the RTRs.
4. xTR 1 encapsulates LISP traffic and forwards it to the RTR in the data plane.
5. The RTR decapsulates the ingress LISP traffic and sends a Map-Request to the Map-Server for the destination EID, for the first packet.
6. The ITR-RLOC of the Map-Request comprises the locators configured under the locator set. The locators are 192.0.2.10 and 192.0.2.21.

   A Map-Request is sent because the static map-cache is configured with the **map-request** command.
7. The Map-Server forwards the Map-Request to the ETR. The Map-Server does because the ITR-RLOC in the Map-Request from the RTR contains RLOCs from site A and site B.
8. The ETR replies to the RTR with the ETR locator information.
9. The RTR populates its map-cache with the ETR locator information.
10. The RTR re-encapsulates LISP traffic forwards the ETR.
11. The ETR receives and sends traffic to the destination end host.

How to Configure LISP Support for Disjointed RLOC Domains

Note
- Map-Servers and RTRs can be connected to eight locator scopes or address spaces.
- Type the **switch# configure terminal** command to enter global configuration mode **(config)#**

RTR configuration on PxTR 1 and the Map-Server:

PxTR 1 or RTR Configuration

Step 1 Configure LISP

```
(config)# feature lisp
```

Step 2 Create two VRF instances on the RTR, one for the underlay (VRF *core*), and one for the overlay (VRF *vrf5000*).

Configure LISP parameters for the *core* VRF

```
(config)# vrf context core
            ip lisp itr-etr
            ip lisp itr map-resolver 192.0.2.9/32
            ip lisp etr map-server 192.0.2.9/32 key 3 a97b0defe7b8ff70
            ip lisp multicast
            lisp encapsulation vxlan
```

- After configuring the LISP ITR and ETR functions on PxTR 1, the LISP Map-Resolver (used by the ITR to send Map-Requests) and Map-Server (used by the ETR to register EIDs) locator addresses are configured.
- Also, LISP multicast transport and LISP Virtual Extensible LAN (VXLAN) encapsulation functions are enabled.

Configure LISP parameters for the *vrf5000* VRF

```
(config)# vrf context vrf5000
            ip lisp proxy-itr 192.0.2.1
            ip lisp proxy-etr
            lisp instance-id 5000
```

The following configuration chunk is specific to connecting disjointed RLOC spaces.

```
          lisp locator-set set5000
              192.0.2.10 priority 1 weight 10
              192.0.2.21 priority 2 weight 20
              exit
          lisp map-request itr-rlocs set5000
          ip lisp locator-vrf core
          ip lisp map-cache 198.51.100.1/24 map-request
          ip lisp map-cache 198.51.100.2/24 map-request
          ip lisp multicast
          lisp encapsulation vxlan
```

- The **lisp locator-set** command specifies a locator set for RTR RLOCs. 192.0.2.10 and 192.0.2.21 are the RLOCs connecting the RTR to each IPv4 locator space.
- The **lisp map-request itr-rlocs** command defines RTR RLOCs used in the Map-Request messages generated by the RTR. You can enable multiple locator sets, but only one of them can be active at a point in time, and that is determined by including the name in the **lisp map-request itr-rlocs** option.
- Since Map-Resolver and Map-Server addresses are enabled in VRF core, VRF core is referenced within VRF vrf5000, in the **locator-vrf core** command.

Step 3 Configure an IP address for routing in the underlay

```
(config)# interface loopback0
             vrf member core
             ip address 192.0.2.1/32
             isis circuit-type level-1-2
             ip router isis 100
```

```
            ip pim sparse-mode
```

The configured loopback interface IP address is used for IS-IS communication within the LISP site, and is added to VRF core.

Step 4 The configurations are relevant for RTR or PxTR 1. Similarly, configure the RTR or PxTR 2 device too.

PxTR 1 or RTR Configuration—RTR Locator-Set Inheritance

An RTR locator set can be defined in the underlay VRF and can then be referenced in an overlay VRF.

Step 1 Configure LISP

```
(config)# feature lisp
```

Step 2 Create two VRF instances on the RTR, one for the underlay (VRF *core*), and one for the overlay (VRF *vrf5000*).

Configure LISP parameters for the *core* VRF

```
(config)# vrf context core
            ip lisp itr-etr
            ip lisp itr map-resolver 192.0.2.9/32
            ip lisp etr map-server 192.0.2.9/32 key 3 a97b0defe7b8ff70
            lisp locator-set setCore
               192.0.2.10 priority 1 weight 10
               192.0.2.21 priority 2 weight 20
               exit
            ip lisp multicast
            lisp encapsulation vxlan
```

Note The LISP locator set setCore is defined in the underlay VRF core and then associated using the **lisp map-request itr-rlocs** command in the overlay VRF vrf5000.

Configure LISP parameters for the *vrf5000* VRF

```
(config)# vrf context vrf5000
            ip lisp proxy-itr 192.0.2.1
            ip lisp proxy-etr
            lisp instance-id 5000
            lisp map-request itr-rlocs setCore
            ip lisp locator-vrf core
            ip lisp map-cache 198.51.100.1/24  map-request
            ip lisp map-cache 198.51.100.2/24  map-request
            ip lisp multicast
            lisp encapsulation vxlan
```

Step 3 Configure an IP address for routing in the underlay

```
(config)# interface loopback0
            vrf member core
            ip address 192.0.2.1/32
            isis circuit-type level-1-2
            ip router isis 100
```

```
ip pim sparse-mode
```

The configured loopback interface IP address is used for IS-IS communication within the LISP site, and is added to VRF core.

Step 4 The configurations are relevant for RTR or PxTR 1. Similarly, configure the RTR or PxTR 2 device too.

Map-Server Configuration

Note

- The Map-Server disjointed RLOC logic is triggered by the existence of locator scope sets. Locator scope sets should be configured for the Map-Server to consider disjointed RLOCs in its Map-Request handling logic.
- A device with IOS XE software is used for the role of Map-Server, and not a Cisco Nexus 7000 Series device. The Map-Server configuration is documented for reference and completeness. For information, see *IP Routing: LISP Configuration Guide, Cisco IOS XE Release 3S*.

Map-Server configuration on a device with IOS XE software (not Cisco Nexus 7000 Series device):

```
(config)# router lisp
            locator-table vrf core
            locator-set SITEAB
               192.0.2.1 priority 1 weight 50
               203.0.113.15 priority 1 weight 50
               exit
            locator-scope site-B
               rtr-locator-set SITEAB
               rloc-prefix 203.0.113.40/32
               rloc-prefix 192.0.2.21/32
               rloc-prefix 203.0.113.25/32
               exit
            locator-scope site-A
               rtr-locator-set SITEAB
               rloc-prefix 192.0.2.5/32
               rloc-prefix 192.0.2.6/32
               rloc-prefix 203.0.113.17/32
               rloc-prefix 192.0.2.10/32
```

Verifying LISP Support for Disjointed RLOC Domains

Testing Reachability from xTR 1 in Site A to the xTR in Site B

In the following example, locator information for both sites (192.0.2.1 in site A and 203.0.113.15 in site B) are displayed. xTR 1 in site A is connected to the xTR in site B.

```
siteA-xTR1# lig 198.51.100.10 instance-id 5000

Mapping information for EID 198.51.100.10 from 192.0.2.9/32 with RTT 2 msecs
198.51.100.10/32, uptime: 00:07:06, expires: 00:14:59, via map-reply, complete

Locator       Uptime    State      Pri/Wgt

192.0.2.1     00:07:06  up           1/50
```

```
203.0.113.15  00:07:06  up           1/50
```

Testing Reachability from PxTR 1 to the xTR in Site B

In the following example, Map-Request, Map-Reply, and map-cache information is displayed. Also, locator information for the xTR in site B is displayed. This signifies that PxTR 1 is connected to the xTR in site B.

```
PxTR1# lig 198.51.100.10 vrf vrf5000

Send map-request to 192.0.2.9 for [5000] 100.3.3.10 ...
Received map-reply from 203.0.113.40 with rtt 0.003248 secs
Map-cache entry for [5000] EID 198.51.100.10 is:
198.51.100.10/32, uptime: 05:05:47, expires: 23:59:58, via map-reply, auth

Locator      Uptime   State  Priority/Data Control  MTU  Weight     in/out    in/out
203.0.113.40 05:05:47  up    10/10          0/0*    2/0  1500
```

EID Space Details in the Map-Server/Map-Resolver (MSMR)

In the following example, you can see that the client with the specified EID, attached to the xTR in site B, is registered with the MSMR. The specified EID, Instance ID and corresponding locator is displayed.

```
MSMR# show lisp site 198.51.100.10 instance-id 5000

LISP Site Registration Information
Site name: site-AAllowed configured locators: anyRequested
EID-prefix: EID-prefix: 198.51.100.10/32 instance-id 5000
            First registered:     00:19:46
            Last registered:      00:19:46
            Routing table tag:    0
            Origin:               Dynamic, more specific of 203.0.0.0/16
            Merge active:         No
            Proxy reply:          No
            TTL:                  1d00h
            State:                complete
            Registration errors:
            Authentication failures:   0
            Allowed locators mismatch: 0

ETR 203.0.113.40, last registered 00:19:46, no proxy-reply, map-notify
            TTL 1d00h, no merge, hash-function sha1, nonce 0x4CC82237-0x6DCB0FC5

            state complete, no security-capability
            xTR-ID 0x90FA8033-0x867FE73F-0x5F32076D-0xE92E8945
            site-ID unspecified
            sourced by reliable transport

Locator       Local  State      Pri/Wgt  Scope
203.0.113.40  yes    up         10/10    site-B
```

In the following example, corresponding LISP site information for the MSMR is displayed. The information includes, EID, IID, and locator information.

```
MSMR# show lisp site detail

EID-prefix: 198.51.100.10/32 instance-id 5000
First registered:     08:12:10
```

```
Last registered:      08:12:10
Routing table tag:    0
Origin:               Dynamic, more specific of 203.0.0.0/16
Merge active:         No
Proxy reply:          No
TTL:                  1d00h
State:                complete

Registration errors:
Authentication failures:   0
Allowed locators mismatch: 0

ETR 203.0.113.40, last registered 08:12:10, no proxy-reply, map-notify
                  TTL 1d00h, no merge, hash-function sha1, nonce 0x4CC82237-0x6DCB0FC5

                  state complete, no security-capability
                  xTR-ID 0x90FA8033-0x867FE73F-0x5F32076D-0xE92E8945
                  site-ID unspecified
                  sourced by reliable transport

Locator       Local  State Pri/Wgt  Scope
203.0.113.40  yes    up    10/10    site-B
```

Verify LISP map-cache Details on PxTR 1

In the following example, map-cache details corresponding to PxTR 1 for the specified EID are displayed. The information includes locator information.

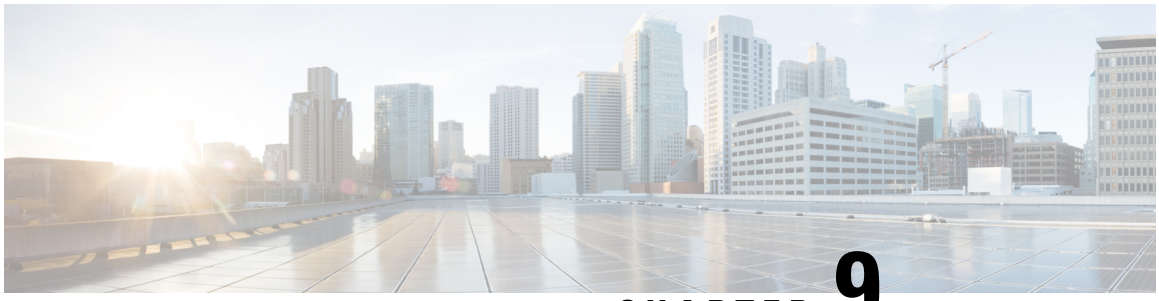
```
PxTR1# show ip lisp map-cache 198.51.100.1 vrf vrf5001

LISP IP Mapping Cache for VRF "vrf5001" (iid 5001), 16 entries
* = Locator data counters are cumulative across all EID-prefixes

198.51.100.1/32, uptime: 1d03h, expires: 20:01:07, via map-reply, auth
  Last activity: 03:58:42
  State: complete, last modified: 1d03h, map-source: 192.0.2.5
  Pending hw update: FALSE
  Locator          Uptime    State       Priority/  Data      Control       MTU
                                         Weight     in/out    in/out
  192.0.2.5        1d03h     up          10/10      0/0*      2/0          1500

  Last up/down state change:          1d03h, state change count: 0
  Last data packet in/out:            never/1d03h
  Last control packet in/out:         03:58:52/never
  Last priority/weight change:        never/never
```

Feature History for LISP Support for Disjointed RLOC Domains

This table lists the release history for this feature.

Table 7: Feature History for LISP Support for Disjointed RLOC Domains

Feature Name	Release	Feature Information	
Connecting LISP Disjointed RLOC Domains	8.1(1)	This feature was introduced.	



CHAPTER 9

PBR support for the VXLAN BGP EVPN fabric

Policy-based routing (PBR) support is provided for the Virtual eXtensible Local Area Network (VXLAN) Border Gateway Protocol (BGP) Ethernet VPN (EVPN) fabric. PBR allows you to configure a defined policy for IPv4 and IPv6 traffic flows, lessening reliance on routes derived from routing protocols. All packets received on a PBR enabled interface are passed through enhanced packet filters or route maps. The route maps dictate the policy, determining where to forward packets. PBR configurations have to be enabled on relevant Top of Rack (ToR) or leaf switches, and spine switches in the VXLAN BGP EVPN fabric. For more information on PBR, see Cisco Nexus 7000 Series NX-OS Unicast Routing Configuration Guide.

This chapter contains the following sections:

Prerequisites for PBR Support for the VXLAN BGP EVPN Fabric

- A Cisco Nexus 7000 Series switch with an F3 or M3 line card.
- Understand how VXLAN BGP EVPN works.
- Enable VXLAN BGP EVPN configurations on the leaf and spine switches.

Guidelines and Limitations for PBR Support for the VXLAN BGP EVPN Fabric

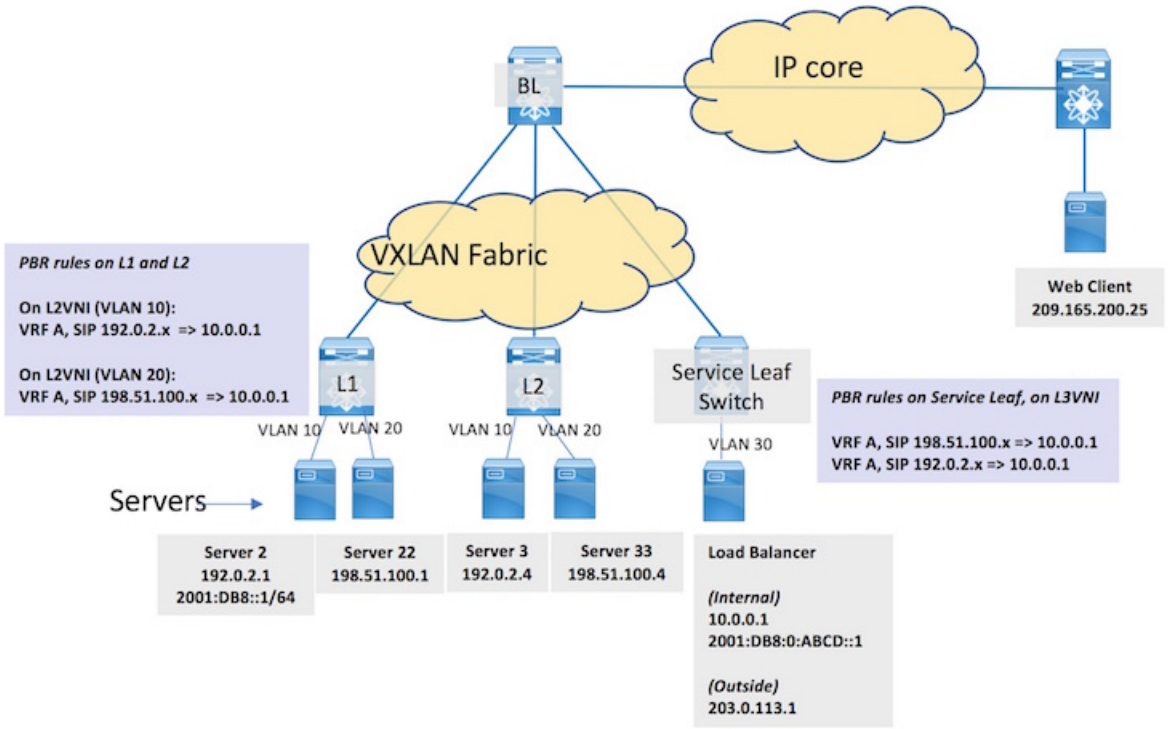
- This feature is not supported on port channels, channel members, Virtual Station Interface (VSI) trunk ports, and tunnel interfaces.
- Equal-Cost Multipath (ECMP) for IPv4/IPv6 adjacencies and BGP EVPN tunnel adjacencies are not supported at the same time.
- Virtual routing and forwarding (VRF) leak scenarios require that VRF context definitions should be consistent across all participating VTEPs.

Information About PBR Support for the VXLAN BGP EVPN Fabric

A sample workflow and PBR rules on ToR switches:

Workflow of PBR Support for the VXLAN BGP EVPN Fabric

Figure 25: Sample topology—PBR support for the VXLAN BGP EVPN fabric



Note In the figure, SIP refers to the source IP address.

Servers, virtual machines (VMs) and containers specific to a service are attached to ToR or leaf switches spread across the fabric (Server 2 and Server 22 attached to L1, and Server 3 and Server 33 attached to L2). The load balancer is attached to a service leaf switch at the right. A web client outside the fabric requests the service. When the request reaches the load balancer through the border leaf switch BL and the service leaf switch, it forwards the service request to an appropriate server (Server 2). PBR configurations should be enabled on L1, L2, and the service leaf switch. The workflow:

1. The web client (IP address 209.165.200.25) sends a request for a specific service available in the servers attached to L1 and L2. The destination IP address in the packets is 203.0.113.1, the load balancer's IP address. This IP address is advertised to clients outside the fabric. The request reaches BL.
2. BL knows from the BGP EVPN control plane that the load balancer is attached to the service leaf switch. BL VXLAN encapsulates the packets and forwards the request to the service leaf switch.

3. The service leaf switch receives it, VXLAN decapsulates the packets and sends the traffic to the load balancer.
4. The load balancer uses a unique IP address 10.0.0.1 (or 2001:DB8:0:ABCD::1 for IPv6) when load balancing traffic to one of the servers hosting the service. The load balancer decides to forward the request to Server 2. In the packet header, the load balancer updates the destination IP address to 192.0.2.1 (or 2001:DB8::1), while the source IP address remains 209.165.200.25 (or a designated IPv6 address), and forwards it to the service leaf switch. The service leaf switch sends the traffic over the VXLAN BGP EVPN fabric towards L1. L1 decapsulates the VXLAN header and forwards the original packet to Server 2.
5. Server 2 responds to the service request. The source IP address is 192.0.2.1 or 2001:DB8::1/64 (Server 2's IP address), and the destination IP address remains 209.165.200.25. The response is sent to L1.
6. On L1, normal packet forwarding determines that the destination address is behind the border leaf switch. However, PBR policy is applied on the interface on which the server is attached such that the packet is forwarded to the service leaf switch instead of the border leaf switch.
7. On the service leaf switch, after VXLAN decapsulation, normal packet forwarding determines that the destination address 209.165.200.25 is behind the border leaf switch. However, PBR policy is applied on the Layer-3 VNI interface such that the packet is forwarded to the service leaf switch instead of the border leaf switch.
8. The service leaf switch forwards it to BL, which forwards the service response to the web client.

PBR Rules on L1 and L2 (Enabled on BDI10 and BDI20)

- For server traffic (with source IP address 192.0.2.x, belonging to VLAN 10, VRF A, and Layer 2 virtual network identifier [VNI] 1000) received on interface BDI10, send traffic to 10.0.0.1 (or 2001:DB8:0:ABCD::1).
- For server traffic (with source IP address 198.51.100.x, belonging to VLAN 20, VRF A and Layer 2 VNI 2000), send traffic to 10.0.0.1 (or 2001:DB8:0:ABCD::1).

PBR Rules on the Service Leaf Switch

For server traffic (with source IP address 192.0.2.x or 198.51.100.x, belonging to VRF A, and Layer 3 VNI 50000) received on the PBR interface, send traffic to 10.0.0.1 (or 2001:DB8:0:ABCD::1).

How to Configure PBR Support for the VXLAN BGP EVPN Fabric

Note Type the **switch# configure terminal** command to enter global configuration mode **(config)#**

Enable PBR Configurations on L1, L2 and the Service Leaf Switch

Step 1 On L1, configure PBR and create an access list:

```
(config)# feature pbr
          ip access-list 1
            permit ip 192.0.2.1 0.0.0.255 host 10.0.0.1
            exit
          ipv6 access list vlan102-112
          10 permit ipv6 2001:DB8::1/64 2001:DB8:0:ABCD::1/64
```

- As per PBR rules, traffic from 192.0.2.1 or 2001:DB8::1/64 (Server 2's IP address) is sent to 10.0.0.1 or 2001:DB8:0:ABCD::1/64 (the load balancer's IP address), respectively.

Step 2 On L1, create a route map and set rules:

```
(config)# route-map equal-access permit 10
            match ip address 1
            set ip vrf A next-hop 10.0.0.1


(config)# route-map equal-access-v6 permit 10
             match ipv6 address vlan102-112
             set ip vrf A next-hop 2001:DB8:0:ABCD::1
```

- An IPv4 route map policy *equal-access*, and an IPv6 route map policy *equal-access-v6* are created.
- The **set ip vrf** command (introduced in this feature) resolves the next hop IP address for VRF A, for the IPv4 and IPv6 route map policies.

Step 3 Enable the route map policy on the BDI:

Note Policy routing is specified on the interface (bdi10) that receives the packets, and not on the interface from which the packets are sent.

```
(config)# interface bdi10
            vrf member A
            ip policy route-map equal-access
            ipv6 policy route-map equal-access-v6
```

Step 4 The configurations are relevant for BDI10. Similarly, enable PBR configurations for BDI 20 on L1.

Step 5 Enable PBR configurations on BDI10 and BDI20 on L2 and service leaf switch.

Verifying PBR Support for VXLAN BGP EVPN Fabric

Verify PBR configurations on L1:

Verifying PBR Route Map Policy Configuration on the BDI

PBR route map policy equal-access is implemented on BDI10:

```
L1# show running-configuration interface Bdi10

…
interface Bdi10
  no shutdown
  vrf member A
  no ip redirects
  ip address 192.0.2.200/24
  fabric forwarding mode anycast-gateway
  ip policy route-map equal-access
  ipv6 policy route-map equal-access-v6
```

Verifying PBR Route Map Policy Details

Route map policy configuration details:

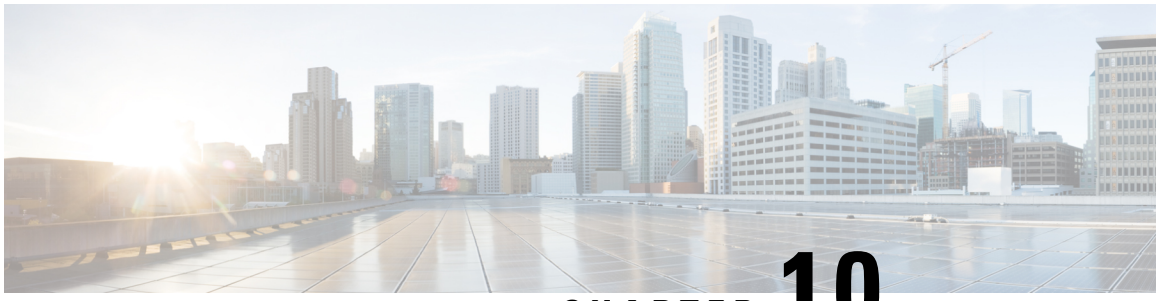
```
L1# show running-configuration rpm

feature pbr
route-map equal-access permit 10
   match ip address 1
   set ip next-hop 10.0.0.1

route-map equal-access-v6 permit 10
   match ipv6 address vlan102-112
   set ipv6 next-hop 2001:DB8:0:ABCD::1

interface Bdi100
   ip policy route-map equal-access
   ipv6 policy route-map equal-access-v6
```

Feature History for PBR Support for the VXLAN BGP EVPN Fabric

This table lists the release history for this feature.

Table 8: Feature History for PBR Support for the VXLAN BGP EVPN fabric

Feature Name	Release	Feature Information	
PBR support for the VXLAN BGP EVPN fabric	8.2(1)	This feature was introduced.	



CHAPTER 10

VXLAN BGP EVPN and OTV Interoperation

A datacenter fabric can be Virtual eXtensible Local Area Network (VXLAN) Border Gateway Protocol (BGP) Ethernet VPN (EVPN) based, classical ethernet (CE) based, or combined. You can connect different datacenters over an IP WAN with Layer 2 (such as Overlay Transport Virtualization [OTV]) and Layer 3 technologies, and also connect end hosts between Layer 2 CE and VXLAN pods within a datacenter. With this feature, you can:

- Configure VXLAN and OTV (with Bridge Domain Interface [BDI]) as a one-box solution. The VXLAN and OTV overlays or tunnels are stitched together on a VXLAN BGP EVPN fabric border leaf switch, ensuring that the Layer 2 traffic between VXLAN and OTV is within the same bridge domain.
- Configure OTV with BDI in a datacenter as a one-box solution, instead of a two box solution used in a legacy datacenter.

OTV as the overlay enables Layer 2 connectivity between separate VXLAN BGP EVPN or CE Layer 2 domains while maintaining resiliency and load-balancing benefits of the IP based interconnection.

Prerequisites for VXLAN BGP EVPN and OTV Interoperation

- A Nexus 7000 or 7700 Series switch with an M3 line card.
- Conceptual and configuration knowledge about VXLAN BGP EVPN and OTV datacenter fabrics.
- For a functioning VXLAN BGP EVPN datacenter, configurations should be enabled on the leaf and spine switches. For more information see the "Configuring the VXLAN BGP EVPN" chapter, or Cisco Programmable Fabric with VXLAN BGP EVPN Configuration Guide.

Guidelines and Limitations for VXLAN BGP EVPN and OTV Interoperation

- A unique, primary gateway IP address should be configured on each BDI for sending ARP requests over OTV. A secondary anycast IP address is configured on each BDI for sending ARP requests over EVPN.
- For Layer 3 multicast traffic, an external, centralized Layer 3 multicast gateway should be enabled. Layer 3 multicast routing support is not available for the VXLAN BGP EVPN and OTV Interoperation feature in release 8.2(1). However, Layer 3 multicast traffic within a VXLAN BGP EVPN fabric is supported as usual.
- For seamless mobility across legacy and VXLAN BGP EVPN fabrics, the anycast gateway MAC address used in the VXLAN fabric should be configured as the HSRP static MAC address in the legacy fabric.
- Only OTV unicast control network (OTV Adjacency Server function) is supported.
- On the same physical Join interface, regular OTV overlays cannot interoperate with OTV overlays that are stitched to VXLAN overlays. However, an OTV overlay and an OTV+VXLAN overlay can be enables on separate physical Join interfaces.
- In an OTV with BDI single box solution, the ARP proxy function option is not supported in the Cisco NX-OS 8.2(1) release.
- Support for this feature is limited to 3 OTV datacenter sites, for the 8.2(1) release.
- For OTV overlays, only Generic Routing Encapsulation (GRE) encapsulation is supported for the 8.2(1) release.

Information About VXLAN BGP EVPN and OTV Interoperation

Two VXLAN BGP EVPN datacenters can be connected with each other and to a legacy datacenter (Sample topology 1). A VXLAN BGP EVPN datacenter can be connected to a legacy datacenter and to a datacenter with a OTV+BDI one box solution implemented in the form of a vPC pair of border switches (Sample topology 2). In either topology, the Layer 3 aggregation switch in the legacy datacenter performs the role of an external, centralized multicast gateway for Layer 3 multicast traffic across the datacenters. The two sample topologies and workflow for the VXLAN BGP EVPN and OTV interoperation in them:

Sample Topologies and Workflow of the VXLAN BGP EVPN and OTV Interoperation

Figure 26: Sample topology 1 - VXLAN BGP EVPN and OTV interoperation

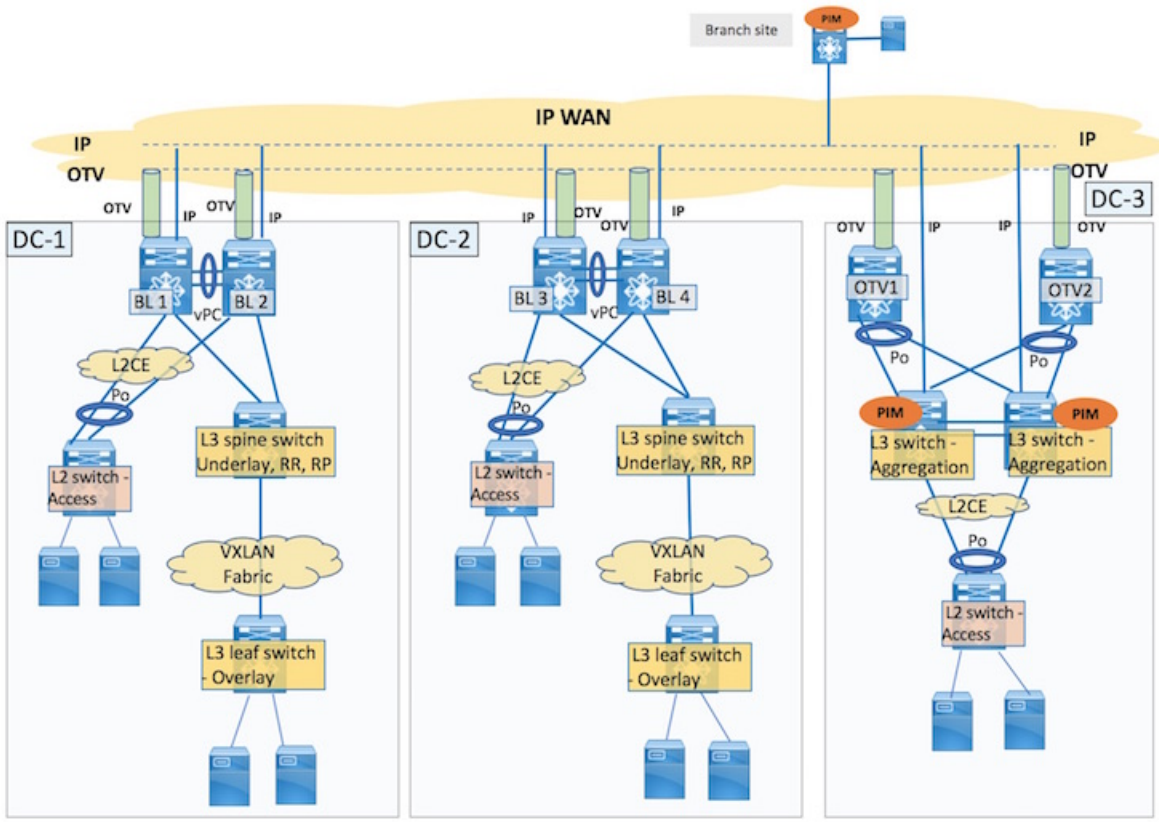
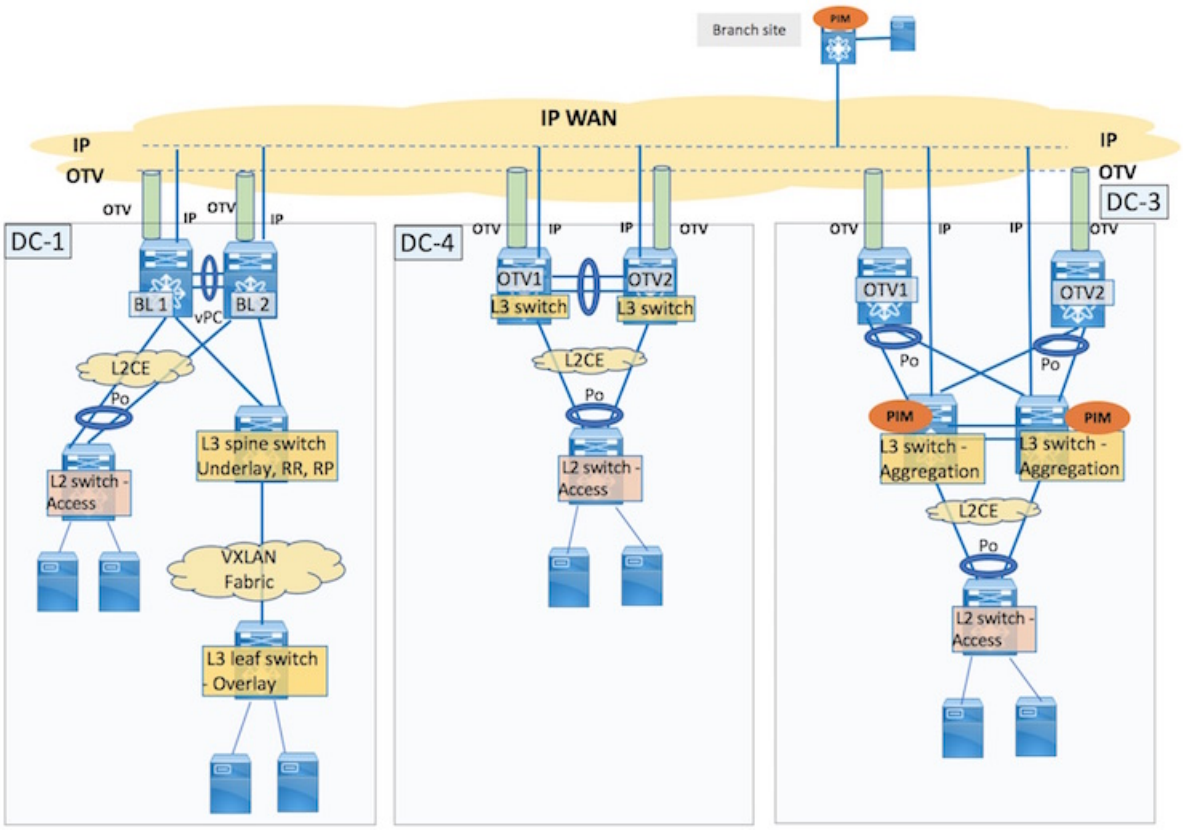


Figure 27: Sample topology 2 - VXLAN BGP EVPN and OTV interoperation



The focus of this feature is the VXLAN+OTV interoperation and OTV+BDI function on a Nexus 7000 or 7700 Series border leaf switch with an M3 line card, and the traffic flow between servers in these and a legacy datacenter. Topology information:

Note Support for this feature is limited to 3 OTV datacenter sites, for the 8.2(1) release.

- Topology 1 displays 3 datacenters, DC-1, DC-2 and DC-3. DC-1 and DC-2 have VXLAN BGP EVPN and CE pods, with VXLAN and OTV (with Bridge Domain Interface [BDI]) configurations) on the Virtual Port Channel (vPC) pair border leaf switches (BL 1 and BL 2, BL 3 and BL 4). DC-3 is a legacy OTV site with OTV switches in separate VDCs (OTV1 and OTV2) at the border.
- Topology 2 displays 3 datacenters, DC-1, DC-4 and DC-3. DC-1 has VXLAN BGP EVPN and CE pods, with VXLAN and OTV (with BDI) enabled on the vPC border leaf switch pair. DC-4 is a OTV+BDI one box solution with configurations implemented on the vPC border switch pair. DC-3 is a legacy OTV site.

Layer 2 Switching

Layer 2 traffic is transported between the datacenters through the border leaf switches (in DC-1 and DC-2) and OTV devices (in DC-3 and DC-4) at the site border, over the IP WAN.

In DC-1 and DC-2, there are 2 scenarios where Layer 2 traffic is transported between VXLAN and OTV overlays or tunnels. On the border leaf switch, traffic from the VXLAN fabric is either sent to a server within the datacenter, or towards another datacenter through OTV. The other way around, the border leaf switch receive traffic from OTV towards the VXLAN fabric or CE pod. When you configure this feature, Layer 2 traffic seamlessly passes between the VXLAN and OTV tunnels on the same device. Packet flow details in DC-1 and DC-2:

- Packet flow within the Layer 2 CE pod and packet flow within the VXLAN BGP EVPN pod (see "Configuring VXLAN BGP EVPN" chapter) remains the same. When a Layer 2 CE pod server sends traffic to a server in the VXLAN fabric within the site or to another site, the packets reach the border leaf switch. The bridge domain, Layer 2/Layer 3 VNI mappings, and MAC routes of the VXLAN fabric are available in the border leaf switch. If the destination server is within the fabric, the border leaf switch VXLAN encapsulates the packet and sends it to the corresponding ToR or leaf switch. The leaf switch VXLAN decapsulates the traffic and sends the original packet to the intended server. If the destination server is in another site, the border leaf switch OTV encapsulates the traffic towards the remote site.

Note Though the simplified sample topology depicts a single switch at the ToR/leaf layer carrying Layer 2 server traffic within the VXLAN BGP EVPN fabric, a real time VXLAN fabric spine-leaf setup will have multiple switches at the ToR/leaf and spine layers, and intra fabric Layer 2 server traffic flows through those non border leaf switches.

- When a VXLAN+OTV border leaf switch receives traffic from another site over OTV, it removes the OTV encapsulation, does a lookup to find out where the destination server resides, and VXLAN encapsulates the traffic towards the corresponding ToR/leaf switch. The leaf switch VXLAN decapsulates the traffic and sends the original packet to the intended server. If the destination server is in the Layer 2 CE pod, the border leaf switch OTV decapsulates the traffic and sends the traffic to the destination server without any encapsulation.
- When a server in the VXLAN BGP EVPN fabric sends traffic to a server in the Layer 2 CE pod, the border leaf switch receives the packets. It VXLAN decapsulates the traffic and sends it to the destination server in the CE pod.

Packet flow details in DC-4:

- When a Layer 2 CE pod server in the datacenter with the OTV+BDI one box solution sends traffic, the destination server is either within the datacenter or outside of it. Traffic flow within the datacenter remains the same. If the destination server is in another site, then the packets reach the Layer 3 OTV (with BDI) switch. The switch OTV encapuslates the traffic towards the legacy or VXLAN+OTV datacenter. The border switch in the destination datacenter receives the traffic, OTV decapsulates it, and forwards it as explained in the earlier sections.
- When the Layer 3 OTV (with BDI) switch receives traffic from another datacenter over OTV, it OTV decapsulates the traffic and sends it towards the corresponding Layer 2 access switch. The access switch forwards the packets to the destination server.

Control Plane

- BGP EVPN is used for advertising MAC and MAC-IP routes across the VXLAN BGP EVPN fabric in DC-1 and DC-2.

- Intermediate-System to Intermediate-System (IS-IS) is used for advertising MAC routes across OTV configured device.
- MAC Route updates in the control plane are reflected across the OTV and VXLAN tunnels.

Layer 3 Unicast Routing

DC-1 and DC-2 (VXLAN BGP EVPN fabric)

Layer 3 routing within the VXLAN BGP EVPN fabric takes place through an underlay Interior Gateway Protocol (IGP) such as Intermediate System-to-Intermediate System (IS-IS) or OSPF.

Layer 3 traffic between the border leaf switches and the IP WAN should be through over Multiprotocol Label Switching (MPLS) L3VPN or virtual routing and forwarding (VRF) Lite. The IGP and external connectivity documentation is available in the *Cisco Programmable Fabric with VXLAN BGP EVPN Configuration Guide*.

A distributed anycast gateway (or BDI) IP address is used for Layer 3 traffic between Layer 2 virtual networks in the VXLAN fabric. This should be configured as the secondary BDI IP address. A unique, primary gateway IP address should be configured on each BDI for sending ARP requests over OTV. Packet flow details in DC-1 and DC-2:

Note

- Though the main focus of the feature is one box solutions for VXLAN+OTV with BDI and OTV with BDI functions, traffic flow from/to the Layer 2 CE pod is also explained for completeness.
- Though the simplified sample topology depicts a border leaf switch carrying Layer 3 server traffic within the VXLAN BGP EVPN fabric, real time intra VXLAN fabric server traffic flow is through a non border leaf switch.

- When a server in the Layer 2 CE pod sends traffic to a server in another VLAN/subnet, either located in the VXLAN BGP EVPN fabric within the site or to a server in a remote site, the traffic first reaches the border leaf switch. The bridge domain, Layer 2/Layer 3 VNI mappings, MAC routes and the appropriate IGP configuration will be available in the border leaf switch. If the destination server is within the fabric, the border leaf switch VXLAN encapsulates the packet and routes it to the corresponding ToR or leaf switch through the fabric underlay routing protocol such as IS-IS or OSPF. The leaf switch VXLAN decapsulates the traffic and sends the original packet to the intended server. If the destination server is in another site, the border leaf switch sends the traffic towards the remote site through a Layer 3 DCI technology like MPLS L3VPN or OTV, depending on how the host route is learnt (through MPLS VPN or OTV).
- When the Layer 3 DCI enabled border switch receives Layer 3 traffic from another site (through MPLS VPN or OTV), it does a lookup to find out where the destination server resides and routes the packets (across VLANs, through the corresponding destination BDI), to the corresponding Layer 2 switch. The switch forwards the packets to the intended destination server.

DC-3, the legacy datacenter

- Layer 3 routing within DC-3 is through an IGP implemented on the aggregation switches. A Layer 3 Hot Standby Router Protocol (HSRP) gateway with First Hop Redundancy Protocol (FHRP) filtering should be configured.

Note FHRP filtering is required to allow for the existence of the same default gateway in different locations and optimize outbound traffic flows (traffic from a server in DC-3 to another datacenter). See Overlay Transport Virtualization Best Practices Guide for more information.

- Configure the anycast gateway MAC address used in the VXLAN fabric as the HSRP MAC address in the legacy fabric for efficient MAC moves.
- Layer 3 traffic between the legacy fabric and the IP WAN should be over OTV, MPLS L3VPN, or VRF Lite.

DC-4, the datacenter with the OTV+BDI switch as the one box solution

- Layer 3 routing within this datacenter is through an IGP implemented on the Layer 3 vPC switch pair at the border. When a server in DC-4 sends traffic to a server in another VLAN/subnet, either located within the site or in a remote site, the traffic first reaches the designated Layer-3 switch. If the destination is within the fabric, it routes the packets (across VLANs, through the corresponding BDI) towards the corresponding Layer 2 switch which forwards it to the destination. If the destination is in another site, the Layer-3 border switch routes the traffic towards the remote site, through a Layer 3 DCI technology like MPLS L3VPN or OTV, depending on how the host route was learnt (through MPLS VPN or OTV).
- When the Layer 3 DCI enabled border switch receives Layer 3 traffic from another site, it does a lookup to find out where the destination server resides and routes the traffic through the IGP in the fabric, to the corresponding Layer 2 switch. The switch forwards the packets to the intended destination server.

ARP requests

- All ARP requests are resolved through the VXLAN and/or OTV overlays.
- When ARP suppression is enabled on the VXLAN overlay NVE interface (for a specific Layer 2 virtual network[s]), then an ARP request is suppressed if the entry is present in the ARP cache. Else, the request is flooded into the VXLAN fabric.
- A Layer 3 gateway generated ARP request sent over OTV uses the primary gateway IP and virtual device context (VDC) MAC addresses, while an ARP request sent over the VXLAN BGP EVPN fabric uses the secondary BDI or anycast gateway IP and corresponding MAC addresses.

Note You should enable the ARP proxy function under the OTV overlay and ARP suppression function under the VXLAN overlay at the same time or you should disable both the functions.

Layer 2 Multicast Forwarding and Layer 3 Multicast Routing

Multicast traffic across the datacenters:

Layer 2 Multicast Forwarding

- When a server in the VXLAN BGP EVPN fabric sends multicast traffic to the attached ToR/leaf switch, the leaf switch forwards the multicast traffic within the fabric, as explained in the Cisco Programmable Fabric with VXLAN BGP EVPN Configuration Guide. If there are receivers in the Layer 2 CE pod

within DC-1, the leaf switch sends traffic towards the border switch, which VXLAN decapsulates the traffic and sends bridged traffic to relevant Layer 2 switches (or receivers in the Layer 2 CE pod). For receivers in DC-2, DC-3, or DC-4, the border leaf switch VXLAN decapsulates the traffic and sends traffic over OTV to DC-2, DC-3 (or DC-4).

- When the DC-2 border leaf switch receives the packets, it has to send traffic to receivers in the VXLAN fabric and in the Layer 2 CE pod. For receivers within the VXLAN fabric, the border leaf switch OTV decapsulates the traffic, VXLAN encapsulates it, and sends it towards relevant ToR/leaf switches. For receivers in the CE pod, the traffic is OTV decapsulated and sent towards relevant Layer 2 CE switches.
- When a DC-3 OTV switch receives the packets, the switch OTV decapsulates the traffic and sends a copy of the bridged traffic towards relevant Layer 2 CE switches/receivers.
- When the designated DC-4 OTV+BDI border vPC switch receives the packets, it OTV decapsulates the traffic and sends a copy of the bridged traffic towards relevant Layer 2 CE switches/receivers.
- Similarly, when a server in the Layer 2 CE pod (in DC-1 or DC-2) sends multicast traffic, traffic flow to receivers within the CE pod remains the same. If there are receivers in the VXLAN fabric in DC-1, and in DC-2 and DC-3, the attached access switch sends it towards the border leaf switch. The border leaf switch sends traffic to receivers in the VXLAN fabric (in DC-1), and towards DC-2 and DC-3, as explained in the previous points. If there are receivers in DC-4 (per topology 2), a copy of the packets is sent towards DC-4.
- When a server in DC-4 (OTV+BDI one box solution at the border) sends Layer 2 multicast traffic, traffic flow to receivers within the CE pod remains the same. If there are receivers in other datacenters, the switch at the datacenter border receives the packets, and sends it over OTV towards the destination datacenters (DC-1 and DC-3). If DC-4 has multicast receivers and receives multicast traffic from a sender in another datacenter, it OTV decapsulates the traffic and sends a copy of the bridged traffic towards relevant Layer 2 CE switches/receivers. The Layer 2 switch(es) forwards the packets to intended destination servers.

Layer 3 multicast routing

When a server in DC-1 or DC-2 (in topology 1), or DC-1/DC-4 (in topology 2) sends Layer 3 multicast traffic across the fabrics, it is routed through the external, centralized multicast gateway in the legacy datacenter, DC-3. Layer 3 multicast routing support is not available for the VXLAN BGP EVPN and OTV Interoperation feature in release 8.2(1). On the border leaf switch, ensure that you do not enable the **ip pim sparse-mode** command on OTV enabled bridge domains.

Attention Layer 3 multicast traffic within a VXLAN BGP EVPN fabric (for VXLAN enabled bridge domains) is supported as usual. This is the use case wherein a sender within the VXLAN fabric sends Layer 3 multicast traffic to receivers located within the fabric. For more details, see "Multicast Routing in the VXLAN Underlay" section, "IP Fabric Underlay" chapter in the *Cisco Programmable Fabric with VXLAN BGP EVPN Configuration Guide*.

Layer 3 multicast packet flow in DC-1 and DC-2:

- If a server in the VXLAN fabric in DC-1 sends multicast traffic to receivers in different VLANs/subnets outside the VXLAN fabric, then the traffic is sent to the Layer 3 switch in DC-3 where the centralized multicast gateway is enabled. First, the traffic reaches the border leaf switch in DC-1. Assuming that a receiver is located in the CE pod in DC-1 and another receiver in the VXLAN fabric in DC-2, the border leaf switch forwards the traffic towards DC-3. On receiving the request, the Layer 3 switch (or centralized

multicast gateway) in DC-3 sends a copy of the routed multicast traffic to the border leaf switch in DC-1 and DC-2. On receiving the traffic, the border leaf switch in DC-2 VXLAN encapsulates the traffic and sends it towards the corresponding ToR/leaf switch. The leaf switch VXLAN decapsulates the packets and sends it to the destination server. The border leaf switch in DC-1 forwards the traffic to the corresponding Layer 2 CE switch, which forwards it to the attached destination server.

Layer 3 multicast packet flow in DC-4:

- If a server in this datacenter sends multicast traffic to receivers in different VLANs/subnets, the traffic first reaches the Layer 3 OTV+BDI switch at the border. The Layer 3 switch forwards it towards DC-3, (the external, centralized multicast gateway) which sends a copy of the routed multicast traffic towards other datacenter fabrics that have receivers. The rest of the flow is the same as explained in the previous points.

How to Configure VXLAN BGP EVPN and OTV Interoperation, and OTV with BDI

Note Type the **switch# configure terminal** command to enter global configuration mode **(config)#**

Configure VXLAN BGP EVPN and OTV Interoperation on the Border Leaf Switches in DC-1 and DC-2

Only configurations relevant to the VXLAN BGP EVPN and OTV Interoperation feature are noted here. If VXLAN BGP EVPN fabric configurations are not enabled on the fabric's leaf and spine switches, enable them. See the "Configuring the VXLAN BGP EVPN" chapter, or Cisco Programmable Fabric with VXLAN BGP EVPN Configuration Guide.

VXLAN BGP EVPN and OTV configurations should be configured on a single box, the border leaf vPC switch pair. BL1 and BL2 configurations on DC-1:

Step 1 Configure tunnel stitching in the VXLAN overlay

The VXLAN BGP EVPN configurations are documented in the *Configuring VXLAN BGP EVPN* chapter. Only VXLAN configurations required for the VXLAN and OTV interoperation for the one-box solution are given.

```
BL1(config)# feature nve
             vni 40000
             system bridge-domain 2500-3500
             bridge-domain 3500
                 member vni 40000
                 exit
             interface nve1
                source-interface loopback0
                tunnel-stitching enable
                member vni 40000
                  no suppress-arp
                  mcast-group 239.1.1.65
```

- The **tunnel-stitching enable** command is the VXLAN command for connecting VXLAN and OTV tunnels.

Step 2 Configure the VXLAN overlay loopback interface

```
BL1(config)# interface loopback0
                ip address 209.165.200.25/32
                ip address 203.0.113.1/32 secondary
```

- Primary and secondary IP addresses are assigned to the source loopback interface on the switch.

Step 3 Configure tunnel switching in the OTV overlay

```
BL1(config)# feature otv
             otv site-vni 40000
             interface Overlay1
                 otv join-interface Ethernet5/5
                 otv extend-vni 10000, 20000
                 otv vni mapping 10000, 20000, 30000 to vlan 1000, 2000, 3000
                 otv use-adjacency-server 10.0.0.1 unicast-only
                 no otv suppress-arp-nd
                 otv tunnel-stitch
                 no shutdown
                 exit
             otv site-identifier 0000.0000.000A
             otv encapsulation-format ip gre
```

- The **otv site-vni** command enables the OTV site specific VNI. This VNI should not be extended over any overlay interface and should be operationally up before it can be configured as the OTV site VNI. At least one interface should be present where the VNI is up. On a VXLAN + OTV pod, the VNI can be configured under the NVE interface. If the **otv site-vlan** configuration is enabled, then you need to remove it before configuring the **otv site-vni** command.
- The **otv tunnel-stitch** command is the OTV command for connecting VXLAN and OTV tunnels.
- For OTV overlays, only Generic Routing Encapsulation (GRE) encapsulation is supported for the 8.2(1) release.

Note You should enable ARP proxy under the OTV overlay and ARP suppression under the VXLAN overlay at the same time or you should disable both the functions.

Step 4 Configure the VXLAN and OTV tunnel stitching configurations on BL2.

Step 5 Configure vPC function on BL1 and BL2

vPC Peer 1 (BL1) configuration

```
BL1(config)# interface Bdi3500
               no shutdown
               vrf member cust1
               no ip redirects
               ip address 198.51.100.20/24
               ip address 198.51.100.1/24 secondary anycast-primary
               ipv6 address 2001:DB8:1::1/64
```

```
                no ipv6 redirects
                fabric forwarding mode anycast-gateway
```

vPC Peer 2 (BL2) configuration

```
BL2(config)# interface Bdi3500
                no shutdown
                vrf member cust1
                no ip redirects
                ip address 198.51.100.30/24
                ip address 198.51.100.1/24 secondary anycast-primary
                ipv6 address 2001:DB8:1::1/64
                no ipv6 redirects
                fabric forwarding mode anycast-gateway
```

- The unique, primary gateway IP address (198.51.100.20 for vPC peer 1, and 198.51.100.30 for vPC peer 2 switches) will be used for sending ARP requests over OTV. The common, secondary anycast gateway IP address (198.51.100.1) will be used for sending ARP requests on the VXLAN side.

Step 6 The configurations are for DC-1. Similarly, configure for DC-2 too.

Configure OTV with BDI Configuration on the Border Switches in DC-4

Note These configurations are relevant to the OTV+BDI single box solution (comprising the vPC switch pair at the border, OTV1 and OTV2) and not to the legacy datacenter, where the two box solution comprises of a separate OTV and aggregation switch.

OTV1 and OTV2 configurations:

Step 1 Configure OTV on OTV1

```
OTV1(config)# feature otv
              feature nv overlay
              feature-set fabric
              feature fabric forwarding
              feature vni
              vni 40000
              system bridge-domain 2500-3500
              bridge-domain 3500
                 member vni 40000
                 exit
              encapsulation profile vni vsi_cisco
                 dot1q 60 vni 40000
                 exit
              interface Ethernet 1/12
                 no shutdown
                 service instance 1 vni
                 encapsulation profile vsi_cisco default
                   no shutdown
```

The **feature nv overlay** command is a required command for this feature.

```
OTV1(config)# no otv site-vlan 111
```

```
otv site-vni 40000
interface Overlay1
   otv join-interface Ethernet2/3
   otv extend-vni 10000, 20000, 30000
   otv vni mapping 10000, 20000, 30000 to vlan 1000, 2001, 3000
   otv use-adjacency-server 10.0.0.1 192.0.2.1 unicast-only
   no otv suppress-arp-nd
   otv adjacency-server unicast-only
   no shutdown
   exit
otv site-identifier 0000.0000.000A
otv encapsulation-format ip gre
```

- The **otv site-vni** command enables the OTV site specific VNI. This VNI should not be extended over any overlay interface and should be operationally up before it can be configured as the OTV site VNI. At least one interface should be present where the VNI is up. On a OTV with BDI pod, the VNI can be brought up on a VSI interface, using an encapsulation profile, as shown in the example. If the **otv site-vlan** configuration is enabled, then you need to remove it before configuring the **otv site-vni** command.
- In an OTV with BDI single box solution, the **otv suppress-arp-nd** option is not supported in the Cisco NX-OS 8.2(1) release.
- For OTV overlays, only Generic Routing Encapsulation (GRE) encapsulation is supported for the 8.2(1) release.

Step 2 Similarly, enable OTV configurations on OTV2.

Step 3 Configure vPC function on OTV1 and OTV2

vPC Peer 1 (OTV1) configuration

```
OTV1(config)# interface Bdi3500
                no shutdown
                vrf member cust1
                no ip redirects
                ip address 209.165.201.10/24
                ip address 209.165.201.20/24 secondary anycast-primary
                fabric forwarding mode anycast-gateway
```

vPC Peer 1 (OTV2) configuration

```
OTV1(config)# interface Bdi3500
                no shutdown
                vrf member cust1
                no ip redirects
                ip address 209.165.201.12/24
                ip address 209.165.201.20/24 secondary anycast-primary
                fabric forwarding mode anycast-gateway
```

- The primary, unique IP address (209.165.201.10 for vPC peer 1 switch [OTV1], and 209.165.201.12 for vPC peer 2 switch [OTV2]) is created for ARP requests over OTV. The common, secondary anycast gateway IP address (209.165.201.20) is used as a Layer 3 gateway for traffic, including ARP requests, from the specified bridge domain Bdi3500 within the datacenter.

Verifying VXLAN BGP EVPN and OTV Interoperation, and OTV with BDI

Verify VXLAN and OTV configurations on BL1:

Display VXLAN Configuration on the Border Leaf Switch BL1

In the following example, you can see the VXLAN overlay information such as the loopback interface information, and the state of the overlay. For vPC switches, primary and secondary IP addresses are configured:

```
BL1# show nve interface

Interface: nve1, State: Up, encapsulation: VXLAN
VPC Capability: VPC-VIP-Only [not-notified]
Local Router MAC: 1005.caf4.cdd9
Host Learning Mode: Control-Plane
Source-Interface: loopback1 (primary: 209.165.200.25, secondary: 203.0.113.1)
```

In the following example, you can view bridge domain information for the specified bridge domain:

```
BL1# show bridge-domain 100

Bridge-domain 100 (2 ports in all)
Name: Bridge-Domain100
Administrative State: UP  Operational State: UP
vni10000
Overlay1
nve1
```

In the following example, you can see VNI information for the VXLAN overlay, including Layer 2/Layer 3 VNI, multicast group mapping, and so on:

```
BL1# show nve vni

Codes: CP - Control Plane        DP - Data Plane
       UC - Unconfigured         SA - Suppress ARP

Interface VNI      Multicast-group   State Mode Type [BD/VRF]      Flags
--------- -------- ----------------- ----- ---- ------------------ -----
nve1      5000     224.1.1.1         Up    CP   L3 [cust1]
```

In the following example, you can see attached VXLAN overlay peer information such as the peer IP address, state, and so on:

```
BL1# show nve peers

Interface Peer-IP      State    LearnType  Uptime   Router-Mac
--------- --------     ----     -----      -------  ----------
nve1      10.1.1.2     Up       CP         4d19h    8c60.4f04.21c2
```

Display OTV Configuration on the Border Leaf Switch BL1

In the following example, you can see the extended VLANs and VNIs in the **Extended vlans** and **Extended vni** fields. Also, the OTV join interface and adjacency server information are displayed:

```
BL1# show otv

OTV Overlay Information
Site Identifier 0000.0000.000a
Encapsulation-Format ip - gre

Overlay interface Overlay1

 VPN name            : Overlay1
 VPN state           : UP
 Extended vlans      : 50 60 100-101 300-301 (Total:6)
 Extended vni        : 10000, 20000, 30000, 40000(total:4)
 Join interface(s)   : Eth5/5 (10.3.3.3)
 Site vlan           : 101 (up)
 AED-Capable         : Yes
 Capability          : Unicast-Only
 Is Adjacency Server : No
 Adjacency Server(s) : 10.0.0.1 / [None]
```

In the following example, site VLAN, site VNI, and other site details are displayed. You should remove the site VLAN using the **no otv site-vlan** command.

```
BL1# show otv site detail

    Full     - Both site and overlay adjacency up
    Partial  - Either site/overlay adjacency down
    Down     - Both adjacencies are down (Neighbor is down/unreachable)
    (!)      - Site-ID mismatch detected

Local Edge Device Information:
    Hostname BL1
    System-ID 002a.6a65.09c1
    Site-Identifier 0000.0000.000a
    Site-VLAN 101 State is Up

    Site-VLAN-Cfg 0
    Site-VNI 10001

Site Information for Overlay1:

Bridge-domain 101  (1 ports in all)
Name:: Bridge-Domain101
Administrative State: UP              Operational State: UP
        vni10001
        nve1
```

Display OTV Overlay State

In the following example, the **Tunnel Stitch** field displays **enabled** state, indicating that the OTV part of the VXLAN OTV tunnel stitching is enabled:

```
BL1# show otv internal overlay detail
```

```
Overlay interface Overlay1 idx: 1635021663
Overlay interface idx: 0x22080001
 VPN name            : Overlay1
 Device ID           : 8c60.4f04.21c6
 Protocol state      : UP           Interface state     : UP
 Tunnel Stitch       : enabled
 Tier Id             : 1
 Pend Tier Id        : 0
 Tier Id State       : Done(4)
 Refcount            : 6
.
.
```

In the following example, the overlay ID and the VXLAN-to-OTV tunnel stitching status are displayed. In the **Enable** column, **Y** indicates that the OTV part of the tunnel is enabled:

```
BL1# show otv internal tunnel-stitch

Overlay    Enable  Tier-id  Tier-pend-id  State  Detail
---------  ------  -------  ------------  -----  -----------
Overlay1       Y        1             0      4   Done
```

In the following example, you can see that ARP proxy is enabled under the OTV overlay:

Note Ensure that you also enable ARP suppression under the VXLAN overlay at the same time. Alternatively, disable the ARP proxy/suppression function under both the overlays.

```
BL1# show otv internal arp-nd status

Overlay: Overlay1
  Suppress arp-nd: Enabled
  VNI Suppress ARP:
  50000      1000      : Enabled
  50001      1001      : Enabled
  50002      1002      : Enabled
  50003      1003      : Enabled
  50004      1004      : Enabled
  50005      1005      : Enabled
  50006      1006      : Enabled
  50007      1007      : Enabled
```

In the following example, for the specified OTV overlay (Overlay1), VNI, BD, and VLAN mapping information is displayed. The **State** field indicates that the overlay is functional.

```
BL1# show otv vni Overlay1

 Overlay    VNI        BD    VLAN  Flag  State
 ---------- ---------- ----- ----- ----- --------------------
 Overlay1   10000      100   1000  0x1   (12)Overlay Logical up
 Overlay1   20000      101   2000  0x1   (12)Overlay Logical up
 Overlay1   30000      300   3000  0x1   (12)Overlay Logical up
 Overlay1   40000      301   3500  0x1   (12)Overlay Logical up
```

Display OTV Adjacencies

In the following example, OTV adjacencies towards the legacy datacenter switches OTV1 and OTV2 in DC-3, BL2 in DC-1, and BL3 in DC-2 are displayed:

```
BL1# show otv adjacency

Overlay Adjacency database

Overlay-Interface Overlay1  :

Hostname      System-ID       Dest Addr       Up Time  State

LEGACY-OTV1   002a.6a65.0045  209.165.200.25  3d01h    UP
LEGACY-OTV2   002a.6a65.0046  203.0.113.1     3d01h    UP
core-BL2      8c60.4f04.21c7  203.0.113.200   3d01h    UP
BL3           8c60.4f04.43c1  203.0.113.250   3d01h    UP
```

Display Tier IDs

In the following example, you can see tier IDs allocated to the VXLAN and OTV overlays. Unique tier IDs are automatically allocated so that packets that are sent from a tunnel are not sent back to the same tunnel, such as multicast packets being sent back to the multicast source. OTV and VXLAN overlay tier IDs are unique:

```
BL1# show forwarding distribution tierpeerid otv

Tier-Peer-id allocations:

Type: Tier ID       Tier ID: 0x1  Tier Peer ID: 0x1000            Data: 0x0

Type: Tier Peer ID  Tier ID: 0x0  Tier Peer ID: 0x3fd   App: OTV  Data: 0x0
Type: Tier Peer ID  Tier ID: 0x1  Tier Peer ID: 0x1001  App: OTV  Data: 0x1
Type: Tier Peer ID  Tier ID: 0x1  Tier Peer ID: 0x1002  App: OTV  Data: 0x2
Type: Tier Peer ID  Tier ID: 0x1  Tier Peer ID: 0x13fd  App: OTV  Data: 0x0


BL1# show forwarding distribution tierpeerid nve

Tier-Peer-id allocations:

Type: Tier ID       Tier ID: 0x2  Tier Peer ID: 0x2000            Data: 0x0

Type: Tier Peer ID  Tier ID: 0x2  Tier Peer ID: 0x2001  App: NVE  Data: 0x1c1c1c1c
Type: Tier Peer ID  Tier ID: 0x2  Tier Peer ID: 0x2002  App: NVE  Data: 0x1b1b1b1b
Type: Tier Peer ID  Tier ID: 0x2  Tier Peer ID: 0x23fd  App: NVE  Data: 0x0
```

Troubleshooting VXLAN BGP EVPN and OTV Interoperation, and OTV with BDI

```
BL1# show tech-support arp
BL1# show tech-support otv
BL1# show tech-support lim
BL1# show tech-support oim
BL1# show tech-support nve
```

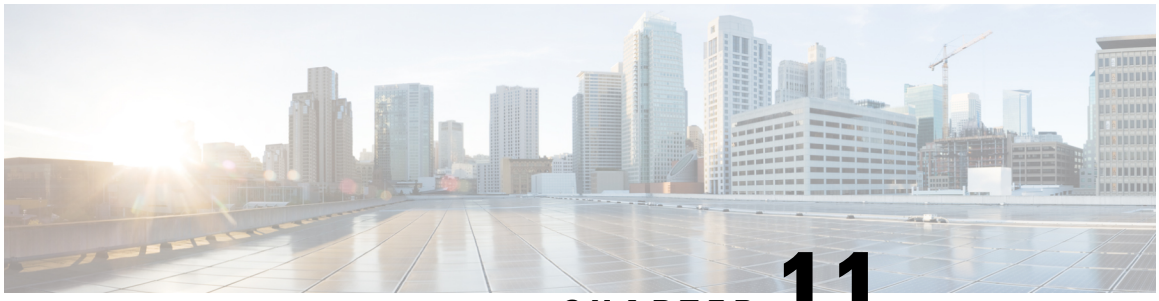
```
BL1# show tech-support vxlan-evpn
```

Feature History for VXLAN BGP EVPN and OTV Interoperation

This table lists the release history for this feature.

Table 9: Feature History for VXLAN BGP EVPN and OTV interoperation

Feature Name	Release	Feature Information	
VXLAN BGP EVPN and OTV interoperation	8.2(1)	This feature was introduced to enable VXLAN and OTV (with BDI) configurations on a single switch (as a one box solution), and to enable OTV+BDI configurations on a single switch (as a one box solution). The following commands were introduced or modified for the OTV overlay: **otv tunnel-stitch** **otv vni mapping** **show otv** **show otv internal overlay detail** **show otv internal tunnel-stitch** **show otv vni overlay** The following command was introduced for the VXLAN overlay: **tunnel-stitching enable** The following command was introduced for the BDI function: **ip address secondary anycast-primary**	



CHAPTER 11

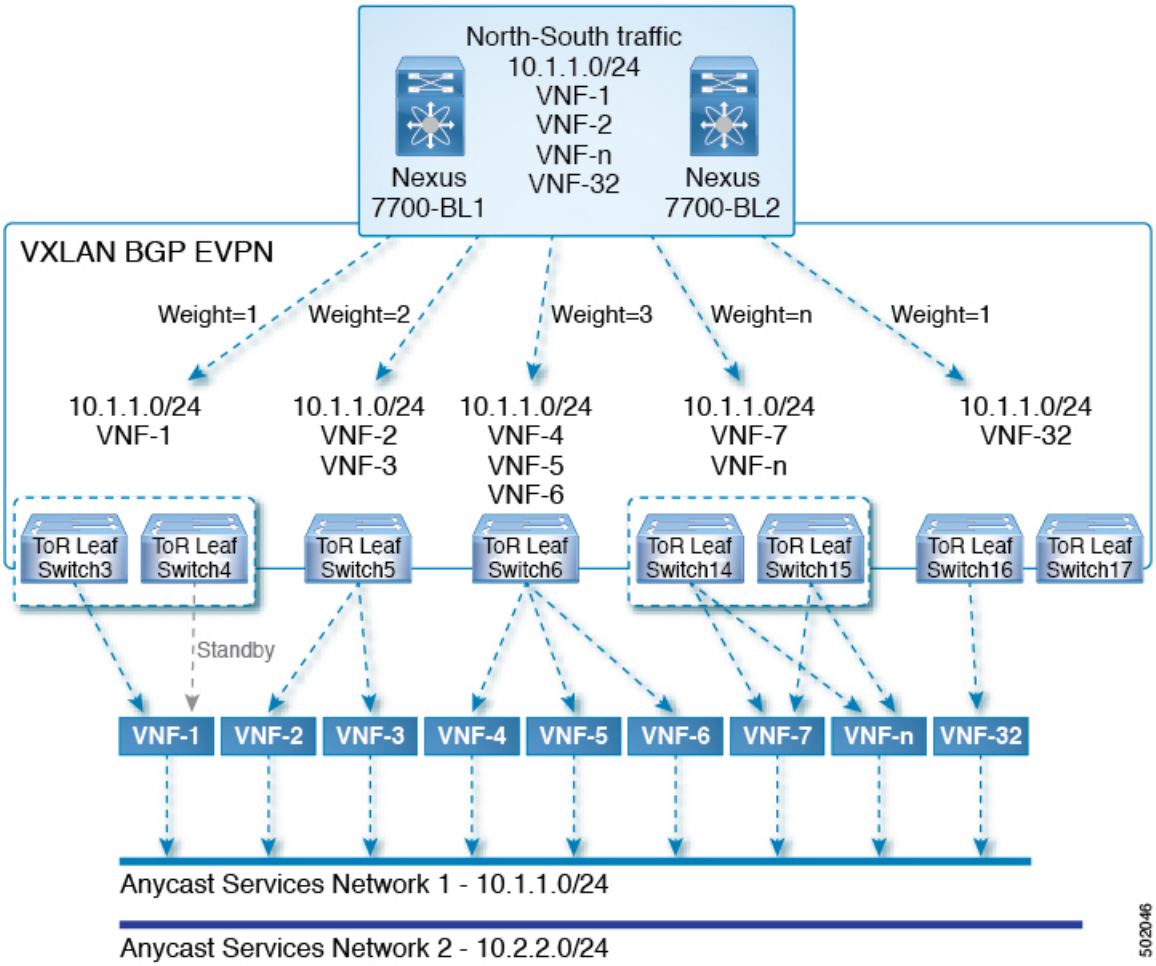
Proportional Multipath for VNF

This chapter contains the following sections:

Information About Proportional Multipath for VNF

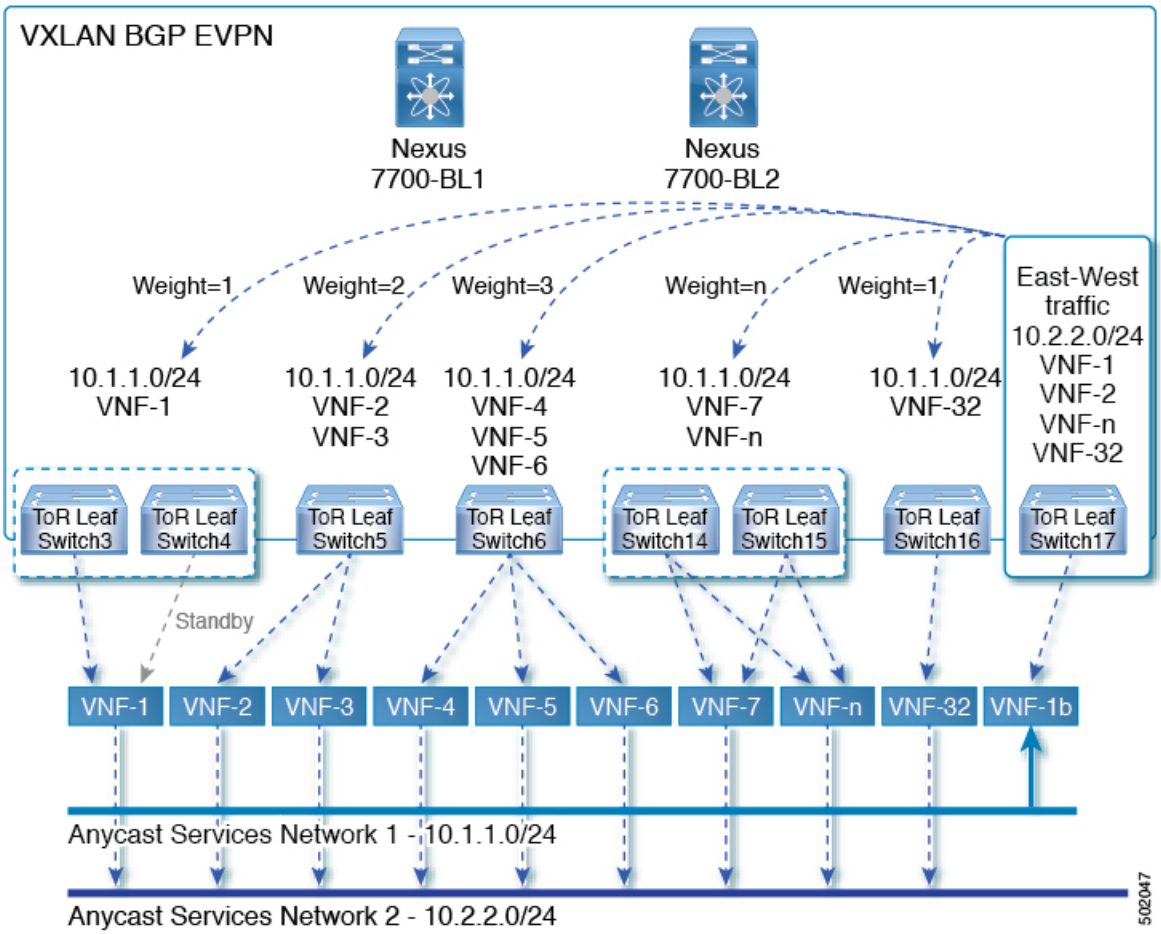
In Network Function Virtualization Infrastructures (NFVi), anycast services networks are advertised from multiple Virtual Network Functions (VNFs). The Proportional Multipath for VNF feature enables advertising of all the available next hops to a given destination network. This feature enables the switch to consider all paths to a given route as equal cost multipath (ECMP) allowing the traffic to be forwarded using all the available links stretched across multiple ToRs.

Figure 28: Sample Topology (North-South Traffic)



As shown in Figure 1, North-South traffic that enters the VXLAN fabric at a border leaf is sent across all egress endpoints with the traffic forwarded proportional to the number of links from the egress Top-Of-Rack (TOR) to the destination network.

Figure 29: Sample Topology (East-West Traffic)



As shown in Figure 2, East-West traffic is forwarded between the VXLAN tunnel End Points (VTEPs) proportional to the number of next hops that are advertised by each Top-Of-Rack (TOR) switch to the destination network.

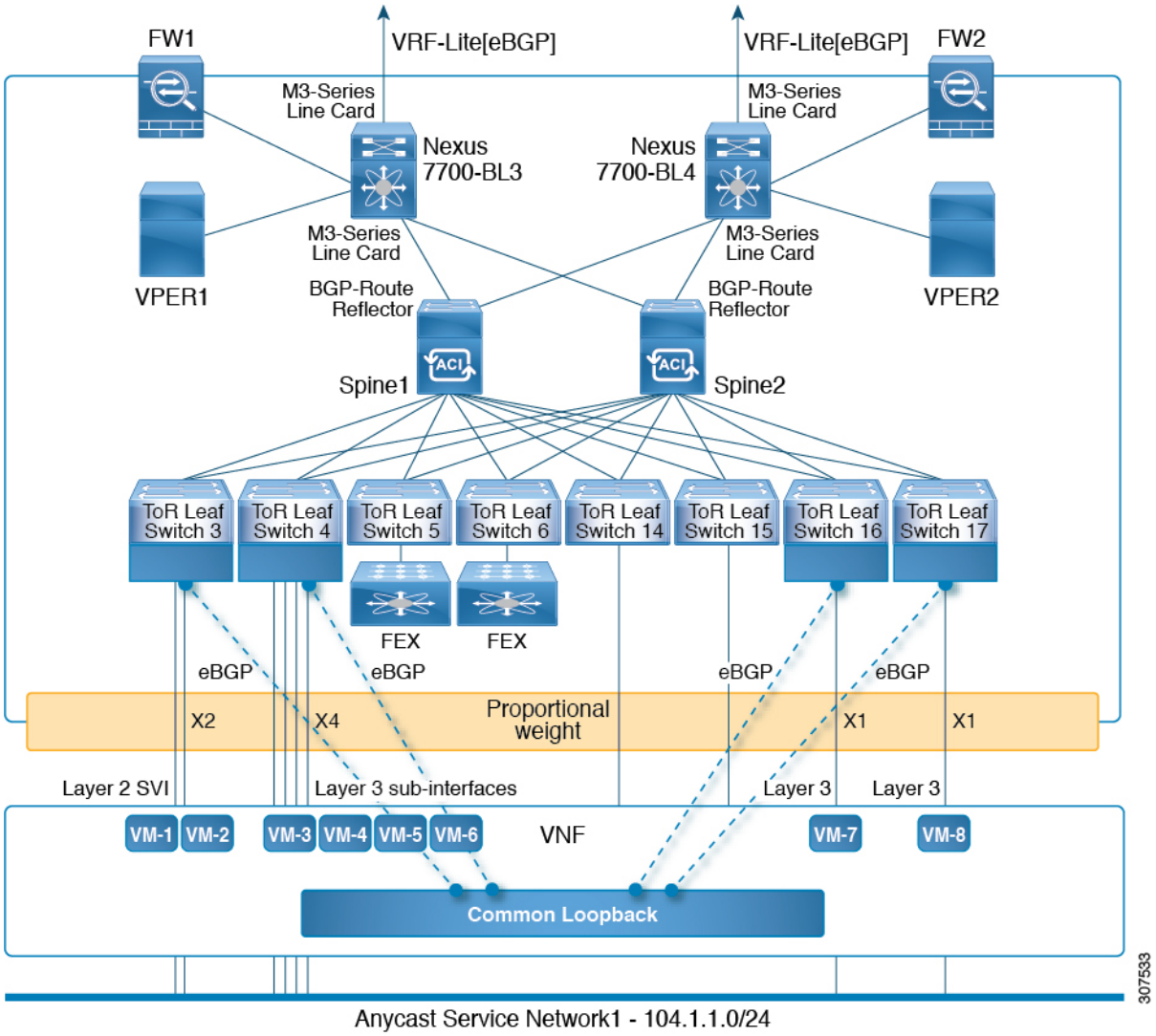
The switch uses BGP to advertise reachability within the fabric using the Layer 2 VPN (L2VPN)/Ethernet VPN (EVPN) address family. If all TOR switches and border leaves are within the same autonomous system (AS), a full internal BGP (iBGP) mesh is configured by using route reflectors or by having each BGP router peer with every other router.

Each TOR and border leaf constitutes a VTEP in the VXLAN fabric. You can use a BGP route reflector to reduce the full mesh BGP sessions across the VTEPs to a single BGP session between a VTEP and the route reflector. Virtual Network Identifiers (VNIs) are globally unique within the overlay. Each Virtual Routing and Forwarding (VRF) instance is mapped to a unique VNI. The inner destination MAC address in the VXLAN header belongs to the receiving VTEP that does the routing of the VXLAN payload. This MAC address is distributed as a BGP attribute along with the EVPN routes.

Multipath flattening is also supported. This leads to flattened IPv4 and IPv6 routes being sent to the FIB. The FIB then has a flattened set of next-hops that are sorted based on the increasing order of IP address.

The alternate deployment topology given below shows how a common loopback address is configured for the BGP connection between the ToR switches and the VNF instance.

Figure 30: Sample Topology for Common Loopback Address



Advertisement of Customer Networks

Customer networks are configured statically or learned locally by using Interior Gateway Protocol (IGP) or external BGP (eBGP) over a Provider Edge(PE)-Customer Edge(CE) link. In the data center fabric, the PE-CE link corresponds to access links from leaf devices to attached hosts (physical devices/VMs) or routers. These networks are redistributed into BGP and advertised to the VXLAN fabric.

The networks that are advertised to the TORs by the Virtual Machines (VMs) attached to them are advertised to the VXLAN fabric as EVPN Type-5 routes with the following:

- The Route Distinguisher (RD) will be the L3VNI's configured RD.
- The gateway IP field will be populated with the next-hop.
- The next-hop of the EVPN route continues to be the VTEP-IP.

- The export route targets of the routes are derived from the configured export route targets of the associated Layer 3 VNI.

Multiple VRF routes may generate the same Type-5 Network Layer Reachability Information (NLRI) differentiated only by the gateway IP field as the routes are advertised with the L3VNI's RD and the gateway IP is not part of the Type-5 NLRI's key. The Network Layer Reachability Information (NLRI) is exchanged between BGP routers using UPDATE messages. These routes are advertised to the EVPN AF by extending the BGP export mechanism to include ECMPs and by using the add-path BGP feature in the EVPN AF.

Each Type-5 route within the EVPN AF that is created by using this feature may have multiple paths that are imported into the corresponding VRF based on the matching of the received route targets and by having ECMP enabled within the VRF and in the EVPN AF. Within the VRF, the route will be a single prefix with multiple paths. Each path represents a Type-5 EVPN path or those paths that are learned locally within the VRF. Those EVPN Type-5 routes that are enabled for this feature will have their next hop (NH) in the VRF derived from their gateway IP field. Use the **export-gateway-ip** command to enable BGP to advertise the gateway IP in the EVPN Type-5 routes.

Use the **maximum-paths mixed** command to enable BGP and the Unicast Routing Information Base (URIB) to consider the following paths as ECMP:

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP.

The paths can be either local to the device (redistributed static or network-originated) or remote (eBGP or iBGP learned over BGP-EVPN or PE-CE). This overrides the default route selection behavior in which local routes are preferred over remote routes. URIB downloads all NHs of the route, including locally learned and user-configured routes, to the Unicast FIB Distribution Module (uFDM)/Forwarding Information Base (FIB).

Legacy Peer Support

Use the **advertise-gw-ip** command to advertise EVPN Type-5 routes with the gateway IP set. TORs will then advertise the gateway IP in the Type-5 NLRI. However, legacy peers running on NX-OS versions older than Cisco NX-OS Release 8.3(1) cannot process the Gateway IP which may lead to unexpected behavior. To prevent this scenario from occurring, use the **no advertise-gw-ip** command. BGP will then set the gateway IP field of the Type-5 NLRI to zero even if the path being advertised has a valid gateway IP.

The **no advertise-gw-ip** command flaps the specified peer session as gracefully as possible. The remote peer triggers graceful restart if the peer supports this capability. When the session is reestablished, the local peer advertises EVPN Type-5 routes with the gateway IP set or with the gateway IP as zero depending on whether the **advertise-gw-ip** command has been used or not. By default, this knob is enabled and the gateway IP field is populated with the appropriate next hop value.

Guidelines and Limitations for Proportional Multipath for VNF

- Static and direct routes have to be redistributed into the BGP when the Proportional Multipath for VNF feature is enabled.
- Routes cannot be redistributed into BGP if OSPF or EIGRP is being used as an IGP.

- If the Proportional Multipath for VNF feature is enabled and the routes are not redistributed into BGP, asymmetric load balancing of traffic may occur as the local routes from URIB may not show up in BGP and on remote TORs as EVPN paths.
- Devices on which mixed-multipath is enabled must support the same load-balancing algorithm.Otherwise, traffic tromboning may occur.
- If a VNF instance is multi-homed to multiple TORs, policies have to be configured or BGP routes have to be originated using a network command. This results in each TOR's connection to the VNF being displayed in the BGP routing table. Each TOR can now see the VNF's direct routes to the other TORs in which the VNF is multi-homed. This allows each TOR to advertise paths to the Gateway IPs through other TORs leading to a next hop resolution loop.

  Consider a scenario in which a VNF is multi-homed to two TORs, TOR1 and TOR2. Individual links to the TORs are addressed as 1.1.1.1 and 2.2.2.2. If the VNF advertises a service 192.168.1.0/24 through the TORs, the TORs advertise EVPN routes to 192.168.1.0/24 with Gateway IPs of 1.1.1.1 and 2.2.2.2 respectively.

  This causes an issue with the Recursive Next Hop (RNH) resolution on a remote TOR (for example, TOR3). The gateway IP is resolved to a /24 route pointing to another gateway IP. That second gateway IP is resolved by a route pointing to the first gateway IP. So, in our scenario, the gateway IP 1.1.1.1 is resolved by 1.1.1.0/24 which points to 2.2.2.2. And 2.2.2.2 is resolved by 2.2.2.0/24 which points to 1.1.1.1.

  The above condition occurs as both TORs connected to the VNF are advertising the VNF’s connected routes. TOR1 is advertising 1.1.1.0/24 and 2.2.2.0/24. However, 1.1.1.0 is advertised without a gateway IP as it is a connected subnet on TOR1. Also, 2.2.2.0 is an OSPF route pointing to 1.1.1.1 which is the VNF’s address connected to TOR1.

  Similarly, TOR2 advertises both subnets and 2.2.2.0/24 is sent without a gateway IP as it is directly connected to TOR2. 1.1.1.0 is learned via OSPF and is sent with a gateway IP of 2.2.2.2 which is the VNF’s address connected to TOR2. 1.1.1.1/32 and 2.2.2.2/32 will not be advertised as they are Adjacency Manager (AM) routes on each TOR.

  This issue does not have a resolution when Type-5 routes are involved. However, this scenario can be avoided if the TORs advertise the gateway IP’s /32 address using a network command. And if the gateway IPs are being resolved by Type-2 EVPN MAC/IP routes, this scenario can be avoided as the gateway IP will be resolved by the /32 IP route.

Default Setting for Proportional Multipath for VNF

Parameter	Default
Proportional Multipath for VNF	Disabled

Configuring Proportional Multipath for VNF

Configuring the Route Reflector

Procedure

Step 1 Enter global configuration mode:

switch# **configure terminal**

Step 2 Assign an autonomous system (AS) number to a device and enter the BGP configuration mode:

switch(config)# **router bgp** *<500000>*

Step 3 Required: Configure Layer-2 VPN EVPN parameters in the VXLAN EVPN fabric:

switch(config-router)# **address-family l2vpn evpn**

Step 4 Configure the capability of sending and receiving additional paths to and from all the neighbors in this address family:

switch(config-router-af)# **additional paths send**

switch(config-router-af)# **additional paths receive**

switch(config-router-af)# **additional paths selection route-map** *<passall>*

Step 5 Exit the address family configuration mode:

switch(config-router-af)# **exit**

Step 6 Exit the BGP configuration mode:

switch(config-router)# **exit**

Step 7 Enter the route-map configuration mode and define the conditions for redistributing routes from one routing protocol to another:

switch(config)# **route-map** *<passall>* **permit** *<10>*

Step 8 Set the path selection criteria:

switch(config-route-map)# **set path-selection all advertise**

Running Configuration

This example shows a running configuration for a route reflector device.

```
configure terminal
  router bgp 500000
    address-family l2vpn evpn
      additional paths send
```

```
    additional paths receive
    additional paths selection route-map passall
route-map passall permit 10
  set path-selection all advertise
```

Configuring the ToR

Procedure

Step 1 Enter global configuration mode:

switch# **configure terminal**

Step 2 Configure BGP:

switch(config)# **router bgp** *<500000>*

Step 3 Required: Configure address family Layer 2 VPN EVPN under router bgp context:

switch(config-router)# **address-family l2vpn evpn**

Step 4 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP

switch(config-router-af)# **maximum-paths mixed** *<32>*

Step 5 The additional-paths configuration for sending:

switch(config-router-af)# **additional paths send**

Step 6 The additional-paths configuration for receiving:

switch(config-router-af)# **additional paths receive**

Step 7 The additional-paths configuration applied for the route-map:

switch(config-router-af)# **additional paths selection route-map** *<passall>*

Step 8 Exits the command mode:

switch(config-router-af)# **exit**

Step 9 Enter the VRF configuration mode:

switch(config-router)# **vrf evpn-tenant-1001**

Step 10 Configure address family for IPv4.

switch(config-router-vrf)# **address-family ipv4 unicast**

Step 11 Enable BGP to advertise the gateway IP in EVPN Type-5 routes:

switch(config-router-vrf-af)# **export-gateway-ip**

Step 12 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP

switch(config-router-vrf-af)# **maximum-paths mixed** *<32>*

Step 13 Exits the command mode:

switch(config-router-vrf-af)# **exit**

Step 14 Enter the address family configuration mode:

switch(config-router-vrf)# **address-family ipv6 unicast**

Step 15 Enable BGP to advertise the gateway IP in EVPN Type-5 routes:

switch(config-router-vrf-af)# **export-gateway-ip**

Step 16 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP

switch(config-router-vrf-af)# **maximum-paths mixed** *<32>*

Step 17 Exits the comand mode:

switch(config-router-vrf-af)# **exit**

Step 18 Configure the route-map:

switch(config)# **route-map passall permit** *<10>*

Step 19 Sets the route-map related to the additional-paths feature:

switch(config-route-map)# **set path-selection all advertise**

Running Configuration

This example shows a running configuration for a ToR device.

```
configure terminal
  router bgp 500000
    address-family l2vpn evpn
      maximum-paths mixed 32
      additional paths send
```

```
    additional paths receive
    additional paths selection route-map passall
  vrf cust_1
    address-family l2vpn evpn
      export-gateway-ip
      maximum-paths mixed 32
route-map passall permit 10
  set path-selection all advertise
```

Configuring the Border Leaf

Procedure

Step 1 Enter global configuration mode:

switch# **configure terminal**

Step 2 Configure BGP:

switch(config)# **router bgp** *<500000>*

Step 3 Required: Configure address family Layer 2 VPN EVPN under router bgp context:

switch(config-router)# **address-family l2vpn evpn**

Step 4 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP.

switch(config-router-af)# **maximum-paths mixed** *<32>*

Step 5 The additional-paths configuration for sending:

switch(config-router-af)# **additional paths send**

Step 6 The additional-paths configuration for receiving:

switch(config-router-af)# **additional paths receive**

Step 7 The additional-paths configuration enables the additional-paths feature:

switch(config-router-af)# **additional paths selection route-map** *<passall>*

Step 8 Exits the command mode:

switch(config-router-af)# **exit**

Step 9 Enter the VRF configuration mode:

switch(config-router)# **vrf evpn-tenant-1001**

Step 10 Configure address family for IPv4:

switch(config-router-vrf)# **address-family ipv4 unicast**

Step 11 Enable BGP to advertise the gateway IP in EVPN Type-5 routes:

switch(config-router-vrf-af)# **export-gateway-ip**

Step 12 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP.

switch(config-router-vrf-af)# **maximum-paths mixed** *<32>*

Step 13 Exit the address family configuration mode:

switch(config-router-vrf-af)# **exit**

Step 14 Enter the address family configuration mode:

switch(config-router-vrf)# **address-family ipv6 unicast**

Step 15 Enable BGP to advertise the gateway IP in EVPN Type-5 routes:

switch(config-router-vrf-af)# **export-gateway-ip**

Step 16 Enables BGP and the Unicast Routing Information Base (URIB) to consider the following paths as Equal Cost Multi Path (ECMP):

- iBGP paths
- eBGP paths
- Paths from other protocols (such as static) that are redistributed or injected into BGP.

switch(config-router-vrf-af)# **maximum-paths mixed** *<32>*

Step 17 Exits the command mode:

switch(config-router-vrf-af)# **exit**

Step 18 Configure the route-map:

switch(config)# **route-map passall permit** *<10>*

Step 19 Sets the route-map related to the additional-paths feature:

switch(config-route-map)# **set path-selection all advertise**

Step 20 Exit the route-map configuration mode.

switch(config-route-map)# **exit**

Step 21 Configure the unicast FIB load sharing algorithm for data traffic.

switch(config)# **ip load-sharing address source-destination rotate** *<32>* **universal-id** *<1>*

Note

- The **universal-id** option sets the random seed for the hash algorithm and shifts the flow from one link to another. You do not need to configure the universal ID. Cisco NX-OS chooses the Universal ID if you do not configure it. The range is from 1 to 4294967295.
- The **rotate** option causes the hash algorithm to rotate the link picking selection so that it does not continually choose the same link across all nodes in the network. It does so by influencing the bit pattern for the hash algorithm. This option shifts the flow from one link to another and load balances the already load-balanced (polarized) traffic from the first ECMP level across multiple links.

  If you specify a **rotate** value, the 64-bit stream is interpreted starting from that bit position in a cyclic rotation. The **rotate** range is from 1 to 63, and the default is 32.
- With multi-tier Layer 3 topology, polarization is possible. To avoid polarization, use a different rotate bit at each tier of the topology.
- To configure a rotation value for port channels, use the **port-channel load-balance src-dst ip-l4port rotate** *rotate*command. For more information on this command, see the *Cisco Nexus 7000 Series NX-OS Interfaces Configuration Guide*.

Running Configuration

This example shows a running configuration for a Border Leaf.

```
configure terminal
  router bgp 500000
    address-family l2vpn evpn
      maximum-paths mixed 32
      additional paths send
      additional paths receive
      additional paths selection route-map passall
    vrf cust_1
      address-family l2vpn evpn
        export-gateway-ip
        maximum-paths mixed 32
  route-map passall permit 10
    set path-selection all advertise
  ip load-sharing address source-destination rotate 32 universal-id 1
```

Configuring a BGP Legacy Peer

Procedure

Step 1 Enter global configuration mode:

switch# **configure terminal**

Step 2 Assign an autonomous system (AS) number to a device and enter the BGP configuration mode:

switch(config)# **router bgp** *<500000>*

Step 3 Configure a BGP neighbor and enter the neighbor configuration mode:

switch(config-router)# **neighbor** *<102.102.102.102>*

Step 4 Specify autonomous system number of the neighbor:

switch(config-router-neighbor)# **remote-as** *<2000000>*

Step 5 Enter the address family configuration mode:

switch(config-router-neighbor)# **address-family l2vpn evpn**

Step 6 Disable the Proportional Multipath for VNF feature for legacy peers:

switch(config-router-neighbor-af)# **no advertise-gw-ip**

Note EVPN Type-5 routes will now be sent with 0 as the gateway IP.

Running Configuration

This example shows a running configuration for a route reflector device.

```
router bgp 500000
  neighbor 102.102.102.102
    remote-as 2000000
    address-family l2vpn evpn
      no advertise-gw-ip
```

Verifying Proportional Multipath for VNF

Command	Purpose
show bgp ipv4 unicast	Displays Border Gateway Protocol (BGP) information for the IPv4 unicast address family.
show bgp l2vpn evpn	Displays BGP information for the Layer-2 Virtual Private Network (L2VPN) Ethernet Virtual Private Network (EVPN) address family.
show ip route	Displays routes from the unicast RIB.

The following example shows how to display BGP information for the L2VPN EVPN address family:

```
switch# show bgp l2vpn evpn 11.1.1.0
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 13.13.13.13:3       //     Remote route
BGP routing table entry for [5]:[0]:[0]:[24]:[11.1.1.0]/224, version 1341
Paths: (3 available, best #1)
Flags: (0x000002) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: eBGP
```

```
  Advertised path-id 1
  Path type: external, path is valid, is best path
             Imported to 2 destination(s)
  Gateway IP: 11.1.1.133
  AS-Path: 2000000 100000 , path sourced external to AS
    11.11.11.11 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 3
      Extcommunity: RT:23456:22001 Route-Import:11.11.11.11:2001 ENCAP:8
          Router MAC:003a.7d7d.1dbd

  Path type: external, path is valid, not best reason: Neighbor Address, multipath
             Imported to 2 destination(s)
  Gateway IP: 11.1.1.233
  AS-Path: 2000000 100 , path sourced external to AS
    33.33.33.33 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 2
      Extcommunity: RT:23456:22001 Route-Import:33.33.33.33:2001 ENCAP:8
          Router MAC:e00e.da4a.589d

  Path type: external, path is valid, not best reason: Neighbor Address, multipath
             Imported to 2 destination(s)
  Gateway IP: 11.1.1.100
  AS-Path: 2000000 500000 , path sourced external to AS
    22.22.22.22 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 1
      Extcommunity: RT:23456:22001 Route-Import:22.22.22.22:2001 ENCAP:8
          Router MAC:e00e.da4a.62a5

  Path-id 1 not advertised to any peer

Route Distinguisher: 4.4.4.4:3    (L3VNI 22001)       //   Local L3VNI
BGP routing table entry for [5]:[0]:[0]:[24]:[11.1.1.0]/224, version 3465
Paths: (3 available, best #1)
Flags: (0x000002) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: eBGP

  Advertised path-id 1
  Path type: external, path is valid, is best path
             Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  Gateway IP: 11.1.1.100
  AS-Path: 2000000 500000 , path sourced external to AS
    22.22.22.22 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 1
      Extcommunity: RT:23456:22001 Route-Import:22.22.22.22:2001 ENCAP:8
          Router MAC:e00e.da4a.62a5

  Path type: external, path is valid, not best reason: newer EBGP path, multipat
h
             Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  Gateway IP: 11.1.1.233
  AS-Path: 2000000 100 , path sourced external to AS
    33.33.33.33 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 2
```

```
      Extcommunity: RT:23456:22001 Route-Import:33.33.33.33:2001 ENCAP:8
          Router MAC:e00e.da4a.589d

  Path type: external, path is valid, not best reason: newer EBGP path, multipat
h
              Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  Gateway IP: 11.1.1.133
  AS-Path: 2000000 100000 , path sourced external to AS
    11.11.11.11 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 3
      Extcommunity: RT:23456:22001 Route-Import:11.11.11.11:2001 ENCAP:8
          Router MAC:003a.7d7d.1dbd

  Path-id 1 not advertised to any peer
```

The following example shows how to display BGP information for the IPv4 unicast address family:

```
switch# show bgp ipv4 unicast 11.1.1.0 vrf cust_1
BGP routing table information for VRF cust_1, address family IPv4 Unicast
BGP routing table entry for 11.1.1.0/24, version 4
Paths: (3 available, best #1)
Flags: (0x80080012) on xmit-list, is in urib, is backup urib route, is in HW
  vpn: version 1093, (0x100002) on xmit-list
Multipath: eBGP iBGP

  Advertised path-id 1, VPN AF advertised path-id 1
  Path type: external, path is valid, is best path, in rib
              Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  AS-Path: 2000000 500000 , path sourced external to AS
    11.1.1.100 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 1
      Extcommunity: RT:23456:22001 Route-Import:22.22.22.22:2001 ENCAP:8
          Router MAC:e00e.da4a.62a5

  Path type: external, path is valid, not best reason: Neighbor Address, multipath, in rib
              Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  AS-Path: 2000000 100 , path sourced external to AS
    11.1.1.233 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 2
      Extcommunity: RT:23456:22001 Route-Import:33.33.33.33:2001 ENCAP:8
          Router MAC:e00e.da4a.589d

  Path type: external, path is valid, not best reason: Neighbor Address, multipath, in rib
              Imported from 13.13.13.13:3:[5]:[0]:[0]:[24]:[11.1.1.0]/224
  AS-Path: 2000000 100000 , path sourced external to AS
    11.1.1.133 (metric 5) from 102.102.102.102 (102.102.102.102)
      Origin incomplete, MED not set, localpref 100, weight 0
      Received label 22001
      Received path-id 3
      Extcommunity: RT:23456:22001 Route-Import:11.11.11.11:2001 ENCAP:8
          Router MAC:003a.7d7d.1dbd

  VRF advertise information:
  Path-id 1 not advertised to any peer

  VPN AF advertise information:
  Path-id 1 not advertised to any peer
```

The following example shows how to display routes from the unicast RIB after the Proportional Multipath for VNF feature has been configured:

```
switch# show ip route 1.1.1.0 vrf cust_1
IP Route Table for VRF "cust_1"
…
1.1.1.0/24, ubest/mbest: 22/0, all-best (0x300003d)
    *via 3.0.0.1, [1/0], 08:13:17, static
         recursive next hop: 3.0.0.1/32
    *via 3.0.0.2, [1/0], 08:13:17, static
         recursive next hop: 3.0.0.2/32
    *via 3.0.0.3, [1/0], 08:13:16, static
         recursive next hop: 3.0.0.3/32
    *via 3.0.0.4, [1/0], 08:13:16, static
         recursive next hop: 3.0.0.4/32
   *via 2.0.0.1, [200/0], 06:09:19, bgp-2, internal, tag 2 (evpn) segid: 3003802 tunnelid:
 0x300003e encap: VXLAN
          BGP-EVPN: VNI=3003802 (EVPN)
         client-specific data: 3b
         recursive next hop: 2.0.0.1/32
         extended route information: BGP origin AS 2 BGP peer AS 2
   *via 2.0.0.2, [200/0], 06:09:19, bgp-2, internal, tag 2 (evpn) segid: 3003802 tunnelid:
 0x300003e encap: VXLAN
          BGP-EVPN: VNI=3003802 (EVPN)
         client-specific data: 3b
         recursive next hop: 2.0.0.2/32
         extended route information: BGP origin AS 2 BGP peer AS 2
```

Refer the topologies in the figures given below for the sample outputs in this section.

Figure 31: Sample Topology - IPv4

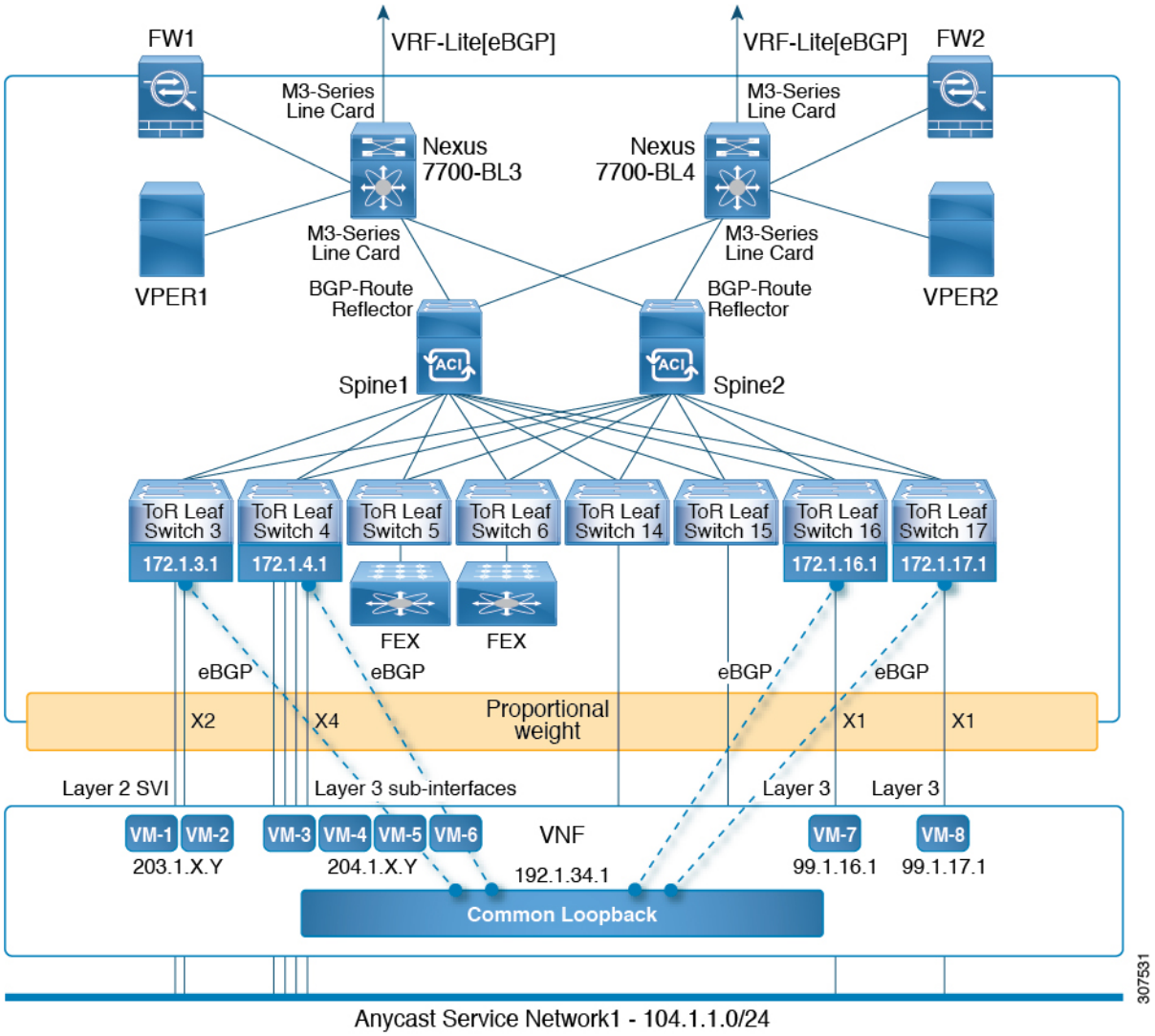
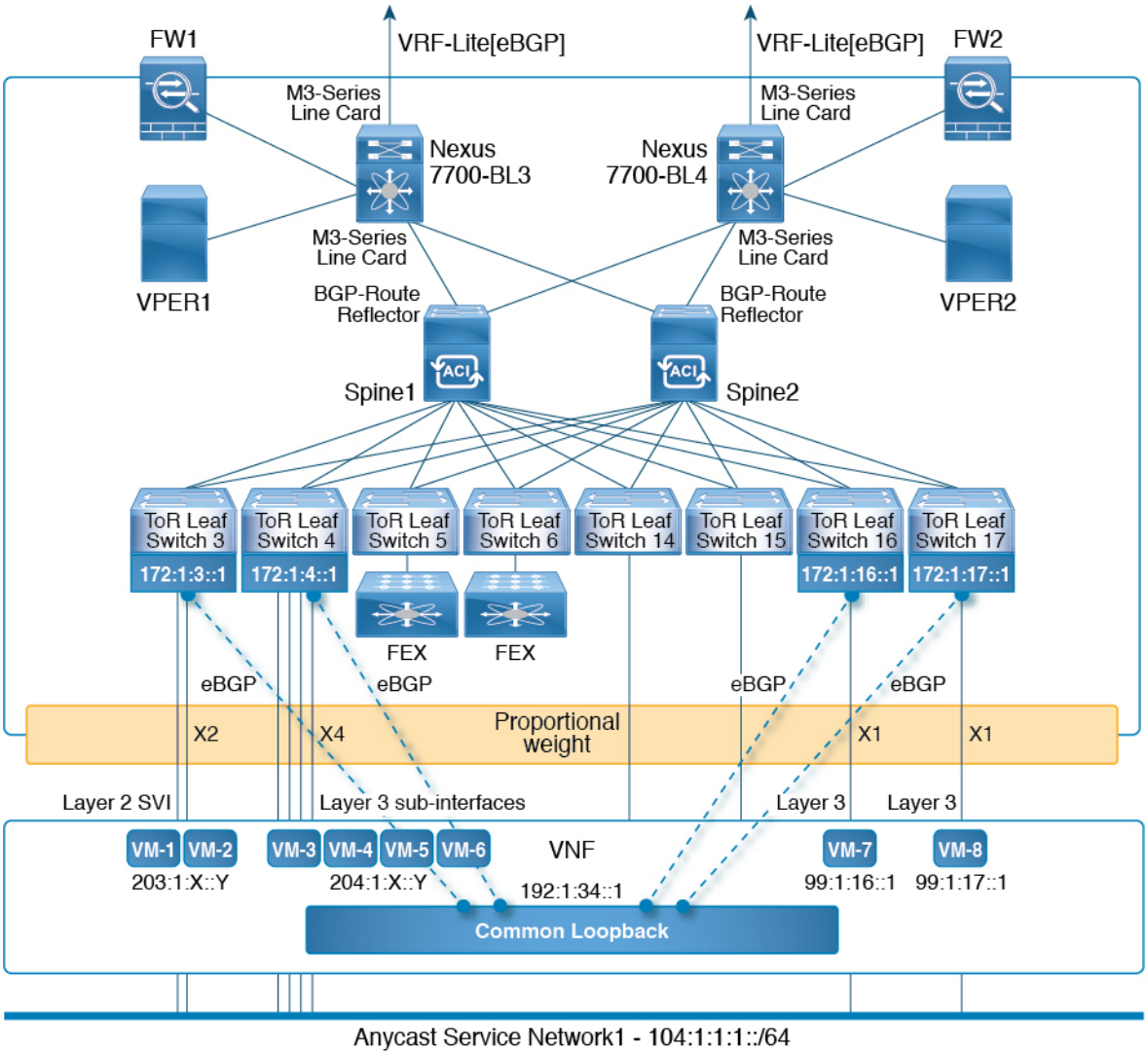


Figure 32: Sample Topology - IPv6



The following example shows how to display the common loopback path for IPv4 addressing scenarios:

```
Nexus-7700-BL3# show ip route 104.1.1.0 vrf os-vrf100
104.1.1.0/24, ubest/mbest: 1/0 time, all-best (0xb011801)
*via 192.1.34.1, [200/0], 12:09:06, bgp-65000, internal, tag 99 (evpn), segid: 10002
tunnelid: 0xb010301 encap: VXLAN
```

The following example shows how to display the total number of recursive next hop (RNH) ECMP paths that point to the gateway IPv4 address in the unicast routing information base (URIB):

```
Nexus-7700-BL3# show ip route 192.1.34.1 vrf os-vrf100
192.1.34.1/32, ubest/mbest: 8/0 time, all-best (0xb011801)
*via 203.1.3.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb010301 encap: VXLAN
*via 203.1.4.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb010301 encap: VXLAN
*via 204.1.5.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb010401 encap: VXLAN
*via 204.1.6.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
```

```
10002 tunnelid: 0xb010401 encap: VXLAN
*via 204.1.7.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb010401 encap: VXLAN
*via 204.1.8.2, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb010401 encap: VXLAN
*via 99.1.16.1, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb011001 encap: VXLAN
*via 99.1.17.1, [200/0], 12:11:39, bgp-65000, internal, tag 65000 (evpn), segid:
10002 tunnelid: 0xb011101 encap: VXLAN
```

The following example shows how to display the total number of RNH ECMP paths that point to the gateway IPv4 address and are flattened in the unicast forwarding information base (UFIB):

```
Nexus-7700-BL3# show forwarding route 104.1.1.0 vrf os-vrf100
slot  9
=======


IPv4 routes for table os-vrf100/base

'*' denotes recursive route
---------------+---------------------------------------+---------------------+-----------------
Prefix         | Next-hop                              | Interface           | Labels
---------------+---------------------------------------+---------------------+-----------------
104.1.1.0/24         11.1.3.1          nve1               (tunnel 0xb010301)
                     11.1.3.1          nve1               (tunnel 0xb010301)
                     11.1.4.1          nve1               (tunnel 0xb010401)
                     11.1.4.1          nve1               (tunnel 0xb010401)
                     11.1.4.1          nve1               (tunnel 0xb010401)
                     11.1.4.1          nve1               (tunnel 0xb010401)
                     11.1.16.1         nve1               (tunnel 0xb011001)
                     11.1.17.1         nve1               (tunnel 0xb011101)
```

The following example shows how to display the common loopback path for IPv6 addressing scenarios:

```
Nexus-7700-BL3# show ipv6 route 104:1:1:1:: vrf os-vrf100
104:1:1:1::/64, ubest/mbest: 1/0, all-best (0xb011801)
*via 192:1:34::1/128, [200/0], 12:19:00, bgp-65000, internal, tag 99 (evpn), segid
10002 tunnel: 0xb010301 encap: VXLAN
```

The following example shows how to display the total number of RNH ECMP paths that point to the gateway IPv6 address in the URIB:

```
Nexus-7700-BL3# show ipv6 route 192:1:34::1 vrf os-vrf100
192:1:34::1/128, ubest/mbest: 8/0, all-best (0xb011801)
*via 203:1:3::2/128, [200/0], 12:20:06, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010301 encap: VXLAN
*via 203:1:4::2/128, [200/0], 12:20:06, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010301 encap: VXLAN
*via 204:1:5::2/128, [200/0], 12:40:59, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010401 encap: VXLAN
*via 204:1:6::2/128, [200/0], 12:40:59, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010401 encap: VXLAN
*via 204:1:7::2/128, [200/0], 12:40:59, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010401 encap: VXLAN
*via 204:1:8::2/128, [200/0], 12:40:59, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb010401 encap: VXLAN
*via 99:1:16::1/128, [200/0], 12:40:38, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb011001 encap: VXLAN
*via 99:1:17::1/128, [200/0], 12:40:45, bgp-65000, internal, tag 65000 (evpn),
segid 10002 tunnel: 0xb011101 encap: VXLAN
```

The following example shows how to display the total number of RNH ECMP paths that point to the gateway IPv6 address and are flattened in the unicast IPv6 forwarding information base (U6FIB):

```
Nexus-7700-BL3# show forwarding ipv6 route 104:1:1:1:: vrf os-vrf100

slot  9
=======


IPv6 routes for table os-vrf100/base

'*' denotes recursive route
-------------------+---------------------------------------+---------------------+----------------
Prefix             | Next-hop                              | Interface           | Labels
-------------------+---------------------------------------+---------------------+----------------
104:1:1:1::/64       11.1.3.1          nve1                (tunnel 0xb010301)
                     11.1.3.1          nve1                (tunnel 0xb010301)
                     11.1.4.1          nve1                (tunnel 0xb010401)
                     11.1.4.1          nve1                (tunnel 0xb010401)
                     11.1.4.1          nve1                (tunnel 0xb010401)
                     11.1.4.1          nve1                (tunnel 0xb010401)
                     11.1.16.1         nve1                (tunnel 0xb011001)
                     11.1.17.1         nve1                (tunnel 0xb011101)
```

The following example shows how to display the IPv4 BGP EVPN route type5 information in a VRF. The sample output shows that the multipath mode is mixed along with the Gateway IP address that is used.

```
Nexus-7700-BL3# show bgp l2vpn evpn 104.1.1.0
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 11.0.3.1:29
BGP routing table entry for [5]:[0]:[0]:[24]:[104.1.1.0]/224, version 1715444
Paths: (2 available, best #2)
Flags: (0x000002) (high32 00000000) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: Mixed

  Path type: internal, path is valid, not best reason: Neighbor Address, no labeled nexthop

  Gateway IP: 192.1.34.1
  AS-Path: 99 98 , path sourced external to AS
    11.1.3.1 (metric 3) from 10.1.2.1 (10.1.2.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.931f
      Originator: 11.0.3.1 Cluster list: 10.1.2.1

  Advertised path-id 1
  Path type: internal, path is valid, is best path, no labeled nexthop
             Imported to 2 destination(s)
             Imported paths list: issu300 default

  Gateway IP: 192.1.34.1
  AS-Path: 99 98 , path sourced external to AS
    11.1.3.1 (metric 3) from 10.1.1.1 (10.1.1.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.931f
      Originator: 11.0.3.1 Cluster list: 10.1.1.1
```

The following example shows how to display the IPv6 BGP EVPN route type5 information in a VRF. The sample output shows that the multipath mode is mixed along with the Gateway IPv6 address that is used.

```
Nexus-7700-BL3# show bgp l2vpn evpn 104:1:1:1::
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 11.0.3.1:29
BGP routing table entry for [5]:[0]:[0]:[64]:[104:1:1:1::]/416, version 1712190
Paths: (2 available, best #2)
```

```
Flags: (0x000002) (high32 00000000) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: Mixed

  Path type: internal, path is valid, not best reason: Neighbor Address, no labeled nexthop

  Gateway IP: 192:1:34::1
  AS-Path: 99 98 , path sourced external to AS
    11.1.3.1 (metric 3) from 10.1.2.1 (10.1.2.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.931f
      Originator: 11.0.3.1 Cluster list: 10.1.2.1

  Advertised path-id 1
  Path type: internal, path is valid, is best path, no labeled nexthop
             Imported to 2 destination(s)
             Imported paths list: issu300 default

  Gateway IP: 192:1:34::1
  AS-Path: 99 98 , path sourced external to AS
    11.1.3.1 (metric 3) from 10.1.1.1 (10.1.1.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.931f
      Originator: 11.0.3.1 Cluster list: 10.1.1.1
```

The following example displays IPv4 Multipath hashing information. This will display the route selected for a particular source and destination address along with the VTEP and the egress interface.

```
Nexus-7700-BL3# show routing hash 200.1.1.1 104.1.1.1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: address source-destination
Universal-id seed: 0xffffffff
Hash for VRF "os-vrf100"
Hash Type is 1
Hashing to path *11.1.4.1 Eth10/24%default
  MPLS[2]: Label=10002 E=0 TTL=0 S=0
  MPLS[1]: Label=10002 E=0 TTL=0 S=0
  MPLS[0]: Label=10002 E=0 TTL=0 S=0
For route:
104.1.1.0/24, ubest/mbest: 1/0 time, all-best (0xb011801)
    *via 192.1.34.1, [200/0], 12:41:23, bgp-65000, internal, tag 99 (evpn), segid: 10002
tunnelid: 0xb010301 encap: VXLAN
```

The following example displays IPv6 Multipath hashing information. This will display the route selected for a particular source and destination address along with the VTEP and the egress interface.

```
Nexus-7700-BL3# show routing ipv6 hash 200:1:1:1::1 104:1:1:1::1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: address source-destination
Universal-id seed: 0xffffffff
No IP protocol specified, defaulting to UDP
Hash for VRF "os-vrf100"
Hash Type is 1
Hashing to path *::ffff:11.1.14.1 Ethernet10/24
  MPLS[1]: Label=10002 E=0 TTL=0 S=0
  MPLS[0]: Label=10002 E=0 TTL=0 S=0
For route:
104:1:1:1::/64, ubest/mbest: 26/0, all-best (0xb011801)
 *via 192:1:34::1/128, [200/0], 00:01:32, bgp-65000, internal, tag 99 (evpn), segid 10002
tunnel: 0xb010301 encap: VXLAN
```

The following example shows how to display the common loopback path for IPv4 addessing scenarios:

```
ToR-Leaf-Switch-3# show ip route 104.1.1.0 vrf os-vrf100
104.1.1.0/24, ubest/mbest: 1/0, all-best (0xb010301)
*via 192.1.34.1, [20/0], 13:24:29, bgp-65000, external, tag 99
```

The following example shows how to display the total number of local and remote RNH ECMP paths that point to the gateway IPv4 address in the URIB:

```
ToR-Leaf-Switch-3# show ip route 192.1.34.1 vrf os-vrf100
192.1.34.1/32, ubest/mbest: 8/0, all-best (0xb010301)
    *via 203.1.3.2, Vlan3, [1/0], 14:46:05, static
    *via 203.1.4.2, Vlan4, [1/0], 14:46:04, static
    *via 204.1.5.2, [200/0], 01:53:23, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb010401 encap: VXLAN

    *via 204.1.6.2, [200/0], 01:52:08, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb010401 encap: VXLAN

    *via 204.1.7.2, [200/0], 01:53:23, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb010401 encap: VXLAN

    *via 204.1.8.2, [200/0], 01:52:08, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb010401 encap: VXLAN

    *via 99.1.16.1, [200/0], 14:45:14, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb011001 encap: VXLAN

    *via 99.1.17.1, [200/0], 14:45:14, bgp-65000, internal, tag 65000 (evpn) segid: 10002
tunnelid: 0xb011101 encap: VXLAN
```

The following example shows how to display the total number of local and remote RNH ECMP paths that point to the gateway IPv4 address in the UFIB:

```
ToR-Leaf-Switch-3# show forwarding route 104.1.1.0 vrf os-vrf100

slot  1
=======


IPv4 routes for table os-vrf100/base

------------------+-----------------------------------+--------------------+---------------+---------------
Prefix            | Next-hop                          | Interface          | Labels
          | Partial Install
------------------+-----------------------------------+--------------------+---------------+---------------
104.1.1.0/24
                    203.1.3.2                           Vlan3
                    203.1.4.2                           Vlan4
                    11.1.4.1          nve1
                    11.1.4.1          nve1
                    11.1.4.1          nve1
                    11.1.4.1          nve1
                    11.1.16.1         nve1
                    11.1.17.1         nve1
```

The following example shows how to display the common loopback path for IPv6 addressing scenarios:

```
ToR-Leaf-Switch-3# show ipv6 route 104:1:1:1:: vrf os-vrf100
104:1:1:1::/64, ubest/mbest: 1/0, all-best (0xb010301)
*via 192:1:34::1/128, [20/0], 02:04:49, bgp-65000, external, tag 99
```

The following example shows how to display the total number of local and remote RNH ECMP paths that point to the gateway IPv6 address in the URIB:

```
ToR-Leaf-Switch-3# show ipv6 route 192:1:34::1 vrf os-vrf100

192:1:34::1/128, ubest/mbest: 8/0, all-best (0xb010301)
```

```
    *via 203:1:3::2, Vlan3, [1/0], 15:00:43, static
    *via 203:1:4::2, Vlan4, [1/0], 15:00:42, static
    *via 204:1:8::2/128, [200/0], 02:06:54, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb010401 encap: VXLAN

    *via 204:1:7::2/128, [200/0], 02:06:54, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb010401 encap: VXLAN

    *via 204:1:5::2/128, [200/0], 02:08:09, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb010401 encap: VXLAN

    *via 204:1:6::2/128, [200/0], 02:08:09, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb010401 encap: VXLAN

    *via 99:1:16::1/128, [200/0], 02:08:09, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb011001 encap: VXLAN

    *via 99:1:17::1/128, [200/0], 02:08:09, bgp-65000, internal, tag 65000 (evpn) segid
10002 tunnel: 0xb011101 encap: VXLAN
```

The following example shows how to display the total number of local and remote RNH ECMP paths that point to the gateway IPv6 address in the U6FIB:

```
N93K-EX-LF3# show forwarding ipv6 route 104:1:1:1:: vrf os-vrf100

slot  1
=======


IPv6 routes for table os-vrf100/base

---------------+-----------------------------------+------------------+---------------+---------------
Prefix            | Next-hop                                  | Interface            | Labels
          | Partial Install
---------------+-----------------------------------+------------------+---------------+---------------
104:1:1:1::/64
                     203:1:3::2                                  Vlan3
                     203:1:4::2                                  Vlan4
                     11.1.4.1               nve1
                     11.1.4.1               nve1
                     11.1.4.1               nve1
                     11.1.4.1               nve1
                     11.1.16.1              nve1
                     11.1.17.1              nve1
```

The following example shows how to display the IPv4 BGP EVPN route type5 information in a VRF. The sample output shows that the multipath mode is mixed along with the Gateway IP address that is used.

```
ToR-Leaf-Switch-3# show bgp l2vpn evpn 104.1.1.0
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 11.0.4.1:28
BGP routing table entry for [5]:[0]:[0]:[24]:[104.1.1.0]/224, version 26579
Paths: (2 available, best #2)
Flags: (0x000002) (high32 00000000) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: Mixed

  Path type: internal, path is valid, not best reason: Neighbor Address, no labeled nexthop

  Gateway IP: 192.1.34.1
  AS-Path: 99 98 , path sourced external to AS
    11.1.4.1 (metric 3) from 10.1.2.1 (10.1.2.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
```

```
    Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.918f
    Originator: 0.0.0.0 Cluster list: 10.1.2.1

  Advertised path-id 1
  Path type: internal, path is valid, is best path, no labeled nexthop
             Imported to 2 destination(s)
             Imported paths list: issu300 default
  Gateway IP: 192.1.34.1
  AS-Path: 99 98 , path sourced external to AS
    11.1.4.1 (metric 3) from 10.1.1.1 (10.1.1.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 10002
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.918f
      Originator: 0.0.0.0 Cluster list: 10.1.1.1
```

The following example shows how to display the IPv6 BGP EVPN route type5 information in a VRF. The sample output shows that the multipath mode is mixed along with the Gateway IP address that is used.

```
ToR-Leaf-Switch-3# show bgp l2vpn evpn 104:1:1:1::
BGP routing table information for VRF default, address family L2VPN EVPN
Route Distinguisher: 11.0.4.1:28
BGP routing table entry for [5]:[0]:[0]:[64]:[104:1:1:1::]/416, version 21947
Paths: (2 available, best #1)
Flags: (0x000002) (high32 00000000) on xmit-list, is not in l2rib/evpn, is not in HW
Multipath: Mixed

  Advertised path-id 1
  Path type: internal, path is valid, is best path, no labeled nexthop
             Imported to 2 destination(s)
             Imported paths list: issu300 default
  Gateway IP: 192:1:34::1
  AS-Path: 99 98 , path sourced external to AS
    11.1.4.1 (metric 3) from 10.1.1.1 (10.1.1.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 51300
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.918f
      Originator: 0.0.0.0 Cluster list: 10.1.1.1

  Path type: internal, path is valid, not best reason: Neighbor Address, no labeled nexthop

  Gateway IP: 192:1:34::1
  AS-Path: 99 98 , path sourced external to AS
    11.1.4.1 (metric 3) from 10.1.2.1 (10.1.2.1)
      Origin IGP, MED not set, localpref 100, weight 0
      Received label 51300
      Received path-id 1
      Extcommunity: RT:65000:51300 ENCAP:8 Router MAC:2cd0.2d56.918f
      Originator: 0.0.0.0 Cluster list: 10.1.2.1
```

The following example displays IPv4 Multipath hashing information. This will display the route selected for a particular source and destination address along with the VTEP and the egress interface. In this example, a local path is selected. This indicates that the border leaf and the access leaf have the same hash result.

```
ToR-Leaf-Switch-3# show routing hash 200.1.1.1 104.1.1.1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: address source-destination gtpu-teid
No IPv4 protocol specified, defaulting to UDP
Hash for VRF "os-vrf100"
Hashing to path *203.1.3.2
    Out Interface: Vlan3

  MPLS[1]: Label=10002 E=0 TTL=0 S=0
  MPLS[0]: Label=10002 E=0 TTL=0 S=0
```

```
For route:
104.1.1.0/24, ubest/mbest: 1/0, all-best (0xb010301)
    *via 192.1.34.1, [20/0], 15:39:16, bgp-65000, external, tag 99
```

The following example also displays IPv4 Multipath hashing information. In this example, a remote path is selected. This indicates that the border leaf and the access leaf have different hash results.

```
ToR-Leaf-Switch-LF17# show routing hash 200.1.2.1 104.1.2.1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: address source-destination gtpu-teid
No IPv4 protocol specified, defaulting to UDP
Hash for VRF "os-vrf100"
Hashing to path *11.1.16.1
    Out Interface: Eth1/50

  MPLS[1]: Label=10002 E=0 TTL=0 S=0
  MPLS[0]: Label=10002 E=0 TTL=0 S=0
For route:
104.1.2.0/24, ubest/mbest: 1/0, all-best (0xb011101)
    *via 192.1.34.1, [20/0], 15:54:05, bgp-65000, external, tag 99
```

Now, go to Leaf 16 and and use the **show routing hash** command. The sample output is as given below.

```
ToR-Leaf-Switch-LF16# show routing hash 200.1.2.1 104.1.2.1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: address source-destination gtpu-teid
No IPv4 protocol specified, defaulting to UDP
Hash for VRF "os-vrf100"
Hashing to path *99.1.16.1
    Out Interface: Eth1/48

  MPLS[1]: Label=10002 E=0 TTL=0 S=0
  MPLS[0]: Label=10002 E=0 TTL=0 S=0
For route:
104.1.2.0/24, ubest/mbest: 1/0, all-best (0xb011001)
    *via 192.1.34.1, [20/0], 15:58:13, bgp-65000, external, tag 99
```

The following example displays IPv6 Multipath hashing information. This will display the route selected for a particular source and destination address along with the VTEP and the egress interface. In this example, a local path is selected. This indicates that the border leaf and the access leaf have the same hash result.

```
ToR-Leaf-Switch-3# show routing ipv6 hash 200:1:1:1::1 104:1:1:1::1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: 6
No IP protocol specified, defaulting to UDP

Hash for VRF "os-vrf100"
Hash Type is 3
Hashing to path *203:1:3::2
Out Interface  Vlan3
For route:
104:1:1:1::/64, ubest/mbest: 1/0, all-best (0xb010301)
    *via 192:1:34::1/128, [20/0], 03:08:55, bgp-65000, external, tag 99
```

The following example also displays IPv6 Multipath hashing information. In this example, a remote path is selected. This indicates that the border leaf and the access leaf have different hash results.

```
ToR-Leaf-Switch-LF17#  show routing ipv6 hash 200:1:1:2::1 104:1:1:2::1 vrf os-vrf100
Load-share parameters used for software forwarding:
load-share mode: 6
No IP protocol specified, defaulting to UDP

Hash for VRF "os-vrf100"
Hash Type is 3
Hashing to path *::ffff:11.1.3.1
```

```
Out Interface  Ethernet1/50
For route:
104:1:1:2::/64, ubest/mbest: 1/0, all-best (0xb011101)
    *via 192:1:34::1/128, [20/0], 03:13:12, bgp-65000, external, tag 99
```

Now, go to Leaf 3 and and use the **show routing ipv6 hash** command. The sample output is as given below.

```
ToR-Leaf-Switch-LF3# show routing ipv6 hash 200:1:1:2::1 104:1:1:2::1 vrf os-vrf100

Load-share parameters used for software forwarding:
load-share mode: 6
No IP protocol specified, defaulting to UDP

Hash for VRF "os-vrf100"
Hash Type is 3
Hashing to path *203:1:3::2
Out Interface  Vlan3
For route:
104:1:1:2::/64, ubest/mbest: 1/0, all-best (0xb010301)
    *via 192:1:34::1/128, [20/0], 03:19:09, bgp-65000, external, tag 99
```

Configuration Examples for Proportional Multipath for VNF

This example shows a running BGP TOR configuration to enable BGP peering with the spine in a different autonomous system.

```
vrf context cust_1
  vni 22001
  rd auto
  address-family ipv4 unicast
    route-target import 23456:22001
    route-target import 23456:22001 evpn
    route-target export 23456:22001
    route-target export 23456:22001 evpn
    route-target both auto
    route-target both auto evpn

    ip route 200.1.1.1 via 10.1.1.1 tag 100
    ip route 200.1.1.1 via 10.1.2.1 tag 100

  route-map REDIST 10 permit 10
  route-map passall permit 10
    set path-selection all advertise

router bgp 500000
  address-family l2vpn evpn
    maximum-paths mixed 32
    additional-paths send
    additional-paths receive
    additional-paths selection route-map passall

  neighbor 102.102.102.102
    remote-as 2000000
    update-source loopback0
    ebgp-multihop 255
    address-family ipv4 unicast
      allowas-in 3
      send-community extended
    address-family l2vpn evpn
      allowas-in 3
```

```
      send-community extended
  neighbor 105.105.105.105
    remote-as 2000000
    update-source loopback0
    ebgp-multihop 255
    address-family ipv4 unicast
      allowas-in 3
      send-community extended
    address-family l2vpn evpn
      allowas-in 3
      send-community extended
      no advertise-gw-ip

vrf cust_1
  address-family ipv4 unicast
    advertise l2vpn evpn
    wait-igp-convergence
    redistribute direct route-map REDIST
    redistribute static route-map REDIST
    export-gateway-ip
    maximum-paths mixed 32
```

This example shows a running legacy peer configuration.

```
router bgp 2000000
  neighbor 4.4.4.4
    remote-as 500000
    update-source loopback0
    ebgp-multihop 255
    address-family ipv4 unicast
    disable-peer-as-check
    send-community extended

  address-family l2vpn evpn
    disable-peer-as-check
    send-community extended

  neighbor 6.6.6.6
    remote-as 100
    update-source loopback0
    ebgp-multihop 255
    address-family ipv4 unicast
      send-community extended
      address-family ipv4 mvpn
        disable-peer-as-check
        send-community extended
        route-map setnh_unchanged out

    address-family l2vpn evpn
      disable-peer-as-check
      send-community extended
      route-map setnh_unchanged out
      no advertise-gw-ip
```

Additional References for Proportional Multipath for VNF

This section describes additional information related to implementing Proportional Multipath for VNF.

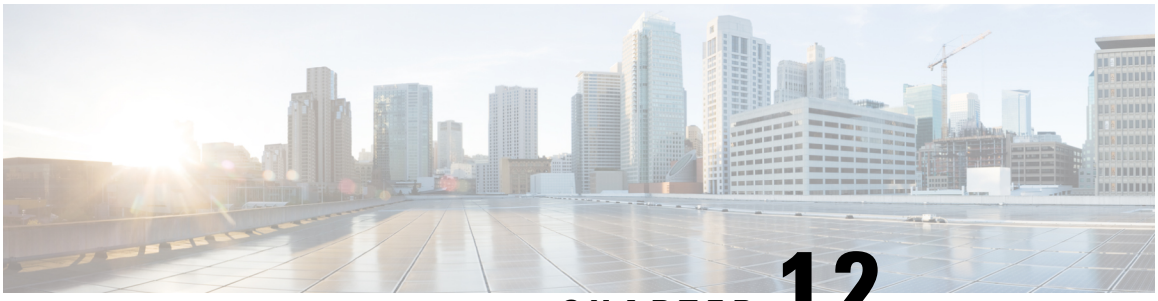
Related Documents

Related Topic	Document Title
Cisco NX-OS licensing	Cisco NX-OS Licensing Guide
Verified Scalability	Cisco Nexus 7000 Series NX-OS Verified Scalability Guide

Feature History for Proportional Multipath for VNF

This table lists the release history for this feature.

Feature Name	Release	Information
Proportional Multipath for VNF	8.3(1)	In Network Function Virtualization Infrastructures (NFVi), anycast services networks are advertised from multiple Virtual Network Functions (VNFs). The Proportional Multipath for VNF feature enables advertising of all the available next hops to a given destination network. This feature enables the switch to consider all paths to a given route as equal cost multipath (ECMP) allowing the traffic to be forwarded using all the available links stretched across multiple ToRs.



CHAPTER 12

Centralized VRF Route-Leaking for VXLAN BGP EVPN Fabrics

VXLAN BGP EVPN uses MP-BGP and its route-policy concept to import and export prefixes. The ability of this very extensive route-policy model allows to leak routes from one VRF to another VRF and vice-versa; any combination of custom VRF or VRF default can be used. VRF route-leaking is a switch-local function at specific to a location in the network, the location where the cross-VRF route-target import/export configuration takes place (leaking point). The forwarding between the different VRFs follows the control-plane, the location of where the configuration for the route-leaking is performed - hence Centralized VRF route-leaking. With the addition of VXLAN BGP EVPN, the leaking point requires to advertise the cross-VRF imported/exported route and advertise them towards the remote VTEPs or External Routers.

The advantage of Centralized VRF route-leaking is that only the VTEP acting as leaking point requires the special capabilities needed, while all other VTEPs in the network are neutral to this function.

You can also enable the VRFs in the EVPN fabric to access shared services in a specific VRF. These shared services are provided by a GOLF or Data Center Interconnect (DCI) device. The hosts located behind the internet or core can access the hosts inside the Application Centric Infrastructure (ACI) fabric. Traffic emanating from the north or core towards the south or ACI fabric will reach the default or shared VRF. The routes are identified for the traffic to reach the host located in the ACI fabric by leaking of host routes from tenant VRFs into the default VRF or internet VRF. This functionality is supported only on Cisco Nexus 7000 M3-Series I/O modules.

The **show ip route** command outputs for a scenario in which the routes from VRF A are leaked to VRF B are as given below. The output logs display the leaked routes along with the source VRF from which the routes were leaked.

```
device# show ip route 100.1.1.0/24 vrf VRF-A
IP Route Table for VRF "VRF-A"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>
100.1.1.0/24, ubest/mbest: 1/0 time
*via 10.1.0.34%default, [20/0], 19:34:43, bgp-200, external, tag 6500 (evpn),
segid: 2850822 tunnelid: 0xa010022 encap: VXLAN

device# show ip route 100.1.1.0/24 vrf VRF-B
IP Route Table for VRF "VRF-B"
'*' denotes best ucast next-hop
'**' denotes best mcast next-hop
'[x/y]' denotes [preference/metric]
'%<string>' in via output denotes VRF <string>
100.1.1.0/24, ubest/mbest: 1/0 time
```

```
*via 10.1.0.34%default, [20/0], 19:34:50, bgp-200, external, tag 6500 (evpn),
segid: 2850822 tunnelid: 0xa010022 src vrf: VRF-A encap: VXLAN
```

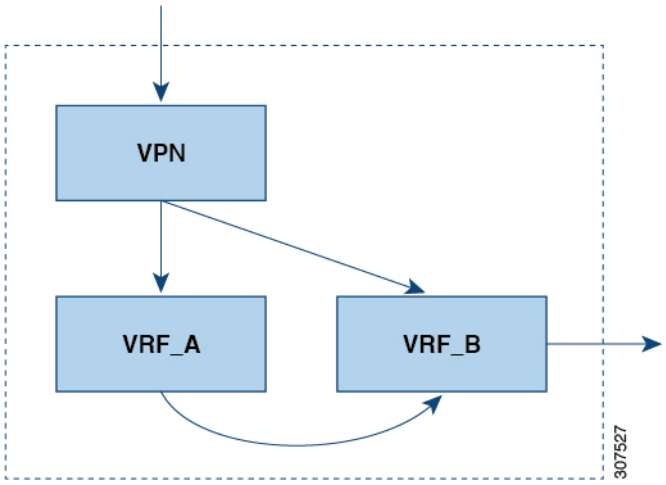

Configuring Route Leaking

Guidelines and Limitations for Centralized VRF Route-Leaking

The following are the guidelines and limitations for Centralized VRF Route-Leaking:

- Each prefix must be imported into each VRF for full cross-VRF reachability.
- The **feature bgp** command is required for the **export vrf default** command.
- If a VTEP has a less specific local prefix in its VRF, the VTEP might not be able to reach a more specific prefix in a different VRF.
- VXLAN routing in hardware and packet reencapsulation at VTEP is required for Centralized VRF Route-Leaking with BGP EVPN.
- The **feature bgp** command has to be used to enable usage of the **export vrf** and **import vrf** commands.
- Duplicate paths pointing to the same remote path may exist in case there are VRFs on which reimporting of routes has been enabled along with the same route-targets. This may have an impact on the performance and memory.

  There may be path duplication due to improper usage of route targets. Consider the following topology followed by the configuration used.




```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both RT_A
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target import RT_A
```

This configuration leads to VRF_B importing the same route via the VPN and VRF_A. This results in loss of multi-path as there are two separate paths in VRF_B having the same next hop but with different source route distinguishers.

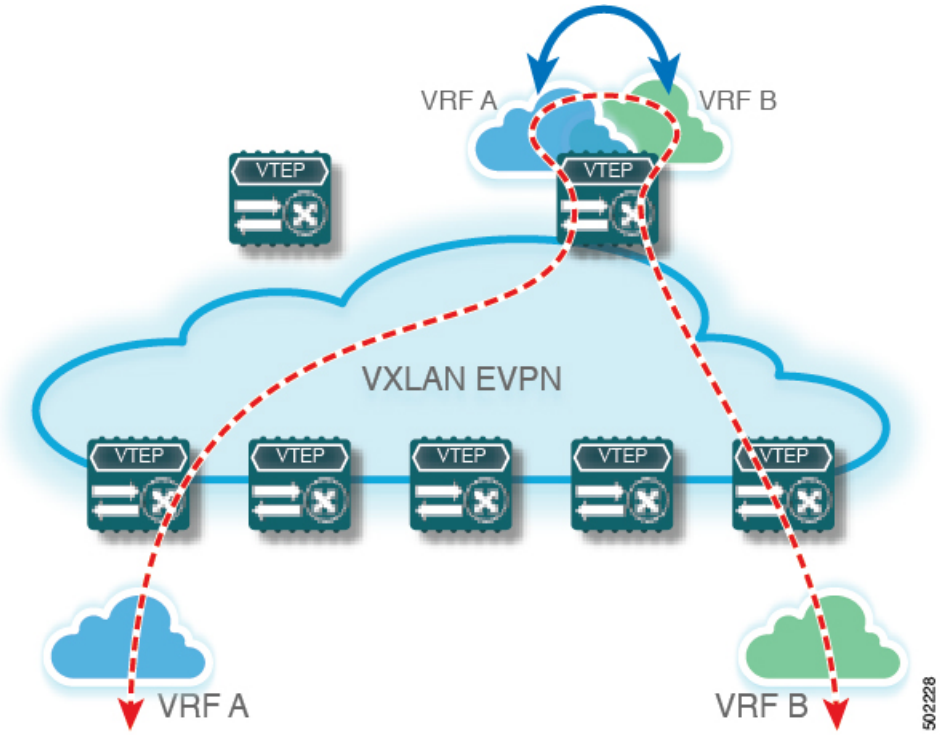
- Be careful when using local route leaking in a leaf-to-leaf case, where border-leaf routers (BLs) are leaking between the same VRFs. This scenario is more prone to routing loops. We recommend using inbound route-maps to exclude the imported routes from other BLs.
- After a remote path gets withdrawn, it can take up to 20 seconds more for BGP to completely clean up the path.

Centralized VRF Route-Leaking Brief - Specific Prefixes Between Custom VRF

Some pointers are given below:

- The Centralized VRF route-leaking for VXLAN BGP EVPN fabrics is depicted within Figure 2.
- BGP EVPN prefixes are cross-VRF leaked by exporting them from VRF Blue with an import into VRF Red and vice-versa. The Centralized VRF route-leaking is performed on the centralized Routing-Block (RBL) and could be any or multiple VTEPs.
- Configured less specific prefixes (aggregates) are advertised from the Routing-Block to the remaining VTEPs in the respective destination VRF.
- BGP EVPN does not export prefixes that were previously imported to prevent the occurrence of routing loops.

Figure 33: Centralized VRF Route-Leaking - Specific Prefixes with Custom VRF



Configuring Centralized VRF Route-Leaking - Specific Prefixes between Custom VRF

Configuring VRF Context on the Routing-Block VTEP

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enter global configuration mode.
Step 2	**vrf context** *vrf-name*	Configure the VRF.
Step 3	**vni** *number*	Specify the VNI. The VNI associated with the VRF is often referred to as Layer-3 VNI, L3VNI or L3VPN. The L3VNI is configured as common identifier across the participating VTEPs.
Step 4	**rd auto**	Specify the VRFs Route Distinguisher (RD). The RD uniquely identifies a VTEP within a L3VNI.

	Command or Action	Purpose
Step 5	**address-family ipv4 unicast**	Configure the IPv4 Unicast address-family. Required for IPv4 over VXLAN with IPv4 underlay.
Step 6	**route-target both {auto** | *as:vni*}	Configure the Route Target (RT) for import/export of IPv4 prefixes within the IPv4 unicast address-family The Route Target (RT) is used for a per-VRF prefix import/export policy. If *as:vni* is entered, the value is in the format of ASN:NN, ASN4:NN, or IPv4:NN.
Step 7	**route-target both {auto** | *as:vni* }**evpn**	Configure the Route Target (RT) for import/export of IPv4 prefixes within the IPv4 unicast address-family The Route Target (RT) is used for a per-VRF prefix import/export policy. If *as:vni* is entered, the value is in the format of ASN:NN, ASN4:NN, or IPv4:NN.
Step 8	**route-target import** *rt-from-different-vrf*	Configure the Route Target (RT) for importing IPv4 prefixes from the leaked-from VRF (ie AS:VNI).
Step 9	**route-target import** *rt-from-different-vrf* **evpn**	Configure the Route Target (RT) for importing IPv4 prefixes from the leaked-from VRF (ie AS:VNI).

Configuring the BGP VRF instance on the Routing-Block

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router bgp** *autonomous-system number*	Configure BGP.
Step 3	**vrf** *vrf-name*	Specify the VRF.
Step 4	**address-family ipv4 unicast**	Configure address family for IPv4
Step 5	**advertise l2vpn evpn**	Enable the advertisement of EVPN routes within IPv4 address-family.
Step 6	**aggregate-address** *prefix/mask*	Create less specific prefix aggregate into the destination VRF.
Step 7	**maximum-paths ibgp** *number*	Enabling equal cost multipathing (ECMP) for iBGP prefixes.

	Command or Action	Purpose
Step 8	**maximum-paths** *number*	Enabling equal cost multipathing (ECMP) for eBGP prefixes

Example - Configuration Centralized VRF Route-Leaking - Specific Prefixes Between Custom VRF

Configuring VXLAN BGP EVPN Routing-Block

The VXLAN BGP EVPN Routing-Block acts as centralized route-leaking point. The leaking configuration is localized such that control-plane leaking and data-path forwarding follow the same path. Most significantly is the VRF configuration of the Routing-Block and the advertisement of the less specific prefixes (aggregates) into the respective destination VRFs.

```
vrf context Blue
  vni 51010
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    route-target import 65002:51020
    route-target import 65002:51020 evpn
!
vlan 2110
  vn-segment 51010
!
interface Vlan2110
  no shutdown
  mtu 9216
  vrf member Blue
  no ip redirects
  ip forward
!
vrf context Red
  vni 51020
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    route-target import 65002:51010
    route-target import 65002:51010 evpn
!
vlan 2120
  vn-segment 51020
!
interface Vlan2120
  no shutdown
  mtu 9216
  vrf member Blue
  no ip redirects
  ip forward
!
interface nve1
  no shutdown
  host-reachability protocol bgp
  source-interface loopback1
  member vni 51010 associate-vrf
  member vni 51020 associate-vrf
!
router bgp 65002
  vrf Blue
```

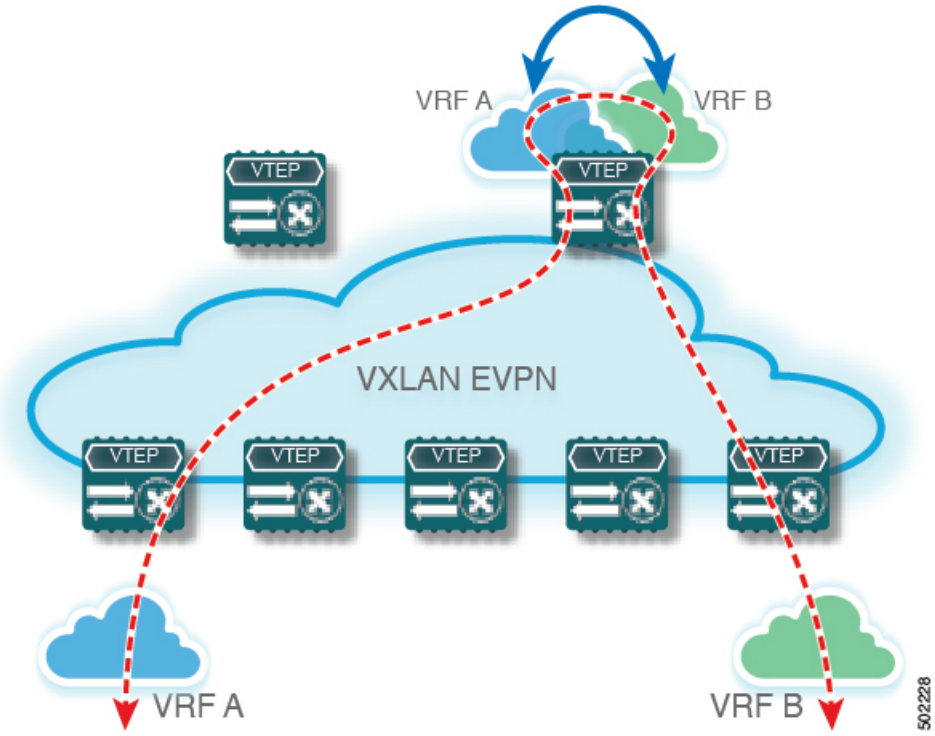
```
  address-family ipv4 unicast
    advertise l2vpn evpn
    aggregate-address 10.20.0.0/16
    maximum-paths ibgp 2
    Maximum-paths 2
vrf Red
  address-family ipv4 unicast
    advertise l2vpn evpn
    aggregate-address 10.10.0.0/16
    maximum-paths ibgp 2
    Maximum-paths 2
```

Centralized VRF Route-Leaking Brief - Shared Internet with Custom VRF

Some pointers follow:

- The Shared Internet with VRF route-leaking for VXLAN BGP EVPN fabrics is depicted in the following figure.
- The default-route is made exported from the Shared Internet VRF and re-advertisement within VRF Blue and VRF Red on the Border Node.
- Ensure the default-route in VRF Blue and VRF Red is not leaked to the Shared Internet VRF.
- The less specific prefixes for VRF Blue and VRF Red are exported for the Shared Internet VRF and re-advertised as necessary.
- Configured less specific prefixes (aggregates) that are advertised from the Border Node to the remaining VTEPs to the destination VRF (Blue or Red).
- BGP EVPN does not export prefixes that were previously imported to prevent the occurrence of routing loops.

Figure 34: Centralized VRF Route-Leaking - Shared Internet with Custom VRF



Configuring Centralized VRF Route-Leaking - Shared Internet with Custom VRF

Configuring Internet VRF on Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enter global configuration mode.
Step 2	**vrf context** *vrf-name*	Configure the VRF.
Step 3	**vni** *number*	Specify the VNI. The VNI associated with the VRF is often referred to as Layer-3 VNI, L3VNI or L3VPN. The L3VNI is configured as common identifier across the participating VTEPs.
Step 4	**ip route 0.0.0.0/0** *next-hop*	Configure default-route in shared internet VRF to external router (example).
Step 5	**rd auto**	Specify the VRFs Route Distinguisher (RD).

	Command or Action	Purpose
		The RD uniquely identifies a VTEP within a L3VNI.
Step 6	**address-family ipv4 unicast**	Configure the IPv4 Unicast address-family. Required for IPv4 over VXLAN with IPv4 underlay.
Step 7	**route-target both {auto** | *as:vni*}	Configure the Route Target (RT) for import/export of EVPN and IPv4 prefixes within the IPv4 unicast address-family.
Step 8	**route-target both** *shared-vrf-rt* **evpn**	Configure a special Route Target (RT) for the import/export of the shared IPv4 prefixes. Additional import/export map for further qualification is supported

Configuring Shared Internet BGP Instance on the Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router bgp** *autonomous-system number*	Configure BGP.
Step 3	**vrf** *vrf-name*	Specify the VRF.
Step 4	**address-family ipv4 unicast**	Configure address family for IPv4
Step 5	**advertise l2vpn evpn**	Enable the advertisement of EVPN routes within IPv4 address-family.
Step 6	**aggregate-address** *prefix/mask*	Create less specific prefix aggregate into the destination VRF.
Step 7	**maximum-paths ibgp** *number*	Enabling equal cost multipathing (ECMP) for iBGP prefixes.
Step 8	**maximum-paths** *number*	Enabling equal cost multipathing (ECMP) for eBGP prefixes.

Configuring Custom VRF on Border Node

This procedure applies equally to IPv6

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**ip prefix-list** *name* **seq 5 permit 0.0.0.0/0**	Configure IPv4 prefix-list for default-route filtering.
Step 3	**route-map** *name* **deny 10**	Create route-map with leading deny statement to prevent the default-route of being leaked.
Step 4	**match ip address prefix-list** *name*	Match against the IPv4 prefix-list that contains the default-route.
Step 5	**route-map** *name* **permit 20**	Create route-map with trailing allow statement to advertise non-matching routes via route-leaking.

Configuring Custom VRF Context on the Border Node - 1

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Configure the VRF.
Step 3	**vni** *number*	Specify the VNI. The VNI associated with the VRF is often referred to as Layer-3 VNI, L3VNI or L3VPN. The L3VNI is configured as the common identifier across the participating VTEPs.
Step 4	**rd auto**	Specify the VRFs Route Distinguisher (RD). The Route Distinguisher (RD) uniquely identifies a VTEP within a L3VNI.
Step 5	**ip route 0.0.0.0/0 Null0**	Configure default-route in common VRF to attract traffic towards Border Node with Shared Internet VRF.
Step 6	**address-family ipv4 unicast**	Configure the IPv4 Unicast address-family. Required for IPv4 over VXLAN with IPv4 underlay.
Step 7	**route-target both {auto** | *as:vni***}**	Configure the Route Target (RT) for import/export of IPv4 prefixes within the IPv4 unicast address-family The Route Target (RT) is used for a per-VRF prefix import/export

	Command or Action	Purpose
		policy. If *as:vni* is entered, the value is in the format of ASN:NN, ASN4:NN, or IPv4:NN.
Step 8	**route-target both {auto** | *as:vni***} evpn**	Configure the Route Target (RT) for import/export of IPv4 prefixes within the IPv4 unicast address-family The Route Target (RT) is used for a per-VRF prefix import/export policy. If *as:vni* is entered, the value is in the format of ASN:NN, ASN4:NN, or IPv4:NN.
Step 9	**import map** *name*	Apply a route-map on routes being imported into this routing table.

Configuring Custom VRF Instance in BGP on the Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router bgp** *autonomous-system-number*	Configure BGP.
Step 3	**vrf** *vrf-name*	Specify the VRF.
Step 4	**address-family ipv4 unicast**	Configure address family for IPv4.
Step 5	**advertise l2vpn evpn**	Enable the advertisement of EVPN routes within IPv4 address-family.
Step 6	**network 0.0.0.0/0**	Creating IPv4 default-route network statement.
Step 7	**maximum-paths ibgp** *number*	Enabling equal cost multipathing (ECMP) for iBGP prefixes.
Step 8	**maximum-paths** *number*	Enabling equal cost multipathing (ECMP) for eBGP prefixes.

Example - Configuration Centralized VRF Route-Leaking - Shared Internet with Custom VRF

An example of Centralized VRF route-leaking with Shared Internet VRF

Configuring VXLAN BGP EVPN Border Node for Shared Internet VRF

The VXLAN BGP EVPN Border Node provides a centralized Shared Internet VRF. The leaking configuration is localized such that control-plane leaking and data-path forwarding following the same path. Most significantly is the VRF configuration of the Border Node and the advertisement of the default-route and less specific prefixes (aggregates) into the respective destination VRFs.

```
vrf context Shared
  vni 51099
  ip route 0.0.0.0/0 10.9.9.1
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    route-target both 99:99
    route-target both 99:99 evpn
!
vlan 2199
  vn-segment 51099
!
interface Vlan2199
  no shutdown
  mtu 9216
  vrf member Shared
  no ip redirects
  ip forward
!
ip prefix-list PL_DENY_EXPORT seq 5 permit 0.0.0.0/0
!
route-map RM_DENY_IMPORT deny 10
 match ip address prefix-list PL_DENY_EXPORT
route-map RM_DENY_IMPORT permit 20
!
vrf context Blue
  vni 51010
  ip route 0.0.0.0/0 Null0
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    route-target both 99:99
    route-target both 99:99 evpn
    import map RM_DENY_IMPORT
!
vlan 2110
  vn-segment 51010
!
interface Vlan2110
  no shutdown
  mtu 9216
  vrf member Blue
  no ip redirects
  ip forward
!
vrf context Red
  vni 51020
  ip route 0.0.0.0/0 Null0
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    route-target both 99:99
    route-target both 99:99 evpn
    import map RM_DENY_IMPORT
!
vlan 2120
  vn-segment 51020
!
interface Vlan2120
  no shutdown
  mtu 9216
```

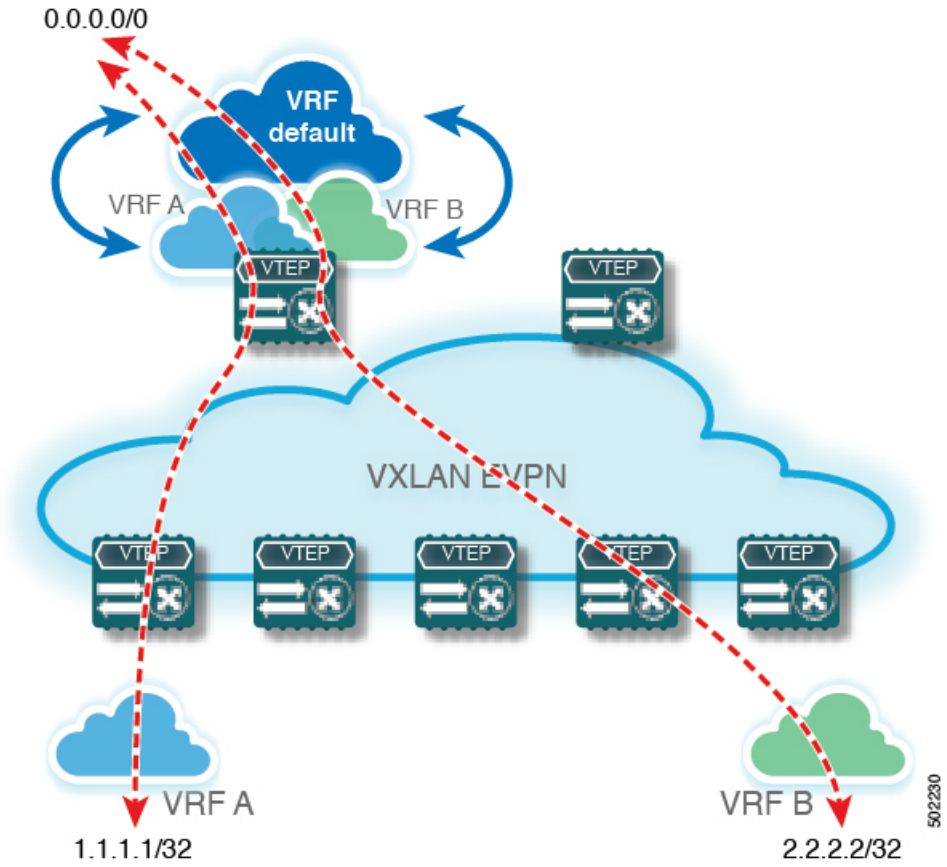
```
  vrf member Blue
  no ip redirects
  ip forward
!
interface nve1
  no shutdown
  host-reachability protocol bgp
  source-interface loopback1
  member vni 51099 associate-vrf
  member vni 51010 associate-vrf
  member vni 51020 associate-vrf
!
router bgp 65002
  vrf Shared
    address-family ipv4 unicast
      advertise l2vpn evpn
      aggregate-address 10.10.0.0/16
      aggregate-address 10.20.0.0/16
      maximum-paths ibgp 2
      maximum-paths 2
  vrf Blue
    address-family ipv4 unicast
      advertise l2vpn evpn
      network 0.0.0.0/0
      maximum-paths ibgp 2
      maximum-paths 2
  vrf Red
    address-family ipv4 unicast
      advertise l2vpn evpn
      network 0.0.0.0/0
      maximum-paths ibgp 2
      maximum-paths 2
```

Centralized VRF Route-Leaking Brief - Shared Internet with VRF Default

Some pointers are given below:

- The Shared Internet with VRF route-leaking for VXLAN BGP EVPN fabrics is depicted within Figure 4.
- The default-route is made exported from VRF default and re-advertisement within VRF Blue and VRF Red on the Border Node.
- Ensure the default-route in VRF Blue and VRF Red is not leaked to the Shared Internet VRF
- The less specific prefixes for VRF Blue and VRF Red are exported to VRF default and re-advertised as necessary.
- Configured less specific prefixes (aggregates) that are advertised from the Border Node to the remaining VTEPs to the destination VRF (Blue or Red).
- BGP EVPN does not export prefixes that were previously imported to prevent the occurrence of routing loops.

Figure 35: Centralized VRF Route-Leaking - Shared Internet with VRF Default



Configuring Centralized VRF Route-Leaking - Shared Internet with VRF Default

Configuring VRF Default on Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**ip route 0.0.0.0/0** *next-hop*	Configure default-route in VRF default to external router (example)

Configuring BGP Instance for VRF Default on the Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router bgp** *autonomous-system number*	Configure BGP.
Step 3	**address-family ipv4 unicast**	Configure address family for IPv4.
Step 4	**aggregate-address** *prefix/mask*	Create less specific prefix aggregate in VRF default.
Step 5	**maximum-paths** *number*	Enabling equal cost multipathing (ECMP) for eBGP prefixes.

Configuring Custom VRF on Border Node

This procedure applies equally to IPv6

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**ip prefix-list** *name* **seq 5 permit 0.0.0.0/0**	Configure IPv4 prefix-list for default-route filtering.
Step 3	**route-map** *name* **deny 10**	Create route-map with leading deny statement to prevent the default-route of being leaked.
Step 4	**match ip address prefix-list** *name*	Match against the IPv4 prefix-list that contains the default-route.
Step 5	**route-map** *name* **permit 20**	Create route-map with trailing allow statement to advertise non-matching routes via route-leaking.

Configuring Filter for Permitted Prefixes from VRF Default on the Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**route-map** *name* **permit 10**	Create route-map with allow statement to advertise routes via route-leaking to the customer VRF and subsequently remote VTEPs.

Configuring Custom VRF Context on the Border Node - 2

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Configure the VRF.
Step 3	**vni** *number*	Specify the VNI. The VNI associated with the VRF is often referred to as Layer-3 VNI, L3VNI or L3VPN. The L3VNI is configured as common identifier across the participating VTEPs.
Step 4	**rd auto**	Specify the VRFs Route Distinguisher (RD). The Route Distinguisher (RD) uniquely identifies a VTEP within a L3VNI.
Step 5	**ip route 0.0.0.0/0 Null0**	Configure default-route in common VRF to attract traffic towards Border Node with Shared Internet VRF.
Step 6	**address-family ipv4 unicast**	Configure the IPv4 Unicast address-family. Required for IPv4 over VXLAN with IPv4 underlay.
Step 7	**route-target both auto** | *AS:VNI*	Configure the Route Target (RT) for import/export of EVPN and IPv4 prefixes within the IPv4 unicast address-family.
Step 8	**route-target both auto** | *AS:VNI* **evpn**	Configure the Route Target (RT) for import/export of EVPN and IPv4 prefixes within the IPv4 unicast address-family.
Step 9	**route-target both** *shared-vrf-rt*	Configure a special Route Target (RT) for the import/export of the Shared IPv4 prefixes. Additional import/export map for further qualification is supported
Step 10	**route-target both** *shared-vrf-rt* **evpn**	Configure a special Route Target (RT) for the import/export of the Shared IPv4 prefixes. Additional import/export map for further qualification is supported
Step 11	**import vrf default map** *name*	Permits all routes, from VRF default, from being imported into the custom VRF according to the specific route-map.

Configuring Custom VRF Instance in BGP on the Border Node

This procedure applies equally to IPv6.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**router bgp** *autonomous-system-number*	Configure BGP.
Step 3	**vrf** *vrf-name*	Specify the VRF.
Step 4	**address-family ipv4 unicast**	Configure address family for IPv4.
Step 5	**advertise l2vpn evpn**	Enable the advertisement of EVPN routes within IPv4 address-family.
Step 6	**network 0.0.0.0/0**	Creating IPv4 default-route network statement.
Step 7	**maximum-paths ibgp** *number*	Enabling equal cost multipathing (ECMP) for iBGP prefixes.
Step 8	**maximum-paths** *number*	Enabling equal cost multipathing (ECMP) for eBGP prefixes.

Example - Configurating Centralized VRF Route-Leaking - VRF Default with Custom VRF

An example of Centralized VRF route-leaking with VRF default

Configuring VXLAN BGP EVPN Border Node for VRF Default

The VXLAN BGP EVPN Border Node provides centralized access to VRF default. The leaking configuration is localized such that control-plane leaking and data-path forwarding following the same path. Most significantly is the VRF configuration of the Border Node and the advertisement of the default-route and less specific prefixes (aggregates) into the respective destination VRFs.

```
ip route 0.0.0.0/0 10.9.9.1
!
ip prefix-list PL_DENY_EXPORT seq 5 permit 0.0.0.0/0
!
route-map permit 10
match ip address prefix-list PL_DENY_EXPORT
route-map RM_DENY_EXPORT permit 20
route-map RM_PERMIT_IMPORT permit 10
!
vrf context Blue
  vni 51010
  ip route 0.0.0.0/0 Null0
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    import vrf default map RM_PERMIT_IMPORT
    export vrf default 100 map RM_DENY_EXPORT allow-vpn
!
vlan 2110
```

```
  vn-segment 51010
!
interface Vlan2110
  no shutdown
  mtu 9216
  vrf member Blue
  no ip redirects
  ip forward
!
vrf context Red
  vni 51020
  ip route 0.0.0.0/0 Null0
  rd auto
  address-family ipv4 unicast
    route-target both auto
    route-target both auto evpn
    import vrf default map RM_PERMIT_IMPORT
    export vrf default 100 map RM_DENY_EXPORT allow-vpn
!
vlan 2120
  vn-segment 51020
!
interface Vlan2120
  no shutdown
  mtu 9216
  vrf member Blue
  no ip redirects
  ip forward
!
interface nve1
  no shutdown
  host-reachability protocol bgp
  source-interface loopback1
  member vni 51010 associate-vrf
  member vni 51020 associate-vrf
!
router bgp 65002
  address-family ipv4 unicast
      aggregate-address 10.10.0.0/16
      aggregate-address 10.20.0.0/16
      maximum-paths 2
      maximum-paths ibgp 2
  vrf Blue
    address-family ipv4 unicast
      advertise l2vpn evpn
      network 0.0.0.0/0
      maximum-paths ibgp 2
      maximum-paths 2
  vrf Red
    address-family ipv4 unicast
      advertise l2vpn evpn
      network 0.0.0.0/0
      maximum-paths ibgp 2
      maximum-paths 2
```

Configuring Routes Imported from a VPN to Leak into the Default VRF

You can configure a VRF to allow routes that are imported from a BGP VPN to be exported to the default VRF. Use this procedure for a non-default VRF. Use this procedure for a non-default VRF.

If you have not already enabled BGP, enable it now using the **feature bgp** command.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Creates a new VRF and enters VRF configuration mode. The name can be any case-sensitive, alphanumeric string up to 32 characters.
Step 3	**address-family ipv4 unicast**	Configure the address family for IPv4.
Step 4	**export vrf default** [*prefix-limit*]**map** *route-map* **allow-vpn**	Configures the current VRF to allow routes that are imported from a BGP VPN to be exported to the default VRF.

Configuring Routes Leaked from the Default-VRF to Export to a VPN

You can configure a VRF to allow routes leaked from the default VRF to be exported to a BGP VPN. Use this procedure for a non-default VRF.

If you have not already enabled BGP, enable it now using the **feature bgp** command.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Creates a new VRF and enters VRF configuration mode. The name can be any case-sensitive, alphanumeric string up to 32 characters.
Step 3	**address-family** *address-family sub-family*	Configure the address family for IPv4.
Step 4	**import vrf default** [*prefix-limit*]**map** *route-map* **advertise-vpn**	Configures the current VRF to allow routes imported from the default VRF to be exported to a BGP VPN.

Configuring Routes Imported from a VPN to Export to a VRF

You can configure a VRF to allow VPN imported routes to be exported to another VRF. Use this procedure for non-default VRFs.

If you have not already enabled BGP, enable it now using the **feature bgp** command.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Creates a new VRF and enters VRF configuration mode. The name can be any case-sensitive, alphanumeric string up to 32 characters.
Step 3	**address-family** *address-family sub-family*	Configure the address family for IPv4.
Step 4	**export vrf allow-vpn**	Configures a VRF to allow routes imported from a BGP VPN to be exported to a non-default VRF.

Configuring Routes Imported from a VRF to Export to a VPN

You can configure a VRF to allow routes imported from another VRF to be exported to a BGP VPN. Use this procedure for non-default VRFs.

If you have not already enabled BGP, enable it now using the **feature bgp** command.

Procedure

	Command or Action	Purpose
Step 1	**configure terminal**	Enters global configuration mode.
Step 2	**vrf context** *vrf-name*	Creates a new VRF and enters VRF configuration mode. The name can be any case-sensitive, alphanumeric string up to 32 characters.
Step 3	**address-family** *address-family sub-family*	Configure the address family for IPv4.
Step 4	**import vrf advertise-vpn**	Configures the current VRF to allow routes that are imported from another VRF to be exported to a BGP VPN.

Configuration Examples

Configuring BGP VPN to Default VRF Reachability

In this example, the configuration enables route re-importation through an intermediate VRF, called VRF_A, which is between the VPN and the default VRF.

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto evpn
  import vrf default map MAP_1 advertise-vpn
  export vrf default map MAP_1 allow-vpn
```

Route re-importation is enabled by using the **advertise-vpn** option to control importing routes from the VPN into VRF_A, and **allow-vpn** for the export map to control exporting VPN-imported routes from VRF_A out to the default VRF. Configuration occurs on the intermediate VRF.

Configuring VPN to VRF-Lite Reachability

In this example, the VPN connects to a tenant VRF, called VRF_A. VRF_A connects a VRF-Lite, called VRF-B. The configuration enables VPN imported routes to be leaked from VRF_A to VRF_B.

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto
  route-target both auto evpn
  route-target import 3:3
  route-target export 2:2
  import vrf advertise-vpn
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target both 1:1
  route-target import 2:2
  route-target export 3:3
```

Route leaking between the two is enabled by using the **allow-vpn** in an export map configured in VRF_A (tenant). The export map in VRF_A allows route imported from the VPN to be leaked into the VRF_B. Routes processed by the export map have the **route-map export** and **export-map** attributes added to the route's set of route targets. The import map uses **advertise-vpn** which enables routes that are imported from the VRF-Lite for be exported out to the VPN.

After a route leaks between the VRFs, it is reoriginated and its route targets are replaced by the route target export and export map attributes specified by the new VRF's configuration.

Leaf-to-Leaf Reachability

In this example, two VPNs exist and two VRFs exist. VPN_1 is connected to VRF_A and VPN_2 is connected to VRF_B. Both VRFs are route distinguishers (RDs).

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto
  route-target both auto evpn
  route-target import 3:3
  route-target export 2:2
  import vrf advertise-vpn
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target both 1:1
  route-target import 2:2
  route-target export 3:3
  import vrf advertise-vpn
  export vrf allow-vpn
```

Route leaking between the two is enabled by using the **allow-vpn**in an export map configured in VRF_A and VRF_B. VPN imported routes have **route-map export** and **export-map** attributes added to the route's set of route targets. The import map uses **advertise-vpn** option which enables routes that are imported from each VRF to be exported out to the VPN.

After a route leaks between the VRFs, it is reoriginated and its route targets are replaced by the route target export and export map attributes specified by the new VRF's configuration.

Leaf-to-Leaf with Loop Prevention

In the leaf-to-leaf configuration, you can inadvertently cause loops between the BLs that are leaking between the same VRFs unless you are careful with your route maps:

- You can use an inbound route map in each BL to deny updates from every other BL.
- If a BL originates a route, a standard community can be applied, which enables other BLs to accept the routes. This community is then stripped in the receiving BL.

In the following example, VTEPs 3.3.3.3, 4.4.4.4 and 5.5.5.5 are the BLs.

```
ip prefix-list BL_PREFIX_LIST seq 5 permit 3.3.3.3/32
ip prefix-list BL_PREFIX_LIST seq 10 permit 4.4.4.4/32
ip prefix-list BL_PREFIX_LIST seq 20 permit 5.5.5.5/32
ip community-list standard BL_COMMUNITY seq 10 permit 123:123
route-map INBOUND_MAP permit 5
match community BL_COMMUNITY
set community none
route-map INBOUND_MAP deny 10
match ip next-hop prefix-list BL_PREFIX_LIST
route-map INBOUND_MAP permit 20
route-map OUTBOUND_SET_COMM permit 10
match evpn route-type 2 mac-ip
set community 123:123
route-map SET_COMM permit 10
set community 123:123
route-map allow permit 10

vrf context vni100
vni 100
address-family ipv4 unicast
route-target import 2:2
route-target export 1:1
route-target both auto
route-target both auto evpn
import vrf advertise-vpn
export vrf allow-vpn

vrf context vni200
vni 200
address-family ipv4 unicast
route-target import 1:1
route-target export 2:2
route-target both auto
route-target both auto evpn
import vrf advertise-vpn
export vrf allow-vpn

router bgp 100
template peer rr
remote-as 100
update-source loopback0
```

```
address-family l2vpn evpn
send-community
send-community extended
route-map INBOUND_MAP in
route-map OUTBOUND_SET_COMM out
neighbor 101.101.101.101
inherit peer rr
neighbor 102.102.102.102
inherit peer rr
vrf vni100
address-family ipv4 unicast
network 3.3.3.100/32 route-map SET_COMM
vrf vni200
address-family ipv4 unicast
network 3.3.3.200/32 route-map SET_COMM
```

In this example, the tenant VRFs for the border leaf (BL) router can leak traffic by enabling extra import export flows, and the route targets in the route maps determine where the routes are imported from or exported to.

Multipath in a VRF

In this example, a VPN has multiple incoming paths. This configuration enables route leaking through an intermediate VRF, called VRF_A, which is between the VPN and another VRF, named VRF_B. Assume that multipathing is enabled in VRF_A.

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto evpn
  route-target export 3:3
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target import 3:3
```

Route leaking is enabled by **allow-vpn** in the export map configured in VRF_A. When two paths for a given prefix are learnt from a VPN and imported into VRF_A, two different paths exist in VRF_B with the same source RD (VRF_A's local RD). Each route is distinguished by the original source RD (remote RD).

Path Duplication

In this example, the configuration enables a single VPN path to be imported into both VRF_A and VRF_B. Because VRF_A is configured with **export vrf allow-vpn**, VRF_A also leaks its routes into VRF_B. VRF_B then has two paths with same source RD (VRF_A's local RD), each one distinguished by the original source RD (remote RD).

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target import 1:1 evpn
  route-target export 1:1 evpn
  route-target export 2:2
export vrf allow-vpn
 vrf context VRF_B
  address-family ipv4 unicast
  route-target import 1:1 evpn
  route-target import 2:2
```

This configuration creates a situation in which multipathing does not exist.

Displaying Centralized Route Leaking Information

The following table shows the commands that display information about the Centralized Route Leaking feature.

Command	Action
show bgp vrf *vrf-name* process	For a default or non-default VRF, shows the enabled state (Yes or No) of the **import advertise-vpn** and **export allow-vpn** options.
show bgp vrf *vrf-name* ipv4 unicast *prefix*	Shows information about imported paths, including a list of destinations a route has been imported from.

Route re-importation is enabled by using the **advertise-vpn** option to control importing routes from the VPN into VRF_A, and **allow-vpn** for the export map to control exporting VPN-imported routes from VRF_A out to the default VRF. Configuration occurs on the intermediate VRF.

Configuring VPN to VRF-Lite Reachability

In this example, the VPN connects to a tenant VRF, called VRF_A. VRF_A connects a VRF-Lite, called VRF-B. The configuration enables VPN imported routes to be leaked from VRF_A to VRF_B.

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto
  route-target both auto evpn
  route-target import 3:3
  route-target export 2:2
  import vrf advertise-vpn
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target both 1:1
  route-target import 2:2
  route-target export 3:3
```

Route leaking between the two is enabled by using the **allow-vpn** in an export map configured in VRF_A (tenant). The export map in VRF_A allows route imported from the VPN to be leaked into the VRF_B. Routes processed by the export map have the **route-map export** and **export-map** attributes added to the route's set of route targets. The import map uses **advertise-vpn** which enables routes that are imported from the VRF-Lite for be exported out to the VPN.

After a route leaks between the VRFs, it is reoriginated and its route targets are replaced by the route target export and export map attributes specified by the new VRF's configuration.

Leaf-to-Leaf Reachability

In this example, two VPNs exist and two VRFs exist. VPN_1 is connected to VRF_A and VPN_2 is connected to VRF_B. Both VRFs are route distinguishers (RDs).

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto
  route-target both auto evpn
```

```
  route-target import 3:3
  route-target export 2:2
  import vrf advertise-vpn
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target both 1:1
  route-target import 2:2
  route-target export 3:3
  import vrf advertise-vpn
  export vrf allow-vpn
```

Route leaking between the two is enabled by using the **allow-vpn**in an export map configured in VRF_A and VRF_B. VPN imported routes have **route-map export** and **export-map** attributes added to the route's set of route targets. The import map uses **advertise-vpn** option which enables routes that are imported from each VRF to be exported out to the VPN.

After a route leaks between the VRFs, it is reoriginated and its route targets are replaced by the route target export and export map attributes specified by the new VRF's configuration.

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In the leaf-to-leaf configuration, you can inadvertently cause loops between the BLs that are leaking between the same VRFs unless you are careful with your route maps:

- You can use an inbound route map in each BL to deny updates from every other BL.
- If a BL originates a route, a standard community can be applied, which enables other BLs to accept the routes. This community is then stripped in the receiving BL.

In the following example, VTEPs 3.3.3.3, 4.4.4.4 and 5.5.5.5 are the BLs.

```
ip prefix-list BL_PREFIX_LIST seq 5 permit 3.3.3.3/32
ip prefix-list BL_PREFIX_LIST seq 10 permit 4.4.4.4/32
ip prefix-list BL_PREFIX_LIST seq 20 permit 5.5.5.5/32
ip community-list standard BL_COMMUNITY seq 10 permit 123:123
route-map INBOUND_MAP permit 5
match community BL_COMMUNITY
set community none
route-map INBOUND_MAP deny 10
match ip next-hop prefix-list BL_PREFIX_LIST
route-map INBOUND_MAP permit 20
route-map OUTBOUND_SET_COMM permit 10
match evpn route-type 2 mac-ip
set community 123:123
route-map SET_COMM permit 10
set community 123:123
route-map allow permit 10

vrf context vni100
vni 100
address-family ipv4 unicast
route-target import 2:2
route-target export 1:1
route-target both auto
route-target both auto evpn
import vrf advertise-vpn
export vrf allow-vpn

vrf context vni200
vni 200
```

```
address-family ipv4 unicast
route-target import 1:1
route-target export 2:2
route-target both auto
route-target both auto evpn
import vrf advertise-vpn
export vrf allow-vpn

router bgp 100
template peer rr
remote-as 100
update-source loopback0
address-family l2vpn evpn
send-community
send-community extended
route-map INBOUND_MAP in
route-map OUTBOUND_SET_COMM out
neighbor 101.101.101.101
inherit peer rr
neighbor 102.102.102.102
inherit peer rr
vrf vni100
address-family ipv4 unicast
network 3.3.3.100/32 route-map SET_COMM
vrf vni200
address-family ipv4 unicast
network 3.3.3.200/32 route-map SET_COMM
```

In this example, the tenant VRFs for the border leaf (BL) router can leak traffic by enabling extra import export flows, and the route targets in the route maps determine where the routes are imported from or exported to.

Multipath in a VRF

In this example, a VPN has multiple incoming paths. This configuration enables route leaking through an intermediate VRF, called VRF_A, which is between the VPN and another VRF, named VRF_B. Assume that multipathing is enabled in VRF_A.

```
vrf context VRF_A
 address-family ipv4 unicast
  route-target both auto evpn
  route-target export 3:3
  export vrf allow-vpn
vrf context VRF_B
 address-family ipv4 unicast
  route-target import 3:3
```

Route leaking is enabled by **allow-vpn** in the export map configured in VRF_A. When two paths for a given prefix are learnt from a VPN and imported into VRF_A, two different paths exist in VRF_B with the same source RD (VRF_A's local RD). Each route is distinguished by the original source RD (remote RD).

Path Duplication

In this example, the configuration enables a single VPN path to be imported into both VRF_A and VRF_B. Because VRF_A is configured with **export vrf allow-vpn**, VRF_A also leaks its routes into VRF_B. VRF_B then has two paths with same source RD (VRF_A's local RD), each one distinguished by the original source RD (remote RD).

```
vrf context VRF_A
 address-family ipv4 unicast
```

```
  route-target import 1:1 evpn
  route-target export 1:1 evpn
  route-target export 2:2
export vrf allow-vpn
 vrf context VRF_B
  address-family ipv4 unicast
  route-target import 1:1 evpn
  route-target import 2:2
```

This configuration creates a situation in which multipathing does not exist.

Displaying Centralized Route Leaking Information

To display information about the RTs that have been configured and to check if the **allow-vpn** and **advertise-vpn** keywords have been configured, use the **show bgp vrf***vrf* **process** command.

```
switch# show bgp vrf vni100 process
Information regarding configured VRFs:
BGP Information for VRF vni100
VRF Id : 3
VRF state : UP
VNID : 100 (valid)
Topo Id : 100
Encap type : VXLAN
VTEP IP : 3.3.3.3
VTEP Virtual IP : 0.0.0.0
VTEP VIP-R : 0.0.0.0
Router-MAC : 5254.000e.7996
VIP Derived MAC : 5254.000e.7996
VIP-R Derived MAC : 0000.0000.0000
Router-ID : 3.3.3.100
Configured Router-ID : 0.0.0.0
Confed-ID : 0
Cluster-ID : 0.0.0.0
No. of configured peers : 0
No. of pending config peers : 0
No. of established peers : 0
VRF RD : 3.3.3.3:3
Information for address family IPv4 Unicast in VRF vni100
Table Id : 0x3
Table state : UP
Peers Active-peers Routes Paths Networks Aggregates
0 0 11 11 1 0
Redistribution
None
Auto RT is configured
EVPN Auto RT is configured
Export RT list:
1:1 100:100
Import RT list:
2:2 100:100
EVPN Export RT list:
100:100
EVPN Import RT list:
100:100
MVPN Export RT list:
100:100
MVPN Import RT list:
100:100
Label mode: per-vrf
Import default limit : 1000
Import default prefix count : 1
```

```
Import default map : allow
Import default advertise-vpn : Yes
Import VRF advertise-vpn : Yes
Export default limit : 1000
Export default prefix count : 6
Export default map : NO_DEFAULT_ROUTE
Export default allow-vpn : Yes
Export VRF allow-vpn : Yes
Nexthop trigger-delay
critical 3000 ms
non-critical 10000 ms
```

To verify if a specific route is being leaked from VRF to another, use the **show bgp vrf** *vrf* **ipv4 unicast** *prefix* command and check the 'Imported to <number-of-destinations> destinations' field in the ouput logs.

```
switch# show bgp vrf vni100 ipv4 unicast 4.4.4.100
BGP routing table information for VRF vni100, address family IPv4 Unicast
BGP routing table entry for 4.4.4.100/32, version 50
Paths: (1 available, best #1)
Flags: (0x8008021e) (high32 00000000) on xmit-list, is in urib, is best urib rou
te, is in HW
vpn: version 97, (0x100002) on xmit-list
Multipath: iBGP
Advertised path-id 1, VPN AF advertised path-id 1
Path type: internal, path is valid, is best path, no labeled nexthop, in rib
Imported from 4.4.4.4:3:[5]:[0]:[0]:[32]:[4.4.4.100]/224
Imported to 2 destination(s)
Imported paths list: vni200 default
AS-Path: NONE, path sourced internal to AS
4.4.4.4 (metric 81) from 101.101.101.101 (101.101.101.101)
Origin IGP, MED not set, localpref 100, weight 0
Received label 100
Extcommunity: RT:1:1 RT:100:100 ENCAP:8 Router MAC:5254.00cd.a816
Originator: 4.4.4.4 Cluster list: 101.101.101.101
VRF advertise information:
Path-id 1 not advertised to any peer
VPN AF advertise information:
Path-id 1 not advertised to any peer
```

Additional References

Table 10: Related Documents

Related Topic	Document Title
Cisco NX-OS Licensing Guide	Cisco NX-OS Licensing Guide

Feature History for Centralized VRF Route Leaking

Table 11: Feature History for IP TCP MSS

Feature Name	Release	Feature Information
Centralized VRF Route Leaking	8.4(1)	VXLAN BGP EVPN uses MP-BGP and its route-policy concept to import and export prefixes. The ability of this very extensive route-policy model allows to leak routes from one VRF to another VRF and vice-versa; any combination of custom VRF or VRF default can be used. VRF route-leaking is a switch-local function at specific to a location in the network, the location where the cross-VRF route-target import/export configuration takes place (leaking point). The forwarding between the different VRFs follows the control-plane, the location of where the configuration for the route-leaking is performed- hence Centralized VRF route-leaking. With the addition of VXLAN BGP EVPN, the leaking point requires to advertise the cross-VRF imported/exported route and advertise them towards the remote VTEPs or External Routers.

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