L2VPN and Ethernet Services Configuration Guide for Cisco NCS 5500 Series Routers, IOS XR Release 6.2.x

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Preface

This product has reached end-of-life status. For more information, see the End-of-Life and End-of-Sale Notices.

This preface contains these sections:

Changes to This Document

This table lists the technical changes made to this document since it was first released.

Table 1: Changes to This Document

Date	Summary
March 2017	Initial release of this document.
July 2017	Republished for Release 6.2.2.

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CHAPTER 1

New and Changed VPN Features

This table summarizes the new and changed feature information for the L2VPN and Ethernet Services Configuration Guide for Cisco NCS 5500 Series Routers, and tells you where they are documented.

New and Changed VPN Features

Table 2: VPN Features Added or Modified in IOS XR Release 6.2.x

Feature	Description	Changed in Release	Where Documented
None	No new features introduced	Not applicable	Not applicable

New and Changed VPN Features

CHAPTER 2

Configure Gigabit Ethernet for Layer 2 VPNs

This chapter introduces you to Layer 2 features and standards, and describes how you can configure L2VPN features.

The distributed Gigabit Ethernet (including 10-Gigabit and 100-Gigabit) architecture and features deliver network scalability and performance, while enabling service providers to offer high-density, high-bandwidth networking solutions designed to interconnect the router with other systems in POPs, including core and edge routers and Layer 2 and Layer 3 switches.

Introduction to Layer 2 Virtual Private Networks

A Layer 2 Virtual Private Network (VPN) emulates a physical sub-network in an IP or MPLS network, by creating private connections between two points. Building a L2VPN network requires coordination between the service provider and customer. The service provider establishes Layer 2 connectivity. The customer builds a network by using the data link resources obtained from the service provider. In a L2VPN service, the service provider does not require information about the customer's network topology and other information. This helps maintain customer privacy, while using the service provider resources to establish the network.

The service provider requires Provider Edge (PE) routers with the following capabilities:

- Encapsulation of L2 protocol data units (PDU) into Layer 3 (L3) packets.
- Interconnection of any-to-any L2 transports.
- Support for MPLS tunneling mechanism.
- Process databases that include all information related to circuits and their connections.

This section introduces Layer 2 Virtual Private Networks (VPNs) and the corresponding Gigabit Ethernet services.

Introduction to Layer 2 VPNs on Gigabit Ethernet Interfaces

A L2VPN network enables service providers (SPs) to provide L2 services to geographically disparate customer sites. Typically, a SP uses an access network to connect the customer to the core network. This access network may use a mixture of L2 technologies, such as Ethernet and Frame Relay. The connection between the customer site and the nearby SP edge router is known as an attachment circuit (AC). Traffic from the customer travels over this link to the edge of the SP core network. The traffic then tunnels through a pseudowire over the SP core network to another edge router. The edge router sends the traffic down another AC to the customer's remote site.

The L2VPN feature enables the connection between different types of L2 attachment circuits and pseudowires, allowing users to implement different types of end-to-end services.

Note BOOTP traffic (dst UDP 68) over any type of pseudowire is unsupported.

Cisco IOS XR software supports a point-to-point end-to-end service, where two Ethernet circuits are connected together. An L2VPN Ethernet port can operate in one of two modes:

- Port Mode—In this mode, all packets reaching the port are sent over the pseudowire, regardless of any VLAN tags that are present on the packets. In Port mode, the configuration is performed under the l2transport configuration mode.
- VLAN Mode—Each VLAN on a CE (customer edge) or access network to PE (provider edge) link can be configured as a separate L2VPN connection (using either VC type 4 or VC type 5). To configure L2VPN on VLANs, see *The Carrier Ethernet Model* chapter in this manual. In VLAN mode, the configuration is performed under the individual sub-interface.

Switching can take place in the following ways:

- AC-to-PW—Traffic reaching the PE is tunneled over a PW (pseudowire) (and conversely, traffic arriving over the PW is sent out over the AC). This is the most common scenario.
- Local switching—Traffic arriving on one AC is immediately sent out of another AC without passing through a pseudowire.
- PW stitching—Traffic arriving on a PW is not sent to an AC, but is sent back into the core over another PW.

Note

- If your network requires that packets are transported transparently, you may need to modify the packet's destination MAC (Media Access Control) address at the edge of the Service Provider (SP) network. This prevents the packet from being consumed by the devices in the SP network.
- The **encapsulation dot1ad** *vlan-id* and **encapsulation dot1ad** *vlan-id* **dot1q any** commands cannot co-exist on the same physical interface or bundle interface. Similarly, the **encapsulation dot1q** *vlan-id* and **encap dot1q** *vlan-id* **second-dot1q any** commands cannot co-exist on the same physical interface or bundle interface. If there is a need to co-exist, it is recommended to use the exact keyword in the single tag encapsulation. For example, **encap dot1ad** *vlan-id* **exact** or **encap dot1q** *vlan-id* **exact**.
- In an interface which already has QinQ configuration, you cannot configure the QinQ Range sub-interface where outer VLAN range of QinQ Range overlaps with outer VLAN of QinQ. Attempting this configuration results in the splitting of the existing QinQ and QinQ Range interfaces. However, the system can be recovered by deleting a recently configured QinQ Range interface.
- In an interface which already has QinQ Range configuration, you cannot configure the QinQ Range sub-interface where outer VLAN range of QinQ Range overlaps with inner VLAN of QinQ Range. Attempting this configuration results in the splitting of the existing QinQ and QinQ Range interfaces. However, the system can be recovered by deleting a recently configured QinQ Range interface.

You can use the **show interfaces** command to display AC and pseudowire information.

Configure Gigabit Ethernet Interfaces for Layer 2 Transport

This section describes how you can configure Gigabit ethernet interfaces for Layer 2 transport.

Configuration Example

```
/* Enter the interface configuration mode */
Router# configure
Router(config)# interface TenGigE 0/0/0/10

/* Configure the ethertype for the 802.1q encapsulation (optional) */
/* For VLANs, the default ethertype is 0x8100. In this example, we configure a value of
0x9100.
/* The other assignable value is 0x9200 */
/* When ethertype is configured on a physical interface, it is applied to all sub-interfaces
 created on this interface */

Router(config-if)# dot1q tunneling ethertype 0x9100

/* Configure Layer 2 transport on the interface, and commit your configuration */
Router(config-if)# l2transport
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# commit
```

Running Configuration

```
configure
 interface TenGigE 0/0/0/10
  dot1q tunneling ethertype 0x9100
  l2transport
 !
```

Verification

Verify that the Ten-Gigabit Ethernet interface is up and operational.

```
router# show interfaces TenGigE 0/0/0/10

...
TenGigE0/0/0/10 is up, line protocol is up
  Interface state transitions: 1
  Hardware is TenGigE, address is 0011.1aac.a05a (bia 0011.1aac.a05a)
  Layer 1 Transport Mode is LAN
  Layer 2 Transport Mode
  MTU 1514 bytes, BW 10000000 Kbit (Max: 10000000 Kbit)
     reliability 255/255, txload 0/255, rxload 0/255
  Encapsulation ARPA,
  Full-duplex, 10000Mb/s, link type is force-up
  output flow control is off, input flow control is off
  Carrier delay (up) is 10 msec
  loopback not set,
```

```
. . .
```

Associated Commands

- l2transport (Ethernet)

CHAPTER 3

Configure Layer 2 Access Control Lists

This chapter introduces you to Layer 2 Access Control Lists and describe how you can configure the Layer 2 access control lists.

Layer 2 Access Control Lists

An Ethernet services access control lists (ACLs) consist of one or more access control entries (ACE) that collectively define the Layer 2 network traffic profile. This profile can then be referenced by Cisco IOS XR software features. Each Ethernet services ACL includes an action element (permit or deny) based on criteria such as source and destination address, Class of Service (CoS), ether-type, or 802.1ad DEI.

Layer 2 ACLs are supported on ingress traffic only. Layer 2 ACLs are not supported on egress traffic.

Layer 2 access control lists are also known as Ethernet services control access lists.

Prerequisites for Configuring Layer 2 Access Control Lists

This prerequisite applies to configuring the access control lists and prefix lists:

You must be in a user group associated with a task group that includes the proper task IDs. The command reference guides include the task IDs required for each command.

If you suspect user group assignment is preventing you from using a command, contact your AAA administrator for assistance.

Layer 2 Access Control Lists Feature Highlights

Layer 2 access control lists have these feature highlights:

- The ability to clear counters for an access list using a specific sequence number.
- The ability to copy the contents of an existing access list to another access list.
- Allows users to apply sequence numbers to permit or deny statements.
- Layer 2 ACLs can be applied on interfaces, VLAN subinterfaces, bundle-Ethernet interfaces, bundle subinterfaces with L2 transport. Atomic replacement of Layer 2 ACLs is supported on these physical and bundle interfaces.

Purpose of Layer 2 Access Control Lists

Layer 2 access control lists perform packet filtering to control which packets move through the network and where. Such controls help to limit incoming and outgoing network traffic and restrict the access of users and devices to the network at the port level.

How a Layer 2 Access Control List Works

A Layer 2 access control list is a sequential list consisting of permit and deny statements that apply to Layer 2 configurations. The access list has a name by which it is referenced.

An access list can be configured and named, but it is not in effect until the access list is referenced by a command that accepts an access list. Multiple commands can reference the same access list. An access list can control Layer 2 traffic arriving at the router, but not traffic originating at the router and leaving the router.

Layer 2 Access Control List Process and Rules

Use this process and rules when configuring Layer 2 access control list:

- The software tests the source or destination address of each packet being filtered against the conditions in the access list, one condition (permit or deny statement) at a time.
- If a packet does not match an access list statement, the packet is then tested against the next statement in the list.
- If a packet and an access list statement match, the remaining statements in the list are skipped and the packet is permitted or denied as specified in the matched statement. The first entry that the packet matches determines whether the software permits or denies the packet. That is, after the first match, no subsequent entries are considered.
- If the access list denies the address or protocol, the software discards the packet.
- If no conditions match, the software drops the packet because each access list ends with an unwritten or implicit deny statement. That is, if the packet has not been permitted or denied by the time it was tested against each statement, it is denied.

- The access list should contain at least one permit statement or else all packets are denied.
- Because the software stops testing conditions after the first match, the order of the conditions is critical. The same permit or deny statements specified in a different order could result in a packet being passed under one circumstance and denied in another circumstance.
- Inbound access lists process packets arriving at the router. An inbound access list is efficient because it saves the overhead of routing lookups if the packet is to be discarded because it is denied by the filtering tests. If the packet is permitted by the tests, it is then processed for routing. For inbound lists, permit means continue to process the packet after receiving it on an inbound interface; deny means discard the packet.
- An access list can not be removed if that access list is being applied by an access group in use. To remove an access list, remove the access group that is referencing the access list and then remove the access list.
- An access list must exist before you can use the **ethernet-services access-group** command.

Create Layer 2 Access Control List

Consider these when creating a Layer 2 access control list:

- Create the access list before applying it to an interface.
- Organize your access list so that more specific references appear before more general ones.

Restrictions for Configuring Layer 2 Access Control Lists

These restrictions apply to configuring Layer 2 access control lists:

- Layer 2 access control lists are not supported over management interfaces.
- NetIO (software slow path) is not supported for Layer 2 access control lists.
- Layer 2 access control lists attachment is possible only in ingress direction on an interface.
- Layer 2 access control lists are supported only for the field's L2 source and destination address, Ether Type, Outer VLAN ID, Class of Service (COS), and VLAN Discard Eligibility Indication (DEI). VLAN range is not supported.

Configuration

This section describes how you can configure Layer 2 access control lists.

```
Router# configure
Router(config)# ethernet-services access-list es_acl_1
Router(config-es-acl)# deny 00ff.eedd.0010 ff00.0000.00ff 0000.0100.0001 0000.0000.ffff
Router(config-es-acl)# permit host 000a.000b.000c host 00aa.ab99.1122 cos 1 dei
Router(config-es-acl)# deny host 000a.000b.000c host 00aa.dc11.ba99 cos 7 dei
Router(config-es-acl)# commit
Router(config)# interface tengige0/0/0/4
```

```
Router(config-if)# l2transport
Router(config-if-l2)# commit
Router(config-if-l2)# exit
Router(config-if)# ethernet-services access-group es_acl_1 ingress
Router(config-if)# commit
```

Running Configuration

```
!
Configure
ethernet-services access-list es_acl_1
10 deny 00ff.eedd.0000 ff00.0000.00ff 0000.0100.0000 0000.0000.ffff
20 permit host 000a.000b.000c host 00aa.ab99.1122 cos 1 dei
30 deny host 000a.000b.000c host 00aa.dc11.ba99 cos 7 dei
!
```

Verification

Verify that you have configured Layer 2 access control lists.

```
/* Verify the Layer 2 access control lists configuration */
Router# show access-lists ethernet-services es_acl_1  hardware ingress location 0/0/CPU0
Fri Oct 21 09:39:52.904 UTC
ethernet-services access-list es_acl_1
10 deny 00ff.eedd.0000 ff00.0000.00ff 0000.0100.0000 0000.0000.ffff (2051 matches)
20 permit host 000a.000b.000c host 00aa.ab99.1122 cos 1 dei
30 deny host 000a.000b.000c host 00aa.dc11.ba99 cos 7 dei (2050 matches)
```

CHAPTER 4

Configure Virtual LANs in Layer 2 VPNs

The Layer 2 Virtual Private Network (L2VPN) feature enables Service Providers (SPs) to provide L2 services to geographically disparate customer sites.

A virtual local area network (VLAN) is a group of devices on one or more LANs that are configured so that they can communicate as if they were attached to the same wire, when in fact they are located on a number of different LAN segments. The IEEE's 802.1Q specification establishes a standard method for inserting VLAN membership information into Ethernet frames.

VLANs are very useful for user and host management, bandwidth allocation, and resource optimization. Using VLANs addresses the problem of breaking large networks into smaller parts so that broadcast and multicast traffic does not consume more bandwidth than necessary. VLANs also provide a higher level of security between segments of internal networks.

The 802.1Q specification establishes a standard method for inserting VLAN membership information into Ethernet frames. Cisco IOS XR software supports VLAN sub-interface configuration on Gigabit Ethernet and 10-Gigabit Ethernet interfaces.

The configuration model for configuring VLAN Attachment Circuits (ACs) is similar to the model used for configuring basic VLANs, where the user first creates a VLAN sub-interface, and then configures that VLAN in sub-interface configuration mode. To create an Attachment Circuit, you need to include the **l2transport** keyword in the **interface** command string to specify that the interface is a L2 interface.

VLAN ACs support the following modes of L2VPN operation:

- Basic Dot1Q Attachment Circuit—The Attachment Circuit covers all frames that are received and sent with a specific VLAN tag.
- QinQ Attachment Circuit—The Attachment Circuit covers all frames received and sent with a specific outer VLAN tag and a specific inner VLAN tag. QinQ is an extension to Dot1Q that uses a stack of two tags.
- Q-in-Any Attachment Circuit—The Attachment Circuit covers all frames received and sent with a specific outer VLAN tag and any inner VLAN tag, as long as that inner VLAN tag is not Layer 3 terminated. Q-in-Any is an extension to QinQ that uses wildcarding to match any second tag.

> **Note** The Q-in-Any mode is a variation of the basic Dot1Q mode. In Q-in-Any mode, the frames have a basic QinQ encapsulation; however, in Q-in-Any mode the inner tag is not relevant, except for the fact that a few specific inner VLAN tags are siphoned for specific services. For example, a tag may be used to provide L3 services for general internet access.

Each VLAN on a CE-to-PE link can be configured as a separate L2VPN connection (using either VC type 4 or VC type 5).

Restrictions and Limitations

To configure VLANs for Layer 2 VPNs, the following restrictions are applicable.

- In a point-to-point connection, the two Attachment Circuits do not have to be of the same type. For example, a port mode Ethernet Attachment Circuit can be connected to a Dot1Q Ethernet Attachment Circuit.
- Pseudowires can run in VLAN mode or in port mode. A pseudowire running in VLAN mode always carries Dot1Q or Dot1ad tag(s), while a pseudowire running in port mode may or may NOT carry tags. To connect these different types of circuits, popping, pushing, and rewriting tags is required.
- The Attachment Circuits on either side of an MPLS pseudowire can be of different types. In this case, the appropriate conversion is carried out at one or both ends of the Attachment Circuit to pseudowire connection.
- You can program a maximum number of 16 virtual MAC addresses on your router.

- Configure VLAN Sub-Interfaces, on page 12
- Introduction to Ethernet Flow Point, on page 15
- Configure VLAN Header Rewrite, on page 17

Configure VLAN Sub-Interfaces

Sub-interfaces are logical interfaces created on a hardware interface. These software-defined interfaces allow for segregation of traffic into separate logical channels on a single hardware interface as well as allowing for better utilization of the available bandwidth on the physical interface.

Sub-interfaces are distinguished from one another by adding an extension on the end of the interface name and designation. For instance, the Ethernet sub-interface 23 on the physical interface designated TenGigE 0/1/0/0 would be indicated by TenGigE 0/1/0/0.23.

Before a sub-interface is allowed to pass traffic, it must have a valid tagging protocol encapsulation and VLAN identifier assigned. All Ethernet sub-interfaces always default to the 802.1Q VLAN encapsulation. However, the VLAN identifier must be explicitly defined.

The sub-interface Maximum Transmission Unit (MTU) is inherited from the physical interface with 4 bytes allowed for the 802.1Q VLAN tag.

The following modes of VLAN sub-interface configuration are supported:

- Basic dot1q Attachment Circuit

- Q-in-Q Attachment Circuit

To configure a basic dot1q Attachment Circuit, use this encapsulation mode:

encapsulation dot1q *vlan extra-id*

To configure a basic dot1ad Attachment Circuit, use this encapsulation mode:

encapsulation dot1ad *vlan-id*

To configure a Q-in-Q Attachment Circuit, use the following encapsulation modes:

- **encapsulation dot1q** *vlan-id* **second-dot1q** *vlan-id*
- **encapsulation dot1ad** *vlan-id* **dot1q** *vlan-id*

Restrictions and Limitations

To configure VLAN sub-interface, the following restrictions are applicable.

- For double tagged packet, the VLAN range is supported only on the inner tag.
- VLAN list is not supported.

  VLANs separated by comma are called a VLAN list. See the example below.

```
Router(config)#interface tenGigE 0/0/0/2.0 l2transport
Router(config-subif)#encapsulation dot1q 1,2  >> VLAN range with comma
Router(config-subif)#commit
```

- If 0x9100/0x9200 is configured as tunneling ether-type, then dot1ad (0x88a8) encapsulation is not supported.
- If any sub-interface is already configured under a main interface, modifying the tunneling ether-type is not supported.
- You can program a maximum number of 16 virtual MAC addresses on your router.
- Following limitations are applicable to both outer and inner VLAN ranges:
  - 32 unique VLAN ranges are supported per system.
  - The overlap between outer VLAN ranges on sub-interfaces of the same Network Processor Unit (NPU) is not supported. A sub-interface with a single VLAN tag that falls into a range configured on another sub-interface of the same NPU is also considered an overlap.
  - The overlap between inner VLAN ranges on sub-interfaces of the same NPU is not supported.
  - Range 'any' does not result in explicit programming of a VLAN range in hardware and therefore does not count against the configured ranges.

Configuration Example

Configuring VLAN sub-interface involves:

- Creating a Ten Gigabit Ethernet sub-interface
- Enabling L2 transport mode on the interface

- Defining the matching criteria (encapsulation mode) to be used in order to map ingress frames on an interface to the appropriate service instance

Configuration of Basic dot1q Attachment Circuit

```
Router# configure
Router(config)# interface TenGigE 0/0/0/10.1 l2transport
Router(config-if)# encapsulation dot1q 10 exact
Router(config-if)# no shutdown
```

Running Configuration

```
configure
 interface TenGigE 0/0/0/10.1
  l2transport
  encapsulation dot1q 10 exact
 !
!
```

Verification

Verify that the VLAN sub-interface is active:

```
router# show interfaces TenGigE 0/0/0/10.1

...
TenGigE0/0/0/10.1 is up, line protocol is up
  Interface state transitions: 1
  Hardware is VLAN sub-interface(s), address is 0011.1aac.a05a
  Layer 2 Transport Mode
  MTU 1518 bytes, BW 10000000 Kbit (Max: 10000000 Kbit)
     reliability Unknown, txload Unknown, rxload Unknown
  Encapsulation 802.1Q Virtual LAN,
    Outer Match: Dot1Q VLAN 10
    Ethertype Any, MAC Match src any, dest any
  loopback not set,
...
```

Associated Commands

- encapsulation dot1ad dot1q
- encapsulation dot1q
- encapsulation dot1q second-dot1q
- l2transport (Ethernet)
- encapsulation dot1ad

Introduction to Ethernet Flow Point

An Ethernet Flow Point (EFP) is a Layer 2 logical sub-interface used to classify traffic under a physical or a bundle interface. An EFP is defined by a set of filters (a set of entries) that are applied to all the ingress traffic to classify the frames that belong to a particular EFP. Each entry usually contains 0, 1 or 2 VLAN tags. You can specify a VLAN or QinQ tagging to match against on ingress. A packet that starts with the same tags as an entry in the filter is said to match the filter; if the start of the packet does not correspond to any entry in the filter, then the packet does not match the filter.

All traffic on ingress are processed by that EFP if a match occurs, and this can in turn change VLAN IDs, add or remove VLAN tags, and change ethertypes. After the frames are matched to a particular EFP, any appropriate feature (such as, any frame manipulations specified by the configuration as well as things such as QoS and ACLs) can be applied.

The benefits of EFP include:

- Identifying all frames that belong to a particular flow on a given interface
- Performing VLAN header rewrites

  (See, Configure VLAN Header Rewrite, on page 17)
- Adding features to the identified frames
- Optionally defining how to forward the identified frames in the data path

Limitations of EFP

Egress EFP filtering is not supported on Cisco IOS XR.

Identify Frames of an EFP

The EFP identifies frames belonging to a particular flow on a given port, independent of their Ethernet encapsulation. An EFP can flexibly map frames into a flow or EFP based on the fields in the frame header. The frames can be matched to an EFP using VLAN tag(s).

The frames cannot be matched to an EFP through this:

- Any information outside the outermost Ethernet frame header and its associated tags such as
  - IPv4, IPv6, or MPLS tag header data
  - C-DMAC, C-SMAC, or C-VLAN

VLAN Tag Identification

Below table describes the different encapsulation types and the EFP identifier corresponding to each.

Encapsulation Type	EFP Identifier
Single tagged frames	802.1Q customer-tagged Ethernet frames

Encapsulation Type	EFP Identifier
Double tagged frames	802.1Q (ethertype 0x9100) double tagged frames 802.1ad (ethertype 0x9200) double tagged frames

You can use wildcards while defining frames that map to a given EFP. EFPs can distinguish flows based on a single VLAN tag, a stack of VLAN tags or a combination of both (VLAN stack with wildcards). It provides the EFP model, a flexibility of being encapsulation agnostic, and allows it to be extensible as new tagging or tunneling schemes are added.

Apply Features

After the frames are matched to a particular EFP, any appropriate features can be applied. In this context, "features" means any frame manipulations specified by the configuration as well as things such as QoS and ACLs. The Ethernet infrastructure provides an appropriate interface to allow the feature owners to apply their features to an EFP. Hence, IM interface handles are used to represent EFPs, allowing feature owners to manage their features on EFPs in the same way the features are managed on regular interfaces or sub-interfaces.

The only L2 features that can be applied on an EFP that is part of the Ethernet infrastructure are the L2 header encapsulation modifications. The L2 features are described in this section.

Encapsulation Modifications

EFP supports these L2 header encapsulation modifications on both ingress and egress:

- Push 1 or 2 VLAN tags
- Pop 1 or 2 VLAN tags

Note This modification can only pop tags that are matched as part of the EFP.

- Rewrite 1 or 2 VLAN tags:
  - Rewrite outer tag
  - Rewrite outer 2 tags
  - Rewrite outer tag and push an additional tag

  For each of the VLAN ID manipulations, these can be specified:

- The VLAN tag type, that is, C-VLAN, S-VLAN, or I-TAG. The ethertype of the 802.1Q C-VLAN tag is defined by the dot1q tunneling type command.
- The VLAN ID. 0 can be specified for an outer VLAN tag to generate a priority-tagged frame.

Note For tag rewrites, the CoS bits from the previous tag should be preserved in the same way as the DEI bit for 802.1ad encapsulated frames.

Define Data-Forwarding Behavior

The EFP can be used to designate the frames belonging to a particular Ethernet flow forwarded in the data path. These forwarding cases are supported for EFPs in Cisco IOS XR software:

- L2 Switched Service (Bridging)—The EFP is mapped to a bridge domain, where frames are switched based on their destination MAC address. This includes multipoint services:
  - Ethernet to Ethernet Bridging
  - Multipoint Layer 2 Services
- L2 Stitched Service (AC to AC xconnect)—This covers point-to-point L2 associations that are statically established and do not require a MAC address lookup.
  - Ethernet to Ethernet Local Switching—The EFP is mapped to an S-VLAN either on the same port or on another port. The S-VLANs can be identical or different.
- Tunneled Service (xconnect)—The EFP is mapped to a Layer 3 tunnel. This covers point-to-point services, such as EoMPLS.

Configure VLAN Header Rewrite

EFP supports the following VLAN header rewrites on both ingress and egress ports:

- Push 1 VLAN tag
- Pop 1 VLAN tag

  Note This rewrite can only pop tags that are matched as part of the EFP.

- Translate 1 or 2 VLAN tags:
  - Translate 1-to-1 tag: Translates the outermost tag to another tag
  - Translate 1-to-2 tags: Translates the outermost tag to two tags
  - Translate 2-to-2 tags: Translates the outermost two tags to two other tags

Various combinations of ingress, egress VLAN rewrites with corresponding tag actions during ingress and egress VLAN translation, are listed in the following sections:

- Valid Ingress Rewrite Actions, on page 20
- Valid Ingress-Egress Rewrite Combinations, on page 21

Limitations

The limitations for VLAN header rewrites are as follows:

- Push 1 is not supported for dot1ad configuration.
- Push 2 is supported only on:

  - Untagged EFP
  - Dot1q EFP with **exact** configuration statement

- Translate 1 to 1 is not supported for dot1ad configuration.
- Translate 1 to 2 is not supported with **dot1q tunneling ethertype** configuration statement.
- Pop 2 is not supported.
- Translate 2 to 1 is not supported.

Configuration Example

This topic covers VLAN header rewrites on various attachment circuits, such as:

- L2 single-tagged sub-interface
- L2 double-tagged sub-interface

Configuring VLAN header rewrite involves:

- Creating a TenGigabit Ethernet sub-interface
- Enabling L2 transport mode on the interface
- Defining the matching criteria (encapsulation mode) to be used in order to map single-tagged frames ingress on an interface to the appropriate service instance
- Specifying the encapsulation adjustment that is to be performed on the ingress frame

Configuration of VLAN Header Rewrite (single-tagged sub-interface)

```
Router# configure
Router(config)# interface TenGigE 0/0/0/10.1 l2transport
Router(config-if)# encapsulation dot1q 10 exact
Router(config-if)# rewrite ingress tag push dot1q 20 symmteric
```

Running Configuration

```
/* Configuration without rewrite */

configure
 interface TenGigE0/0/0/0.1 l2transport
  encapsulation dot1q 10 exact
 !
!

/* Configuration with rewrite */

/* PUSH 1 */
interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10
 rewrite ingress tag push dot1q 20 symmteric
 !
!
```

```
/* POP 1 */
interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10
  rewrite ingress tag pop 1
 !
!

/* TRANSLATE 1-1 */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10
  rewrite ingress tag translate 1-to-1 dot1q 20
 !
!

/* TRANSLATE 1-2 */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10
  rewrite ingress tag translate 1-to-2 dot1q 20 second-dot1q 30
 !
!
```

Running Configuration (VLAN header rewrite on double-tagged sub-interface)

```
/* Configuration without rewrite */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10 second-dot1q 11
 !
!

/* Configuration with rewrite */

/* PUSH 1 */
interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10 second-dot1q 11
  rewrite ingress tag push dot1q 20 symmteric
 !
!

/* TRANSLATE 1-1 */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10 second-dot1q 11
  rewrite ingress tag translate 1-to-1 dot1q 20
 !
!

/* TRANSLATE 1-2 */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10 second-dot1q 11
  rewrite ingress tag translate 1-to-2 dot1q 20 second-dot1q 30
 !
!

/* TRANSLATE 2-2 */

interface TenGigE0/0/0/0.1 l2transport
 encapsulation dot1q 10 second-dot1q 11
  rewrite ingress tag translate 2-to-2 dot1q 20 second-dot1q 30
```

```
  !
!
```

Associated Commands

- encapsulation dot1ad dot1q
- encapsulation dot1q
- encapsulation dot1q second-dot1q
- l2transport (Ethernet)
- rewrite ingress tag

Valid Ingress Rewrite Actions

Table 3: Valid Ingress Rewrite Actions

Interface Configuration	Ingress Rewrite Action
dot1q	No rewrite
dot1q	Pop 1
dot1q	Push 1
dot1q	Push 2
dot1q	Translate 1 to 1
dot1q	Translate 1 to 2
dot1q range	No rewrite
dot1q range	Push 1
dot1q range	Push 2
QinQ	No rewrite
QinQ	Pop 1
QinQ	Push 1
QinQ	Translate 1 to 1
QinQ	Translate 1 to 2
QinQ	Translate 2 to 2
QinQ range	No rewrite
QinQ range	Pop 1

Interface Configuration	Ingress Rewrite Action
QinQ range	Push 1
QinQ range	Translate 1 to 1
QinQ range	Translate 1 to 2
QinAny	No rewrite
QinAny	Pop 1
QinAny	Push 1
QinAny	Translate 1 to 1
QinAny	Translate 1 to 2
Untagged	No rewrite
Untagged	Push 1
Untagged	Push 2

The following notations are used for the rewrite actions mentioned in the table:

- Translate 1-to-1 tag: Translates the outermost tag to another tag.
- Translate 1-to-2 tags: Translates the outermost tag to two tags.
- Translate 2-to-2 tags: Translates the outermost two tags to two other tags.

Valid Ingress-Egress Rewrite Combinations

Table 4: Valid Ingress-Egress Rewrite Combinations

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q	No rewrite	dot1q	No rewrite
dot1q	No rewrite	dot1q	Pop 1
dot1q	No rewrite	dot1q	Push 1
dot1q	No rewrite	dot1q	Translate 1-to-1
dot1q	Pop 1	dot1q	No rewrite
dot1q	Pop 1	dot1q	Pop 1
dot1q	Push 1	dot1q	No rewrite
dot1q	Push 1	dot1q	Push 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q	Push 1	dot1q	Push 2
dot1q	Push 1	dot1q	Translate 1-to-1
dot1q	Push 1	dot1q	Translate 1-to-2
dot1q	Push 2 / Translate 1-to-2	dot1q	Push 1
dot1q	Push 2 / Translate 1-to-2	dot1q	Push 2
dot1q	Push 2 / Translate 1-to-2	dot1q	Translate 1-to-2
dot1q	Translate 1-to-1	dot1q	No rewrite
dot1q	Translate 1-to-1	dot1q	Push 1
dot1q	Translate 1-to-1	dot1q	Translate 1-to-1
dot1q	No rewrite	dot1q range	No rewrite
dot1q	No rewrite	dot1q range	Push 1
dot1q	Pop 1	dot1q range	No rewrite
dot1q	Push 1	dot1q range	No rewrite
dot1q	Push 1	dot1q range	Push 1
dot1q	Push 1	dot1q range	Push 2
dot1q	Translate 1-to-1	dot1q range	No rewrite
dot1q	Translate 1-to-1	dot1q range	Push 1
dot1q	Translate 1-to-2	dot1q range	Push 1
dot1q	Translate 1-to-2	dot1q range	Push 2
dot1q	No rewrite / Translate 1-to-1	QinQ	No rewrite
dot1q	No rewrite / Translate 1-to-1	QinQ	Pop 1
dot1q	No rewrite / Translate 1-to-1	QinQ	Push 1
dot1q	No rewrite / Translate 1-to-1	QinQ	Translate 1-to-1
dot1q	Pop 1	QinQ	No rewrite
dot1q	Pop 1	QinQ	Pop 1
dot1q	Push 1	QinQ	No rewrite
dot1q	Push 1	QinQ	Pop 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q	Push 1	QinQ	Push 1
dot1q	Push 1	QinQ	Translate 1-to-1
dot1q	Push 1	QinQ	Translate 1-to-2
dot1q	Push 1	QinQ	Translate 2-to-2
dot1q	Push 2 / Translate 1-to-2	QinQ	No rewrite
dot1q	Push 2 / Translate 1-to-2	QinQ	Push 1
dot1q	Push 2 / Translate 1-to-2	QinQ	Translate 1-to-1
dot1q	Push 2 / Translate 1-to-2	QinQ	Translate 1-to-2
dot1q	Push 2 / Translate 1-to-2	QinQ	Translate 2-to-2
dot1q	No rewrite / Translate 1-to-1	QinQ range / QinAny	No rewrite
dot1q	No rewrite / Translate 1-to-1	QinQ range / QinAny	Pop 1
dot1q	No rewrite / Translate 1-to-1	QinQ range / QinAny	Push 1
dot1q	No rewrite / Translate 1-to-1	QinQ range / QinAny	Translate 1-to-1
dot1q	Pop 1	QinQ range / QinAny	No rewrite
dot1q	Pop 1	QinQ range / QinAny	Pop 1
dot1q	Push 1	QinQ range / QinAny	No rewrite
dot1q	Push 1	QinQ range / QinAny	Pop 1
dot1q	Push 1	QinQ range / QinAny	Push 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q	Push 1	QinQ range / QinAny	Translate 1-to-1
dot1q	Push 1	QinQ range / QinAny	Translate 1-to-2
dot1q	Push 2 / Translate 1-to-2	QinQ range / QinAny	No rewrite
dot1q	Push 2 / Translate 1-to-2	QinQ range / QinAny	Push 1
dot1q	Push 2 / Translate 1-to-2	QinQ range / QinAny	Translate 1-to-1
dot1q	Push 2 / Translate 1-to-2	QinQ range / QinAny	Translate 1-to-2
dot1q	No rewrite	QinQ range / QinAny	No rewrite
dot1q	No rewrite	Untagged	Push 1
dot1q	Pop 1	Untagged	No rewrite
dot1q	Push 1	Untagged	Push 1
dot1q	Push 1	Untagged	Push 2
dot1q	Push 2	Untagged	Push 2
dot1q	Translate 1-to-1	Untagged	Push 1
dot1q	Translate 1-to-2	Untagged	Push 2
dot1q range	No rewrite	dot1q range	No rewrite
dot1q range	No rewrite	dot1q range	Push 1
dot1q range	Push 1	dot1q range	No rewrite
dot1q range	Push 1	dot1q range	Push 1
dot1q range	Push 1	dot1q range	Push 2
dot1q range	Push 2	dot1q range	Push 1
dot1q range	Push 2	dot1q range	Push 2

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q range	No rewrite	QinQ	No rewrite
dot1q range	No rewrite	QinQ	Pop 1
dot1q range	No rewrite	QinQ	Push 1
dot1q range	No rewrite	QinQ	Translate 1-to-1
dot1q range	Push 1	QinQ	No rewrite
dot1q range	Push 1	QinQ	Pop 1
dot1q range	Push 1	QinQ	Push 1
dot1q range	Push 1	QinQ	Translate 1-to-1
dot1q range	Push 1	QinQ	Translate 1-to-2
dot1q range	Push 1	QinQ	Translate 2-to-2
dot1q range	Push 2	QinQ	No rewrite
dot1q range	Push 2	QinQ	Push 1
dot1q range	Push 2	QinQ	Translate 1-to-1
dot1q range	Push 2	QinQ	Translate 1-to-2
dot1q range	Push 2	QinQ	Translate 2-to-2
dot1q range	No rewrite	QinQ range / QinAny	No rewrite
dot1q range	No rewrite	QinQ range / QinAny	Pop 1
dot1q range	No rewrite	QinQ range / QinAny	Push 1
dot1q range	No rewrite	QinQ range / QinAny	Translate 1-to-1
dot1q range	Push 1	QinQ range / QinAny	No rewrite
dot1q range	Push 1	QinQ range / QinAny	Pop 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
dot1q range	Push 1	QinQ range / QinAny	Push 1
dot1q range	Push 1	QinQ range / QinAny	Translate 1-to-1
dot1q range	Push 1	QinQ range / QinAny	Translate 1-to-2
dot1q range	Push 2	QinQ range / QinAny	No rewrite
dot1q range	Push 2	QinQ range / QinAny	Push 1
dot1q range	Push 2	QinQ range / QinAny	Translate 1-to-1
dot1q range	Push 2	QinQ range / QinAny	Translate 1-to-2
dot1q range	No rewrite	Untagged	No rewrite
dot1q range	No rewrite	Untagged	Push 1
dot1q range	Push 1	Untagged	Push 1
dot1q range	Push 1	Untagged	Push 2
dot1q range	Push 2	Untagged	Push 2
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	No rewrite
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	Pop 1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	Push 1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	Translate 1-to-1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	Translate 1-to-2

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ	Translate 2-to-2
QinQ	Pop 1	QinQ	No rewrite
QinQ	Pop 1	QinQ	Pop 1
QinQ	Pop 1	QinQ	Push 1
QinQ	Pop 1	QinQ	Translate 1-to-1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ	No rewrite
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ	Push 1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ	Translate 1-to-1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ	Translate 1-to-2
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ	Translate 2-to-2
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	No rewrite
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Pop 1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Push 1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Translate 1-to-1
QinQ	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Translate 1-to-2
QinQ	Pop 1	QinQ range / QinAny	No rewrite
QinQ	Pop 1	QinQ range / QinAny	Pop 1
QinQ	Pop 1	QinQ range / QinAny	Push 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
QinQ	Pop 1	QinQ range / QinAny	Translate 1-to-1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ range / QinAny	No rewrite
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ range / QinAny	Push 1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ range / QinAny	Translate 1-to-1
QinQ	Translate 1-to-2 / Translate 2-to-2	QinQ range / QinAny	Translate 1-to-2
QinQ	No rewrite	Untagged	No rewrite
QinQ	No rewrite	Untagged	Push 1
QinQ	No rewrite	Untagged	Push 2
QinQ	Pop 1	Untagged	No rewrite
QinQ	Pop 1	Untagged	Push 1
QinQ	Push 1 / Translate 1-to-1	Untagged	Push 1
QinQ	Push 1 / Translate 1-to-1	Untagged	Push 2
QinQ	Translate 1-to-2 / Translate 2-to-2	Untagged	Push 2
QinQ range / QinAny	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	No rewrite
QinQ range / QinAny	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Pop 1
QinQ range / QinAny	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Push 1
QinQ range / QinAny	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Translate 1-to-1
QinQ range / QinAny	No rewrite / push 1 / Translate 1-to-1	QinQ range / QinAny	Translate 1-to-2

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
QinQ range / QinAny	Pop 1	QinQ range / QinAny	No rewrite
QinQ range / QinAny	Pop 1	QinQ range / QinAny	Pop 1
QinQ range / QinAny	Pop 1	QinQ range / QinAny	Push 1
QinQ range / QinAny	Pop 1	QinQ range / QinAny	Translate 1-to-1
QinQ range / QinAny	Translate 1-to-2	QinQ range / QinAny	No rewrite
QinQ range / QinAny	Translate 1-to-2	QinQ range / QinAny	Push 1
QinQ range / QinAny	Translate 1-to-2	QinQ range / QinAny	Translate 1-to-1
QinQ range / QinAny	Translate 1-to-2	QinQ range / QinAny	Translate 1-to-2
QinQ range / QinAny	No rewrite	Untagged	No rewrite
QinQ range / QinAny	No rewrite	Untagged	Push 1
QinQ range / QinAny	No rewrite	Untagged	Push 2
QinQ range / QinAny	Pop 1	Untagged	No rewrite
QinQ range / QinAny	Pop 1	Untagged	Push 1
QinQ range / QinAny	Push 1 / Translate 1-to-1	Untagged	Push 1

Ingress Interface Configuration	Ingress Interface Rewrite Action	Egress Interface Configuration	Egress Interface Rewrite Action
QinQ range / QinAny	Push 1 / Translate 1-to-1	Untagged	Push 2
QinQ range / QinAny	Translate 1-to-2	Untagged	Push 2
Untagged	No rewrite	Untagged	No rewrite
Untagged	Push 1	Untagged	Push 1
Untagged	Push 2	Untagged	Push 2

The following notations are used for the rewrite actions mentioned in the table:

- Translate 1-to-1 tag: Translates the outermost tag to another tag
- Translate 1-to-2 tags: Translates the outermost tag to two tags
- Translate 2-to-2 tags: Translates the outermost two tags to two other tags

CHAPTER 5

Configure Link Bundles for Layer 2 VPNs

An ethernet link bundle is a group of one or more ports that are aggregated together and treated as a single link. Each bundle has a single MAC, a single IP address, and a single configuration set (such as ACLs or QoS).

The advantages of link bundling are:

- Redundancy - Because bundles have multiple links, the failure of a single link does not cause a loss of connectivity.
- Increased bandwidth - On bundled interfaces traffic is forwarded over all available members of the bundle aggregating individual port capacity.

There are two types of link bundling supported depending on the type of interface forming the bundle:

- Ethernet interfaces
- VLAN interfaces (bundle sub-interfaces)

This section describes the configuration of ethernet and VLAN link bundles for use in Layer 2 VPNs.

Configure Gigabit Ethernet Link Bundle

Cisco IOS XR software supports the EtherChannel method of forming bundles of Ethernet interfaces. EtherChannel is a Cisco proprietary technology that allows the user to configure links to join a bundle, but has no mechanisms to check whether the links in a bundle are compatible.

IEEE 802.3ad encapsulation employs a Link Aggregation Control Protocol (LACP) to ensure that all the member links in an ethernet bundle are compatible. Links that are incompatible or have failed are automatically removed from the bundle.

Cisco NCS 5500 Series Router supports 100G link bundles.

Restrictions

- All links within a single ethernet link bundle must be configured either to run 802.3ad (LACP) or Etherchannel (non-LACP). Mixed links within a single bundle are not supported.
- MAC accounting is not supported on Ethernet link bundles.

- The maximum number of supported links in each ethernet link bundle is 64 .
- The maximum number of supported ethernet link bundles is 128 .

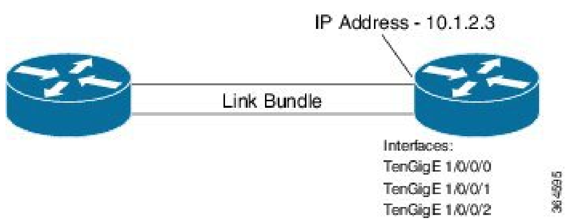
Configuration Example

To create a link bundle between two routers, you must complete the following configurations:

1. Create a bundle instance
2. Map physical interface (s) to the bundle.

Sample values are provided in the following figure.

Figure 1: Link Bundle Topology



For an Ethernet bundle to be active, you must perform the same configuration on both connection endpoints of the bundle.

Configuration

```
/* Enter the global configuration mode and create the ethernet link bundle */
Router# configure
Router(config)# interface Bundle-Ether 3
Router(config-if)# ipv4 address 10.1.2.3 255.0.0.0
Router(config-if)# bundle maximum-active links 32 hot-standby
Router(config-if)# bundle minimum-active links 1
Router(config-if)# bundle minimum-active bandwidth 30000000
Router(config-if)# exit

/* Map physical interfaces to the bundle */
/* Note: Mixed link bundle mode is supported only when active-standby operation is configured
 */
Router(config)# interface TenGigE 1/0/0/0
Router(config-if)# bundle id 3 mode on
Router(config-if)# no shutdown
Router(config)# exit

Router(config)# interface TenGigE 1/0/0/1
Router(config-if)# bundle id 3 mode on
Router(config-if)# no shutdown
Router(config-if)# exit

Router(config)# interface TenGigE 1/0/0/2
Router(config-if)# bundle id 3 mode on
Router(config-if)# no shutdown
Router(config-if)# exit
```

Running Configuration

```
Router# show running-configuration
configure
interface Bundle-Ether 3
 ipv4 address 10.1.2.3 255.0.0.0
 bundle maximum-active links 32 hot-standby
 bundle minimum-active links 1
 bundle minimum-active bandwidth 30000000
!
interface TenGigE 1/0/0/0
 bundle-id 3 mode on
!

interface TenGigE 1/0/0/1
 bundle-id 3 mode on
!
interface TenGigE 1/0/0/2
 bundle-id 3 mode on
!
```

Verification

Verify that interfaces forming the bundle are active and the status of the bundle is Up.

```
Router# show bundle bundle-ether 3
Tue Feb  4 18:24:25.313 UTC

Bundle-Ether1
  Status:                                    Up
  Local links <active/standby/configured>:   3 / 0 / 3
  Local bandwidth <effective/available>:     30000000 (30000000) kbps
  MAC address (source):                      1234.1234.1234 (Configured)
  Inter-chassis link:                        No
  Minimum active links / bandwidth:          1 / 1 kbps
  Maximum active links:                      32
  Wait while timer:                          2000 ms
  Load balancing:                            Default
  LACP:                                      Not operational
    Flap suppression timer:                  Off
    Cisco extensions:                        Disabled
    Non-revertive:                           Disabled
  mLACP:                                     Not configured
  IPv4 BFD:                                  Not configured

  Port                  Device           State        Port ID         B/W, kbps
  --------------------  ---------------  -----------  --------------  ----------
  Te1/0/0/0            Local            Active       0x8000, 0x0000     10000000
      Link is Active
  Te1/0/0/1            Local            Active       0x8000, 0x0000     10000000
      Link is Active
  Te1/0/0/2            Local            Active       0x8000, 0x0000     10000000
      Link is Active

------------------------------------------------------------------------
```

Associated Commands

- bundle maximum-active links
- interface Bundle-Ether

- show bundle Bundle-Ether

Configure VLAN Bundle

The procedure for creating VLAN bundle is the same as the procedure for creating VLAN sub-interfaces on a physical ethernet interface.

Configuration Example

To configure VLAN bundles, complete the following configurations:

- Create a bundle instance.
- Create a VLAN interface (bundle sub-interface).
- Map the physical interface(s) to the bundle.

For a VLAN bundle to be active, you must perform the same configuration on both end points of the VLAN bundle.

Configuration

```
/* Enter global configuration mode and create VLAN bundle */
Router# configure
Router(config)# interface Bundle-Ether 2
Router(config-if)# ipv4 address 50.0.0.1/24
Router(config-if)# bundle maximum-active links 32 hot-standby
Router(config-if)# bundle minimum-active bandwidth 30000000
Router(config-if)# bundle minimum-active links 1
Router(config-if)# commit

/* Create VLAN sub-interface and add to the bundle */
Router(config)# interface Bundle-Ether 2.201
Router(config-subif)# ipv4 address 12.22.1.1 255.255.255.0
Router(config-subif)# encapsulation dot1q 201
Router(config-subif)# commit

/* Map the physical interface to the bundle */
Router(config)# interface TenGigE 0/0/0/14
Router(config-if)# bundle id 2 mode on
Router(config-if)# no shutdown
Router(config-if)# commit

/* Repeat the above steps for all the member interfaces:
   0/0/0/15, 0/0/0/16 and 0/0/0/17 in this example */
```

Running Configuration

```
configure
interface Bundle-Ether2
 ipv4 address 50.0.0.1 255.255.255.0
 mac-address 1212.1212.1212
 bundle maximum-active links 32 hot-standby
 bundle minimum-active links 1
 bundle minimum-active bandwidth 30000000
!
```

```
interface Bundle-Ether2.201
 ipv4 address 12.22.1.1 255.255.255.0
 encapsulation dot1q 201
!
interface TenGigE0/0/0/14
 bundle id 2 mode on
!
interface TenGigE0/0/0/15
 bundle id 2 mode on
!
interface TenGigE0/0/0/16
 bundle id 2 mode on
!
interface TenGigE0/0/0/17
 bundle id 2 mode on
!
```

Verification

Verify that the VLAN status is UP.

```
Router# show interfaces bundle-ether 2.201

Wed Feb  5 17:19:53.964 UTC
Bundle-Ether2.201 is up, line protocol is up
  Interface state transitions: 1
  Hardware is VLAN sub-interface(s), address is 28c7.ce01.dc7b
  Internet address is 12.22.1.1/24
  MTU 1518 bytes, BW 20000000 Kbit (Max: 20000000 Kbit)
     reliability 255/255, txload 0/255, rxload 0/255
  Encapsulation 802.1Q Virtual LAN, VLAN Id 201,  loopback not set,
  Last link flapped 07:45:25
  ARP type ARPA, ARP timeout 04:00:00
  Last input 00:00:00, output never
  Last clearing of "show interface" counters never
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     2938 packets input, 311262 bytes, 0 total input drops
  - - -
  - - -
```

Associated Commands

- bundle maximum-active links
- interface Bundle-Ether
- show bundle Bundle-Ether

References for Configuring Link Bundles

This section provides references to configuring link bundles. For an overview of link bundles and configurations, see Configure Link Bundles for Layer 2 VPNs, on page 31.

Characteristics of Link Bundles

- Any type of Ethernet interfaces can be bundled, with or without the use of LACP (Link Aggregation Control Protocol).
- Physical layer and link layer configuration are performed on individual member links of a bundle.
- Configuration of network layer protocols and higher layer applications is performed on the bundle itself.
- A bundle can be administratively enabled or disabled.
- Each individual link within a bundle can be administratively enabled or disabled.
- Ethernet link bundles are created in the same way as Etherokinet channels, where the user enters the same configuration on both end systems.
- The MAC address that is set on the bundle becomes the MAC address of the links within that bundle.
- When LACP configured, each link within a bundle can be configured to allow different keepalive periods on different members.
- Load balancing is done by flow instead of by packet. Data is distributed to a link in proportion to the bandwidth of the link in relation to its bundle.
- QoS is supported and is applied proportionally on each bundle member.
- Link layer protocols, such as CDP, work independently on each link within a bundle.
- Upper layer protocols, such as routing updates and hello messages, are sent over any member link of an interface bundle.
- Bundled interfaces are point to point.
- A link must be in the UP state before it can be in distributing state in a bundle.
- Access Control List (ACL) configuration on link bundles is identical to ACL configuration on regular interfaces.
- Multicast traffic is load balanced over the members of a bundle. For a given flow, internal processes select the member link and all traffic for that flow is sent over that member.

Methods of Forming Bundles of Ethernet Interfaces

Cisco IOS-XR software supports the following methods of forming bundles of Ethernet interfaces:

- IEEE 802.3ad—Standard technology that employs a Link Aggregation Control Protocol (LACP) to ensure that all the member links in a bundle are compatible. Links that are incompatible or have failed are automatically removed from a bundle.

  For each link configured as bundle member, information is exchanged between the systems that host each end of the link bundle:

  - A globally unique local system identifier
  - An identifier (operational key) for the bundle of which the link is a member
  - An identifier (port ID) for the link

- The current aggregation status of the link

This information is used to form the link aggregation group identifier (LAG ID). Links that share a common LAG ID can be aggregated. Individual links have unique LAG IDs.

The system identifier distinguishes one router from another, and its uniqueness is guaranteed through the use of a MAC address from the system. The bundle and link identifiers have significance only to the router assigning them, which must guarantee that no two links have the same identifier, and that no two bundles have the same identifier.

The information from the peer system is combined with the information from the local system to determine the compatibility of the links configured to be members of a bundle.

Bundle MAC addresses in the routers come from a set of reserved MAC addresses in the backplane. This MAC address stays with the bundle as long as the bundle interface exists. The bundle uses this MAC address until the user configures a different MAC address. The bundle MAC address is used by all member links when passing bundle traffic. Any unicast or multicast addresses set on the bundle are also set on all the member links.

Note It is recommended that you avoid modifying the MAC address, because changes in the MAC address can affect packet forwarding.

- EtherChannel—Cisco proprietary technology that allows the user to configure links to join a bundle, but has no mechanisms to check whether the links in a bundle are compatible.

Link Aggregation Through LACP

The optional Link Aggregation Control Protocol (LACP) is defined in the IEEE 802 standard. LACP communicates between two directly connected systems (or peers) to verify the compatibility of bundle members. For a router, the peer can be either another router or a switch. LACP monitors the operational state of link bundles to ensure these:

- All links terminate on the same two systems.
- Both systems consider the links to be part of the same bundle.
- All links have the appropriate settings on the peer.

LACP transmits frames containing the local port state and the local view of the partner system's state. These frames are analyzed to ensure both systems are in agreement.

CHAPTER 6

Configure Multipoint Layer 2 Services

This module provides the conceptual and configuration information for Multipoint Layer 2 Bridging Services, also called Virtual Private LAN Services (VPLS).

Note VPLS supports Layer 2 VPN technology and provides transparent multipoint Layer 2 connectivity for customers. This approach enables service providers to host a multitude of new services such as broadcast TV and Layer 2 VPNs.

Prerequisites for Implementing Multipoint Layer 2 Services

Before configuring Multipoint Layer 2 Services, ensure that these tasks and conditions are met:

- You must be in a user group associated with a task group that includes the proper task IDs. The command reference guides include the task IDs required for each command.

  If you suspect user group assignment is preventing you from using a command, contact your AAA administrator for assistance.

- Configure IP routing in the core so that the provider edge (PE) routers can reach each other through IP.

- Configure a loopback interface to originate and terminate Layer 2 traffic. Make sure that the PE routers can access the other router's loopback interface.

  Note The loopback interface is not needed in all cases. For example, tunnel selection does not need a loopback interface when Multipoint Layer 2 Services are directly mapped to a TE tunnel.

Information About Implementing Multipoint Layer 2 Services

To implement Multipoint Layer 2 Services, you must understand these concepts:

Multipoint Layer 2 Services Overview

Multipoint Layer 2 Services enable geographically separated local-area network (LAN) segments to be interconnected as a single bridged domain over an MPLS network. The full functions of the traditional LAN such as MAC address learning, aging, and switching are emulated across all the remotely connected LAN segments that are part of a single bridged domain. A service provider can offer VPLS service to multiple customers over the MPLS network by defining different bridged domains for different customers. Packets from one bridged domain are never carried over or delivered to another bridged domain, thus ensuring the privacy of the LAN service.

Note VPLS PW is not supported over BGP multipath.

Some of the components present in a Multipoint Layer 2 Services network are described in these sections.

Note Multipoint Layer 2 services are also called as Virtual Private LAN Services.

Bridge Domain

The native bridge domain refers to a Layer 2 broadcast domain consisting of a set of physical or virtual ports (including VFI). Data frames are switched within a bridge domain based on the destination MAC address. Multicast, broadcast, and unknown destination unicast frames are flooded within the bridge domain. In addition, the source MAC address learning is performed on all incoming frames on a bridge domain. A learned address is aged out. Incoming frames are mapped to a bridge domain, based on either the ingress port or a combination of both an ingress port and a MAC header field.

Pseudowires

A pseudowire is a point-to-point connection between pairs of PE routers. Its primary function is to emulate services like Ethernet over an underlying core MPLS network through encapsulation into a common MPLS format. By encapsulating services into a common MPLS format, a pseudowire allows carriers to converge their services to an MPLS network.

Access Pseudowire is not supported over VPLS Bridge Domain

Access PW is not supported over VPLS bridge domain. Only core PW which is configured under VFI is supported.

Configuration Example

```
l2vpn
 bridge group bg1
  bridge-domain l2vpn
```

```
   interface TenGigE0/0/0/13.100
   !
  vfi 1
   neighbor 192.0.2.1 pw-id 12345
    pw-class mpls_csr
  !
 !
!
```

Virtual Forwarding Instance

VPLS is based on the characteristic of virtual forwarding instance (VFI). A VFI is a virtual bridge port that is capable of performing native bridging functions, such as forwarding, based on the destination MAC address, source MAC address learning and aging, and so forth.

A VFI is created on the PE router for each VPLS instance. The PE routers make packet-forwarding decisions by looking up the VFI of a particular VPLS instance. The VFI acts like a virtual bridge for a given VPLS instance. More than one attachment circuit belonging to a given VPLS are connected to the VFI. The PE router establishes emulated VCs to all the other PE routers in that VPLS instance and attaches these emulated VCs to the VFI. Packet forwarding decisions are based on the data structures maintained in the VFI.

VPLS for an MPLS-based Provider Core

VPLS is a multipoint Layer 2 VPN technology that connects two or more customer devices using bridging techniques. A bridge domain, which is the building block for multipoint bridging, is present on each of the PE routers. The access connections to the bridge domain on a PE router are called attachment circuits. The attachment circuits can be a set of physical ports, virtual ports, or both that are connected to the bridge at each PE device in the network.

After provisioning attachment circuits, neighbor relationships across the MPLS network for this specific instance are established through a set of manual commands identifying the end PEs. When the neighbor association is complete, a full mesh of pseudowires is established among the network-facing provider edge devices, which is a gateway between the MPLS core and the customer domain.

The MPLS/IP provider core simulates a virtual bridge that connects the multiple attachment circuits on each of the PE devices together to form a single broadcast domain. This also requires all of the PE routers that are participating in a VPLS instance to form emulated virtual circuits (VCs) among them.

Now, the service provider network starts switching the packets within the bridged domain specific to the customer by looking at destination MAC addresses. All traffic with unknown, broadcast, and multicast destination MAC addresses is flooded to all the connected customer edge devices, which connect to the service provider network. The network-facing provider edge devices learn the source MAC addresses as the packets are flooded. The traffic is unicasted to the customer edge device for all the learned MAC addresses.

VPLS for Layer 2 Switching

VPLS technology includes the capability of configuring the router to perform Layer 2 bridging. In this mode, the router can be configured to operate like other Cisco switches.

Note The storm control configuration is supported only on one sub-interface under a main interface, though the system allows you to configure storm control on more than one sub-interface. However, only the first storm control configuration under a main interface takes effect, though the running configuration shows all the storm control configurations that are committed. After reload, any of the storm control configurations may take effect irrespective of the order of configuration.

The storm control that is applied to multiple subinterfaces of the same physical port pertains to that physical port only. All subinterfaces with storm control configured are policed as aggregate under a single policer rate shared by all EFPs. None of the subinterfaces are configured with a dedicated policer rate. When a storm occurs on several subinterfaces simultaneously, and because subinterfaces share the policer, you can slightly increase the policer rate to accommodate additional policing.

These features are supported:

- Bridging IOS XR Trunk Interfaces
- Bridging on EFPs

Interoperability Between Cisco IOS XR and Cisco IOS on VPLS LDP Signaling

The Cisco IOS Software encodes the NLRI length in the fist byte in bits format in the BGP Update message. However, the Cisco IOS XR Software interprets the NLRI length in 2 bytes. Therefore, when the BGP neighbor with VPLS-VPWS address family is configured between the IOS and the IOS XR, NLRI mismatch can happen, leading to flapping between neighbors. To avoid this conflict, IOS supports **prefix-length-size 2** command that needs to be enabled for IOS to work with IOS XR. When the **prefix-length-size 2** command is configured in IOS, the NLRI length is encoded in bytes. This configuration is mandatory for IOS to work with IOS XR.

This is a sample IOS configuration with the **prefix-length-size 2** command:

```
router bgp 1
 address-family l2vpn vpls
  neighbor 5.5.5.2 activate
  neighbor 5.5.5.2 prefix-length-size 2 --------> NLRI length = 2 bytes
 exit-address-family
```

MAC Address-related Parameters

The MAC address table contains a list of the known MAC addresses and their forwarding information. In the current VPLS design, the MAC address table and its management are maintained on the route processor (RP) card.

These topics provide information about the MAC address-related parameters:

MAC Address Flooding

Ethernet services require that frames that are sent to broadcast addresses and to unknown destination addresses be flooded to all ports. To obtain flooding within VPLS broadcast models, all unknown unicast, broadcast, and multicast frames are flooded over the corresponding pseudowires and to all attachment circuits. Therefore, a PE must replicate packets across both attachment circuits and pseudowires.

MAC Address-based Forwarding

To forward a frame, a PE must associate a destination MAC address with a pseudowire or attachment circuit. This type of association is provided through a static configuration on each PE or through dynamic learning, which is flooded to all bridge ports.

MAC Address Source-based Learning

When a frame arrives on a bridge port (for example, pseudowire or attachment circuit) and the source MAC address is unknown to the receiving PE router, the source MAC address is associated with the pseudowire or attachment circuit. Outbound frames to the MAC address are forwarded to the appropriate pseudowire or attachment circuit.

MAC address source-based learning uses the MAC address information that is learned in the hardware forwarding path. The updated MAC tables are propagated and programs the hardware for the router.

Note Static MAC move is not supported from one port, interface, or AC to another port, interface, or AC. For example, if a static MAC is configured on AC1 (port 1) and then, if you send a packet with the same MAC as source MAC on AC2 (port 2), then you can’t attach this MAC to AC2 as a dynamic MAC. Therefore, do not send any packet with a MAC as any of the static MAC addresses configured.

The number of learned MAC addresses is limited through configurable per-port and per-bridge domain MAC address limits.

MAC Address Aging

A MAC address in the MAC table is considered valid only for the duration of the MAC address aging time. When the time expires, the relevant MAC entries are repopulated. When the MAC aging time is configured only under a bridge domain, all the pseudowires and attachment circuits in the bridge domain use that configured MAC aging time.

A bridge forwards, floods, or drops packets based on the bridge table. The bridge table maintains both static entries and dynamic entries. Static entries are entered by the network manager or by the bridge itself. Dynamic entries are entered by the bridge learning process. A dynamic entry is automatically removed after a specified length of time, known as *aging time*, from the time the entry was created or last updated.

If hosts on a bridged network are likely to move, decrease the aging-time to enable the bridge to adapt to the change quickly. If hosts do not transmit continuously, increase the aging time to record the dynamic entries for a longer time, thus reducing the possibility of flooding when the hosts transmit again.

MAC Address Limit

The MAC address limit is used to limit the number of learned MAC addresses.

When a limit is exceeded, the system is configured to perform these notifications:

- Syslog (default)
- Simple Network Management Protocol (SNMP) trap
- Syslog and SNMP trap
- None (no notification)

To generate syslogs messages and SNMP trap notifications, use the **mac limit notification both** command in the L2VPN bridge-domain configuration mode.

MAC address limit action applies only when the number of local MAC addresses exceeds the configured limit. The software unlearns the MAC addresses until it reaches the configured MAC limit threshold value. Later, the router restarts learning new MAC addresses. In the event when the MAC limit threshold is not configured, the default threshold is 75% of the configured MAC address limit.

MAC Address Withdrawal

For faster VPLS convergence, you can remove or unlearn the MAC addresses that are learned dynamically. The Label Distribution Protocol (LDP) Address Withdrawal message is sent with the list of MAC addresses, which need to be withdrawn to all other PEs that are participating in the corresponding VPLS service.

For the Cisco IOS XR VPLS implementation, a portion of the dynamically learned MAC addresses are cleared by using the MAC addresses aging mechanism by default. The MAC address withdrawal feature is added through the LDP Address Withdrawal message. To enable the MAC address withdrawal feature, use the **withdrawal** command in l2vpn bridge group bridge domain MAC configuration mode. To verify that the MAC address withdrawal is enabled, use the **show l2vpn bridge-domain** command with the **detail** keyword.

Note By default, the LDP MAC Withdrawal feature is enabled on Cisco IOS XR.

The LDP MAC Withdrawal feature is generated due to these events:

- Attachment circuit goes down. You can remove or add the attachment circuit through the CLI.
- MAC withdrawal messages are received over a VFI pseudowire. RFC 4762 specifies that both wildcards (by means of an empty Type, Length and Value [TLV]) and a specific MAC address withdrawal. Cisco IOS XR software supports only a wildcard MAC address withdrawal.

Configuration Examples for Multipoint Layer 2 Services

This section includes these configuration examples:

Multipoint Layer 2 Services Configuration for Provider Edge-to-Provider Edge: Example

These configuration examples show how to create a Layer 2 VFI with a full-mesh of participating Multipoint Layer 2 Services provider edge (PE) nodes.

This configuration example shows how to configure PE 1:

```
configure
 l2vpn
  bridge group 1
   bridge-domain PE1-VPLS-A
    interface TenGigE0/0/0/0
    vfi 1
     neighbor 10.2.2.2 pw-id 1
     neighbor 10.3.3.3 pw-id 1
     !
```

```
  !
 interface loopback 0
  ipv4 address 10.1.1.1 255.255.255.255
```

This configuration example shows how to configure PE 2:

```
configure
 l2vpn
  bridge group 1
   bridge-domain PE2-VPLS-A
    interface TenGigE0/0/0/1

    vfi 1
     neighbor 10.1.1.1 pw-id 1
     neighbor 10.3.3.3 pw-id 1
     !
   !
 interface loopback 0
  ipv4 address 10.2.2.2 255.255.255.255
```

This configuration example shows how to configure PE 3:

```
configure
 l2vpn
  bridge group 1
   bridge-domain PE3-VPLS-A
    interface TenGigE0/0/0/2
    vfi 1
     neighbor 10.1.1.1 pw-id 1
     neighbor 10.2.2.2 pw-id 1
     !
   !
 interface loopback 0
  ipv4 address 10.3.3.3 255.255.255.255
```

Multipoint Layer 2 Services Configuration for Provider Edge-to-Customer Edge: Example

This configuration shows how to configure Multipoint Layer 2 Services for a PE-to-CE nodes:

```
configure
 interface TenGigE0/0/0/0
  l2transport---AC interface

  no ipv4 address
  no ipv4 directed-broadcast
  negotiation auto
  no cdp enable
```

Displaying MAC Address Withdrawal Fields: Example

This sample output shows the MAC address withdrawal fields:

```
RP/0/RSP0/CPU0:router# show l2vpn bridge-domain detail

Legend: pp = Partially Programmed.
Bridge group: 222, bridge-domain: 222, id: 0, state: up, ShgId: 0, MSTi: 0
  Coupled state: disabled
  MAC learning: enabled
```

```
  MAC withdraw: enabled
    MAC withdraw sent on: bridge port up
    MAC withdraw relaying (access to access): disabled
  Flooding:
    Broadcast & Multicast: enabled
    Unknown unicast: enabled
  MAC aging time: 300 s, Type: inactivity
  MAC limit: 4000, Action: none, Notification: syslog
  MAC limit reached: no
  MAC port down flush: enabled
  MAC Secure: disabled, Logging: disabled
  Split Horizon Group: none
  Dynamic ARP Inspection: disabled, Logging: disabled
  IP Source Guard: disabled, Logging: disabled
  DHCPv4 snooping: disabled
  IGMP Snooping: enabled
  IGMP Snooping profile: none
  MLD Snooping profile: none
  Storm Control: disabled
  Bridge MTU: 1500
  MIB cvplsConfigIndex: 1
  Filter MAC addresses:
  P2MP PW: disabled
  Create time: 01/03/2017 11:01:11 (00:21:33 ago)
  No status change since creation
  ACs: 1 (1 up), VFIs: 1, PWs: 1 (1 up), PBBs: 0 (0 up)
  List of ACs:
    AC: TenGigE0/2/0/1.7, state is up
      Type VLAN; Num Ranges: 1
      Outer Tag: 21
      VLAN ranges: [22, 22]
      MTU 1508; XC ID 0x208000b; interworking none
      MAC learning: enabled
      Flooding:
        Broadcast & Multicast: enabled
        Unknown unicast: enabled
      MAC aging time: 300 s, Type: inactivity
      MAC limit: 4000, Action: none, Notification: syslog
      MAC limit reached: no
      MAC port down flush: enabled
      MAC Secure: disabled, Logging: disabled
      Split Horizon Group: none
      Dynamic ARP Inspection: disabled, Logging: disabled
      IP Source Guard: disabled, Logging: disabled
      DHCPv4 snooping: disabled
      IGMP Snooping: enabled
      IGMP Snooping profile: none
      MLD Snooping profile: none
      Storm Control: bridge-domain policer
      Static MAC addresses:
      Statistics:
        packets: received 714472608 (multicast 0, broadcast 0, unknown unicast 0, unicast
0), sent 97708776
        bytes: received 88594603392 (multicast 0, broadcast 0, unknown unicast 0, unicast
0), sent 12115888224
        MAC move: 0
      Storm control drop counters:
        packets: broadcast 0, multicast 0, unknown unicast 0
        bytes: broadcast 0, multicast 0, unknown unicast 0
      Dynamic ARP inspection drop counters:
        packets: 0, bytes: 0
      IP source guard drop counters:
        packets: 0, bytes: 0
  List of VFIs:
```

```
VFI 222 (up)
  PW: neighbor 1.1.1.1, PW ID 222, state is up ( established )
    PW class not set, XC ID 0xc000000a
    Encapsulation MPLS, protocol LDP
    Source address 21.21.21.21
    PW type Ethernet, control word disabled, interworking none
    Sequencing not set

    PW Status TLV in use
      MPLS         Local                          Remote
      ------------ ------------------------------ -------------------------
      Label        24017                          24010
      Group ID     0x0                            0x0
      Interface    222                            222
      MTU          1500                           1500
      Control word disabled                       disabled
      PW type      Ethernet                       Ethernet
      VCCV CV type 0x2                            0x2
                   (LSP ping verification)        (LSP ping verification)
      VCCV CC type 0x6                            0x6
                   (router alert label)           (router alert label)
                   (TTL expiry)                   (TTL expiry)
      ------------ ------------------------------ -------------------------
    Incoming Status (PW Status TLV):
      Status code: 0x0 (Up) in Notification message
    MIB cpwVcIndex: 3221225482
    Create time: 01/03/2017 11:01:11 (00:21:33 ago)
    Last time status changed: 01/03/2017 11:21:01 (00:01:43 ago)
    Last time PW went down: 01/03/2017 11:15:21 (00:07:23 ago)
    MAC withdraw messages: sent 0, received 0
    Forward-class: 0
    Static MAC addresses:
    Statistics:
      packets: received 95320440 (unicast 0), sent 425092569
      bytes: received 11819734560 (unicast 0), sent 52711478556
      MAC move: 0
    Storm control drop counters:
      packets: broadcast 0, multicast 0, unknown unicast 0
      bytes: broadcast 0, multicast 0, unknown unicast 0
  DHCPv4 snooping: disabled
  IGMP Snooping profile: none
  MLD Snooping profile: none
  VFI Statistics:
    drops: illegal VLAN 0, illegal length 0
```

Bridging on IOS XR Trunk Interfaces: Example

This example shows how to configure a Cisco NCS 5500 Series Routers as a simple L2 switch.

Important notes:

Create a bridge domain that has four attachment circuits (AC). Each AC is an IOS XR trunk interface (i.e. not a subinterface/EFP).

- This example assumes that the running config is empty, and that all the components are created.
- This example provides all the necessary steps to configure the Cisco NCS 5500 Series Routers to perform switching between the interfaces. However, the commands to prepare the interfaces such as no shut, negotiation auto, etc., have been excluded.
- The bridge domain is in a no shut state, immediately after being created.

- Only trunk (i.e. main) interfaces are used in this example.
- The trunk interfaces are capable of handling tagged (i.e. IEEE 802.1Q) or untagged (i.e. no VLAN header) frames.
- The bridge domain learns, floods, and forwards based on MAC address. This functionality works for frames regardless of tag configuration.
- The bridge domain entity spans the entire system. It is not necessary to place all the bridge domain ACs on a single LC. This applies to any bridge domain configuration.
- The show bundle and the show l2vpn bridge-domain commands are used to verify that the router was configured as expected, and that the commands show the status of the new configurations.
- The ACs in this example use interfaces that are in the admin down state.

Configuration Example

```
RP/0/RSP0/CPU0:router#config
RP/0/RSP0/CPU0:router(config)#interface Bundle-ether10
RP/0/RSP0/CPU0:router(config-if)#l2transport
RP/0/RSP0/CPU0:router(config-if-l2)#interface GigabitEthernet0/2/0/5
RP/0/RSP0/CPU0:router(config-if)#bundle id 10 mode active
RP/0/RSP0/CPU0:router(config-if)#interface GigabitEthernet0/2/0/6
RP/0/RSP0/CPU0:router(config-if)#bundle id 10 mode active
RP/0/RSP0/CPU0:router(config-if)#interface GigabitEthernet0/2/0/0
RP/0/RSP0/CPU0:router(config-if)#l2transport
RP/0/RSP0/CPU0:router(config-if-l2)#interface GigabitEthernet0/2/0/1
RP/0/RSP0/CPU0:router(config-if)#l2transport
RP/0/RSP0/CPU0:router(config-if-l2)#interface TenGigE0/1/0/2
RP/0/RSP0/CPU0:router(config-if)#l2transport
RP/0/RSP0/CPU0:router(config-if-l2)#l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)#bridge group examples
RP/0/RSP0/CPU0:router(config-l2vpn-bg)#bridge-domain test-switch
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)#interface Bundle-ether10
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#exit
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)#interface GigabitEthernet0/2/0/0
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#exit
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)#interface GigabitEthernet0/2/0/1
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#exit
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)#interface TenGigE0/1/0/2
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#commit
RP/0/RSP0/CPU0:Jul 26 10:48:21.320 EDT: config[65751]: %MGBL-CONFIG-6-DB_COMMIT :
Configuration committed by user 'lab'. Use 'show configuration commit changes 1000000973'
to view the changes.
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#end
RP/0/RSP0/CPU0:Jul 26 10:48:21.342 EDT: config[65751]: %MGBL-SYS-5-CONFIG_I : Configured
from console by lab
RP/0/RSP0/CPU0:router#show bundle Bundle-ether10

Bundle-Ether10
  Status:                                    Down
  Local links <active/standby/configured>:   0 / 0 / 2
  Local bandwidth <effective/available>:     0 (0) kbps
  MAC address (source):                      0024.f71e.22eb (Chassis pool)
  Minimum active links / bandwidth:          1 / 1 kbps
  Maximum active links:                      64
  Wait while timer:                          2000 ms
  LACP:                                      Operational
    Flap suppression timer:                  Off
  mLACP:                                     Not configured
  IPv4 BFD:                                  Not configured
```

```
  Port                  Device          State        Port ID         B/W, kbps
  --------------------  --------------- -----------  --------------  ----------
  Gi0/2/0/5             Local           Configured   0x8000, 0x0001     1000000
      Link is down
  Gi0/2/0/6             Local           Configured   0x8000, 0x0002     1000000
      Link is down

RP/0/RSP0/CPU0:router#
RP/0/RSP0/CPU0:router#show l2vpn bridge-domain group examples
Bridge group: examples, bridge-domain: test-switch, id: 2000, state: up, ShgId: 0, MSTi: 0
  Aging: 300 s, MAC limit: 4000, Action: none, Notification: syslog
  Filter MAC addresses: 0
  ACs: 4 (1 up), VFIs: 0, PWs: 0 (0 up), PBBs: 0 (0 up)
  List of ACs:
    BE10, state: down, Static MAC addresses: 0
    Gi0/2/0/0, state: up, Static MAC addresses: 0
    Gi0/2/0/1, state: down, Static MAC addresses: 0
    Te0/5/0/1, state: down, Static MAC addresses: 0
  List of VFIs:
RP/0/RSP0/CPU0:router#
```

This table lists the configuration steps (actions) and the corresponding purpose for this example:

SUMMARY STEPS

1. **configure**
2. **interface Bundle-ether10**
3. **l2transport**
4. **interface GigabitEthernet0/2/0/5**
5. **bundle id 10 mode active**
6. **interface GigabitEthernet0/2/0/6**
7. **bundle id 10 mode active**
8. **interface GigabitEthernet0/2/0/0**
9. **l2transport**
10. **interface GigabitEthernet0/2/0/1**
11. **l2transport**
12. **interface TenGigE0/1/0/2**
13. **l2transport**
14. **l2vpn**
15. **bridge group examples**
16. **bridge-domain test-switch**
17. **interface Bundle-ether10**
18. **exit**
19. **interface GigabitEthernet0/2/0/0**
20. **exit**
21. **interface GigabitEthernet0/2/0/1**
22. **exit**
23. **interface TenGigE0/1/0/2**
24. Use the **commit** or **end** command.

DETAILED STEPS

Step 1 **configure**

Enters global configuration mode.

Step 2 **interface Bundle-ether10**

Creates a new bundle trunk interface.

Step 3 **l2transport**

Changes Bundle-ether10 from an L3 interface to an L2 interface.

Step 4 **interface GigabitEthernet0/2/0/5**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/2/0/5.

Step 5 **bundle id 10 mode active**

Establishes GigabitEthernet0/2/0/5 as a member of Bundle-ether10. The **mode active** keywords specify LACP protocol.

Step 6 **interface GigabitEthernet0/2/0/6**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/2/0/6.

Step 7 **bundle id 10 mode active**

Establishes GigabitEthernet0/2/0/6 as a member of Bundle-ether10. The **mode active** keywords specify LACP protocol.

Step 8 **interface GigabitEthernet0/2/0/0**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/2/0/0.

Step 9 **l2transport**

Change GigabitEthernet0/2/0/0 from an L3 interface to an L2 interface.

Step 10 **interface GigabitEthernet0/2/0/1**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/2/0/1.

Step 11 **l2transport**

Change GigabitEthernet0/2/0/1 from an L3 interface to an L2 interface.

Step 12 **interface TenGigE0/1/0/2**

Enters interface configuration mode. Changes configuration mode to act on TenGigE0/1/0/2.

Step 13 **l2transport**

Changes TenGigE0/1/0/2 from an L3 interface to an L2 interface.

Step 14 **l2vpn**

Enters L2VPN configuration mode.

Step 15 **bridge group examples**

Creates the bridge group **examples**.

Step 16 **bridge-domain test-switch**

Creates the bridge domain **test-switch**, that is a member of bridge group **examples**.

Step 17 **interface Bundle-ether10**

Establishes Bundle-ether10 as an AC of bridge domain test-switch.

Step 18 **exit**

Exits bridge domain AC configuration submode, allowing next AC to be configured.

Step 19 **interface GigabitEthernet0/2/0/0**

Establishes GigabitEthernet0/2/0/0 as an AC of bridge domain **test-switch**.

Step 20 **exit**

Exits bridge domain AC configuration submode, allowing next AC to be configured.

Step 21 **interface GigabitEthernet0/2/0/1**

Establishes GigabitEthernet0/2/0/1 as an AC of bridge domain **test-switch**.

Step 22 **exit**

Exits bridge domain AC configuration submode, allowing next AC to be configured.

Step 23 **interface TenGigE0/1/0/2**

Establishes interface TenGigE0/1/0/2 as an AC of bridge domain **test-switch**.

Step 24 Use the **commit** or **end** command.

commit - Saves the configuration changes and remains within the configuration session.

end - Prompts user to take one of these actions:

- **Yes** - Saves configuration changes and exits the configuration session.
- **No** - Exits the configuration session without committing the configuration changes.
- **Cancel** - Remains in the configuration mode, without committing the configuration changes.

Bridging on Ethernet Flow Points: Example

This example shows how to configure a Cisco NCS 5500 Series Router to perform Layer 2 switching on traffic that passes through Ethernet Flow Points (EFPs). EFP traffic typically has one or more VLAN headers. Although both IOS XR trunks and IOS XR EFPs can be combined as attachment circuits in bridge domains, this example uses EFPs exclusively.

Important notes:

- An EFP is a Layer 2 subinterface. It is always created under a trunk interface. The trunk interface must exist before the EFP is created.
- In an empty configuration, the bundle interface trunk does not exist, but the physical trunk interfaces are automatically configured. Therefore, only the bundle trunk is created.

- In this example the subinterface number and the VLAN IDs are identical, but this is out of convenience, and is not a necessity. They do not need to be the same values.
- The bridge domain test-efp has three attachment circuits (ACs). All the ACs are EFPs.
- Only frames with a VLAN ID of 999 enter the EFPs. This ensures that all the traffic in this bridge domain has the same VLAN encapsulation.
- The ACs in this example use interfaces that are in the admin down state (**unresolved** state). Bridge domains that use nonexistent interfaces as ACs are legal, and the commit for such configurations does not fail. In this case, the status of the bridge domain shows **unresolved** until you configure the missing interface.

Configuration Example

```
RP/0/RSP1/CPU0:router#configure
RP/0/RSP1/CPU0:router(config)#interface Bundle-ether10
RP/0/RSP1/CPU0:router(config-if)#interface Bundle-ether10.999 l2transport
RP/0/RSP1/CPU0:router(config-subif)#encapsulation dot1q 999
RP/0/RSP1/CPU0:router(config-subif)#interface GigabitEthernet0/6/0/5
RP/0/RSP1/CPU0:router(config-if)#bundle id 10 mode active
RP/0/RSP1/CPU0:router(config-if)#interface GigabitEthernet0/6/0/6
RP/0/RSP1/CPU0:router(config-if)#bundle id 10 mode active
RP/0/RSP1/CPU0:router(config-if)#interface GigabitEthernet0/6/0/7.999 l2transport
RP/0/RSP1/CPU0:router(config-subif)#encapsulation dot1q 999
RP/0/RSP1/CPU0:router(config-subif)#interface TenGigE0/1/0/2.999 l2transport
RP/0/RSP1/CPU0:router(config-subif)#encapsulation dot1q 999
RP/0/RSP1/CPU0:router(config-subif)#l2vpn
RP/0/RSP1/CPU0:router(config-l2vpn)#bridge group examples
RP/0/RSP1/CPU0:router(config-l2vpn-bg)#bridge-domain test-efp
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd)#interface Bundle-ether10.999
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd-ac)#exit
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd)#interface GigabitEthernet0/6/0/7.999
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd-ac)#exit
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd)#interface TenGigE0/1/0/2.999
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd-ac)#commit
RP/0/RSP1/CPU0:router(config-l2vpn-bg-bd-ac)#end
RP/0/RSP1/CPU0:router#
RP/0/RSP1/CPU0:router#show l2vpn bridge group examples
Fri Jul 23 21:56:34.473 UTC Bridge group: examples, bridge-domain: test-efp, id: 0, state:
 up, ShgId: 0, MSTi: 0
Aging: 300 s, MAC limit: 4000, Action: none, Notification: syslog
  Filter MAC addresses: 0
  ACs: 3 (0 up), VFIs: 0, PWs: 0 (0 up), PBBs: 0 (0 up)
  List of ACs:
    BE10.999, state: down, Static MAC addresses: 0
    Gi0/6/0/7.999, state: unresolved, Static MAC addresses: 0
    Te0/1/0/2.999, state: down, Static MAC addresses: 0
  List of VFIs:
RP/0/RSP1/CPU0:router#
```

This table lists the configuration steps (actions) and the corresponding purpose for this example:

SUMMARY STEPS

1. **configure**
2. **interface Bundle-ether10**
3. **interface Bundle-ether10.999 l2transport**
4. **encapsulation dot1q 999**

5. **interface GigabitEthernet0/6/0/5**
6. **bundle id 10 mode active**
7. **interface GigabitEthernet0/6/0/6**
8. **bundle id 10 mode active**
9. **interface GigabitEthernet0/6/0/7.999 l2transport**
10. **encapsulation dot1q 999**
11. **interface TenGigE0/1/0/2.999 l2transport**
12. **encapsulation dot1q 999**
13. **l2vpn**
14. **bridge group examples**
15. **bridge-domain test-efp**
16. **interface Bundle-ether10.999**
17. **exit**
18. **interface GigabitEthernet0/6/0/7.999**
19. **exit**
20. **interface TenGigE0/1/0/2.999**
21. Use the **commit** or **end** command.

DETAILED STEPS

Step 1 **configure**

Enters global configuration mode.

Step 2 **interface Bundle-ether10**

Creates a new bundle trunk interface.

Step 3 **interface Bundle-ether10.999 l2transport**

Creates an EFP under the new bundle trunk.

Step 4 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

Step 5 **interface GigabitEthernet0/6/0/5**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/6/0/5.

Step 6 **bundle id 10 mode active**

Establishes GigabitEthernet0/6/0/5 as a member of Bundle-ether10. The **mode active** keywords specify LACP protocol.

Step 7 **interface GigabitEthernet0/6/0/6**

Enters interface configuration mode. Changes configuration mode to act on GigabitEthernet0/6/0/6.

Step 8 **bundle id 10 mode active**

Establishes GigabitEthernet0/6/0/6 as a member of Bundle-ether10. The **mode active** keywords specify LACP protocol.

Step 9 **interface GigabitEthernet0/6/0/7.999 l2transport**

Creates an EFP under GigabitEthernet0/6/0/7.

Step 10 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

Step 11 **interface TenGigE0/1/0/2.999 l2transport**

Creates an EFP under TenGigE0/1/0/2.

Step 12 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

Step 13 **l2vpn**

Enters L2VPN configuration mode.

Step 14 **bridge group examples**

Creates the bridge group named **examples**.

Step 15 **bridge-domain test-efp**

Creates the bridge domain named **test-efp**, that is a member of bridge group **examples**.

Step 16 **interface Bundle-ether10.999**

Establishes Bundle-ether10.999 as an AC of the bridge domain named **test-efp**.

Step 17 **exit**

Exits bridge domain AC configuration submode, allowing next AC to be configured.

Step 18 **interface GigabitEthernet0/6/0/7.999**

Establishes GigabitEthernet0/6/0/7.999 as an AC of the bridge domain named **test-efp**.

Step 19 **exit**

Exits bridge domain AC configuration submode, allowing next AC to be configured.

Step 20 **interface TenGigE0/1/0/2.999**

Establishes interface TenGigE0/1/0/2.999 as an AC of bridge domain named **test-efp**.

Step 21 Use the **commit** or **end** command.

commit - Saves the configuration changes and remains within the configuration session.

end - Prompts user to take one of these actions:

- **Yes** - Saves configuration changes and exits the configuration session.
- **No** - Exits the configuration session without committing the configuration changes.
- **Cancel** - Remains in the configuration mode, without committing the configuration changes.

CHAPTER 7

Configure Point-to-Point Layer 2 Services

This section introduces you to point-to-point Layer 2 services, and also describes the configuration procedures to implement it.

The following point-to-point services are supported:

- Local Switching—A point-to-point internal circuit on a router, also known as local connect.
- Attachment circuit—A connection between a PE-CE router pair.
- Pseudowires—A virtual point-to-point circuit from one PE router to another. Pseudowires are implemented over the MPLS network.

Note Point-to-point Layer 2 services are also called as MPLS Layer 2 VPNs.

Ethernet over MPLS

Ethernet-over-MPLS (EoMPLS) provides a tunneling mechanism for Ethernet traffic through an MPLS-enabled Layer 3 core, and encapsulates Ethernet protocol data units (PDUs) inside MPLS packets (using label stacking) to forward them across the MPLS network.

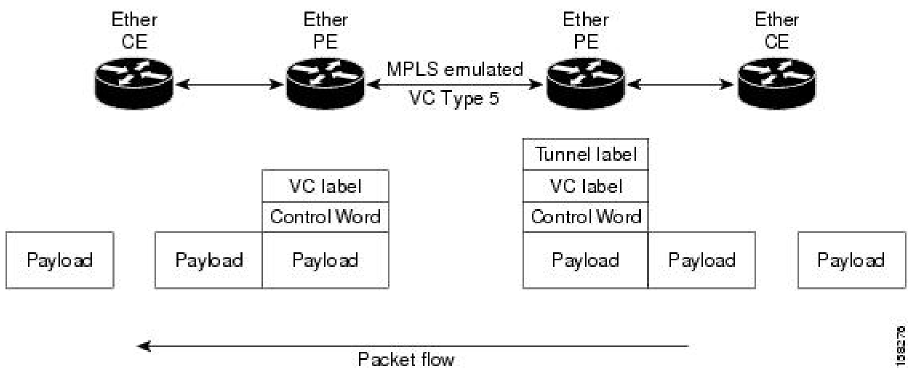
The following sections describe the different modes of implementing EoMPLS.

Ethernet Port Mode

In Ethernet port mode, both ends of a pseudowire are connected to Ethernet ports. In this mode, the port is tunneled over the pseudowire or, using local switching (also known as an *attachment circuit-to-attachment* *circuit cross-connect*) switches packets or frames from one attachment circuit (AC) to another AC attached to the same PE node.

This figure shows a sample ethernet port mode packet flow:

Figure 2: Ethernet Port Mode Packet Flow

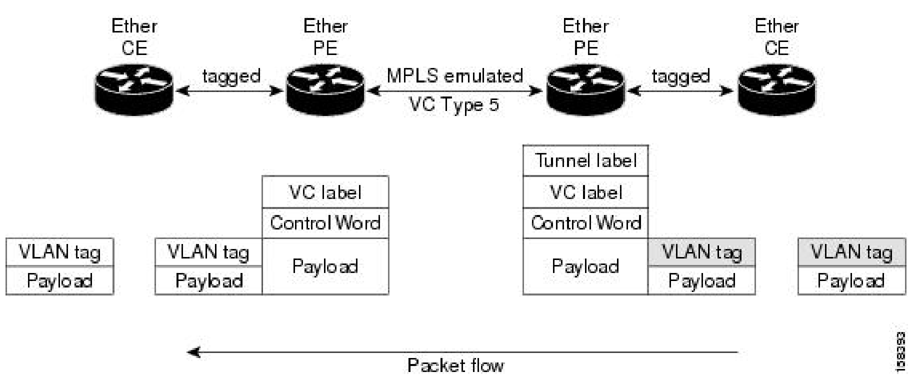


VLAN Mode

In VLAN mode, each VLAN on a customer-end to provider-end link can be configured as a separate L2VPN connection using virtual connection (VC) type 4 or VC type 5. VC type 5 is the default mode.

As illustrated in the following figure, the Ethernet PE associates an internal VLAN-tag to the Ethernet port for switching the traffic internally from the ingress port to the pseudowire; however, before moving traffic into the pseudowire, it removes the internal VLAN tag.

Figure 3: VLAN Mode Packet Flow



At the egress VLAN PE, the PE associates a VLAN tag to the frames coming off of the pseudowire and after switching the traffic internally, it sends out the traffic on an Ethernet trunk port.

Note Because the port is in trunk mode, the VLAN PE doesn't remove the VLAN tag and forwards the frames through the port with the added tag.

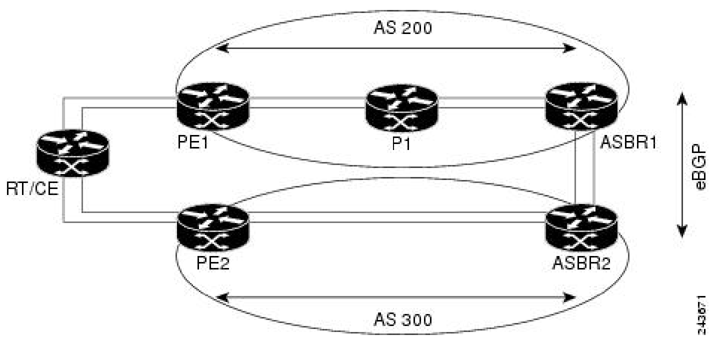
Inter-AS Mode

Inter-AS is a peer-to-peer type model that allows extension of VPNs through multiple provider or multi-domain networks. This lets service providers peer up with one another to offer end-to-end VPN connectivity over extended geographical locations.

EoMPLS support can assume a single AS topology where the pseudowire connecting the PE routers at the two ends of the point-to-point EoMPLS cross-connects resides in the same autonomous system; or multiple AS topologies in which PE routers can reside on two different ASs using iBGP and eBGP peering.

The following figure illustrates MPLS over Inter-AS with a basic double AS topology with iBGP/LDP in each AS.

Figure 4: EoMPLS over Inter-AS: Basic Double AS Topology



QinQ Mode

QinQ is an extension of 802.1Q for specifying multiple 802.1Q tags (IEEE 802.1QinQ VLAN Tag stacking). Layer 3 VPN service termination and L2VPN service transport are enabled over QinQ sub-interfaces.

Cisco NCS 500x Series Router implement the Layer 2 tunneling or Layer 3 forwarding depending on the sub-interface configuration at provider edge routers. This function only supports up to two QinQ tags on the router:

- Layer 2 QinQ VLANs in L2VPN attachment circuit: QinQ L2VPN attachment circuits are configured under the Layer 2 transport sub-interfaces for point-to-point EoMPLS based cross-connects using both virtual circuit type 4 and type 5 pseudowires and point-to-point local-switching-based cross-connects including full inter-working support of QinQ with 802.1q VLANs and port mode.
- Layer 3 QinQ VLANs: Used as a Layer 3 termination point, both VLANs are removed at the ingress provider edge and added back at the remote provider edge as the frame is forwarded.

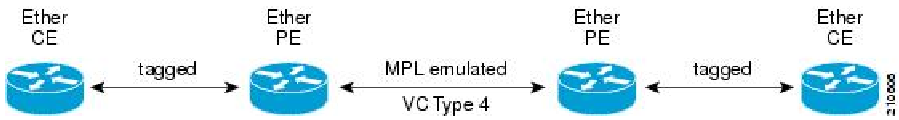
Layer 3 services over QinQ include:

- IPv4 unicast and multicast
- IPv6 unicast and multicast
- MPLS
- Connectionless Network Service (CLNS) for use by Intermediate System-to-Intermediate System (IS-IS) Protocol

In QinQ mode, each CE VLAN is carried into an SP VLAN. QinQ mode should use VC type 5, but VC type 4 is also supported. On each Ethernet PE, you must configure both the inner (CE VLAN) and outer (SP VLAN).

The following figure illustrates QinQ using VC type 4.

Figure 5: EoMPLS over QinQ Mode



Note EoMPLS does not support pseudowire stitching or multi segments.

QinAny Mode

In the QinAny mode, the service provider VLAN tag is configured on both the ingress and the egress nodes of the provider edge VLAN. QinAny mode is similar to QinQ mode using a Type 5 VC, except that the customer edge VLAN tag is carried in the packet over the pseudowire, as the customer edge VLAN tag is unknown.

Configure Local Switching Between Attachment Circuits

Local switching involves the exchange of L2 data from one attachment circuit (AC) to the other, and between two interfaces of the same type on the same router. The two ports configured in a local switching connection form an attachment circuit (AC). A local switching connection works like a bridge domain that has only two bridge ports, where traffic enters from one port of the local connection and leaves through the other.

These are some of the characteristics of Layer 2 local switching:

- Layer 2 local switching uses Layer 2 MAC addresses instead of the Layer 3 IP addresses.
- Because there is no bridging involved in a local connection, there is neither MAC learning nor flooding.
- Unlike in a bridge domain, the ACs in a local connection are not in the UP state if the interface state is DOWN.
- Local switching ACs utilize a full variety of Layer 2 interfaces, including Layer 2 trunk (main) interfaces, bundle interfaces, and EFPs.
- Same-port local switching allows you to switch Layer 2 data between two circuits on the same interface.

Restrictions

- All sub-interfaces under the given physical port support only two Tag Protocol Identifiers (TPIDs), such as:
    - 0x88a8, 0x8100
    - 0x9100, 0x8100

    - 0x9200, 0x8100

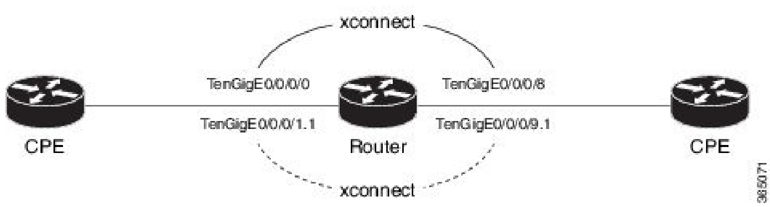
- VLAN and TPID-based ingress packet filtering is not supported.
- Egress TPID rewrite is not supported.

Topology

An Attachment Circuit (AC) binds a Customer Edge (CE) router to a Provider Edge (PE) router. The PE router uses a pseudowire over the MPLS network to exchange routes with a remote PE router. To establish a point-to-point connection in a Layer 2 VPN from one Customer Edge (CE) router to another (remote router), a mechanism is required to bind the attachment circuit to the pseudowire. A Cross-Connect Circuit (CCC) is used to bind attachment circuits to pseudowires to emulate a point-to-point connection in a Layer 2 VPN.

The following topology is used for configuration.

Figure 6: Local Switching Between Attachment Circuits



Configuration

To configure an AC-AC local switching, complete the following configuration:

- Enable Layer 2 transport on main interfaces.
- Create sub-interfaces with Layer 2 transport enabled, and specify the respective encapsulation for each.
- Enable local switching between the main interfaces, and between the sub-interfaces.
    - Create a cross-connect group.
    - Create a point-to-point cross connect circuit (CCC).
    - Assign interface(s) to the point-to-point cross connect group.

```
/* Enter the interface configuration mode and configure
  L2 transport on the TenGigE interfaces */
Router# configure
Router(config)# interface TenGigE 0/0/0/1 l2transport
Router(config-if-l2)# no shutdown
Router(config-if)# exit
Router(config)# interface TenGigE 0/0/0/9 l2transport
Router(config-if-l2)# no shutdown
Router(config-if-l2)# commit

/* Configure L2 transport and encapsulation on the VLAN sub-interfaces */
Router# configure
Router(config)# interface TenGigE 0/0/0/0.1 l2transport
Router(config-subif)# encapsulation dot1q 5
Router(config-subif)# exit
```

```
Router(config)# interface TenGigE 0/0/0/8.1 l2transport
Router(config-subif)# encapsulation dot1q 5
Router(config-subif)# commit


/* Configure ethernet link bundles */
Router# configure
Router(config)# interface Bundle-Ether 3
Router(config-if)# ipv4 address 10.1.3.3 255.0.0.0
Router(config-if)# bundle maximum-active links 32 hot-standby
Router(config-if)# bundle minimum-active links 1
Router(config-if)# bundle minimum-active bandwidth 30000000
Router(config-if)# exit

Router(config)# interface Bundle-Ether 2
Router(config-if)# ipv4 address 10.1.2.2 255.0.0.0
Router(config-if)# bundle maximum-active links 32 hot-standby
Router(config-if)# bundle minimum-active links 1
Router(config-if)# bundle minimum-active bandwidth 30000000
Router(config-if)# exit

/* Add physical interfaces to the ethernet link bundles */
Router(config)# interface TenGigE 0/0/0/1
Router(config-if)# bundle id 3 mode on
Router(config-if)# no shutdown
Router(config)# exit
Router(config)# interface TenGigE 0/0/0/2
Router(config-if)# bundle id 3 mode on
Router(config-if)# no shutdown
Router(config)# exit
Router(config)# interface TenGigE 0/0/0/9
Router(config-if)# bundle id 2 mode on
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# interface TenGigE 0/0/0/8
Router(config-if)# bundle id 2 mode on
Router(config-if)# no shutdown
Router(config-if)# exit

/* Configure Layer 2 transport on the ethernet link bundles */
Router(config)# interface Bundle-Ether 3 l2transport
Router(config-if-l2)# no shutdown
Router(config-if)# exit
Router(config)# interface Bundle-Ether 2 l2transport
Router(config-if-l2)# no shutdown
Router(config-if-l2)# commit

/* Configure local switching on the TenGigE Interfaces */
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group XCON1
Router(config-l2vpn-xc)# p2p XCON1_P2P3
Router(config-l2vpn-xc-p2p)# interface TenGigE0/0/0/1
Router(config-l2vpn-xc-p2p)# interface TenGigE0/0/0/9
Router(config-l2vpn-xc-p2p)# commit
Router(config-l2vpn-xc-p2p)# exit

/* Configure local switching on the VLAN sub-interfaces */
Router(config-l2vpn-xc)# p2p XCON1_P2P1
Router(config-l2vpn-xc-p2p)# interface TenGigE0/0/0/0.1
Router(config-l2vpn-xc-p2p)# interface TenGigE0/0/0/8.1
Router(config-l2vpn-xc-p2p)# commit
Router(config-l2vpn-xc-p2p)# exit
```

```
/* Configure local switching on ethernet link bundles */
Router(config-l2vpn-xc)# p2p XCON1_P2P4
Router(config-l2vpn-xc-p2p)# interface Bundle-Ether 3
Router(config-l2vpn-xc-p2p)# interface Bundle-Ether 2
Router(config-l2vpn-xc-p2p)# commit
```

Running Configuration

```
configure
 interface tenGigE 0/0/0/1 l2transport
 !
 interface tenGigE 0/0/0/9 l2transport
 !
!

interface tenGigE 0/0/0/0.1 l2transport
 encapsulation dot1q 5
 rewrite ingress tag push dot1q 20 symmetric
 !
interface tenGigE 0/0/0/8.1 l2transport
  encapsulation dot1q 5
 !
interface Bundle-Ether 3 l2transport
 !
interface Bundle-Ether 2 l2transport
!

l2vpn
 xconnect group XCON1
   p2p XCON1_P2P3
    interface TenGigE0/0/0/1
    interface TenGigE0/0/0/9
    !
   !
 !
l2vpn
 xconnect group XCON1
   p2p XCON1_P2P1
    interface TenGigE0/0/0/0.1
    interface TenGigE0/0/0/8.1
    !
   !
 !
l2vpn
 xconnect group XCON1
   p2p XCON1_P2P4
    interface Bundle-Ether 3
    interface Bundle-Ether 2
    !
   !
 !
```

Verification

- Verify if the configured cross-connect is UP

```
router# show l2vpn xconnect brief
```

```
Locally Switching

  Like-to-Like                        UP         DOWN        UNR

    EFP                                1            0          0

    Total                              1            0          0


  Total                                1            0          0

Total: 1 UP, 0 DOWN, 0 UNRESOLVED


router# show l2vpn xconnect

Legend: ST = State, UP = Up, DN = Down, AD = Admin Down, UR = Unresolved,
        SB = Standby, SR = Standby Ready, (PP) = Partially Programmed

XConnect                   Segment 1                      Segment 2
Group      Name        ST   Description            ST      Description        ST
------------------------   --------------------------------------------------------------
XCON1      XCON_P2P1 UP    Te0/0/0/1        UP  Te0/0/0/9       UP
XCON1      XCON_P2P3 UP    Te0/0/0/0.1      UP  Te0/0/0/8.1     UP
-------------------------------------------------------------------------------------
```

Associated Commands

- interface (p2p)
- l2vpn
- p2p
- xconnect group

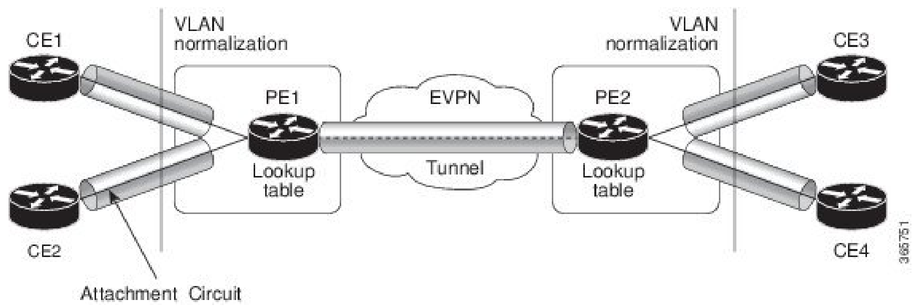
Flexible Cross-Connect Service

The flexible cross-connect service feature enables aggregation of attachment circuits (ACs) across multiple endpoints in a single Ethernet VPN Virtual Private Wire Service (EVPN-VPWS) service instance, on the same Provider Edge (PE). ACs are represented either by a single VLAN tag or double VLAN tags. The associated AC with the same VLAN tag(s) on the remote PE is cross-connected. The VLAN tags define the matching criteria to be used in order to map the frames on an interface to the appropriate service instance. As a result, the VLAN rewrite value must be unique within the flexible cross-connect (FXC) instance to create the lookup table. The VLAN tags can be made unique using the rewrite configuration. The lookup table helps determine the path to be taken to forward the traffic to the corresponding destination AC. This feature reduces the number of tunnels by muxing VLANs across many interfaces. It also reduces the number of MPLS labels used by a router. This feature supports both single-homing and multi-homing.

Flexible Cross-Connect Service - Single-Homed

Consider the following topology in which the traffic flows from CE1 and CE2 to PE1 through ACs. ACs are aggregated across multiple endpoints on the same PE. The VLAN (rewrite) creates the lookup table based on the rewrite configured at AC interfaces on PE1. PE1 uses BGP to exchange routes with PE2 and creates a tunnel over EVPN MPLS network. The VLANs (rewrite) on PE2 must match the rewrite configured on PE1. Based on the rewrite tag, the PE2 forwards the traffic to the corresponding ACs. For example, if the ACs for CE1 and CE3 are configured with the same rewrite tag, the end-to-end traffic is sent from CE1 to CE3.

Figure 7: Flexible Cross-Connect Service

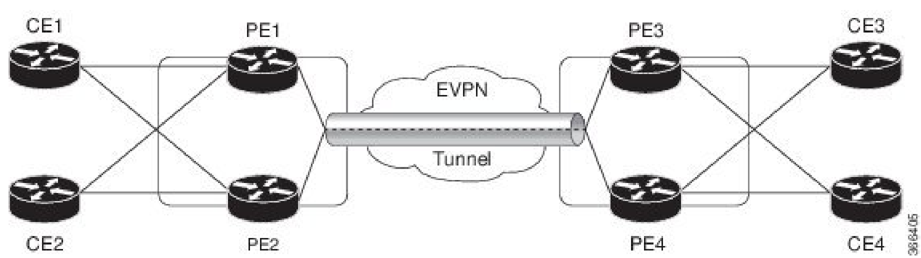


Flexible Cross-Connect Service - Multi-Homed

The Flexible Cross-Connect Service multihoming capability enables you to connect a customer edge (CE) device to two or more provider edge (PE) devices to provide load balancing and redundant connectivity. Flow-based load balancing is used to send the traffic between PEs and CEs. Flow-based load balancing is used to connect source and remote PEs as well. The customer edge device is connected to PE through Ethernet bundle interface.

When a CE device is multi-homed to two or more PEs and when all PEs can forward traffic to and from the multi-homed device for the VLAN, then such multihoming is referred to as all-active multihoming.

Figure 8: Flexible Cross-Connect Service Multi-Homed



Consider the topology in which CE1 and CE2 are multi-homed to PE1 and PE2; CE3 and CE4 are multi-homed to PE3 and PE4. PE1 and PE2 advertise Ethernet A-D Ethernet Segment (ES-EAD) route to remote PEs that is PE3 and PE4. Similarly, PE3 and PE4 advertise ES-EAD route to remote PEs that is PE1 and PE2. The ES-EAD route is advertised per main interface.

Consider a traffic flow from CE1 to CE3. Traffic is sent to either PE1 or PE2. The selection of path is dependent on the CE implementation for forwarding over a LAG. Traffic is encapsulated at each PE and forwarded to the remote PEs (PE 3 and PE4) through the MPLS tunnel. Selection of the destination PE is established by flow-based load balancing. PE3 and PE4 send the traffic to CE3. The selection of path from PE3 or PE4 to CE3 is established by flow-based load balancing.

Flexible Cross-Connect Service Supported Modes

The Flexible Cross-Connect Service feature supports the following modes:

- VLAN Unaware
- VLAN Aware
- Local Switching

VLAN Unaware

In this mode of operation, a group of normalized ACs on a single ES that are destined to a single endpoint or interface are multiplexed into a single EVPN VPWS tunnel represented by a single VPWS service ID. The VLAN-Unaware FXC reduces the number of BGP states. VLAN failure is not signaled over BGP. One EVI/EAD route is advertised per VLAN-Unaware FXC rather than per AC. In multihoming scenario, there will be ES-EAD route as well. EVI can be shared with other VLAN-Unaware FXC or EVPN VPWS. If AC goes down on PE1, the remote PE is not be informed of the failure, and PE3 or PE4 continues to send the traffic to PE1 and PE2 resulting in packet drop.

Multihoming is supported on VLAN Unaware FXC only if all ACs belong to the same main interface.

If you have multiple ESIs, regardless of whether it is a zero-ESI or non-zero ESI, only ESI 0 is signalled. Only single-home mode is supported in this scenario.

Configure Single-Homed Flexible Cross-Connect Service using VLAN Unaware

This section describes how you can configure single-homed flexible cross-connect service using VLAN unaware

```
/* Configure PE1 */
Router# configure
Router(config)# interface GigabitEthernet 0/2/0/3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface GigabitEthernet 0/2/0/0.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxs1
Router(config-l2vpn-fxs-vu)# interface GigabitEthernet 0/2/0/3.1
Router(config-l2vpn-fxs-vu)# interface GigabitEthernet 0/2/0/0.1
Router(config-l2vpn-fxs-vu)# neighbor evpn evi 1 target 1
Router(config-l2vpn-fxs-vu)# commit
```

```
/* Configure PE2 */
Router# configure
Router(config)# interface GigabitEthernet 0/0/0/3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100
 symetric
```

```
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface GigabitEthernet 0/0/0/0.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxs1
Router(config-l2vpn-fxs-vu)# interface GigabitEthernet 0/0/0/3.1
Router(config-l2vpn-fxs-vu)# interface GigabitEthernet 0/0/0/0.1
Router(config-l2vpn-fxs-vu)# neighbor evpn evi 1 target 1
Router(config-l2vpn-fxs-vu)# commit
```

Running Configuration

```
/* On PE1 */
!
Configure
interface GigabitEthernet 0/2/0/3.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100 symetric
!

Configure
interface GigabitEthernet 0/2/0/0.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200 symetric
!

l2vpn
  flexible-xconnect-service vlan-unaware fxs1
   interface GigabitEthernet 0/2/0/3.1
   interface GigabitEthernet0/2/0/0.1
   neighbor evpn evi 1 target 1

!

/* On PE2 */
!
Configure
interface GigabitEthernet 0/0/0/3.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100 symetric
!

Configure
interface GigabitEthernet 0/0/0/0.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200 symetric
!

l2vpn
  flexible-xconnect-service vlan-unaware fxs1
   interface GigabitEthernet 0/0/0/3.1
   interface GigabitEthernet0/0/0/0.1
   neighbor evpn evi 1 target 1

!
```

Configure Multi-Homed Flexible Cross-Connect Service using VLAN Unaware

This section describes how you can configure multi-homed flexible cross-connect service using VLAN unaware.

```
/* Configure PE1 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxc1_16
Router(config-l2vpn-fxs)# interface Bundle-Ether10.11
Router(config-l2vpn-fxs)# interface Bundle-Ether10.12
Router(config-l2vpn-fxs)# neighbor evpn evi 1 target 16
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether10.11 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether10.12 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-subif)# commit
Router(config-subif)# exit
Router(config)# evpn
Router (config-evpn)# interface Bundle-Ether10
Router (config-evpn-ac)# ethernet-segment
Router (config-evpn-ac-es)# identifier type  0 00.01.00.ac.ce.55.00.0a.00
Router (config-evpn-ac-es)# commit
```

```
/* Configure PE2 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxc1_16
Router(config-l2vpn-fxs-vu)# interface Bundle-Ether10.11
Router(config-l2vpn-fxs)# interface Bundle-Ether10.12
Router(config-l2vpn-fxs)# neighbor evpn evi 1 target 16
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether10.11 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether10.12 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-subif)# commit
Router(config-subif)# exit
Router(config)# evpn
Router (config-evpn)# interface Bundle-Ether10
Router (config-evpn-ac)# ethernet-segment
Router (config-evpn-ac-es)# identifier type  0 00.01.00.ac.ce.55.00.0a.00
Router (config-evpn-ac-es)# commit
```

```
/* Configure PE3 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxc1_16
Router(config-l2vpn-fxs-vu)# interface Bundle-Ether20.11
Router(config-l2vpn-fxs)# interface Bundle-Ether20.12
```

```
Router(config-l2vpn-fxs)# neighbor evpn evi 1 target 16
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether20.11 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-subif)# exit
Router(config)# interface Bundle-Ether20.12 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-subif)# exit
Router(config)# evpn
Router (config-evpn)# interface Bundle-Ether20
Router (config-evpn-ac)# ethernet-segment
Router (config-evpn-ac-es)# identifier type  0 00.01.00.ac.ce.55.00.14.00
Router (config-evpn-ac-es)# commit

/* Configure PE4 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-unaware fxc1_16
Router(config-l2vpn-fxs-vu)# interface Bundle-Ether20.11
Router(config-l2vpn-fxs)# interface Bundle-Ether20.12
Router(config-l2vpn-fxs)# neighbor evpn evi 1 target 16
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether20.11 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-subif)# exit
Router(config)# interface Bundle-Ether20.12 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-subif)# exit
Router(config)# evpn
Router (config-evpn)# interface Bundle-Ether20
Router (config-evpn-ac)# ethernet-segment
Router (config-evpn-ac-es)# identifier type  0 00.01.00.ac.ce.55.00.14.00
Router (config-evpn-ac-es)# commit
```

Running Configuration

```
/* On PE1 */

configure
l2vpn
 flexible-xconnect-service vlan-unaware fxc1_16
  interface Bundle-Ether10.11
  interface Bundle-Ether10.12
  neighbor evpn evi 1 target 16

!

configure
interface Bundle-Ether10.11 l2transport
  encapsulation dot1q 1
```

```
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!


configure
interface Bundle-Ether10.12 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric

!

evpn
  interface Bundle-Ether10
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.0a.00

!

/* On PE2 */

configure
l2vpn
 flexible-xconnect-service vlan-unaware fxc1_16
  interface Bundle-Ether10.11
  interface Bundle-Ether10.12
  neighbor evpn evi 1 target 16

!

configure
interface Bundle-Ether10.11 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!


configure
interface Bundle-Ether10.12 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric

!

evpn
  interface Bundle-Ether10
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.0a.00

!

/* On PE3 */

configure
l2vpn
 flexible-xconnect-service vlan-unaware fxc1_16
  interface Bundle-Ether20.11
  interface Bundle-Ether20.12
  neighbor evpn evi 1 target 16

!

configure
interface Bundle-Ether20.11 l2transport
  encapsulation dot1q 1
```

```
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether20.12 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric

!

evpn
  interface Bundle-Ether20
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.14.00

!

/* On PE4 */

configure
l2vpn
 flexible-xconnect-service vlan-unaware fxc1_16
  interface Bundle-Ether20.11
  interface Bundle-Ether20.12
  neighbor evpn evi 1 target 16

!

configure
interface Bundle-Ether20.11 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether20.12 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric

!

evpn
  interface Bundle-Ether20
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.14.00

!
```

VLAN Aware

In this mode of operation, normalized ACs across different Ethernet segments and interfaces are multiplexed into a single EVPN VPWS service tunnel. This single tunnel is represented by many VPWS service IDs (one per normalized VLAN ID (VID)) and these normalized VIDs are signaled using EVPN BGP. The VLAN-Aware FXC reduces the number of PWs; but it does not reduce the BGP states. VLAN failure is signaled over BGP. The VLAN-Aware FXC advertises one EAD route per AC rather than per FXC. For VLAN-Aware FXC, the EVI must be unique to the FXC itself. It cannot be shared with any other service such as FXC, EVPN, EVPN-VPWS, PBB-EVPN. If a single AC goes down on PE1, it withdraws only the EAD routes associated with that AC. The ES-EAD route will also be withdrawn on failure of the main interface. The equal-cost multipath (ECMP) on PE3 or PE4 stops sending traffic for this AC to PE1, and only sends it to PE2.

For the same VLAN-Aware FXC, you can either configure all non-zero ESIs or all zero-ESIs. You cannot configure both zero-ESI and non-zero ESI for the same VLAN-Aware FXC. This applies only to single-home mode.

Configure Single-Homed Flexible Cross-Connect using VLAN Aware

This section describes how you can configure single-homed flexible cross-connect service using VLAN aware.

```
/* Configure PE1 */
Router# configure
Router(config)#  interface GigabitEthernet 0/2/0/7.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)#  interface GigabitEthernet 0/2/0/7.2 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 4
Router(config-l2vpn-fxs-va)# interface GigabitEthernet 0/2/0/7.1
Router(config-l2vpn-fxs-va)# interface GigabitEthernet 0/2/0/7.2
Router(config-l2vpn-fxs-va)# commit
```

```
/* Configure PE2 */
Router# configure
Router(config)#  interface GigabitEthernet 0/0/0/7.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)#  interface GigabitEthernet 0/0/0/7.2 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200
 symetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 4
Router(config-l2vpn-fxs-va)# interface GigabitEthernet 0/0/0/7.1
Router(config-l2vpn-fxs-va)# interface GigabitEthernet 0/0/0/7.2
Router(config-l2vpn-fxs-va )# commit
```

Running Configuration

```
/* On PE1 */
!
Configure
interface GigabitEthernet 0/2/0/7.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100 symetric
!

Configure
interface GigabitEthernet 0/2/0/7.2 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200 symetric
```

```
!

l2vpn
  flexible-xconnect-service vlan-aware evi 4
   interface GigabitEthernet 0/2/0/7.1
   interface GigabitEthernet 0/2/0/7.2


!

/* On PE2 */
!
Configure
interface GigabitEthernet 0/0/0/7.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 500 second-dot1q 100 symetric
!

Configure
interface GigabitEthernet 0/0/0/7.2 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-2 dot1q 600 second-dot1q 200 symetric
!

l2vpn
  flexible-xconnect-service vlan-aware evi 4
   interface GigabitEthernet 0/0/0/7.1
   interface GigabitEthernet 0/0/0/7.2

!
```

Configure Multi-Homed Flexible Cross-Connect Service using VLAN Aware

This section describes how you can configure multi-homed flexible cross-connect service using VLAN aware.

```
/* Configure PE1 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs-va)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether2.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether2
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 22.33.44.55.66.77.88.99.aa
Router(config-evpn-ac-es)# commit
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether3
Router(config-evpn-ac)# ethernet-segment
```

```
Router(config-evpn-ac-es)# identifier type 0 33.44.55.66.77.88.99.aa.bb
Router(config-evpn-ac-es)# commit

/* Configure PE2 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs-va)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether2.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether2
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 22.33.44.55.66.77.88.99.aa
Router(config-evpn-ac-es)# commit
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether3
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 33.44.55.66.77.88.99.aa.bb
Router(config-evpn-ac-es)# commit

/* Configure PE3 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether4.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether5.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs-va)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether4.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether5.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether4
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.14.00
Router(config-evpn-ac-es)# commit
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether5
Router(config-evpn-ac)# ethernet-segment
```

```
Router(config-evpn-ac-es)# identifier type identifier type 0 00.01.00.ac.ce.55.00.15.00
Router(config-evpn-ac-es)# commit
```

```
/* Configure PE4 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether4.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether5.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs-va)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether4.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 11 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether5.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 2
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether4
Router(config-evpn-ac)# ethernet-segment
Router config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.14.00
Router(config-evpn-ac-es)# commit
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether5
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type identifier type 0 00.01.00.ac.ce.55.00.15.00
Router(config-evpn-ac-es)# commit
```

Running Configuration

```
/* On PE1 */
!
configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether2.1
  interface Bundle-Ether3.1

!

configure
interface Bundle-Ether2.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether3.1 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
!

evpn
  interface Bundle-Ether2
   ethernet-segment identifier type 0 22.33.44.55.66.77.88.99.aa
  interface Bundle-Ether3
```

```
   ethernet-segment identifier type 0 33.44.55.66.77.88.99.aa.bb

!

/* On PE2 */
!
configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether2.1
  interface Bundle-Ether3.1

!

configure
interface Bundle-Ether2.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether3.1 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
!

evpn
  interface Bundle-Ether2
   ethernet-segment identifier type 0 22.33.44.55.66.77.88.99.aa
  interface Bundle-Ether3
   ethernet-segment identifier type 0 33.44.55.66.77.88.99.aa.bb

!

/* On PE3 */
!
configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether4.1
  interface Bundle-Ether5.1

!

configure
interface Bundle-Ether4.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether5.1 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
!

evpn
  interface Bundle-Ether4
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.14.00
  interface Bundle-Ether5
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.15.00
```

```
!

/* On PE4 */
!
configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether4.1
  interface Bundle-Ether5.1

!

configure
interface Bundle-Ether4.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-1 dot1q 11 symmetric

!

configure
interface Bundle-Ether5.1 l2transport
  encapsulation dot1q 2
  rewrite ingress tag translate 1-to-1 dot1q 12 symmetric
!

evpn
  interface Bundle-Ether4
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.14.00
  interface Bundle-Ether5
   ethernet-segment identifier type 0 00.01.00.ac.ce.55.00.15.00

!
```

Local Switching

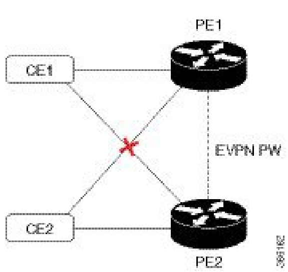
Traffic between the two ACs is locally switched within the PE when two ACs belonging to different Ethernet Segment have the same normalization VLANs. Local switching is supported only on FXC VLAN-aware.

Consider a topology in which CE1 and CE2 have different Ethernet Segment. However, they both have the same normalized VLANs. Hence, when a traffic is sent from CE1 to CE2, PE1 routes the traffic to CE2 using local switching.

If there is a failure and when the link from CE1 to PE1 goes down, PE1 sends the traffic to PE2 through EVPN pseudowire. Then the PE2 sends the traffic to CE2.

CE1 and CE2 must be on different non-zero ESI.

Figure 9: Local Switching



Configure Multi-Homed Flexible Cross-Connect Service using Local Switching

This section describes how you can configure multi-homed flexible cross-connect service using local switching.

```
/* Configure PE1 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether2.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3
symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3
symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether2
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 22.33.44.55.66.77.88.99.aa
Router(config-evpn-ac-es)# commit
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether3
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 33.44.55.66.77.88.99.aa.bb
Router(config-evpn-ac-es)# commit
```

```
/* Configure PE2 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# flexible-xconnect-service vlan-aware evi 6
Router(config-l2vpn-fxs-va)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs-va)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs-va)# commit
Router(config-l2vpn-fxs)# exit
Router(config-l2vpn)# exit
Router(config)# interface Bundle-Ether2.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3
symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# interface Bundle-Ether3.1 l2transport
Router(config-l2vpn-subif)# encapsulation dot1q 1
Router(config-l2vpn-subif)# rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3
symmetric
Router(config-l2vpn-subif)# commit
Router(config-l2vpn-subif)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether2
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 22.33.44.55.66.77.88.99.aa
Router(config-evpn-ac-es)# commit
```

```
Router(config-evpn-ac-es)# exit
Router(config-evpn-ac)# exit
Router(config-evpn)# interface Bundle-Ether3
Router(config-evpn-ac)# ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 33.44.55.66.77.88.99.aa.bb
Router(config-evpn-ac-es)# commit
```

Running Configuration

```
/* On PE1 */

configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether2.1
  interface Bundle-Ether3.1

!

configure
interface Bundle-Ether2.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3 symmetric

!

configure
interface Bundle-Ether3.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3 symmetric
!

evpn
  interface Bundle-Ether2
   ethernet-segment identifier type 0 22.33.44.55.66.77.88.99.aa
  interface Bundle-Ether3
   ethernet-segment identifier type 0 33.44.55.66.77.88.99.aa.bb

!

/* On PE2 */

configure
l2vpn
 flexible-xconnect-service vlan-aware evi 6
  interface Bundle-Ether2.1
  interface Bundle-Ether3.1

!

configure
interface Bundle-Ether2.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3 symmetric

!

configure
interface Bundle-Ether3.1 l2transport
  encapsulation dot1q 1
  rewrite ingress tag translate 1-to-2 dot1q 3 second-dot1q 3 symmetric
!

evpn
```

```
  interface Bundle-Ether2
   ethernet-segment identifier type 0 22.33.44.55.66.77.88.99.aa
  interface Bundle-Ether3
   ethernet-segment identifier type 0 33.44.55.66.77.88.99.aa.bb


!
```

Configure Preferred Tunnel Path

Preferred tunnel path functionality lets you map pseudowires to specific traffic-engineering tunnels. Attachment circuits are cross-connected to specific MPLS traffic engineering tunnel interfaces instead of remote PE router IP addresses (reachable using IGP or LDP).

When using a preferred tunnel path, it is assumed that the traffic engineering tunnel that transports the Layer 2 traffic runs between the two PE routers (that is, its head starts at the imposition PE router and its tail terminates on the disposition PE router).

Configuration

```
/* Enter global configuration mode */
Router# configure
Router(config)# l2vpn

/* Configure pseudowire class name */
Router(config-l2vpn)# pw-class path1

/* Configure MPLS encapsulation for the pseudowire */
Router(config-l2vpn-pwc)# encapsulation mpls


/* Configure preferred path tunnel settings.
If fallback disable configuration is used, and when
 the TE/ tunnel is configured,
 if the preferred path goes down,
 the corresponding pseudowire can also go down. */

Router(config-l2vpn-pwc-encap-mpls)# preferred-path
                   interface tunnel-te 11 fallback disable

/* Commit your configuration */
Router(config-l2vpn-pwc)# exit
Router(config-l2vpn)# commit
```

Running Configuration

```
Router# show running-configuration
!
l2vpn
 pw-class path1
  encapsulation mpls
   preferred-path interface tunnel-te 11 fallback disable
  !
 !
!
```

Multisegment Pseudowire

The Multisegment Pseudowire feature allows you to extend L2VPN pseudowires across an inter-AS boundary or across two separate MPLS networks. A multisegment pseudowire connects two or more contiguous pseudowire segments to form an end-to-end multi-hop pseudowire as a single point-to-point pseudowire. These segments act as a single pseudowire, allowing you to:

- Manage the end-to-end service by separating administrative or provisioning domains.
- Keep IP addresses of provider edge (PE) nodes private across interautonomous system (inter-AS) boundaries. Use IP address of autonomous system boundary routers (ASBRs) and treat them as pseudowire aggregation routers. The ASBRs join the pseudowires of the two domains.

A multisegment pseudowire can span either an inter-AS boundary or two multiprotocol label switching (MPLS) networks.

A pseudowire is a tunnel between two PE nodes. There are two types of PE nodes:

- A Switching PE (S-PE) node
    - Terminates PSN tunnels of the preceding and succeeding pseudowire segments in a multisegment pseudowire.
    - Switches control and data planes of the preceding and succeeding pseudowire segments of the multisegment pseudowire.
- A Terminating PE (T-PE) node
    - Located at both the first and last segments of a multisegment pseudowire.
    - Where customer-facing attachment circuits (ACs) are bound to a pseudowire forwarder.

Note Every end of a multisegment pseudowire must terminate at a T-PE.

A multisegment pseudowire is used in two general cases when:

- It is not possible to establish a PW control channel between the source and destination PE nodes.

  For the PW control channel to be established, the remote PE node must be accessible. Sometimes, the local PE node may not be able to access the remote node due to topology, operational, or security constraints.

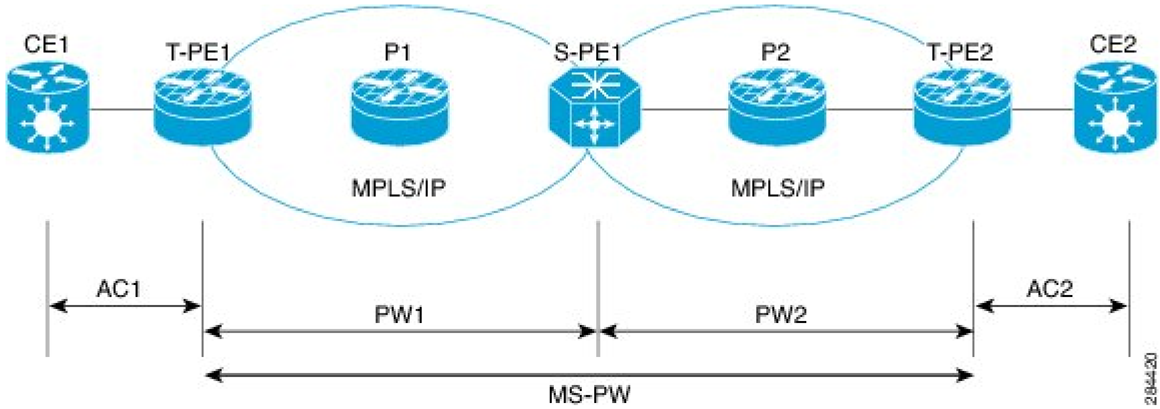
  A multisegment pseudowire dynamically builds two discrete pseudowire segments and performs a pseudowire switching to establish a PW control channel between the source and destination PE nodes.

- Pseudowire Edge To Edge Emulation (PWE3) signaling and encapsulation protocols are different.

  The PE nodes are connected to networks employing different PW signaling and encapsulation protocols. Sometimes, it is not possible to use a single segment PW.

  A multisegment pseudowire, with the appropriate interworking performed at the PW switching points, enables PW connectivity between the PE nodes in the network.

Figure 10: Multisegment Pseudowire



The topology shows MS-PW stitching between PW1 and PW2. You can configure a set of two or more contiguous PW segments that behave and function as a single point-to-point PW. You can configure static or dynamic multisegment PW (MS-PW). The maximum number of contiguous PW segments is 254. Each end of an MS-PW terminates on a T-PE. A switching PE (S-PE) terminates the PSN tunnels of the preceding and succeeding PW segments in an MS-PW. The S-PE switches the control and data planes of the preceding and succeeding PW segments of the MS-PW. An MS-PW is up when all the SS-PWs are up.

Restrictions

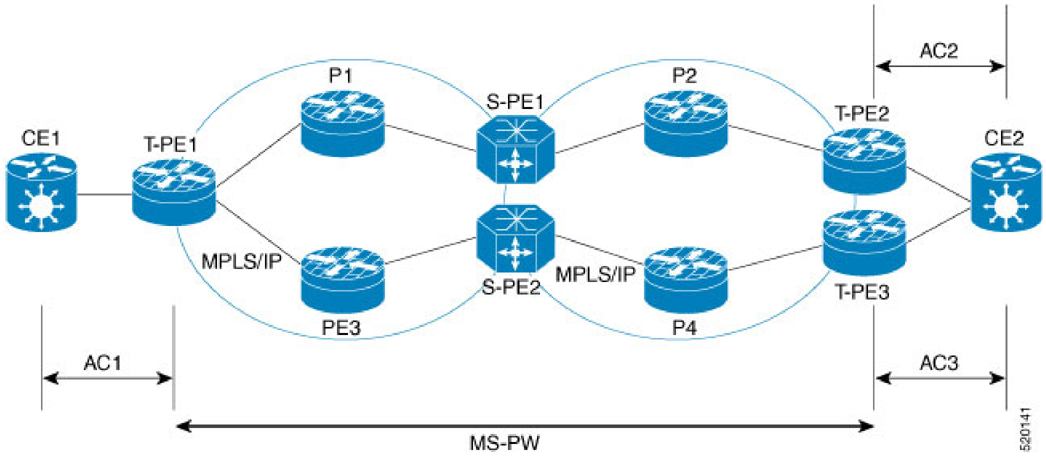
You must consider the following restrictions while configuring the Multisegment Pseudowire feature:

- Connect both segments of an MS-PW to different peers.
- Supports only LDP and does not support L2TPv3. Each PW segment in the MS-PW xconnect can be either static or dynamic.
- The neighbor pw-id pair of each PW segment of an MS-PW is unique on the node.
- The end-to-end pw-type has to be the same. Hence, both segments of an MS-PW must have the same transport mode.
- You cannot configure PW redundancy on an MS-PW xconnect at the S-PE. You can configure PW redundancy at the T-PEs.
- Both segments of an MS-PW xconnect can not have the same preferred path.
- Supports MS-PW over LDP, MPLS-TE, SR, and SR-TE as transport protocols.
- Does not support MS-PW over BGP-LU and LDPoTE.
- When you enable MSPW on an S-PE, configure the *ip-ttl-propagation disable* command for the MSPW ping and traceroute to work. Alternatively, use *segment-count 255 option* for MSPW ping to work from T-PE1. MSPW does not support the partial ping.

Multisegment Pseudowire Redundancy

Pseudowire redundancy enables you to create backup MS-PWs between the T-PEs. Pseudowire redundancy allows you to configure your network to detect a failure in the network. And reroute the Layer 2 service to another endpoint that can continue to provide service.

Figure 11: Multisegment Pseudowire Redundancy



Consider a topology where you create two MS-PWs and multihome CE2 to T-PE2 and T-PE3. Create a primary MS-PW between T-PE1 and T-PE2 connected through P1, S-PE1, and P2. Create a standby MS-PW between T-PE1 and T-PE3 connected through P3, S-PE2, and P4.

When a segment of the primary PW fails, the S-PE1 receives label withdraw message or LDP transport goes down. S-PE1 sends label withdraw message on the other PW segment and this triggers the switch-over to the backup at the T-PE. For example:

- T-PE1 detects LDP transport down, sends label withdraw message to S-PE1 and switches over to the backup MS-PW.
- S-PE1 receives the label withdraw message and sends a label withdraw message to T-PE2.
- T-PE2 performs "Tx Disable" of AC2 after it receives the label withdraw message.
- CE2 starts sending and receiving traffic on AC3.

Configure Pseudowire Redundancy

Pseudowire redundancy allows you to configure your network to detect a failure in the network and reroute the Layer 2 service to another endpoint that can continue to provide service. This feature provides the ability to recover from a failure of either the remote provider edge (PE) router or the link between the PE and customer edge (CE) routers.

L2VPNs can provide pseudowire resiliency through their routing protocols. When connectivity between end-to-end PE routers fails, an alternative path to the directed LDP session and the user data takes over. However, there are some parts of the network in which this rerouting mechanism does not protect against interruptions in service.

Pseudowire redundancy enables you to set up backup pseudowires. You can configure the network with redundant pseudowires and redundant network elements.

Prior to the failure of the primary pseudowire, the ability to switch traffic to the backup pseudowire is used to handle a planned pseudowire outage, such as router maintenance.

Note Pseudowire redundancy is provided only for point-to-point Virtual Private Wire Service (VPWS) pseudowires.

Configuration

This section describes the configuration for pseudowire redundancy.

```
/* Configure a cross-connect group with a static point-to-point
cross connect */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group A
Router(config-l2vpn-xc)# p2p xc1
ROuter(config-l2vpn-xc-p2p)# interface tengige 0/0/0/0.2
Router(config-l2vpn-xc-p2p)# neighbor 10.1.1.2 pw-id 2

/*Configure the pseudowire segment for the cross-connect group */
Router(config-l2vpn-xc-p2p-pw)#pw-class path1

/*Configure the backup pseudowire segment for the cross-connect group */
Router(config-l2vpn-xc-p2p-pw)# backup neighbor 10.2.2.2 pw-id 5
Router(config-l2vpn-xc-p2p-pw-backup)#end

/*Commit your configuration */
Router(config-l2vpn-xc-p2p-pw-backup)#commit
Uncommitted changes found, commit them before exiting(yes/no/cancel)?
[cancel]: yes
```

Running Configuration

```
Router# show-running configuration
...
l2vpn
 encapsulation mpls
 !
 xconnect group A
  p2p xc1
   interface tengige 0/0/0/0.2
   neighbor ipv4 10.1.1.2 pw-id 2
    pw-class path1
    backup neighbor 10.2.2.2 pw-id 5
    !
   !
...
```

CHAPTER 8

EVPN Features

This chapter describes how to configure Layer 2 Ethernet VPN (EVPN) features on the router.

EVPN Overview

Ethernet VPN (EVPN) is a next generation solution that provides Ethernet multipoint services over MPLS networks. EVPN operates in contrast to the existing Virtual Private LAN Service (VPLS) by enabling control-plane based MAC learning in the core. In EVPN, PEs participating in the EVPN instances learn customer MAC routes in control-plane using MP-BGP protocol. Control-plane MAC learning brings a number of benefits that allow EVPN to address the VPLS shortcomings, including support for multi-homing with per-flow load balancing.

EVPN provides the solution for network operators for the following emerging needs in their network:

- Data center interconnect operation (DCI)
- Cloud and services virtualization
- Remove protocols and network simplification
- Integration of L2 and L3 services over the same VPN
- Flexible service and workload placement
- Multi-tenancy with L2 and L3 VPN
- Optimal forwarding and workload mobility
- Fast convergence
- Efficient bandwidth utilization

EVPN Benefits

The EVPN provides the following benefits:

- Integrated Services: Integrated L2 and L3 VPN services, L3VPN-like principles and operational experience for scalability and control, all-active multi-homing and PE load-balancing using ECMP, and enables load balancing of traffic to and from CEs that are multihomed to multiple PEs.
- Network Efficiency: Eliminates flood and learn mechanism, fast-reroute, resiliency, and faster reconvergence when the link to dual-homed server fails, optimized Broadcast, Unknown-unicast, Multicast (BUM) traffic delivery.
- Service Flexibility: MPLS data plane encapsulation, support existing and new services types (E-LAN, E-Line), peer PE auto-discovery, and redundancy group auto-sensing.

EVPN Modes

The following EVPN modes are supported:

- Single-homing - This enables you to connect a customer edge (CE) device to one provider edge (PE) device.
- Multihoming - This enables you to connect a customer edge (CE) device to more than one provider edge (PE) device. Multihoming ensures redundant connectivity. The redundant PE device ensures that there is no traffic disruption when there is a network failure. Following are the types of multihoming:
  - Single-Active - In single-active mode only a single PE among a group of PEs attached to the particular Ethernet-Segment is allowed to forward traffic to and from that Ethernet Segment.
  - All-Active - In all-active mode all the PEs attached to the particular Ethernet-Segment is allowed to forward traffic to and from that Ethernet Segment.

EVPN Timers

The following table shows various EVPN timers:

Table 5: EVPN Timers

Timer	Range	Default Value	Trigger	Applicability	Action	Sequence
startup-cost-in	30-86400	disabled	node recovered*	Single-Homed, All-Active, Single-Active	Postpone EVPN startup procedure and Hold AC link(s) down to prevent CE to PE forwarding. Startup-cost-in timer allows PE to set core protocols first.	1

Timer	Range	Default Value	Trigger	Applicability	Action	Sequence
recovery	20-3600s	30s	node recovered, interface recovered **	Single-Homed***, Single-Active	Postpone EVPN Startup procedure. Recovery timer allows PE to set access protocols (STP) before reachability towards EVPN core is advertised.	2
peering	0-3600s	3s	node recovered, interface recovered	All-Active, Single-Active	Starts after sending EVPN RT4 to postpone rest of EVPN startup procedure. Peering timer allows remote PE (multihoming AC with same ESI) to process RT4 before DF election will happen.	3

Note

- The timers are available in EVPN global configuration mode and in EVPN interface sub-configuration mode.
- Startup-cost-in is available in EVPN global configuration mode only.
- Timers are triggered in sequence (if applicable).
- Cost-out in EVPN global configuration mode brings down AC link(s) to prepare node for reload or software upgrade.

* indicates all required software components are loaded.

** indicates link status is up.

*** you can change the recovery timer on Single-Homed AC if you do not expect any STP protocol convergence on connected CE.

EVPN Concepts

To implement EVPN features, you need to understand the following concepts:

- Ethernet Segment (ES): An Ethernet segment is a set of Ethernet links that connects a multihomed device. If a multi-homed device or network is connected to two or more PEs through a set of Ethernet links, then that set of links is referred to as an Ethernet segment. The Ethernet segment route is also referred to as Route Type 4. This route is used for designated forwarder (DF) election for BUM traffic.
- Ethernet Segment Identifier (ESI): Ethernet segments are assigned a unique non-zero identifier, which is called an Ethernet Segment Identifier (ESI). ESI represents each Ethernet segment uniquely across the network.
- EVI: The EVPN instance (EVI) is represented by the virtual network identifier (VNI). An EVI represents a VPN on a PE router. It serves the same role of an IP VPN Routing and Forwarding (VRF), and EVIs are assigned import/export Route Targets (RTs). Depending on the service multiplexing behaviors at the User to Network Interface (UNI), all traffic on a port (all-to-one bundling), or traffic on a VLAN (one-to-one mapping), or traffic on a list/range of VLANs (selective bundling) can be mapped to a Bridge Domain (BD). This BD is then associated to an EVI for forwarding towards the MPLS core.
- EAD/ES: Ethernet Auto Discovery Route per ES is also referred to as Route Type 1. This route is used to converge the traffic faster during access failure scenarios. This route has Ethernet Tag of 0xFFFFFFFF.
- EAD/EVI: Ethernet Auto Discovery Route per EVI is also referred to as Route Type 1. This route is used for aliasing and load balancing when the traffic only hashes to one of the switches. This route cannot have Ethernet tag value of 0xFFFFFF to differentiate it from the EAD/ES route.
- Aliasing: It is used for load balancing the traffic to all the connected switches for a given Ethernet segment using the Route Type 1 EAD/EVI route. This is done irrespective of the switch where the hosts are actually learned.
- Mass Withdrawal: It is used for fast convergence during the access failure scenarios using the Route Type 1 EAD/ES route.
- DF Election: It is used to prevent forwarding of the loops. Only a single router is allowed to decapsulate and forward the traffic for a given Ethernet Segment.

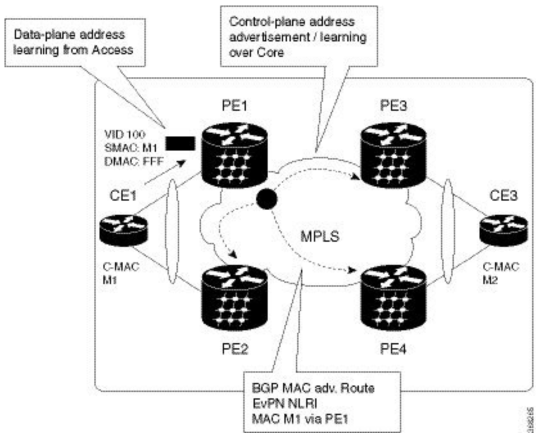
EVPN Operation

At startup, PEs exchange EVPN routes in order to advertise the following:

- **VPN membership**: The PE discovers all remote PE members of a given EVI. In the case of a multicast ingress replication model, this information is used to build the PEs flood list associated with an EVI. BUM labels and unicast labels are exchanged when MAC addresses are learned.
- **Ethernet segment reachability**: In multihoming scenarios, the PE auto-discovers remote PE and their corresponding redundancy mode (all-active or single-active). In case of segment failures, PEs withdraw the routes used at this stage in order to trigger fast convergence by signaling a MAC mass withdrawal on remote PEs.

- **Redundancy Group membership**: PEs connected to the same Ethernet segment (multihoming) automatically discover each other and elect a Designated Forwarder (DF) that is responsible for forwarding Broadcast, Unknown unicast and Multicast (BUM) traffic for a given EVI.

Figure 12: EVPN Operation



EVPN can operate in single-homing or dual-homing mode. Consider single-homing scenario, when EVPN is enabled on PE, Route Type 3 is advertised where each PE discovers all other member PEs for a given EVPN instance. When an unknown unicast (or BUM) MAC is received on the PE, it is advertised as EVPN Route Type 2 to other PEs. MAC routes are advertised to the other PEs using EVPN Route Type 2. In multihoming scenarios, Route Types 1, 3, and 4 are advertised to discover other PEs and their redundancy modes (single-active or all-active). Use of Route Type 1 is to auto-discover other PE which hosts the same CE. The other use of this route type is to fast route unicast traffic away from a broken link between CE and PE. Route Type 4 is used for electing designated forwarder. For instance, consider the topology when customer traffic arrives at the PE, EVPN MAC advertisement routes distribute reachability information over the core for each customer MAC address learned on local Ethernet segments. Each EVPN MAC route announces the customer MAC address and the Ethernet segment associated with the port where the MAC was learned from and its associated MPLS label. This EVPN MPLS label is used later by remote PEs when sending traffic destined to the advertised MAC address.

Behavior Change due to ESI Label Assignment

To adhere to RFC 7432 recommendations, the encoding or decoding of MPLS label is modified for extended community. Earlier, the lower 20 bits of extended community were used to encode the split-horizon group (SHG) label. Now, the SHG label encoding uses from higher 20 bits of extended community.

According to this change, routers in same ethernet-segment running old and new software release versions decodes extended community differently. This change causes inconsistent SHG labels on peering EVPN PE routers. Almost always, the router drops BUM packets with incorrect SHG label. However, in certain conditions, it may cause remote PE to accept such packets and forward to CE potentially causing a loop. One such instance is when label incorrectly read as NULL.

To overcome this problem, Cisco recommends you to:

- Minimize the time both PEs are running different software release versions.
- Before upgrading to a new release, isolate the upgraded node and shutdown the corresponding AC bundle.
- After upgrading both the PEs to the same release, you can bring both into service.

Similar recommendations are applicable to peering PEs with different vendors with SHG label assignment that does not adhere to RFC 7432.

EVPN Route Types

The EVPN network layer reachability information (NLRI) provides different route types.

Table 6: EVPN Route Types

Route Type	Name	Usage
1	Ethernet Auto-Discovery (AD) Route	Few routes are sent per ES, carries the list of EVIs that belong to ES
2	MAC/IP Advertisement Route	Advertise MAC, address reachability, advertise IP/MAC binding
3	Inclusive Multicast Ethernet Tag Route	Multicast Tunnel End point discovery
4	Ethernet Segment Route	Redundancy group discovery, DF election
5	IP Prefix Route	Advertise IP prefixes.

Route Type 1: Ethernet Auto-Discovery (AD) Route

The Ethernet Auto-Discovery (AD) routes are advertised on per EVI and per ESI basis. These routes are sent per ES. They carry the list of EVIs that belong to the ES. The ESI field is set to zero when a CE is single-homed. This route type is used for mass withdrawal of MAC addresses and aliasing for load balancing.

Route Type 2: MAC/IP Advertisement Route

These routes are per-VLAN routes, so only PEs that are part of a VNI require these routes. The host's IP and MAC addresses are advertised to the peers within NRLI. The control plane learning of MAC addresses reduces unknown unicast flooding.

Route Type 3: Inclusive Multicast Ethernet Tag Route

This route establishes the connection for broadcast, unknown unicast, and multicast (BUM) traffic from a source PE to a remote PE. This route is advertised on per VLAN and per ESI basis.

Route Type 4: Ethernet Segment Route

Ethernet segment routes enable to connect a CE device to two or PE devices. ES route enables the discovery of connected PE devices that are connected to the same Ethernet segment.

Route Type 5: IP Prefix Route

The IP prefixes are advertised independently of the MAC-advertised routes. With EVPN IRB, host route /32 is advertised using RT-2 and subnet /24 is advertised using RT-5.

Note With EVPN IRB, host route /32 are advertised using RT-2 and subnet /24 are advertised using RT-5.

Configure EVPN L2 Bridging Service

Perform the following steps to configure EVPN L2 bridging service.

Note Always ensure to change the label mode from per-prefix to per-VRF label mode. Since L2FIB and VPNv4 route (labels) shares the same resource, BVI ping fails when you exhaust the resources.

Note Flooding disable is not supported on EVPN bridge domains.

```
/* Configure address family session in BGP */
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router#(config)# router bgp 200
RP/0/RSP0/CPU0:router#(config-bgp)# bgp router-id 209.165.200.227
RP/0/RSP0/CPU0:router#(config-bgp)# address-family l2vpn evpn
RP/0/RSP0/CPU0:router#(config-bgp)# neighbor 10.10.10.10
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# remote-as 200
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# description MPLSFACING-PEER
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# update-source Loopback 0
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# address-family l2vpn evpn

/* Configure EVI and define the corresponding BGP route targets */

Router# configure
Router(config)# evpn
Router(config-evpn)# evi 6005
Router(config-evpn-evi)# bgp
Router(config-evpn-evi-bgp)# rd 200:50
Router(config-evpn-evi-bgp)# route-target import 100:6005
Router(config-evpn-evi-bgp)# route-target export 100:6005
Router(config-evpn-evi-bgp)# exit
Router(config-evpn-evi)# advertise-mac

/* Configure a bridge domain */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# bridge group 1
Router(config-l2vpn-bg)# bridge-domain 1-1
Router(config-l2vpn-bg-bd)# interface GigabitEthernet 0/0/0/1.1
Router(config-l2vpn-bg-bd-ac)# evi 6005
Router(config-l2vpn-bg-bd-ac-evi)# commit
Router(config-l2vpnbg-bd-ac-evi)# exit
```

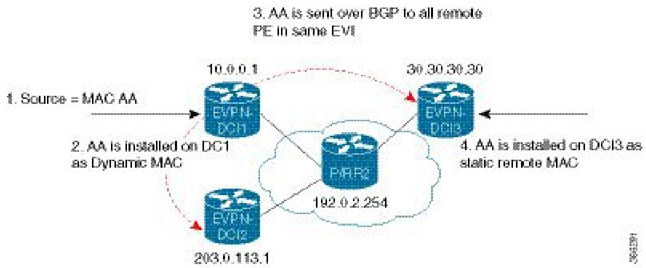
Running Configuration

```
router bgp 200 bgp
 router-id 209.165.200.227
 address-family l2vpn evpn
 neighbor 10.10.10.10
  remote-as 200 description MPLS-FACING-PEER
  updatesource Loopback0
  addressfamily l2vpn evpn
!

configure
evpn
 evi 6005
  bgp
   rd 200:50
   route-target import 100:6005
   route-target export 100:6005
!
  advertise-mac


configure
l2vpn
 bridge group 1
  bridge-domain 1-1
   interface GigabitEthernet 0/0/0/1.1

    evi 6005
!
```

EVPN Software MAC Learning

The MAC addresses learned on one device needs to be learned or distributed on the other devices in a VLAN. EVPN Software MAC Learning feature enables the distribution of the MAC addresses learned on one device to the other devices connected to a network. The MAC addresses are learnt from the remote devices using BGP.

Figure 13: EVPN Software MAC Learning



The above figure illustrates the process of software MAC learning. The following are the steps involved in the process:

1. Traffic comes in on one port in the bridge domain.
2. The source MAC address (AA) is learnt on the PE and is stored as a dynamic MAC entry.

3. The MAC address (AA) is converted into a type-2 BGP route and is sent over BGP to all the remote PEs in the same EVI.
4. The MAC address (AA) is updated on the PE as a remote MAC address.

Configure EVPN Software MAC Learning

The following section describes how you can configure EVPN Software MAC Learning:

Note On EVPN bridge domain, the Cisco NCS 5500 router does not support control word and does not enable control word by default.

Note The router does not support flow-aware transport (FAT) pseudowire.

```
/* Configure bridge domain. */

RP/0/RSP0/CPU0:router(config)# l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)# bridge group EVPN_SH
RP/0/RSP0/CPU0:router(config-l2vpn-bg)# bridge-domain EVPN_2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface TenGigE0/4/0/10.2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# exit
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface BundleEther 20.2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# storm-control broadcast pps 10000 ← Enabling
 storm-control is optional
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# exit
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# evi 2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-evi)# commit

/* Configure address family session in BGP. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router bgp 200
RP/0/RSP0/CPU0:router(config-bgp)# bgp router-id 209.165.200.227
RP/0/RSP0/CPU0:router(config-bgp)# address-family l2vpn evpn
RP/0/RSP0/CPU0:router(config-bgp)# neighbor 10.10.10.10
RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 200
RP/0/RSP0/CPU0:router(config-bgp-nbr)# description MPLSFACINGPEER
RP/0/RSP0/CPU0:router(config-bgp-nbr)# update-source Loopback 0
RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family l2vpn evpn
```

Supported Modes for EVPN Software MAC Learning

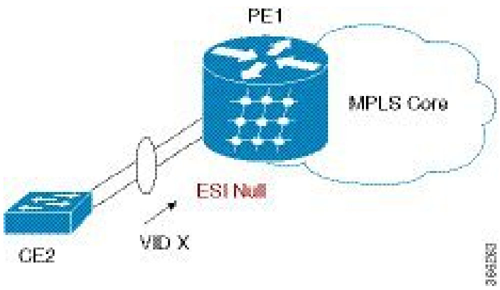
The following are the modes in which EVPN Software MAC Learning is supported:

- Single Home Device (SHD) or Single Home Network (SHN)
- Dual Home Device (DHD)—All Active Load Balancing

Single Home Device or Single Home Network Mode

The following section describes how you can configure EVPN Software MAC Learning feature in single home device or single home network (SHD/SHN) mode:

Figure 14: Single Home Device or Single Home Network Mode



In the above figure, the PE (PE1) is attached to Ethernet Segment using bundle or physical interfaces. Null Ethernet Segment Identifier (ESI) is used for SHD/SHN.

Configure EVPN in Single Home Device or Single Home Network Mode

This section describes how you can configure EVPN Software MAC Learning feature in single home device or single home network mode.

```
/* Configure bridge domain. */

RP/0/RSP0/CPU0:router(config)# l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)# bridge group EVPN_ALL_ACTIVE
RP/0/RSP0/CPU0:router(config-l2vpn-bg)# bridge-domain EVPN_2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface Bundle-Ether1.2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# evi 2001


/* Configure advertisement of MAC routes. */

RP/0/RSP0/CPU0:router(config)# evpn
RP/0/RSP0/CPU0:router(config-evpn)# evi 2001
RP/0/RSP0/CPU0:router(config-evpn-evi)# advertise-mac


/* Configure address family session in BGP. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router#(config)# router bgp 200
RP/0/RSP0/CPU0:router#(config-bgp)# bgp router-id 09.165.200.227
RP/0/RSP0/CPU0:router#(config-bgp)# address-family l2vpn evpn
RP/0/RSP0/CPU0:router#(config-bgp)# neighbor 10.10.10.10
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# remote-as 200
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# description MPLSFACING-PEER
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# update-source Loopback 0
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# address-family l2vpn evpn
```

Running Configuration

```
l2vpn
bridge group EVPN_ALL_ACTIVE
 bridge-domain EVPN_2001
  interface BundleEther1.2001
  evi 2001
```

```
!
evpn
 evi 2001
  advertise-mac
!
router bgp 200 bgp
 router-id 40.40.40.40
 address-family l2vpn evpn
 neighbor 10.10.10.10
  remote-as 200 description MPLS-FACING-PEER
  updatesource Loopback0
  addressfamily l2vpn evpn
```

Verification

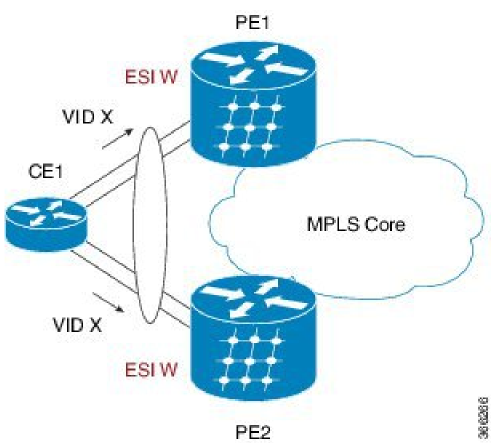
Verify EVPN in single home devices.

```
RP/0/RSP0/CPU0:router# show evpn ethernet-segment interface Te0/4/0/10 detail

Ethernet Segment Id    Interface   Nexthops
--------------------   ----------  ----------
N/A                    Te0/4/0/10  20.20.20.20
..............
 Topology :
 Operational : SH
 Configured : Single-active (AApS) (default)
```

Dual Home Device—All-Active Load Balancing Mode

The following section describes how you can configure EVPN Software MAC Learning feature in dual home device (DHD) in all-active load balancing mode:

Figure 15: Dual Home Device —All-Active Load Balancing Mode



All-active load-balancing is known as Active/Active per Flow (AApF). In the above figure, identical Ethernet Segment Identifier is used on both EVPN PEs. PEs are attached to Ethernet Segment using bundle interfaces. In the CE, single bundles are configured towards two EVPN PEs. In this mode, the MAC address that is learnt is stored on both PE1 and PE2. Both PE1 and PE2 can forward the traffic within the same EVI.

Configure EVPN Software MAC Learning in Dual Home Device—All-Active Mode

This section describes how you can configure EVPN Software MAC Learning feature in dual home device—all-active mode:

```
/* Configure bridge domain. */

RP/0/RSP0/CPU0:router(config)# l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)# bridge group EVPN_ALL_ACTIVE
RP/0/RSP0/CPU0:router(config-l2vpn-bg)# bridge-domain EVPN_2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface Bundle-Ether1.2001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# evi 2001


/* Configure advertisement of MAC routes. */

RP/0/RSP0/CPU0:router(config)# evpn
RP/0/RSP0/CPU0:router(config-evpn)# evi 2001
RP/0/RSP0/CPU0:router(config-evpn-evi)# advertise-mac
RP/0/RSP0/CPU0:router(config-evpn-evi)# exit
RP/0/RSP0/CPU0:router(config-evpn)# interface bundle-ether1
RP/0/RSP0/CPU0:router(config-evpn-ac)# ethernet-segment
RP/0/RSP0/CPU0:router(config-evpn-ac-es)# identifier type 0 01.11.00.00.00.00.00.00.01


/* Configure address family session in BGP. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router#(config)# router bgp 200
RP/0/RSP0/CPU0:router#(config-bgp)# bgp router-id 209.165.200.227
RP/0/RSP0/CPU0:router#(config-bgp)# address-family l2vpn evpn
RP/0/RSP0/CPU0:router#(config-bgp)# neighbor 10.10.10.10
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# remote-as 200
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# description MPLSFACING-PEER
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# update-source Loopback 0
RP/0/RSP0/CPU0:router#(config-bgp-nbr)# address-family l2vpn evpn


/* Configure Link Aggregation Control Protocol (LACP) bundle. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# interface Bundle-Ether1.300
RP/0/RSP0/CPU0:router(config-if)# lacp switchover suppress-flaps 300
RP/0/RSP0/CPU0:router(config-if)# exit


/* Configure VLAN Header Rewrite.*/

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# interface bundle-Ether1.2001 l2transport
RP/0/RSP0/CPU0:router(config-if)# encapsulation dot1q 10
RP/0/RSP0/CPU0:router(config-if)# rewrite ingress tag pop 1 symmetric
```

Running Configuration

```
l2vpn
bridge group EVPN_ALL_ACTIVE
 bridge-domain EVPN_2001
 interface Bundle-Ether1.2001
 !
 evi 2001
 !
!
```

```
evpn
 evi 2001
 !
 advertise-mac
 !
 interface bundle-ether1
  ethernet-segment
  identifier type 0 01.11.00.00.00.00.00.00.01
  !
 !
router bgp 200
bgp router-id  209.165.200.227
address-family l2vpn evpn
!
neighbor 10.10.10.10
 remote-as 200
 description MPLS-FACING-PEER
 update-source Loopback0
 address-family l2vpn evpn
!
interface Bundle-Ether1
lacp switchover suppress-flaps 300
load-interval 30
!
interface bundle-Ether1.2001 l2transport
 encapsulation dot1aq 2001
 rewrite ingress tag pop 1 symmetric
!
```

Verification

Verify EVPN in dual home devices in All-Active mode.

Note With the EVPN IRB, the supported label mode is per-VRF.

```
RP/0/RSP0/CPU0:router# show evpn ethernet-segment interface bundle-Ether 1 carvin$

Ethernet Segment Id        Interface  Nexthops
-------- ----------        --------   --------
0100.211b.fce5.df00.0b00   BE11       10.10.10.10
 209.165.201.1
Topology :
 Operational : MHN
 Configured : All-active (AApF) (default)
 Primary Services : Auto-selection
 Secondary Services: Auto-selection
 Service Carving Results:
 Forwarders : 4003
 Elected : 2002
 EVI E : 2000, 2002, 36002, 36004, 36006, 36008
 ........
 Not Elected : 2001
 EVI NE : 2001, 36001, 36003, 36005, 36007, 36009

 MAC Flushing mode : Invalid

Peering timer : 3 sec [not running]
 Recovery timer : 30 sec [not running]
 Local SHG label : 34251
```

```
Remote SHG labels : 1
 38216 : nexthop 209.165.201.1
```

Verify EVPN Software MAC Learning

Verify the packet drop statistics.

Note Disable CW configuration if any in EVPN peer nodes, as CW is not supported in EVPN Bridging.

```
RP/0/RSP0/CPU0:router# show l2vpn bridge-domain bd-name EVPN_2001 details

Bridge group: EVPN_ALL_ACTIVE, bridge-domain: EVPN_2001, id: 1110,
state: up, ShgId: 0, MSTi: 0
 List of EVPNs:
 EVPN, state: up
 evi: 2001
 XC ID 0x80000458
 Statistics:
 packets: received 28907734874 (unicast 9697466652), sent
76882059953
 bytes: received 5550285095808 (unicast 1861913597184), sent
14799781851396
 MAC move: 0
 List of ACs:
 AC: TenGigE0/4/0/10.2001, state is up
 Type VLAN; Num Ranges: 1
...
 Statistics:
 packets: received 0 (multicast 0, broadcast 0, unknown
unicast 0, unicast 0), sent 45573594908
 bytes: received 0 (multicast 0, broadcast 0, unknown unicast
0, unicast 0), sent 8750130222336
 MAC move: 0
 ........
```

Verify the EVPN EVI information with the VPN-ID and MAC address filter.

```
RP/0/RSP0/CPU0:router# show evpn evi vpn-id 2001 neighbor

Neighbor IP    vpn-id
-----------   --------
209.165.200.225   2001
209.165.201.30   2001
```

Verify the BGP L2VPN EVPN summary.

```
RP/0/RSP0/CPU0:router# show bgp l2vpn evpn summary
...
Neighbor         Spk    AS     MsgRcvd  MsgSent   TblVer     InQ  OutQ  Up/Down   St/PfxRcd
209.165.200.225  0     200      216739  229871   200781341  0     0      3d00h    348032
209.165.201.30   0     200      6462962 4208831  200781341  10    0      2d22h    35750
```

Verify the MAC updates to the L2FIB table in a line card.

```
RP/0/RSP0/CPU0:router# show l2vpn mac mac all location 0/6/cPU0
```

```
Topo ID Producer Next Hop(s)     Mac Address    IP Address
------- -------- -----------     -------------- ----------
1112    0/6/CPU0 Te0/6/0/1.36001 00a3.0001.0001
```

Verify the MAC updates to the L2FIB table in a route switch processor (RSP).

```
RP/0/RSP0/CPU0:router# show l2vpn mac mac all location 0/6/cPU0

Topo ID  Producer Next Hop(s)     Mac Address    IP Address
-------  -------- -----------     -------------- ----------
1112     0/6/CPU0 0/6/0/1.36001 00a3.0001.0001
```

Verify the summary information for the MAC address.

```
RP/0/RSP0/CPU0:router# show l2vpn forwarding bridge-domain EVPN_ALL_ACTIVE:EVPN_2001
mac-address location 0/6/CPU0

.....
Mac Address     Type      Learned from/Filtered on   LC learned   Resync Age/Last Change
Mapped to
0000.2001.5555  dynamic   Te0/0/0/2/0.2001           N/A          11 Jan 14:37:22
N/A <-- local dynamic
00bb.2001.0001 dynamic    Te0/0/0/2/0.2001           N/A          11 Jan 14:37:22
N/A
0000.2001.1111 EVPN       BD id: 1110                N/A          N/A
N/A <-- remote static
00a9.2002.0001 EVPN       BD id: 1110                N/A          N/A
N/A
```

Verify the EVPN EVI information with the VPN-ID and MAC address filter.

```
RP/0/RSP0/CPU0:router# show evpn evi vpn-id 2001 mac

EVI    MAC address     IP address        Nexthop      Label
----   -------------   -----------       -------      ------
2001   00a9.2002.0001  ::                10.10.10.10  34226      <-- Remote MAC
2001   00a9.2002.0001  ::                209.165.201.30  34202

2001   0000.2001.5555  20.1.5.55         TenGigE0/0/0/2/0.2001 34203    <-- local MAC


RP/0/RSP0/CPU0:router# RP/0/RSP0/CPU0:router# show evpn evi vpn-id 2001 mac 00a9.2002.0001
 detail

EVI     MAC address      IP address  Nexthop      Label
----    --------------   ----------  -------      -----
2001    00a9.2002.0001   ::          10.10.10.10  34226

2001    00a9.2002.0001   ::          209.165.201.30  34202

 Ethernet Tag : 0
 Multi-paths Resolved : True <--- aliasing to two remote PE with All-Active load balancing

 Static : No
 Local Ethernet Segment : N/A
 Remote Ethernet Segment : 0100.211b.fce5.df00.0b00
 Local Sequence Number : N/A
 Remote Sequence Number : 0
 Local Encapsulation : N/A
```

```
 Remote Encapsulation : MPLS
```

Verify the BGP routes associated with EVPN with bridge-domain filter.

```
RP/0/RSP0/CPU0:router# show bgp l2vpn evpn bridge-domain EVPN_2001 route-type 2

*> [2][0][48][00bb.2001.0001][0]/104
                        0.0.0.0           0 i <------ locally learnt MAC
*>i[2][0][48][00a9.2002.00be][0]/104
                        10.10.10.10 100    0 i <----- remotely learnt MAC
* i 209.165.201.30 100 0 i
```

EVPN Out of Service

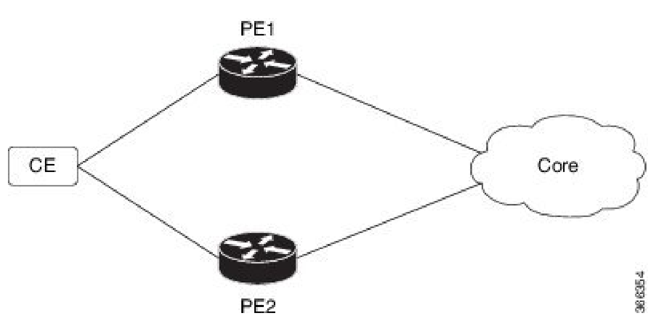
The EVPN Out of Service feature enables you to control the state of bundle interfaces that are part of an Ethernet segment that have Link Aggregation Control protocol (LACP) configured. This feature enables you to put a node out of service (OOS) without having to manually shutdown all the bundles on their provider edge (PE).

Use the **cost-out** command to bring down all the bundle interfaces belonging to an Ethernet VPN (EVPN) Ethernet segment on a node. The Ethernet A-D Ethernet Segment (ES-EAD) routes are withdrawn before shutting down the bundles. The PE signals to the connected customer edge (CE) device to bring down the corresponding bundle member. This steers away traffic from this PE node without traffic disruption. The traffic that is bound for the Ethernet segment from the CE is directed to the peer PE in a multi-homing environment.

Note EVPN cost-out is supported only on manually configured ESIs.

In the following topology, the CE is connected to PE1 and PE2. When you configure the **cost-out** command on PE1, all the bundle interfaces on the Ethernet segment are brought down. Also, the corresponding bundle member is brought down on the CE. Hence, the traffic for this Ethernet segment is now sent to PE2 from the CE.

Figure 16: EVPN Out of Service



To bring up the node into service, use **no cost-out** command. This brings up all the bundle interfaces belonging to EVPN Ethernet segment on the PE and the corresponding bundle members on the CE.

When the node is in cost-out state, adding a new bundle Ethernet segment brings that bundle down. Similarly, removing the bundle Ethernet segment brings that bundle up.

Use **startup-cost-in** command to bring up the node into service after the specified time on reload. The node will cost-out when EVPN is initialized and remain cost-out until the set time. If you execute **evpn no startup-cost-in** command while timer is running, the timer stops and node is cost-in.

The 'cost-out' configuration always takes precedence over the 'startup-cost-in' timer. So, if you reload with both the configurations, cost-out state is controlled by the 'cost-out' configuration and the timer is not relevant. Similarly, if you reload with the startup timer, and configure 'cost-out' while timer is running, the timer is stopped and OOS state is controlled only by the 'cost-out' configuration.

If you do a proc restart while the startup-cost-in timer is running, the node remains in cost-out state and the timer restarts.

Configure EVPN Out of Service

This section describes how you can configure EVPN Out of Service.

```
/* Configuring node cost-out on a PE */

Router# configure
Router(config)# evpn
Router(config-evpn)# cost-out
Router(config-evpn)commit

/* Bringing up the node into service */

Router# configure
Router(config)# evpn
Router(config-evpn)# no cost-out
Router(config-evpn)commit

/* Configuring the timer to bring up the node into service after the specified time on
reload */

Router# configure
Router(config)# evpn
Router(config-evpn)# startup-cost-in 6000
Router(config-evpn)commit
```

Running Configuration

```
configure
evpn
 cost-out
!

configure
evpn
 startup-cost-in 6000
!
```

Verification

Verify the EVPN Out of Service configuration.

```
/* Verify the node cost-out configuration */

Router# show evpn summary
Fri Apr  7 07:45:22.311 IST
Global Information
-----------------------------
Number of EVIs                : 2
Number of Local EAD Entries   : 0
Number of Remote EAD Entries  : 0
Number of Local MAC Routes    : 0
Number of Local MAC Routes    : 5
          MAC                 : 5
          MAC-IPv4            : 0
          MAC-IPv6            : 0
Number of Local ES:Global MAC : 12
Number of Remote MAC Routes   : 7
          MAC                 : 7
          MAC-IPv4            : 0
          MAC-IPv6            : 0
Number of Local IMCAST Routes : 56
Number of Remote IMCAST Routes: 56
Number of Internal Labels     : 5
Number of ES Entries          : 9
Number of Neighbor Entries    : 1
EVPN Router ID                : 192.168.0.1
BGP Router ID                 : ::
BGP ASN                       : 100
PBB BSA MAC address           : 0207.1fee.be00
Global peering timer          :      3 seconds
Global recovery timer         :     30 seconds
EVPN cost-out                 : TRUE
      startup-cost-in timer   : Not configured


/* Verify the no cost-out configuration */

Router# show evpn summary
Fri Apr  7 07:45:22.311 IST
Global Information
-----------------------------
Number of EVIs                : 2
Number of Local EAD Entries   : 0
Number of Remote EAD Entries  : 0
Number of Local MAC Routes    : 0
Number of Local MAC Routes    : 5
          MAC                 : 5
          MAC-IPv4            : 0
          MAC-IPv6            : 0
Number of Local ES:Global MAC : 12
Number of Remote MAC Routes   : 7
          MAC                 : 7
          MAC-IPv4            : 0
          MAC-IPv6            : 0
Number of Local IMCAST Routes : 56
Number of Remote IMCAST Routes: 56
Number of Internal Labels     : 5
Number of ES Entries          : 9
Number of Neighbor Entries    : 1
EVPN Router ID                : 192.168.0.1
BGP Router ID                 : ::
BGP ASN                       : 100
PBB BSA MAC address           : 0207.1fee.be00
Global peering timer          :      3 seconds
```

```
Global recovery timer          :     30 seconds
EVPN cost-out                  : FALSE
      startup-cost-in timer    : Not configured


/* Verify the startup-cost-in timer configuration */

Router# show evpn summary
Fri Apr  7 07:45:22.311 IST
Global Information
-----------------------------
Number of EVIs                 : 2
Number of Local EAD Entries    : 0
Number of Remote EAD Entries   : 0
Number of Local MAC Routes     : 0
Number of Local MAC Routes     : 5
          MAC                  : 5
          MAC-IPv4             : 0
          MAC-IPv6             : 0
Number of Local ES:Global MAC  : 12
Number of Remote MAC Routes    : 7
          MAC                  : 7
          MAC-IPv4             : 0
          MAC-IPv6             : 0
Number of Local IMCAST Routes  : 56
Number of Remote IMCAST Routes: 56
Number of Internal Labels      : 5
Number of ES Entries           : 9
Number of Neighbor Entries     : 1
EVPN Router ID                 : 192.168.0.1
BGP Router ID                  : ::
BGP ASN                        : 100
PBB BSA MAC address            : 0207.1fee.be00
Global peering timer           :      3 seconds
Global recovery timer          :     30 seconds
EVPN node cost-out             : TRUE
        startup-cost-in timer  : 6000
```

EVPN Routing Policy

The EVPN Routing Policy feature provides the route policy support for address-family L2VPN EVPN. This feature adds EVPN route filtering capabilities to the routing policy language (RPL). The filtering is based on various EVPN attributes.

A routing policy instructs the router to inspect routes, filter them, and potentially modify their attributes as they are accepted from a peer, advertised to a peer, or redistributed from one routing protocol to another.

This feature enables you to configure route-policies using EVPN network layer reachability information (NLRI) attributes of EVPN route type 1 to 5 in the route-policy match criteria, which provides more granular definition of route-policy. For example, you can specify a route-policy to be applied to only certain EVPN route-types or any combination of EVPN NLRI attributes. This feature provides flexibility in configuring and deploying solutions by enabling route-policy to filter on EVPN NLRI attributes.

To implement this feature, you need to understand the following concepts:

- Routing Policy Language
- Routing Policy Language Structure
- Routing Policy Language Components

- Routing Policy Language Usage
- Policy Definitions
- Parameterization
- Semantics of Policy Application
- Policy Statements
- Attach Points

For information on these concepts, see Implementing Routing Policy.

Currently, this feature is supported only on BGP neighbor "in" and "out" attach points. The route policy can be applied only on inbound or outbound on a BGP neighbor.

EVPN Route Types

The EVPN NLRI has the following different route types:

Route Type 1: Ethernet Auto-Discovery (AD) Route

The Ethernet (AD) routes are advertised on per EVI and per Ethernet Segment Identifier (ESI) basis. These routes are sent per Ethernet segment (ES). They carry the list of EVIs that belong to the ES. The ESI field is set to zero when a CE is single-homed.

An Ethernet A-D route type specific EVPN NLRI consists of the following fields:

```
+---------------------------------------+
|Route Type (1 octet)                   |*
+---------------------------------------+
|Length (1 octet)                       |
+---------------------------------------+
|Route Distinguisher (RD) (8 octets)    |*
+---------------------------------------+
|Ethernet Segment Identifier (10 octets)|*
+---------------------------------------+
|Ethernet Tag ID (4 octets)             |*
+---------------------------------------+
|MPLS Label (3 octets)                  |
+---------------------------------------+
```

NLRI Format: Route-type 1:

`[Type][Len][RD][ESI][ETag][MPLS Label]`

Net attributes: `[Type][RD][ESI][ETag]`

Path attributes: `[MPLS Label]`

Example

```
route-policy evpn-policy
  if rd in (1.1.1.1:0) [and/or evpn-route-type is 1] [and/or esi in (0a1.a2a3.a4a5.a6a7.a8a9)]
 [and/or etag is 4294967295] then
    set ..
```

```
  endif
end-policy
!
route-policy evpn-policy
  if rd  in (1.1.1.2:0) [and/or evpn-route-type is 1] [and/or esi in
(00a1.a2a3.a4a5.a6a7.a8a9)] [and/or etag is 4294967295] then
    set ..
  endif
end-policy
```

Route Type 2: MAC/IP Advertisement Route

The host's IP and MAC addresses are advertised to the peers within NLRI. The control plane learning of MAC addresses reduces unknown unicast flooding.

A MAC/IP Advertisement Route type specific EVPN NLRI consists of the following fields:

```
+---------------------------------------+
|Route Type (1 octet)                   |*
+---------------------------------------+
|Length (1 octet)                       |
+---------------------------------------+
|RD (8 octets)                          |*
+---------------------------------------+
|Ethernet Segment Identifier (10 octets)|
+---------------------------------------+
|Ethernet Tag ID (4 octets)             |*
+---------------------------------------+
|MAC Address Length (1 octet)           |*
+---------------------------------------+
|MAC Address (6 octets)                 |*
+---------------------------------------+
|IP Address Length (1 octet)            |*
+---------------------------------------+
|IP Address (0, 4, or 16 octets)        |*
+---------------------------------------+
|MPLS Label1 (3 octets)                 |
+---------------------------------------+
|MPLS Label2 (0 or 3 octets)            |
+---------------------------------------+
```

366356

NLRI Format: Route-type 2:

`[Type][Len][RD][ESI][ETag][MAC Addr Len][MAC Addr][IP Addr Len][IP Addr][MPLS Label1][MPLS Label2]`

Net attributes: `[Type][RD][ETag][MAC Addr Len][MAC Addr][IP Addr Len][IP Addr]`

Path attributes: `[ESI], [MPLS Label1], [MPLS Label2]`

Example

```
route-policy evpn-policy
  if rd in (1.1.1.2:0) [and/or evpn-route-type is 2] [and/or esi in
(0000.0000.0000.0000.0000)] [and/or etag is 0] [and/or macaddress in (0013.aabb.ccdd)]
[and/or destination in (1.2.3.4/32)] then
    set ..
  endif
end-policy
```

Route Type 3: Inclusive Multicast Ethernet Tag Route

This route establishes the connection for broadcast, unknown unicast, and multicast (BUM) traffic from a source PE to a remote PE. This route is advertised on per VLAN and per ESI basis.

An Inclusive Multicast Ethernet Tag route type specific EVPN NLRI consists of the following fields:

```
+---------------------------------------+
|  Route Type (1 octet)                 |*
+---------------------------------------+
|  Length (1 octet)                     |
+---------------------------------------+
|  RD (8 octets)                        |*
+---------------------------------------+
|  Ethernet Tag ID (4 octets)           |*
+---------------------------------------+
|  IP Address Length (1 octet)          |*
+---------------------------------------+
|  Originating Router's IP Address      |*
|  (4 or 16 octets)                     |
+---------------------------------------+
```

308357

NLRI Format: Route-type 3:

`[Type][Len][RD][ETag][IP Addr Len][Originating Router's IP Addr]`

Net attributes: `[Type][RD][ETag][IP Addr Len][Originating Router's IP Addr]`

Example

```
route-policy evpn-policy
  if rd  in (1.1.1.1:300) [and/or evpn-route-type is 3] [and/or etag is 0] [and/or
evpn-originator in (1.1.1.1)] then
    set ..
  endif
end-policy
```

Route Type 4: Ethernet Segment Route

Ethernet segment routes enable to connect a CE device to two or PE devices. ES route enables the discovery of connected PE devices that are connected to the same Ethernet segment.

An Ethernet Segment route type specific EVPN NLRI consists of the following fields:

```
+---------------------------------------+
|Route Type (1 octet)                   |*
+---------------------------------------+
|Length (1 octet)                       |
+---------------------------------------+
|RD (8 octets)                          |*
+---------------------------------------+
|Ethernet Segment Identifier (10 octets)|*
+---------------------------------------+
|IP Address Length (1 octet)            |*
+---------------------------------------+
|Originating Router's IP Address        |*
|(4 or 16 octets)                       |
+---------------------------------------+
```

NLRI Format: Route-type 4:

`[Type][Len][RD][ESI][IP Addr Len][Originating Router's IP Addr]`

Net attributes: `[Type][RD][ESI][IP Addr Len][Originating Router's IP Addr]`

Example

```
route-policy evpn-policy
  if rd  in (1.1.1.1:0) [and/or evpn-route-type is 4] [and/or esi in
(00a1.a2a3.a4a5.a6a7.a8a9)] [and/or evpn-originator in (1.1.1.1)] then
    set ..
  endif
end-policy
```

Route Type 5: IP Prefix Route

An IP Prefix Route type specific EVPN NLRI consists of the following fields:

```
+---------------------------------------+
|Route Type (1 octet)                   |*
+---------------------------------------+
|Length (1 octet)                       |
+---------------------------------------+
|RD   (8 octets)                        |*
+---------------------------------------+
|Ethernet Segment Identifier (10 octets)|
+---------------------------------------+
|Ethernet Tag ID (4 octets)             |*
+---------------------------------------+
|IP Address Length (1 octet)            |*
+---------------------------------------+
|IP Address (4 or 16 octets)            |*
+---------------------------------------+
|GW IP Address (4 or 16 octets)         |
+---------------------------------------+
|MPLS Label (3 octets)                  |
+---------------------------------------+
```

NLRI Format: Route-type 5:

`[Type][Len][RD][ESI][ETag][IP Addr Len][IP Addr][GW IP Addr][Label]`

Net attributes: `[Type][RD][ETag][IP Addr Len][IP Addr]`

Path attributes: `[ESI], [GW IP Addr], [Label]`

Example

```
route-policy evpn-policy
  if rd in (30.30.30.30:1) [and/or evpn-route-type is 5] [and/or esi in
(0000.0000.0000.0000.0000)] [and/or etag is 0] [and/or destination in (12.2.0.0/16)] [and/or
 evpn-gateway in (0.0.0.0)] then
    set ..
  endif
end-policy
```

EVPN RPL Attribute

Route Distinguisher

A Route Distinguisher (rd) attribute consists of eight octets. An rd can be specified for each of the EVPN route types. This attribute is not mandatory in route-policy.

Example

```
rd in (1.2.3.4:0)
```

EVPN Route Type

EVPN route type attribute consists of one octet. This specifies the EVPN route type. The EVPN route type attribute is used to identify a specific EVPN NLRI prefix format. It is a net attribute in all EVPN route types.

Example

```
evpn-route-type is 3
```

```
The following are the various EVPN route types that can be used:
1 - ethernet-ad
2 – mac-advertisement
3 - inclusive-multicast
4 - ethernet-segment
5 – ip-advertisement
```

IP Prefix

An IP prefix attribute holds IPv4 or IPv6 prefix match specification, each of which has four parts: an address, a mask length, a minimum matching length, and a maximum matching length. The address is required, but the other three parts are optional. When IP prefix is specified in EVPN route type 2, it represents either a IPv4 or IPv6 host IP Address (/32 or /128). When IP prefix is specified in EVPN route type 5, it represents either IPv4 or IPv6 subnet. It is a net attribute in EVPN route type 2 and 5.

Example

```
destination in (128.47.10.2/32)
destination in (128.47.0.0/16)
destination in (128:47::1/128)
destination in (128:47::0/112)
```

esi

An Ethernet Segment Identifier (ESI) attribute consists of 10 octets. It is a net attribute in EVPN route type 1 and 4, and a path attribute in EVPN route type 2 and 5.

Example

```
esi in (ffff.ffff.ffff.ffff.fff0)
```

etag

An Ethernet tag attribute consists of four octets. An Ethernet tag identifies a particular broadcast domain, for example, a VLAN. An EVPN instance consists of one or more broadcast domains. It is a net attribute in EVPN route type 1, 2, 3 and 5.

Example

```
etag in (10000)
```

mac

The mac attribute consists of six octets. This attribute is a net attribute in EVPN route type 2.

Example

```
mac in (0206.acb1.e806)
```

evpn-originator

The evpn-originator attribute specifies the originating router's IP address (4 or 16 octets). This is a net attribute in EVPN route type 3 and 4.

Example

```
evpn-originator in (1.2.3.4)
```

evpn-gateway

The evpn-gateway attribute specifies the gateway IP address. The gateway IP address is a 32-bit or 128-bit field (IPv4 or IPv6), and encodes an overlay next-hop for the IP prefixes. The gateway IP address field can be zero if it is not used as an overlay next-hop. This is a path attribute in EVPN route type 5.

Example

```
evpn-gateway in (1.2.3.4)
```

EVPN RPL Attribute Set

In this context, the term set is used in its mathematical sense to mean an unordered collection of unique elements. The policy language provides sets as a container for groups of values for matching purposes. Sets are used in conditional expressions. The elements of the set are separated by commas. Null (empty) sets are allowed.

prefix-set

A prefix-set holds IPv4 or IPv6 prefix match specifications, each of which has four parts: an address, a mask length, a minimum matching length, and a maximum matching length. The address is required, but the other three parts are optional. The prefix-set specifies one or more IP prefixes.

Example

```
prefix-set ip_prefix_set
14.2.0.0/16,
54.0.0.0/16,
12.12.12.0/24,
50:50::1:0/112
end-set
```

mac-set

The mac-set specifies one or more MAC addresses.

Example

```
mac-set mac_address_set
1234.2345.6789,
2345.3456.7890
end-set
```

esi-set

The esi-set specifies one or more ESI's.

Example

```
esi-set evpn_esi_set
1234.2345.3456.4567.5678,
1234.2345.3456.4567.5670
end-set
```

etag-set

The etag-set specifies one or more Ethernet tags.

Example

```
etag-set evpn_etag_set
10000,
20000
end-set
```

Configure EVPN RPL Feature

The following section describe how to configure mac-set, esi-set, evpn-gateway, and evpn-originator.

```
/* Configuring a mac-set and refering it in a route-policy (Attach point - neighbor-in) */
Router# configure
Router(config)# mac-set demo_mac_set
Router(config-mac)# 1234.ffff.aaa3,
Router(config-mac)# 2323.4444.ffff
Router(config-mac)# end-set
Router(config)# !
Router(config)# route-policy policy_use_pass_mac_set
Router(config-rpl)# if mac in demo_mac_set then
Router(config-rpl-if)# set med 200
Router(config-rpl-if)# else
Router(config-rpl-else)# set med 1000
Router(config-rpl-else)# endif
Router(config-rpl)# end-policy
Router(config)# commit
```

```
Router(config)# router bgp 100
Router(config-bgp)# address-family ipv4 unicast
Router(config-bgp-af)# !
Router(config-bgp-af)# neighbor 10.0.0.10
Router(config-bgp-nbr)# remote-as 8
Router(config-bgp-nbr)# address-family ipv4 unicast
Router(config-bgp-nbr-af)# route-policy policy_use_pass_mac_set in
Router(config-bgp-nbr-af)# commit

/* Configuring a esi-set and refering it in a route-policy (Attach point - neighbor-in) */
Router# configure
Router(config)# esi-set demo_esi
Router(config-esi)# ad34.1233.1222.ffff.44ff,
Router(config-esi)# ad34.1233.1222.ffff.6666
Router(config-esi)# end-set
Router(config)# !
Router(config)# route-policy use_esi
Router(config-rpl)# if esi in demo_esi then
Router(config-rpl-if)# set local-preference 100
Router(config-rpl-if)# else
Router(config-rpl-else)# set local-preference 300
Router(config-rpl-else)# endif
Router(config-rpl)# end-policy
Router(config)# commit

/* Configuring evpn-gateway/evpn-originator in a route-policy (Attach point - neighbor-in
and out) */
Router# configure
Router(config)# route-policy gateway_demo
Router(config-rpl)# if evpn-gateway in (10.0.0.0/32) then
Router(config-rpl-if)# pass
Router(config-rpl-if)# endif
Router(config-rpl)# end-policy
Router(config)# commit
Router(config)# route-policy originator_demo
Router(config-rpl)# if evpn-originator in (10.0.0.1/32) then
Router(config-rpl-if)# set local-preference 100
Router(config-rpl-if)# else
Router(config-rpl-else)# set med 200
Router(config-rpl-else)# endif
Router(config-rpl)# end-policy
Router(config)# commit
Router(config)# router bgp 100
Router(config-bgp)# address-family ipv4 unicast
Router(config-bgp-af)# !
Router(config-bgp-af)# neighbor 10.0.0.10
Router(config-bgp-nbr)# remote-as 8
Router(config-bgp-nbr)# address-family ipv4 unicast
Router(config-bgp-nbr-af)# route-policy gateway_demo in
Router(config-bgp-nbr-af)# route-policy originator_demo out
Router(config-bgp-nbr-af)# commit
```

Running Configuration

```
/* Configuring a mac-set and refering it in a route-policy (Attach point - neighbor-in) */
mac-set demo_mac_set
  1234.ffff.aaa3,
  2323.4444.ffff
end-set
!
route-policy policy_use_pass_mac_set
```

```
  if mac in demo_mac_set then
    set med 200
  else
    set med 1000
  endif
end-policy
!
router bgp 100
 address-family ipv4 unicast
 !
 neighbor 10.0.0.10
  remote-as 8
  address-family ipv4 unicast
  route-policy policy_use_pass_mac_set in
  !
 !
!
end

/* Configuring a esi-set and refering it in a route-policy (Attach point - neighbor-in) */
Wed Oct 26 11:52:23.720 IST
esi-set demo_esi
  ad34.1233.1222.ffff.44ff,
  ad34.1233.1222.ffff.6666
end-set
!
route-policy use_esi
  if esi in demo_esi then
    set local-preference 100
  else
    set local-preference 300
  endif
end-policy
```

EVPN Route Policy Examples

```
route-policy ex_2
  if rd in (2.2.18.2:1004) and evpn-route-type is 1 then
    drop
  elseif rd in (2.2.18.2:1009) and evpn-route-type is 1 then
    drop
  else
    pass
  endif
end-policy
!
route-policy ex_3
  if evpn-route-type is 5 then
    set extcommunity bandwidth (100:9999)
  else
    pass
  endif
end-policy
!
route-policy samp
end-policy
!
route-policy samp1
  if rd in (30.0.101.2:0) then
    pass
  endif
end-policy
```

```
!
route-policy samp2
  if rd in (30.0.101.2:0, 1:1) then
    pass
  endif
end-policy
!
route-policy samp3
  if rd in (*:*) then
    pass
  endif
end-policy
!
route-policy samp4
  if rd in (30.0.101.2:*) then
    pass
  endif
end-policy
!
route-policy samp5
  if evpn-route-type is 1 then
    pass
  endif
end-policy
!
route-policy samp6
  if evpn-route-type is 2 or evpn-route-type is 5 then
    pass
  endif
end-policy
!
route-policy samp7
  if evpn-route-type is 4 or evpn-route-type is 3 then
    pass
  endif
end-policy
!
route-policy samp8
  if evpn-route-type is 1 or evpn-route-type is 2 or evpn-route-type is 3 then
    pass
  endif
end-policy
!
route-policy samp9
  if evpn-route-type is 1 or evpn-route-type is 2 or evpn-route-type is 3 or evpn-route-type
 is 4 then
    pass
  endif
end-policy
!
route-policy test1
  if evpn-route-type is 2 then
    set next-hop 10.2.3.4
  else
    pass
  endif
end-policy
!
route-policy test2
  if evpn-route-type is 2 then
    set next-hop 10.10.10.10
  else
    drop
  endif
```

```
end-policy
!
route-policy test3
  if evpn-route-type is 1 then
    set tag 9988
  else
    pass
  endif
end-policy
!
route-policy samp21
  if mac in (6000.6000.6000) then
    pass
  endif
end-policy
!
route-policy samp22
  if extcommunity rt matches-any (100:1001) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp23
  if evpn-route-type is 1 and esi in (aaaa.bbbb.cccc.dddd.eeee) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp24
  if evpn-route-type is 5 and extcommunity rt matches-any (100:1001) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp25
  if evpn-route-type is 2 and esi in (1234.1234.1234.1234.1236) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp26
  if etag in (20000) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp27
  if destination in (99.99.99.1) and etag in (20000) then
    pass
  else
    drop
  endif
end-policy
!
```

```
route-policy samp31
  if evpn-route-type is 1 or evpn-route-type is 2 or evpn-route-type is 3 or evpn-route-type
 is 4 or evpn-route-type is 5 then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp33
  if esi in evpn_esi_set1 then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp34
  if destination in (90:1:1::9/128) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp35
  if destination in evpn_prefix_set1 then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp36
  if evpn-route-type is 3 and evpn-originator in (80:1:1::3) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp37
  if evpn-gateway in (10:10::10) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp38
  if mac in evpn_mac_set1 then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp39
  if mac in (6000.6000.6002) then
    pass
  else
    drop
  endif
end-policy
```

```
!
route-policy samp41
  if evpn-gateway in (10.10.10.10, 10:10::10) then
    pass
  else
    drop
  endif
end-policy
!
route-policy samp42
  if evpn-originator in (24.162.160.1/32, 70:1:1::1/128) then
    pass
  else
    drop
  endif
end-policy
!
route-policy example
  if rd in (62300:1903) and evpn-route-type is 1 then
    drop
  elseif rd in (62300:19032) and evpn-route-type is 1 then
    drop
  else
    pass
  endif
end-policy
!
route-policy samp100
  if evpn-route-type is 4 or evpn-route-type is 5 then
    drop
  else
    pass
  endif
end-policy
!
route-policy samp101
  if evpn-route-type is 4 then
    drop
  else
    pass
  endif
end-policy
!
route-policy samp102
  if evpn-route-type is 4 then
    drop
  elseif evpn-route-type is 5 then
    drop
  else
    pass
  endif
end-policy
!
route-policy samp103
  if evpn-route-type is 2 and destination in evpn_prefix_set1 then
    drop
  else
    pass
  endif
end-policy
!
route-policy samp104
  if evpn-route-type is 1 and etag in evpn_etag_set1 then
    drop
```

```
  elseif evpn-route-type is 2 and mac in evpn_mac_set1 then
    drop
  elseif evpn-route-type is 5 and esi in evpn_esi_set1 then
    drop
  else
    pass
  endif
end-policy
!
```

CHAPTER 9

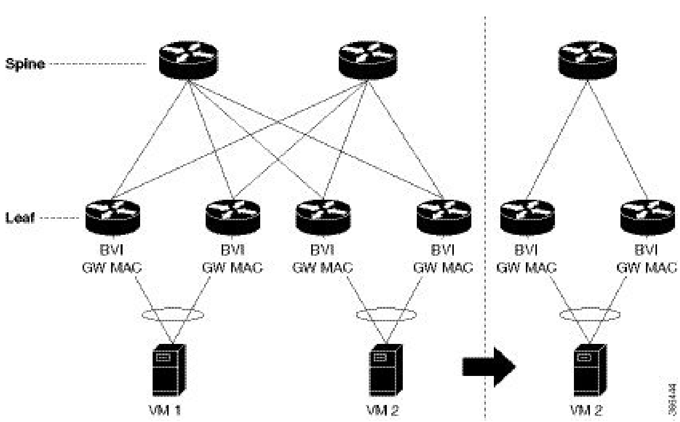
Configure EVPN IRB

This chapter introduces you to Ethernet VPN (EVPN) Integrated Routing and Bridging (IRB) feature and describe how you can configure the EVPN IRB feature.

EVPN IRB

EVPN IRB feature enables a Layer 2 VPN and an Layer 3 VPN overlay that allows end hosts across the overlay to communicate with each other within the same subnet and across different subnets within the VPN.

Figure 17: EVPN IRB



The benefit of EVPN IRB is that it allows the hosts in an IP subnet to be provisioned anywhere in the data center. When a virtual machine (VM) in a subnet is provisioned behind a EVPN PE, and another VM is required in the same subnet, it can be provisioned behind another EVPN PE. The VMs do not have to be localized; they need not be directly connected; or be in the same complex. The VM is allowed to move across in the same subnet. Availability of IP MPLS network across all the EVPN PEs enables the provisioning of VM mobility. The EVPN PEs route traffic to each other through MPLS encapsulation.

The EVPN PEs are connected to each other by a spine so they have IP reachability to each other's loopback interfaces. The IP network and MPLS tunnels existing between these EVPN PEs constitute the IP MPLS underlay fabric.

You can configure the MPLS tunnels to tunnel Layer 2 traffic, and to overlay VPN on these tunnels. EVPN control plane distributes both Layer 2 MAC reachability and Layer 3 IP reachability for hosts within the context of the VPN; it overlays a tenant's VPN network on top of the MPLS underlay fabric. Thus you can have tenant's hosts, which are in the same subnet layer 2 domain, but distributed across the fabric, communicate to each other as if they are in a Layer 2 network.

The Layer 2 VLAN and the corresponding IP subnet are not only a network of physically connected hosts on Layer 2 links, but an overlayed network on top of underlayed IP MPLS fabric which is spread across the datacenter.

A routing service, which enables stretching of the subnet across the fabric, is available. It also provides Layer 3 VPN and performs routing between subnets within the context of the Layer 3 VPN. The EVPN PEs provide Layer 2 bridging service between hosts that are spread across the fabric within a Layer 2 domain that is stretched across the fabric, and Layer 3 VPN service or inter-subnet routing service for hosts in different subnets within Layer 3 VPN. For example, as shown in the above topology diagram, the two VM are in the same subnet but they are not connected directly through each other through a Layer 2 link. The Layer 2 link is replaced by MPLS tunnels that are connecting them. The whole fabric acts as a single switch and bridges traffic from one VM to the other. This also enables VM mobility.

Note Egress marking is not supported on L2 interfaces in a bridge domain.

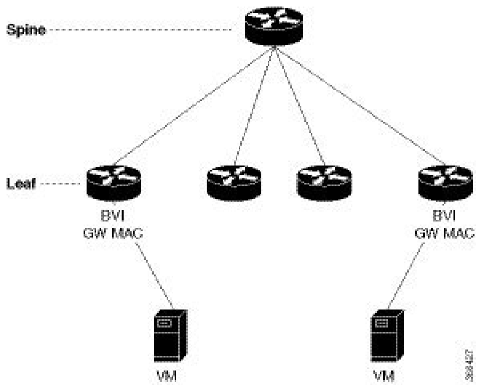
In the above topology diagram, the VMs, VM1 and VM2 are connected each other. When VM2 migrates to a different switch and different server, the VM's current MAC address and IP address are retained. When the subnet is stretched between two EVPN PEs, the same IRB configuration is applied on both the devices.

For stretching within the same subnet, you must configure the AC interface and the EVI; it is not required to configure IRB interface or VRF.

EVPN Single-Homing Access Gateway

The EVPN provider edge (PE) devices learn the MAC address and IP address from the ARP traffic that they receive from the customer edge (CE) devices. The PEs create the MAC+IP routes. The PEs advertise the MAC+IP routes to MPLS core. They inject the host IP routes to IP-VPN gateway. Subnet routes are also advertised from the access EVPN PEs in addition to host routes. All the PE nodes add the host routes in the IP-VRF table. The EVPN PE nodes add MAC route to the MAC-VRF table. The IP-VPN PE advertise the subnet routes to the provider edge devices which add the subnet routes to IP-VRF table. On the PE devices, IRB gateway IP addresses and MAC addresses are not advertised through BGP. IRB gateway IP addresses or MAC addresses are used to send ARP requests towards the datacenter CEs.

Figure 18: EVPN Single-Homing Access Gateway

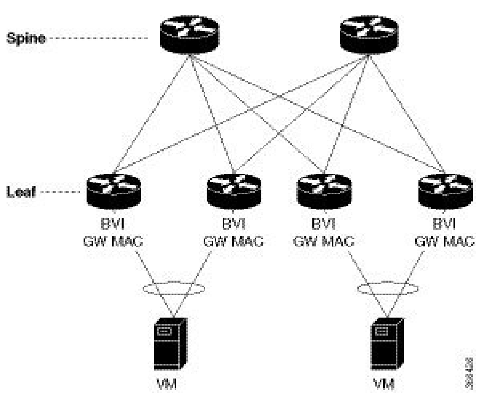


The above topology depicts how EVPN single-homing access gateway enables network connectivity by allowing a CE device to connect to one PE device. The PE device is attached to the Ethernet Segment through bundle or physical interfaces. Null Ethernet Segment Identifier (ESI) is used for single-homing.

EVPN Multihoming All-Active

In EVPN IRB, both EVPN and IP VPN (both VPNv4 and VPNv6) address families are enabled between routers and Data Center Interconnect (DCI) gateways. When Layer 2 (L2) stretch is not available in multiple data centers (DC), routing is established through VPNv4 or VPNv6 routes. When Layer 2 stretch is available, host routing is applied where IP-MAC routes are learnt by ARP and are distributed to EVPN/BGP. In remote peer gateway, these IP-MAC EVPN routes are imported into IP VPN routing table from EVPN route-type 2 routes with secondary label and Layer 3 VRF route-target.

Figure 19: EVPN Multi-Homing All-Active



The above topology describes how EVPN Multi-homing access gateway enables redundant network connectivity by allowing a CE device to connect to more than one PE device. Disruptions to the network connectivity are prevented by allowing a CE device to be connected to a PE device or several PE devices through multi-homing. Ethernet segment is the bunch of Ethernet links through which a CE device is connected to more than one PE devices. The All-Active Link Aggregation Group bundle operates as an Ethernet segment. Only MC bundles that operates between two chassis are supported.

Enable Auto-BGP RT with Manual ESI Configuration

Configuring an ES-Import RT was previously mandatory for Type 0 ESI. The ES-Import RT is auto-extracted by default, and the configuration serves to override the default value. This feature is based on RFC 7432 but applied specifically to ESI Type 0. For more information, see Section 5 of RFC 7432.

Supported EVPN IRB Scenarios

EVPN IRB supports the following scenarios:

- Dual-homing supports the following methods:
    - Only one EFP is supported per ESI per EVI
    - Only all-active mode is supported
    - Only two PE gateways in a redundancy group
- Single-homing supports the following methods:
    - Physical
    - VLAN
    - Bundle-ethernet
    - QinQ access
- Only IPv4 is supported.
- Subnet-stretch feature with EVPN IRB is only supported in VRF and is not supported in global VRF. in other words, EVPN IRB with EV-LAG multihoming is supported in global VRF without subnet being stretched beyond the multi-homing leafs

Distributed Anycast Gateway

EVPN IRB for the given subnet is configured on all the EVPN PEs that are hosted on this subnet. To facilitate optimal routing while supporting transparent virtual machine mobility, hosts are configured with a single default gateway address for their local subnet. That single (anycast) gateway address is configured with a single (anycast) MAC address on all EVPN PE nodes locally supporting that subnet. This process is repeated for each locally defined subnet requires Anycast Gateway support.

The host-to-host Layer 3 traffic, similar to Layer 3 VPN PE-PE forwarding, is routed on the source EVPN PE to the destination EVPN PE next-hop over an IP or MPLS tunnel, where it is routed again to the directly connected host. Such forwarding is also known as Symmetric IRB because the Layer 3 flows are routed at both the source and destination EVPN PEs.

The following are the solutions that are part of the Distributed Anycast Gateway feature:

EVPN IRB with All-Active Multi-Homing without Subnet Stretch or Host-Routing across the Fabric

For those subnets that are local to a set of multi-homing EVPN PEs, EVPN IRB Distributed Anycast Gateway is established through subnet routes that are advertised using EVPN Route Type 5 to VRF-hosting remote leafs. Though there is no need for the /32 routes within the subnet to be advertised, host MAC and ARP entries have to synced across the EVPN PE to which the servers are multi-homed.

This type of multi-homing has the following characteristics:

- All-active EV LAG on access
- Layer 3 ECMP for the fabric for dual-homed hosts based on subnet routes
- Absence of Layer 2 subnet stretch over the fabric
- Layer 2 stretch within redundancy group of leafs with orphan ports

Prefix-routing solution for a non-stretched subnet is summarized as below:

Across multi-homing EVPN PEs:

- Local ARP cache and MAC addresses are synchronized for dual-homed hosts through EVPN MAC+IP host route advertisements. They are imported as local, and are based on the local ESI match, for optimal forwarding to the access gateway.
- Orphan MAC addresses and host IP addresses are installed as remote addresses over the fabric.
- ES/EAD routes are exchanges for the designated forwarder (DF) election and split-horizon label.

Across remote EVPN PEs:

- Dual-homed MAC+IP EVPN Route Type 2 is exchanged with the ESI, EVI Label, Layer 2-Route Type. It is not imported across the fabric, if there is no subnet stretch or host-routing.
- The subnet IP EVPN Route Type 5 is exchanged with VRF label and Layer 3-Route Type.
- Layer 3 Route Type for the VRFs is imported that are present locally.
- Layer 2 Route Type for locally present BDs is imported. It is only imported from the leaf in the same redundancy group, if BD is not stretched.

EVPN IRB with All-Active Multihoming with Subnet Stretch or Host-Routing across the Fabric

For a bridge domain or subnet that is stretched across remote EVPN PEs, both /32 host routes and MAC routes are distributed in a EVPN overlay control plane to enable Layer 2 and Layer 3 traffic to the end points in a stretched subnet.

This type of multihoming has the following characteristics:

- All-active EV-LAG on the access gateway
- Layer 2 or Layer 3 ECMP for the fabric for dual-homed hosts based on Route Type 1 and Route Type 2

- Layer 3 unipath over the fabric for single-homed hosts based on Route Type 2
- Layer 2 subnet stretch over the fabric
- Layer 2 stretch within redundancy group of leafs with orphan ports

MAC and host routing solution for a stretched subnet is summarized as follows:

Across multihoming EVPN PEs:

- The Local ARP cache and MAC addresses are synchronized for dual-homed hosts through EVPN MAC+IP host route advertisements. They are imported as local, based on the local ESI match, for optimal forwarding to the access gateway.
- Synchronized MAC+IP are re-originated for inter-subnet Layer 3 ECMP.
- Orphan MAC address and host IP address are installed as remote addresses over the fabric.
- ES/EAD route is exchanged for designated forwarder (DF) election and split-horizon label.

Across remote EVPN PEs:

- Dual-homed MAC+IP EVPN Route Type 2 is exchange with ESI, EVI label, Layer 2-Route Type, VRF label, and Layer 3-Route Type.
- Subnet IP EVPN Route Type 5 is exchanged for VRF label, Layer 3-Route Type for silent hosts, and non-stretched subnets.
- Layer 3 Route Type is imported for locally present VRFs.
- Layer 2 Route Type is imported for locally present bridge domains.

MAC and IP Unicast Control Plane

This use case has following types:

Prefix Routing or No Subnet Stretch

IP reachability across the fabric is established using subnet prefix routes that are advertised using EVPN Route Type 5 with the VPN label and VRF RTs. Host ARP and MAC sync are established across multi-homing EVPN PEs using MAC+IP Route Type 2 based on a shared ESI to enable local switching through both the multi-homing EVPN PEs.

Host Routing or Stretched Subnet

When a host is discovered through ARP, the MAC and IP Route Type 2 is advertised with both MAC VRF and IP VRF router targets, and with VPN labels for both MAC-VRF and IP-VRF. Particularly, the VRF route targets and Layer 3 VPN label are associated with Route Type 2 to achieve PE-PE IP routing identical to traditional L3VPNs. A remote EVPN PE installs IP/32 entries directly in Layer 3 VRF table through the advertising EVPN PE next-hop with the Layer 3 VPN label encapsulation, much like a Layer 3 VPN imposition PE. This approach avoids the need to install separate adjacency rewrites for each remote host in a stretched subnet. Instead, it inherits a key Layer 3 VPN scale benefit of being able to share a common forwarding rewrite or load-balance resource across all IP host entries reachable through a set of EVPN PEs.

ARP and MAC sync

For hosts that are connected through LAG to more that one EVPN PE, the local host ARP and MAC entries are learnt in data plane on either or both of the multihoming EVPN PEs. Local ARP and MAC entries are synced across the two multihoming EVPN PEs using MAC and IP Route Type 2 based on a shared ESI to enable local switching through both the multihoming EVPN PEs. Essentially, a MAC and IP Route Type 2 that is received with a local ESI causes the installation of a synced MAC entry that points to the local AC port, and a synced ARP entry that is installed on the local BVI interface.

Note Only one Ethernet Flow Point (EFP) is supported per non-Zero ESI per bridge domain or EVI. This is a limitation of EVPN.

MAC and IP Route Re-origination

MAC and IP Route Type 2 received with a local ESI, which is used to sync MAC and ARP entries, is also re-originated from the router that installs a SYNC entry, if the host is not locally learnt and advertised based on local learning. This route re-origination is required to establish overlay IP ECMP paths on remote EVPN PEs, and to minimize traffic hit on local AC link failures, that can result in MAC and IP route withdraw in the overlay.

Note If custom or static MAC address is configured on a BVI interface, the MAC address on the wire may be different than what is configured. This has no operational or functional impact.

Intra-subnet Unicast Data Plane

The Layer 2 traffic is bridged on the source EVPN PE using ECMP paths to remote EVPN PEs, established through MAC+IP RT2, for every ES and for every EVI, ES and EAD Route Type 2 routes that are advertised from the local EVPN PEs.

Inter-subnet Unicast Data Plane

Inter-subnet traffic is routed on the source ToRs through overlay ECMP to the destination ToR next-hops. Data packet are encapsulated with the VPN label advertised from the ToR and tunnel label for the BGP next-hop towards the spine. It is then routed again on the destination ToR using a local ARP adjacency towards the host. IP ECMP on the remote ToRs is established through local and re-originated routes advertised from the local ToRs.

VM Mobility Support

VM mobility is the ability of virtual machines to migrate between one server and another while retaining their existing MAC and IP addresses.

The following are the two key components in EVPN Route Type 2 that enable VM Mobility:

- Host MAC advertisement component that is imported into local bridge MAC table, and Layer 2 bridged traffic across the network overlay.
- Host IP advertisement component that is imported into the IP routing table in a symmetric IRB design, enables routed traffic across the network overlay.

The above-mentioned components are advertised together in a single MAC + IP host route advertisement. An additional MAC-only route could also be advertised.

The following behaviors of VM are supported. The VM can:

- retain existing MAC and acquire a new IP address
- retain existing IP address and acquire a new MAC
- retain both existing MAC and IP address

MAC and MAC-IP Sequence Numbers

The IRB gateway device assigns, manages, and advertises sequence numbers that are associated with the locally learnt MAC routes through hardware learning, and the locally learnt MAC-IP routes through ARP.

Synchronized MAC and MAC-IP Sequence Numbers

In a host that is multi-homed to two ToRs, the locally learnt MAC and MAC-IP routes are synchronized across the two multi-homing peers through Route Type 2 learnt routes with a local ESI. So a device could have either MAC and MAC-IP, or both of them, learnt through both synchronized and local learning. Sequence numbers are synchronized across local and synchronized routes, because of which the sequence number that is advertised from the two ToRs for a given route is always the same.In certain situations, remote-sync route with same ESI can have a higher sequence number than a local route. In such a case, the local route sequence number is bumped up to match remote-sync route sequence number.

Local Sequence Number Updates

Host mobility is triggered when a local route is learnt while a remote route already exists. When mobility occurs, the local route is assigned a sequence number that is one higher than the existing remote route. This new local route is then advertised to the rest of the network.

Best Route Selection after Host Movement

When a host moves, the EVPN-PE at the new location of the host generates and advertises a higher sequence route to the network. When a higher sequence number route is received, as per RFC 7432, it is considered as the new best route and it is used for forwarding traffic. Best route selection is done for both MAC and MAC-IP routes.

Stale Route Deletion after a Host Movement

After a host moves from local to remote ESI, if a remote route from a different ESI is received and if a local route for the same host with a lower sequence number exists, then the local route is deleted and is withdrawn from the network.

The new higher sequence number remote MAC route is now considered best and is used to forward traffic. An ARP probe is sent to the host at the old local location. Because the host is at new remote location, probe will not succeed, resulting in clearing old local MAC-IP route.

Host Movement Detection through GARP

If a host sends a Gratuitous ARP (GARP) at its new location after a movement, the local MAC and local MAC-IP learning independently trigger mobility for both routes.

Host Move Detection with Silent Host

If a host does not send a GARP or a data packet at its new location following a move, the aging of the local MAC at the old location triggers mobility for both routes.

Host Move Detection without GARP with Data Packet

If the host does not send a GARP following a move, a data packet from the host triggers a proactive ARP probe to discover host MAC-IP and trigger mobility for this host across the overlay.

Duplicate MAC Detection

Duplicate MAC detection and freezing is supported as per RFC 7432.

Detection: Duplicate detection and recovery parameters are configurable. The default configuration is five times in 180 seconds and route freezing after three duplicate cycles. With the default configuration, when a host moves five times in 180 seconds, it is marked as duplicate for 30 seconds. Route advertisement for hosts in Duplicate state is suppressed. Host is taken out of duplicate state after 30 seconds. After a host is detected as duplicate for 3 times, on the fourth duplicate cycle, the host is permanently frozen. All route advertisements are suppressed for the frozen hosts.

In multi-homed hosts, a MAC is not necessarily learnt locally but is learnt through synchronization. Duplicate detection is supported for both local and remote-sync hosts. Remote-sync routes are differentiated from remote routes.

MAC-IP Handling: If the MAC route is in duplicate or frozen state, the corresponding local MAC-IP is updated, except that the route deletes are not withheld.

Duplicate State Handling: When a host is in duplicate state, route advertisements are suppressed. However, local routes are programmed in hardware so that traffic on local EVPN-PE is forwarded to the local host.

Recovery: It is possible to unfreeze permanently frozen hosts. The following is the recommended procedure to clear frozen hosts:

- Shutdown the host which is causing duplicate traffic.
- Use the **clear l2route evpn frozen-mac frozen-flag** command to clear the frozen hosts.

Configuring EVPN IRB

```
/* Configure CEF to prefer RIB prefixes over adjacency prefixes.*/

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# interface Bundle-Ether 3
RP/0/RSP0/CPU0:router(config-if)# lacp system mac 1.1.1
RP/0/RSP0/CPU0:router(config-if)# exit
RP/0/RSP0/CPU0:router(config)# cef adjacency route override rib
```

```
/* Configure EVPN L3VRF per DC tenant. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# vrf irb1
RP/0/RSP0/CPU0:router(config-vrf)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-vrf-af)# import route-target 1000:1
RP/0/RSP0/CPU0:router(config-vrf-af)# export route-target 1000:1
RP/0/RSP0/CPU0:router(config-vrf-af)# exit


/* Configure Layer 2 attachment circuit (AC) from multichassis (MC) bundle interface, and
bridge-group virtual interface (BVI) per bridge domain. */
/* Note: When a VM migrates from one subnet to another (subnet stretching), apply the
following IRB configuration to both the EVPN PEs. *\

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# interface bvi 1001
RP/0/RSP0/CPU0:router(config-if)# host-routing
RP/0/RSP0/CPU0:router(config-if)# ipv4 address 10.10.0.4 255.255.255.0
RP/0/RSP0/CPU0:router(config-if)# ipv4 address 172.16.0.1 secondary
RP/0/RSP0/CPU0:router(config-if)# mac-address 2001:DB8::1

/* Configure EVPN Layer 2 bridging service. Note: This configuration is performed in Layer
 2 gateway or bridging scenario. */

Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# bridge group 1
Router(config-l2vpn-bg)# bridge-domain 1-1
Router(config-l2vpn-bg-bd)# interface GigabitEthernet 0/0/0/1.1
Router(config-l2vpn-bg-bd-ac)# evi 1
Router(config-l2vpn-bg-bd-ac-evi)# commit
Router(config-l2vpnbg-bd-ac-evi)# exit


/* Configure BGP. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# router bgp 3107
RP/0/RSP0/CPU0:router(config-bgp)# vrf irb1
RP/0/RSP0/CPU0:router(config-bgp-vrf)# rd auto
RP/0/RSP0/CPU0:router(config-bgp-vrf)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-vrf-af)# redistribute connected
RP/0/RSP0/CPU0:router(config-bgp-vrf-af)# redistribute static
RP/0/RSP0/CPU0:router(config-bgp-vrf-af)# exit
RP/0/RSP0/CPU0:router(config-bgp-vrf-af)# redistribute connected
RP/0/RSP0/CPU0:router(config-bgp-vrf-af)# redistribute static


/* Configure EVPN, and configure main bundle ethernet segment parameters in EVPN. */

RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# evpn
RP/0/RSP0/CPU0:router(config-evpn)# evi 2001
RP/0/RSP0/CPU0:router(config-evpn-evi)# bgp
RP/0/RSP0/CPU0:router(config-evpn-evi-bgp)# route-target import 1000:1
RP/0/RSP0/CPU0:router(config-evpn-evi-bgp)# route-target export 1000:1
RP/0/RSP0/CPU0:router(config-evpn-evi-bgp)# exit
RP/0/RSP0/CPU0:router(config-evpn-evi)# advertise-mac
RP/0/RSP0/CPU0:router(config-evpn-evi)# unknown-unicast-suppression


/* Configure Layer 2 VPN. */
```

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)# bridge group irb
RP/0/RSP0/CPU0:router(config-l2vpn-bg)# bridge-domain irb1
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface bundle-Ether3.1001
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# routed interface BVI100
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-bvi)# split-horizon group core
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-bvi)# evi 10001
```

Running Configuration for EVPN IRB

```
/* Configure LACP */

interface Bundle-Ether3
 lacp system mac 1.1.1
!

/* Configure CEF adjacency overwrite. */

cef adjacency route override rib

/* Configure EVPN Layer 3 VRF per DC tenant. */

vrf irb1
address-family ipv4 unicast
  import route-target
   1000:1
  !
  export route-target
   1000:1
  !

!
!

/* Configure Layer 2 attachment circuit (AC) from multichassis (MC) bundle interface, and
bridge-group virtual interface (BVI) per bridge domain./*


interface Bundle-Ether3.1001 l2transport
 encapsulation dot1q 1001
 rewrite ingress tag pop 1 symmetric
!
interface BVI1001
 host-routing
 vrf irb1
 ipv4 address 10.0.1.1 255.255.255.0
 mac-address 0000.3030.1
!

/* Configure BGP. */

router bgp 3107
 vrf irb1
  rd auto
  address-family ipv4 unicast
  redistribute connected
  redistribute static
!
!
```

```
/* Configure EVPN. */

evpn
evi 10001
  bgp
   route-target import 1000:1
   route-target export 1000:1
  !
  advertise-mac
  unknown-unicast-suppression
!

/* Configure Layer2 VPN. */

l2vpn
bridge group irb
  bridge-domain irb1
   interface Bundle-Ether3.1001
   !
   routed interface BVI1001
    split-horizon group core
   !
   evi 10001
   !
  !
```

Verify EVPN IRB

Verify the Address Resolution Protocol (ARP) protocol entries, and synced entries in multi-homing scenarios; only multi-homing active-active mode is supported for EVPN IRB.

```
RP/0/RP0/CPU0:router# show arp vrf evpn1

-----------------------------------------------------------------
0/1/CPU0
-----------------------------------------------------------------
Address    Age        Hardware Addr   State      Type   Interface

10.1.1.1    -         0010.0001.0001  Interface  ARPA   BVI1
10.1.1.11 02:23:46    1000.0001.0001  Dynamic    ARPA   BVI1
10.1.1.93   -         0000.f65a.357c  EVPN_SYNC  ARPA   BVI1
10.1.2.1    -         0011.0112.0001  Interface  ARPA   BVI2
10.1.2.91 02:24:14    0000.f65a.3570  Dynamic    ARPA   BVI2
10.1.2.93 02:21:52    0000.f65a.357d  Dynamic    ARPA   BVI2
---------------------------------------------------------------
0/0/CPU0
---------------------------------------------------------------
Address   Age         Hardware Addr   State      Type  Interface

10.1.1.1  -           0010.0001.0001  Interface  ARPA  BVI1
10.1.1.11 02:23:46    1000.0001.0001  Dynamic    ARPA  BVI1
10.1.1.93 -           0000.f65a.357c  EVPN_SYNC  ARPA  BVI1
10.1.2.1  -           0011.0112.0001  Interface  ARPA BVI2
10.1.2.91 02:24:14    0000.f65a.3570  Dynamic    ARPA BVI2
10.1.2.93 02:21:52    0000.f65a.357d  Dynamic    ARPA BVI2
```

Verify the adjacency entries, particularly verify newly added information for synced IPv4 and IP ARP entries.

```
RP/0/RP0/CPU0:router# show adjacency ipv4 BVI 1 internal detail location 0/0/CPU0

BVI1, 10.1.1.93 (ipv4)
Version: 1169, references: 2, transient lock: 0
Encapsulation information (14 bytes) 0000f65a357c0000f65a357c0800 MTU: 1500
 Adjacency pointer is: 0x770a9278
 Platform adjacency pointer is: 0x7d7bc380
 Last updated: Feb 28 15:58:21.998
 Adjacency producer: arp (prod_id: 10)
 Flags: incomplete adj,
 Additional Adjacency Information (4 bytes long),
 Upto first 4 bytes (in hex): 01000000
 Netio idb pointer not cached Cached interface type: 78

Adjacency references:
bfd_agent (JID 150, PID 3637), 0 reference
l2fib_mgr (JID 185, PID 4003), 0 reference
fib_mgr (JID 294, PID 3605), 1 reference
aib (JID 314, PID 3590), 1 reference

BVI1, 10.1.1.11 (ipv4) Version: 1493,
references: 3, transient lock: 0
Encapsulation information (14 bytes) 1000000100010010000100010800
MTU: 1500
Adjacency pointer is: 0x770ab778
Platform adjacency pointer is: 0x7d7bcb10
Last updated: Mar 2 17:22:00.544
Adjacency producer: arp (prod_id: 10)
Flags: incomplete adj,
Netio idb pointer not cached Cached interface type: 78
Adjacency references:
bfd_agent (JID 150, PID 3637), 0 reference
l2fib_mgr (JID 185, PID 4003), 1 reference
fib_mgr (JID 294, PID 3605), 1 reference
aib (JID 314, PID 3590), 1 reference
```

Verify the entries to obtain details learnt in L2FIB line cards. In multi-homing active-active scenario, the link-local addresses are also updated and distributed to EVPN peer gateways.

```
RP/0/RP0/CPU0:router# show l2vpn mac-learning mac-ipv4 all location 0/RP0/CPU0

Topo ID  Producer  Next Hop(s)  Mac Address     IP Address

6         0/0/CPU0   BV1        1000.0001.0001      10.1.1.11
7         0/0/CPU0   BV2        0000.f65a.3570      10.1.2.91
7        0/0/CPU0    BV2        0000.f65a.357d      10.1.2.93

RP/0/RP0/CPU0:router# show l2vpn mac-learning mac-ipv6 all location 0/RP0/CPU0

Topo ID  Producer  Next Hop(s)  Mac Address    IP Address

6      0/0/CPU0    BV1       0000.f65a.357c    fe80::200:f6ff:fe5a:357c
7      0/0/CPU0    BV2       0000.f65a.3570    10:1:2::91
7      0/0/CPU0    BV2       0000.f65a.357d    10:1:2::93
7      0/0/CPU0    BV2       0000.f65a.3570    fe80::200:f6ff:fe5a:3570
```

Verify sequence ID for VM mobility.

```
RP/0/RP0/CPU0:router# show l2route evpn mac-ip all detail

Sun Apr 30 18:09:19.368 PDT
Flags: (Stt)=Static; (L)=Local; (R)=Remote; (F)=Flood;
(N)=No Redistribution; (Rtr)=Router MAC; (B)=Best Route;
(P)=Probe; (S)=Peer Sync; (F)=Flush;
(D)=Duplicate MAC; (Z)=Frozen MAC;

Topo ID    Mac Address     IP Address  Prod   Next Hop(s)         Seq No  Flags
Opaque Data Type    Opaque Data Len   Opaque Data Value
-------    -----------     ----------  ----   ----------          ------  -----
----------------    ---------------   -----------------
33         0022.6730.0001  10.130.0.2  L2VPN  Bundle-Ether6.1300  0       SB 0 12
0x06000000          0x22000080        0x00000000

Last Update: Sun Apr 30 15:00:01.911 PDT

33         0022.6730.0002 10.130.0.3  LOCAL  Bundle-Ether6.1300   0       B           N/A
                  N/A               N/A


RP/0/RP0/CPU0:router# show l2route evpn mac all detail


Flags:  (Stt)=Static; (L)=Local; (R)=Remote; (F)=Flood;
        (N)=No Redistribution; (Rtr)=Router MAC; (B)=Best Route;
        (S)=Peer Sync; (Spl)=Split; (Rcv)=Recd;
        (D)=Duplicate MAC; (Z)=Frozen MAC;

Topo ID  Mac Address     Prod   Next Hop(s)         Seq No  Flags  Slot ESI   Opaque Data
Type  Opaque Data Len Opaque Data Value
-------- -------------- ------ -----------        ------  ------ ---- ----  ----------------
  --------------- -----------------
36       0022.5830.0001  L2VPN  Bundle-Ether5.1300  0       BSSpl  0    (F)    0
      12             0x06000000 0x25000080 0x00000000

Last Update: Thu Apr 20 09:04:44.358 PDT
```

Verify duplicate detection and recovery parameters.

```
/* Use the show run evpn mac to verify the current parameters:  *\

RP/0/RP0/CPU0:router# show run evpn mac

evpn
mac
  secure
   freeze-time 5
   move-count 1000
   move-interval 60
   retry-count 1000
  !
!
!


/* Perform the following steps to change the existing parameters. */

RP/0/RP0/CPU0:EVPN-LF1# configure
```

```
RP/0/RP0/CPU0:EVPN-LF1(config)# evpn
RP/0/RP0/CPU0:EVPN-LF1(config-evpn)# mac
RP/0/RP0/CPU0:EVPN-LF1(config-evpn-mac)# secure
RP/0/RP0/CPU0:EVPN-LF1(config-evpn-mac-secure)# move-count 1000
RP/0/RP0/CPU0:EVPN-LF1(config-evpn-mac-secure)# end

/* Use the show run evpn mac to verify the changed parameters:  *\

RP/0/RP0/CPU0:router# show run evpn mac

evpn
mac
  secure
   move-count 1000
  !
!
!
```

Verify the entries to obtain details learnt in L2FIB RP when it is an aggregator. Route processor (RP) entries are aggregated entries obtained from the line cards. In some cases of MAC move, there could be different states for the same MAC. This is displayed in RP aggregated entries. RP determines the update to be sent to L2RIB according to MAC-Learning algorithms.

```
RP/0/RP0/CPU0:router#  show l2vpn mac-learning mac-ipv4 all location 0/RP0/CPU0

Topo ID  Producer        Next Hop(s)        Mac Address         IP Address
-------      --------    -----------        --------------      ----------
6            0/0/CPU0       BV1            1000.0001.0001      10.1.1.11
7            0/0/CPU0       BV2            0000.f65a.3570      10.1.2.91
7            0/0/CPU0       BV2            0000.f65a.357d      10.1.2.93
```

Verify the entries in L2RIB that are updated by RP L2FIB. Note the following when you verify the entries:

- The entries with producer as L2VPN and NH as remote IP are learnt from the remote peer gateways, which are learnt from BGP, updated to EVPN, and then updated to L2RIB. So these entries are not from local IP-MAC learning.
- The entries with producer as L2VPN and NH as local bundle interfaces are synced entries from MH-AA peer gateway.
- The entries with producer as LOCAL and NH as local bundle interfaces are dynamically learnt local entries.

```
RP/0/RP0/CPU0:router# show l2route evpn mac-ip evi 6

Topo ID      Mac Address        IP Address               Prod        Next Hop(s)
--------     ---------------    ----------------         ------      -------------
6            0000.f65a.3569     10.1.1.101               L2VPN     172.16.0.2/24014/ME
6            0000.f65a.3575     10.1.1.97                L2VPN     172.16.0.7/24025/ME
6            0000.f65a.3575     10:1:1::97               L2VPN     172.16.0.7/24025/ME
6            0000.f65a.3575     fe80::200:f6ff:fe5a:3575 L2VPN     172.16.0.7/24025/ME
6            0000.f65a.357c     10.1.1.93                L2VPN      Bundle-Ether1.11
6            0000.f65a.357c     10:1:1::93               L2VPN      Bundle-Ether1.11
6            0000.f65a.357c     fe80::200:f6ff:fe5a:357c LOCAL      Bundle-Ether1.11
6            0010.0001.0012     10.1.1.12                L2VPN      172.16.0.7/24025/ME
6            1000.0001.0001     10.1.1.11                LOCAL      Bundle-Ether1.11
```

```
6           90e2.ba8e.c0c9     10.1.1.102              L2VPN      172.16.0.2/24014/ME
```

Verify entries to obtain details of EVPN.

```
RP/0/RP0/CPU0:router# show evpn evi vpn-id 1 mac ipv4 10.1.1.93 detail

EVI       MAC address         IP address           Nexthop             Label
----      ---------------     ----------           ----------          -----
1          0000.f65a.357c      10.1.1.93           172.16.0.2          24014

Ethernet Tag : 0
Multi-paths Resolved : True
Static : No
Local Ethernet Segment : N/A
Remote Ethernet Segment : 0100.6cbc.a77c.c180.0000
Local Sequence Number : N/A
Remote Sequence Number : 0
Local Encapsulation : N/A
Remote Encapsulation : MPLS
```

Verify local BGP entries with appropriate second label and second IP VRF route-target.

```
RP/0/RP0/CPU0:router# show bgp l2vpn evpn rd 172.16.0.1:1
[2][0][48][0000.f65a.357c][32][10.1.1.93]/136

BGP routing table entry for [2][0][48][0000.f65a.357c][32][10.1.1.93]/136, Route
Distinguisher: 172.16.0.1:1
Versions:
Process bRIB/RIB SendTblVer
Speaker 3772 3772
Local Label: 24013
Last Modified: Feb 28 16:06:37.073 for 2d19h
Paths: (2 available, best #1)
Advertised to peers (in unique update groups):
172.16.0.9
Path #1: Received by speaker 0
Advertised to peers (in unique update groups):
172.16.0.9
Local
0.0.0.0 from 0.0.0.0 (172.16.0.1)
Second Label 24027                              >>>>  Second label when IRB host-routing
 is enabled.
Origin IGP, localpref 100, valid, redistributed, best, group-best, import-candidate,
rib-install
Received Path ID 0, Local Path ID 0, version 3772
Extended community: SoO:172.16.0.2:1 RT:100:100
EVPN ESI: 0100.6cbc.a77c.c180.0000
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 (metric 101) from 172.16.0.9 (172.16.0.2)
Received Label 24014, Second Label 24031
Origin IGP, localpref 100, valid, internal, add-path, import-candidate, imported, rib-install
Received Path ID 0, Local Path ID 2, version 3769
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100  >>>  Second RT is IP VRF RT for
remote to import into IP VRF routing table.
Originator: 172.16.0.2, Cluster list: 172.16.0.9
```

```
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
```

```
RP/0/RP0/CPU0:router# show bgp l2vpn evpn rd 172.16.0.1:1
[2][0][48][0000.f65a.357c][128][10:1:1::93]/232

[2][0][48][0000.f65a.357c][128][10:1:1::93]/232
BGP routing table entry for [2][0][48][0000.f65a.357c][128][10:1:1::93]/232, Route
Distinguisher: 172.16.0.1:1
Versions:
Process bRIB/RIB SendTblVer
Speaker 3172 3172
Local Label: 24013
Last Modified: Feb 28 11:34:33.073 for 3d00h
Paths: (2 available, best #1)
Advertised to peers (in unique update groups):
172.16.0.9
Path #1: Received by speaker 0
Advertised to peers (in unique update groups):
172.16.0.9
Local
0.0.0.0 from 0.0.0.0 (172.16.0.1)
Second Label 24029
Origin IGP, localpref 100, valid, redistributed, best, group-best, import-candidate,
rib-install
Received Path ID 0, Local Path ID 0, version 3172
Extended community: SoO:172.16.0.2:1 RT:100:100
EVPN ESI: 0100.6cbc.a77c.c180.0000
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 (metric 101) from 172.16.0.9 (172.16.0.2)
Received Label 24014, Second Label 24033
Origin IGP, localpref 100, valid, internal, add-path, import-candidate, imported, rib-install
Received Path ID 0, Local Path ID 2, version 3167
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 172.16.0.9
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
```

Verify the remote peer gateway BGP entries with correct label and route-target. Particularly verify the local auto-generated RD on a remote EVPN gateway. EVPN type-2 routes are imported into EVPN. The host routes of IPv4 /32 addresses are imported only into IP VRF route-table in the remote EVPN gateway, but not in the local EVPN gateway where local BVI adjacency is used to overwrite RIB entries.

```
RP/0/RP0/CPU0:router#  show bgp l2vpn evpn rd 172.16.0.7:1
[2][0][48][0000.f65a.357c][32][10.1.1.93]/136
BGP routing table entry for [2][0][48][0000.f65a.357c][32][10.1.1.93]/136, Route
Distinguisher: 172.16.0.7:1
Versions:
Process bRIB/RIB SendTblVer
Speaker 16712 16712
Last Modified: Feb 28 16:06:36.448 for 2d19h
Paths: (2 available, best #1)
Not advertised to any peer
Path #1: Received by speaker 0
```

```
Not advertised to any peer
Local
172.16.0.1 from 172.16.0.9 (172.16.0.1)
Received Label 24013, Second Label 24027 >>>> First label for L2 MAC unicast bridging;
second label for EVPN IRB host-routing
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported,
rib-install
Received Path ID 0, Local Path ID 0, version 16712
Extended community: SoO:172.16.0.2:1 RT:100:1 RT:100:100
Originator: 172.16.0.1, Cluster list: 172.16.0.9
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.1:1
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 from 172.16.0.9 (172.16.0.2)
Received Label 24014, Second Label 24031
Origin IGP, localpref 100, valid, internal, backup, add-path, import-candidate, imported,
rib-install
Received Path ID 0, Local Path ID 1, version 16706
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 172.16.0.9
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
```

```
RP/0/RP0/CPU0:router# show bgp l2vpn evpn rd 172.16.0.7:1
[2][0][48][0000.f65a.357c][128][10:1:1::93]/232

BGP routing table entry for [2][0][48][0000.f65a.357c][128][10:1:1::93]/232, Route
Distinguisher: 172.16.0.7:1
Versions:
Process bRIB/RIB SendTblVer
Speaker 6059 6059
Last Modified: Feb 28 12:03:22.448 for 2d23h
Paths: (2 available, best #1)
Not advertised to any peer
Path #1: Received by speaker 0
Not advertised to any peer
Local
172.16.0.1 from 172.16.0.9 (172.16.0.1)
Received Label 24013, Second Label 24029
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported,
rib-install
Received Path ID 0, Local Path ID 0, version 6043
Extended community: SoO:172.16.0.2:1 RT:100:1 RT:100:100
Originator: 172.16.0.1, Cluster list: 172.16.0.9
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.1:1
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 from 172.16.0.9 (172.16.0.2)
Received Label 24014, Second Label 24033
Origin IGP, localpref 100, valid, internal, backup, add-path, import-candidate, imported,
rib-install
Received Path ID 0, Local Path ID 1, version 6059
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 172.16.0.9
EVPN ESI: 0100.6cbc.a77c.c180.0000
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
```

Verify the remote peer gateway with host routes of IPv4 /32 addresses imported into the IP VRF routing table.

```
RP/0/RP0/CPU0:router#  show bgp vpnv4 unicast vrf evpn1 10.1.1.93/32

BGP routing table entry for 10.1.1.93/32, Route Distinguisher: 172.16.0.7:11
Versions:
Process bRIB/RIB SendTblVer
Speaker 22202 22202
Last Modified: Feb 28 16:06:36.447 for 2d19h
Paths: (2 available, best #1)
Not advertised to any peer
Path #1: Received by speaker 0
Not advertised to any peer
Local
172.16.0.1 from 172.16.0.9 (172.16.0.1)
Received Label 24027
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
Received Path ID 0, Local Path ID 0, version 22202
Extended community: SoO:172.16.0.2:1 RT:100:1 RT:100:100
Originator: 172.16.0.1, Cluster list: 172.16.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.1:1
>>>> The source from L2VPN and from synced ARP entry.
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 from 172.16.0.9 (172.16.0.2)
Received Label 24031
Origin IGP, localpref 100, valid, internal, backup, add-path, import-candidate, imported
Received Path ID 0, Local Path ID 1, version 22201
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 17.0.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
>>>> source from L2VPN and from dynamic ARP entry
```

```
RP/0/RP0/CPU0:router# show bgp vpnv6 unicast vrf evpn1 10:1:1::93/128

BGP routing table entry for 10:1:1::93/128, Route Distinguisher: 172.16.0.7:11
Versions:
Process bRIB/RIB SendTblVer
Speaker 22163 22163
Last Modified: Feb 28 12:09:30.447 for 2d23h
Paths: (2 available, best #1)
Not advertised to any peer
Path #1: Received by speaker 0
Not advertised to any peer
Local
172.16.0.1 from 172.16.0.9 (172.16.0.1)
Received Label 24029
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
Received Path ID 0, Local Path ID 0, version 22163
Extended community: SoO:172.16.0.2:1 RT:100:1 RT:100:100
Originator: 172.16.0.1, Cluster list: 172.16.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.1:1 >>>
Source from L2VPN and from synced ARP entry.
```

```
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 from 172.16.0.9 (172.16.0.2)
Received Label 24033
Origin IGP, localpref 100, valid, internal, backup, add-path, import-candidate, imported
Received Path ID 0, Local Path ID 1, version 22163
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 172.16.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1 >>>
Source from L2VPN and from dynamic ARP entry.
```

```
RP/0/RP0/CPU0:router# show bgp vpnv6 unicast vrf evpn1 10:1:1::93/128

BGP routing table entry for 10:1:1::93/128, Route Distinguisher: 172.16.0.7:11
Versions:
Process bRIB/RIB SendTblVer
Speaker 22163 22163
Last Modified: Feb 28 12:09:30.447 for 2d23h
Paths: (2 available, best #1)
Not advertised to any peer
Path #1: Received by speaker 0
Not advertised to any peer
Local
172.16.0.1 from 172.16.0.9 (172.16.0.1)
Received Label 24029
Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
Received Path ID 0, Local Path ID 0, version 22163
Extended community: SoO:172.16.0.2:1 RT:100:1 RT:100:100
Originator: 172.16.0.1, Cluster list: 172.16.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.1:1
Path #2: Received by speaker 0
Not advertised to any peer
Local
172.16.0.2 from 172.16.0.9 (172.16.0.2)
Received Label 24033
Origin IGP, localpref 100, valid, internal, backup, add-path, import-candidate, imported
Received Path ID 0, Local Path ID 1, version 22163
Extended community: SoO:172.16.0.2:1 RT:200:1 RT:700:100
Originator: 172.16.0.2, Cluster list: 172.16.0.9
Source AFI: L2VPN EVPN, Source VRF: default, Source Route Distinguisher: 172.16.0.2:1
```

Verify local forwarding with local adjacency which overwrite the RIB entries, and remote peer that use the IP VRF host route entries for IP VPN forwarding.

```
RP/0/RP0/CPU0:router#  show bgp vpnv4 unicast vrf evpn1 10.1.1.93/32

-- For local routing and forwarding
RP/0/RP0/CPU0:PE11-R1#show route vrf evpn1 10.1.1.93
Routing entry for 10.1.1.93/32
Known via "bgp 3107", distance 200, metric 0, type internal
Installed Feb 28 15:57:28.154 for 2d20h
Routing Descriptor Blocks
```

```
172.16.0.2, from 172.16.0.9       >>>  From MH-AA peer.
Nexthop in Vrf: "default", Table: "default", IPv4 Unicast, Table Id: 0xe0000000
Route metric is 0
No advertising protos.

RP/0/RP0/CPU0:PE11-R1# show cef vrf evpn1 10.1.1.93 location 0/0/CPU0
10.1.1.93/32, version 0, internal 0x1120001 0x0 (ptr 0x7b40052c) [1], 0x0 (0x7b286010), 0x0
 (0x0)
Updated Feb 28 15:58:22.688
local adjacency 10.1.1.93
Prefix Len 32, traffic index 0, Adjacency-prefix, precedence n/a, priority 15
via 10.1.1.93/32, BVI1, 2 dependencies, weight 0, class 0 [flags 0x0]
path-idx 0 NHID 0x0 [0x7f531f88 0x0]
next hop
local adjacency             >>> Forwarding with local synced ARP adjacency entries.


For remote routing and forwarding:

RP/0/RP0/CPU0:router# show route vrf evpn1 10.1.1.93

Routing entry for 10.1.1.93/32
Known via "bgp 3107", distance 200, metric 0
Number of pic paths 1 , type internal
Installed Feb 28 16:06:36.431 for 2d20h
Routing Descriptor Blocks
172.16.0.1, from 172.16.0.9
Nexthop in Vrf: "default", Table: "default", IPv4 Unicast, Table Id: 0xe0000000
Route metric is 0
172.16.0.2, from 172.16.0.9, BGP backup path
Nexthop in Vrf: "default", Table: "default", IPv4 Unicast, Table Id: 0xe0000000
Route metric is 0
No advertising protos.

RP/0/RP0/CPU0:router# show cef vrf evpn1 10.1.1.93 location 0/0/CPU0

10.1.1.93/32, version 86, internal 0x5000001 0x0 (ptr 0x99fac884) [1], 0x0 (0x0), 0x208
(0x96c58494)
Updated Feb 28 16:06:39.285
Prefix Len 32, traffic index 0, precedence n/a, priority 3
via 172.16.0.1/32, 15 dependencies, recursive [flags 0x6000]
path-idx 0 NHID 0x0 [0x97955380 0x0]
recursion-via-/32
next hop VRF - 'default', table - 0xe0000000
next hop 172.16.0.1/32 via 34034/0/21
next hop 100.0.57.5/32 Te0/0/0/3 labels imposed {ImplNull 24011 24027}
next hop 100.0.67.6/32 Te0/0/0/1 labels imposed {ImplNull 24009 24027}
via 172.16.0.2/32, 11 dependencies, recursive, backup [flags 0x6100]
path-idx 1 NHID 0x0 [0x979554a0 0x0]
recursion-via-/32
next hop VRF - 'default', table - 0xe0000000
next hop 172.16.0.2/32 via 34035/0/21
next hop 100.0.57.5/32 Te0/0/0/3 labels imposed {ImplNull 24012 24031}
next hop 100.0.67.6/32 Te0/0/0/1 labels imposed {ImplNull 24010 24031}
```

The following sections describe how to verify the subnet stretching.

Verify the VRF.

```
RP/0/RP0/CPU0:leafW# show run vrf cust130

vrf cust130
address-family ipv4 unicast
  import route-target
   130:130
  !
  export route-target
   130:130
  !
!
!
```

Verify the BGP configuration.

```
 RP/0/RP0/CPU0:leafW# show run router bgp | begin vrf cust130

vrf cust130
  rd auto
  address-family ipv4 unicast
   label mode per-vrf
   maximum-paths ibgp 10
   redistribute connected
  !
!
```

Verify the L2VPN.

```
RP/0/RP0/CPU0:leafW# show run l2vpn bridge group bg130

l2vpn
bridge group bg130
  bridge-domain bd130
   interface Bundle-Ether1.1300
   !
   interface Bundle-Ether5.1300
   !
   routed interface BVI130
   evi 130
   !
  !
!
!
```

EVPN Automatic Unfreezing of MAC and IP Addresses

The EVPN Automatic Unfreezing of MAC and IP Addresses feature unfreezes the permanently frozen MAC and IP addresses automatically. This feature provides a configurable option to enable a MAC or IP address to undergo infinite duplicate detection and recovery cycles without being frozen permanently. The MAC or IP address is permanently frozen when duplicate detection and recovery events occur three times within a 24-hour window. If any of the duplicate detection events happen outside the 24-hour window, the MAC or IP address undergoes only one duplicate detection event and all previous events are ignored.

Use the **infinity** keyword to prevent freezing of the duplicate MAC or IP address permanently.

Example

```
host ipv4-address duplicate-detection retry-count infinity
host ipv6-address duplicate-detection retry-count infinity
host mac-address duplicate-detection retry-count infinity
```

Use the **no** form of the above command to enable permanent freezing of MAC or IP address after the default retry count.

Example

```
no host ipv4-address duplicate-detection retry-count infinity
no host ipv6-address duplicate-detection retry-count infinity
no host mac-address duplicate-detection retry-count infinity
```

The 24-hour check for consecutive duplicate detection and recovery events before permanent freezing is enabled by default. Use the **reset-freeze-count-interval** keyword to configure a non-default interval after which the retry-count is reset. The range is from is 1 hour to 48 hours. The default is 24 hours.

Example

```
host ipv4-address duplicate-detection reset-freeze-count-interval 20
host ipv6-address duplicate-detection reset-freeze-count-interval 20
host mac-address duplicate-detection reset-freeze-count-interval 20
```

Use the following commands to manually unfreeze frozen MAC, IPv4 and IPV6 addresses respectively:

- **clear l2route evpn mac** { *mac-address* } | **all** [**evi** *evi*] **frozen-flag**
- **clear l2route evpn ipv4** { *ipv4-address* } | **all** [**evi** *evi*] **frozen-flag**
- **clear l2route evpn ipv6** { *ipv6-address* } | **all** [**evi** *evi*] **frozen-flag**

CHAPTER 10

EVPN Virtual Private Wire Service (VPWS)

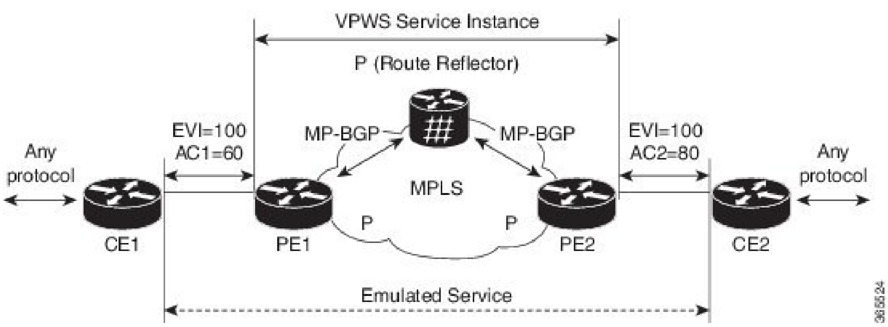
The EVPN-VPWS is a BGP control plane solution for point-to-point services. It implements the signaling and encapsulation techniques for establishing an EVPN instance between a pair of PEs. It has the ability to forward traffic from one network to another without MAC lookup. The use of EVPN for VPWS eliminates the need for signaling single-segment and multi-segment PWs for point-to-point Ethernet services. The EVPN-VPWS technology works on IP and MPLS core; IP core to support BGP and MPLS core for switching packets between the endpoints.

EVPN-VPWS support both single-homing and multi-homing.

EVPN-VPWS Single Homed

The EVPN-VPWS single homed solution requires per EVI Ethernet Auto Discovery route. EVPN defines a new BGP Network Layer Reachability Information (NLRI) used to carry all EVPN routes. BGP Capabilities Advertisement used to ensure that two speakers support EVPN NLRI (AFI 25, SAFI 70) as per RFC 4760.

The architecture for EVPN VPWS is that the PEs run Multi-Protocol BGP in control-plane. The following image describes the EVPN-VPWS configuration:



- The VPWS service on PE1 requires the following three elements to be specified at configuration time:
  - The VPN ID (EVI)
  - The local AC identifier (AC1) that identifies the local end of the emulated service.
  - The remote AC identifier (AC2) that identifies the remote end of the emulated service.

PE1 allocates a MPLS label per local AC for reachability.

- The VPWS service on PE2 is set in the same manner as PE1. The three same elements are required and the service configuration must be symmetric.

  PE2 allocates a MPLS label per local AC for reachability.

- PE1 advertise a single EVPN per EVI Ethernet AD route for each local endpoint (AC) to remote PEs with the associated MPLS label.

  PE2 performs the same task.

- On reception of EVPN per EVI EAD route from PE2, PE1 adds the entry to its local L2 RIB. PE1 knows the path list to reach AC2, for example, next hop is PE2 IP address and MPLS label for AC2.

  PE2 performs the same task.

Configure EVPN-VPWS Single Homed

This section describes how you can configure single-homed EVPN-VPWS feature.

```
Router# configure
Router(config)# router bgp 100
Router(config-bgp)# address-fmaily l2vpn evpn

Router(config-bgp-af)# neighbor 10.10.10.1
Router(config-bgp-af)# commit
Router(config-bgp-af)# exit
Router(config-bgp)# exit
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group evpn-vpws
Router(config-l2vpn-xc)# p2p evpn1
Router(config-l2vpn-xc-p2p)# interface TenGigE0/1/0/2
Router(config-l2vpn-xc-p2p)# neighbor evpn evi 100 target 12 source 10
Router(config-l2vpn-xc-p2p)# commit

Router(config-l2vpn-xc-p2p)# exit
```

Running Configuration

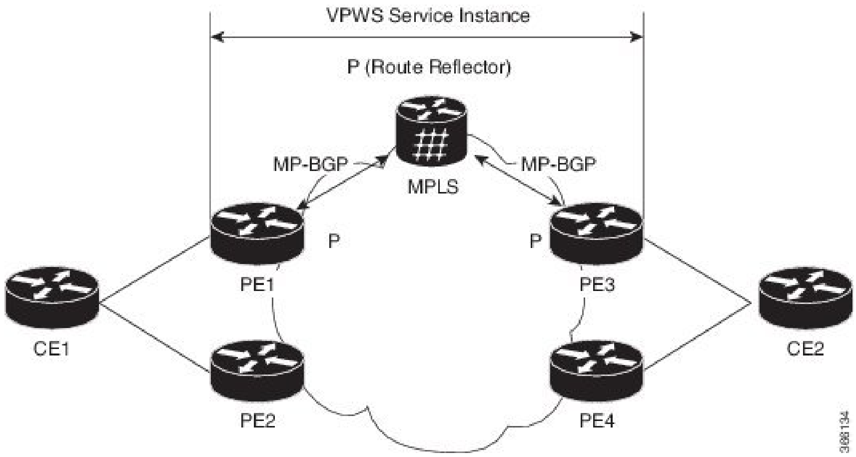
```
configure
router bgp 100
 address-fmaily l2vpn evpn
  neighbor 10.10.10.1
!

configure
l2vpn
 xconnect group evpn-vpws
  p2p evpn1
   interface TenGigE0/1/0/2
   neighbor evpn evi 100 target 12 source 10
!
```

EVPN-VPWS Multi-Homed

The EVPN VPWS feature supports all-active multihoming capability that enables you to connect a customer edge device to two or more provider edge (PE) devices to provide load balancing and redundant connectivity. The load balancing is done using equal-cost multipath (ECMP).

When a CE device is multi-homed to two or more PEs and when all PEs can forward traffic to and from the multi-homed device for the VLAN, then such multihoming is referred to as all-active multihoming.

Figure 20: EVPN VPWS Multi-Homed



Consider the topology in which CE1 is multi-homed to PE1 and PE2; CE2 is multi-homed to PE3 and PE4. PE1 and PE2 will advertise an EAD per EVI route per AC to remote PEs which is PE3 and PE4, with the associated MPLS label. The ES-EAD route is advertised per ES (main interface), and it will not have a label. Similarly, PE3 and PE4 advertise an EAD per EVI route per AC to remote PEs, which is PE1 and PE2, with the associated MPLS label.

Consider a traffic flow from CE1 to CE2. Traffic is sent to either PE1 or PE2. The selection of path is dependent on the CE implementation for forwarding over a LAG. Traffic is encapsulated at each PE and forwarded to the remote PEs (PE 3 and PE4) through MPLS core. Selection of the destination PE is established by flow-based load balancing. PE3 and PE4 send the traffic to CE2. The selection of path from PE3 or PE4 to CE2 is established by flow-based load balancing.

If there is a failure and when the link from CE1 to PE1 goes down, the PE1 withdraws the ES-EAD route; sends a signal to the remote PEs to switch all the VPWS service instances associated with this multi-homed ES to backup PE, which is PE2.

Configure EVPN-VPWS Multi-Homed

This section describes how you can configure multi-homed EVPN-VPWS feature.

```
/* Configure PE1 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)#  xconnect group evpn_vpws
Router(config-l2vpn-xc)#  p2p e1_5-6
Router(config-l2vpn-xc-p2p)#  interface Bundle-Ether10.2
```

```
Router(config-l2vpn-xc-p2p)#  neighbor evpn evi 1 target 5 source 6
Router(config-l2vpn-xc-p2p)# exit

Router(config-l2vpn-xc)# exit
Router(config-l2vpn)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether10
Router(config-evpn-ac)#  ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.0a.00
Router(config-evpn-ac-es)# commit

/* Configure PE2 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)#  xconnect group evpn_vpws
Router(config-l2vpn-xc)#  p2p e1_5-6
Router(config-l2vpn-xc-p2p)#  interface Bundle-Ether10.2
Router(config-l2vpn-xc-p2p)#  neighbor evpn evi 1 target 5 source 6
Router(config-l2vpn-xc-p2p)# exit

Router(config-l2vpn-xc)# exit
Router(config-l2vpn)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether10
Router(config-evpn-ac)#  ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.0a.00
Router(config-evpn-ac-es)# commit

/* Configure PE3 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)#  xconnect group evpn_vpws
Router(config-l2vpn-xc)#  p2p e1_5-6
Router(config-l2vpn-xc-p2p)#  interface Bundle-Ether20.1
Router(config-l2vpn-xc-p2p)#  neighbor evpn evi 1 target 6 source 5
Router(config-l2vpn-xc-p2p)# exit

Router(config-l2vpn-xc)# exit
Router(config-l2vpn)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether20
Router(config-evpn-ac)#  ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.14.00
Router(config-evpn-ac-es)# commit

/* Configure PE4 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)#  xconnect group evpn_vpws
Router(config-l2vpn-xc)#  p2p e1_5-6
Router(config-l2vpn-xc-p2p)#  interface Bundle-Ether20.1
Router(config-l2vpn-xc-p2p)#  neighbor evpn evi 1 target 6 source 5
Router(config-l2vpn-xc-p2p)# exit
Router(config-l2vpn-xc)# exit
Router(config-l2vpn)# exit
Router(config)# evpn
Router(config-evpn)# interface Bundle-Ether20
Router(config-evpn-ac)#  ethernet-segment
Router(config-evpn-ac-es)# identifier type 0 00.01.00.ac.ce.55.00.14.00
Router(config-evpn-ac-es)# commit
```

Running Configuration

```
/* On PE1 */
!
configure
l2vpn xconnect group evpn_vpws
 p2p e1_5-6
  interface Bundle-Ether10.2
  neighbor evpn evi 1 target 5 source 6
!
evpn
interface Bundle-Ether10
  ethernet-segment
   identifier type 0 00.01.00.ac.ce.55.00.0a.00

!


/* On PE2 */
!
configure
l2vpn xconnect group evpn_vpws
 p2p e1_5-6
  interface Bundle-Ether10.2
  neighbor evpn evi 1 target 5 source 6
!
evpn
interface Bundle-Ether10
  ethernet-segment
   identifier type 0 00.01.00.ac.ce.55.00.0a.00

!

/* On PE3 */
!
configure
l2vpn xconnect group evpn_vpws
 p2p e1_5-6
  interface Bundle-Ether20.1
  neighbor evpn evi 1 target 6 source 5
!
evpn
interface Bundle-Ether20
  ethernet-segment
      identifier type 0 00.01.00.ac.ce.55.00.14.00

!

/* On PE4 */
!
configure
l2vpn xconnect group evpn_vpws
 p2p e1_5-6
  interface Bundle-Ether20.1
  neighbor evpn evi 1 target 6 source 5
!
evpn
interface Bundle-Ether20
  ethernet-segment
      identifier type 0 00.01.00.ac.ce.55.00.14.00

!
```

CHAPTER 11

References

This section provides additional information on understanding and implementing Layer 2 VPNs.

Gigabit Ethernet Protocol Standards

The 10-Gigabit Ethernet architecture and features deliver network scalability and performance, while enabling service providers to offer high-density, high-bandwidth networking solutions designed to interconnect the router with other systems in the point-of-presence (POP), including core and edge routers and L2 and Layer 3 (L3) switches.

The Gigabit Ethernet interfaces in Cisco NCS 5500 Series Routers support these standards:

- Protocol standards:
  - IEEE 802.3 Physical Ethernet Infrastructure
  - IEEE 802.3ae 10 Gbps Ethernet
- Ethernet standards
  - Ethernet II framing also known as DIX
  - IEEE 802.3 framing also includes LLC and LLC/SNAP protocol frame formats
  - IEEE 802.1q VLAN tagging
  - IEEE 802.1ad Provider Bridges

For more information, see Carrier Ethernet Model References, on page 147.

Carrier Ethernet Model References

This topic covers the references for Gigabit Ethernet Protocol Standards.

IEEE 802.3 Physical Ethernet Infrastructure

The IEEE 802.3 protocol standards define the physical layer and MAC sublayer of the data link layer of wired Ethernet. IEEE 802.3 uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access at a variety of speeds over a variety of physical media. The IEEE 802.3 standard covers 10 Mbps Ethernet. Extensions to the IEEE 802.3 standard specify implementations for Gigabit Ethernet, 10-Gigabit Ethernet, and Fast Ethernet.

IEEE 802.3ae 10 Gbps Ethernet

Under the International Standards Organization's Open Systems Interconnection (OSI) model, Ethernet is fundamentally a L2 protocol. 10-Gigabit Ethernet uses the IEEE 802.3 Ethernet MAC protocol, the IEEE 802.3 Ethernet frame format, and the minimum and maximum IEEE 802.3 frame size. 10 Gbps Ethernet conforms to the IEEE 802.3ae protocol standards.

Just as 1000BASE-X and 1000BASE-T (Gigabit Ethernet) remained true to the Ethernet model, 10-Gigabit Ethernet continues the natural evolution of Ethernet in speed and distance. Because it is a full-duplex only and fiber-only technology, it does not need the carrier-sensing multiple-access with the CSMA/CD protocol that defines slower, half-duplex Ethernet technologies. In every other respect, 10-Gigabit Ethernet remains true to the original Ethernet model.

General Ethernet Standards

- IEEE 802.1q VLAN tagging—This standard defines VLAN tagging, and also the traditional VLAN trunking between switches. Cisco NCS 5500 Series Routers do NOT support ISL.
- IEEE 802.1ad Provider Bridges—This standard is a subset of 802.1q and is often referred to as 802.1ad. Cisco NCS 5500 Series Routers do not adhere to the entire standard, but large portions of the standard's functionality are supported.

Ethernet MTU

The Ethernet Maximum Transmission Unit (MTU) is the size of the largest frame, minus the 4-byte Frame Check Sequence (FCS), that can be transmitted on the Ethernet network. Every physical network along the destination of a packet can have a different MTU.

Cisco NCS 5500 Series Routers support two types of frame forwarding processes:

- Fragmentation for IPV4 packets—In this process, IPv4 packets are fragmented as necessary to fit within the MTU of the next-hop physical network.

  Note IPv6 does not support fragmentation.

- MTU discovery process determines largest packet size—This process is available for all IPV6 devices, and for originating IPv4 devices. In this process, the originating IP device determines the size of the largest IPv6 or IPV4 packet that can be sent without being fragmented. The largest packet is equal to the smallest MTU of any network between the IP source and the IP destination devices. If a packet is larger than the smallest MTU of all the networks in its path, that packet will be fragmented as necessary. This process ensures that the originating device does not send an IP packet that is too large.

Jumbo frame support is automatically enable for frames that exceed the standard frame size. The default value is 1514 for standard frames and 1518 for 802.1Q tagged frames. These numbers exclude the 4-byte FCS.

Flow Control on Ethernet Interfaces

The flow control used on 10-Gigabit Ethernet interfaces consists of periodically sending flow control pause frames. It is fundamentally different from the usual full- and half-duplex flow control used on standard management interfaces. By default, both ingress and egress flow control are off on Cisco NCS 5500 Series Routers.

Default Configuration Values for Gigabit Ethernet and 10-Gigabit Ethernet

The below table describes the default interface configuration parameters that are present when an interface is enabled on a Gigabit Ethernet or 10-Gigabit Ethernet modular services card and its associated PLIM.

Note You must use the **shutdown** command to bring an interface administratively down. The interface default is **no shutdown**. When a modular services card is first inserted into the router, if there is no established preconfiguration for it, the configuration manager adds a shutdown item to its configuration. This shutdown can be removed only be entering the **no shutdown** command.

Table 7: Gigabit Ethernet and 10-Gigabit Ethernet Modular Services Card Default Configuration Values

Parameter	Configuration File Entry	Default Value	Restrictions
Flow control	**flow-control**	egress on ingress off	none
MTU	**mtu**	1514 bytes for normal frames 1518 bytes for 802.1Q tagged frames 1522 bytes for QinQ frames	none
MAC address	**mac address**	Hardware burned-in address (BIA[2])	L3 only
L2 port	**l2transport**	off/L3	L2 subinterfaces must have L3 main parent interface
Egress filtering	**Ethernet egress-filter**	off	none
Link negotiation	**negotiation**	off	physical main interfaces only
Tunneling Ethertype	**tunneling ethertype**	0X8100	configured on main interface only; applied to subinterfaces only

Parameter	Configuration File Entry	Default Value	Restrictions
VLAN tag matching	**encapsulation**	all frames for main interface; only ones specified for subinterfaces	encapsulation command only subinterfaces

1. The restrictions are applicable to L2 main interface, L2 subinterface, L3 main interface, interflex L2 interface etc.
2. burned-in address

References for Configuring Link Bundles

This section provides references to configuring link bundles. For an overview of link bundles and configurations, see Configure Link Bundles for Layer 2 VPNs, on page 31.

Characteristics of Link Bundles

- Any type of Ethernet interfaces can be bundled, with or without the use of LACP (Link Aggregation Control Protocol).
- Physical layer and link layer configuration are performed on individual member links of a bundle.
- Configuration of network layer protocols and higher layer applications is performed on the bundle itself.
- A bundle can be administratively enabled or disabled.
- Each individual link within a bundle can be administratively enabled or disabled.
- Ethernet link bundles are created in the same way as Etherokinet channels, where the user enters the same configuration on both end systems.
- The MAC address that is set on the bundle becomes the MAC address of the links within that bundle.
- When LACP configured, each link within a bundle can be configured to allow different keepalive periods on different members.
- Load balancing is done by flow instead of by packet. Data is distributed to a link in proportion to the bandwidth of the link in relation to its bundle.
- QoS is supported and is applied proportionally on each bundle member.
- Link layer protocols, such as CDP, work independently on each link within a bundle.
- Upper layer protocols, such as routing updates and hello messages, are sent over any member link of an interface bundle.
- Bundled interfaces are point to point.
- A link must be in the UP state before it can be in distributing state in a bundle.
- Access Control List (ACL) configuration on link bundles is identical to ACL configuration on regular interfaces.

- Multicast traffic is load balanced over the members of a bundle. For a given flow, internal processes select the member link and all traffic for that flow is sent over that member.

Methods of Forming Bundles of Ethernet Interfaces

Cisco IOS-XR software supports the following methods of forming bundles of Ethernet interfaces:

- IEEE 802.3ad—Standard technology that employs a Link Aggregation Control Protocol (LACP) to ensure that all the member links in a bundle are compatible. Links that are incompatible or have failed are automatically removed from a bundle.

  For each link configured as bundle member, information is exchanged between the systems that host each end of the link bundle:

  - A globally unique local system identifier
  - An identifier (operational key) for the bundle of which the link is a member
  - An identifier (port ID) for the link
  - The current aggregation status of the link

  This information is used to form the link aggregation group identifier (LAG ID). Links that share a common LAG ID can be aggregated. Individual links have unique LAG IDs.

  The system identifier distinguishes one router from another, and its uniqueness is guaranteed through the use of a MAC address from the system. The bundle and link identifiers have significance only to the router assigning them, which must guarantee that no two links have the same identifier, and that no two bundles have the same identifier.

  The information from the peer system is combined with the information from the local system to determine the compatibility of the links configured to be members of a bundle.

  Bundle MAC addresses in the routers come from a set of reserved MAC addresses in the backplane. This MAC address stays with the bundle as long as the bundle interface exists. The bundle uses this MAC address until the user configures a different MAC address. The bundle MAC address is used by all member links when passing bundle traffic. Any unicast or multicast addresses set on the bundle are also set on all the member links.

  Note It is recommended that you avoid modifying the MAC address, because changes in the MAC address can affect packet forwarding.

- EtherChannel—Cisco proprietary technology that allows the user to configure links to join a bundle, but has no mechanisms to check whether the links in a bundle are compatible.

Link Aggregation Through LACP

The optional Link Aggregation Control Protocol (LACP) is defined in the IEEE 802 standard. LACP communicates between two directly connected systems (or peers) to verify the compatibility of bundle members. For a router, the peer can be either another router or a switch. LACP monitors the operational state of link bundles to ensure these:

- All links terminate on the same two systems.
- Both systems consider the links to be part of the same bundle.
- All links have the appropriate settings on the peer.

LACP transmits frames containing the local port state and the local view of the partner system's state. These frames are analyzed to ensure both systems are in agreement.