L2VPN and Ethernet Services Configuration Guide for Cisco NCS 5000 Series Routers, IOS XR Release 6.0.x

First Published: 2015-12-23

- To receive timely, relevant information from Cisco, sign up at Cisco Profile Manager.

- To get the business impact you're looking for with the technologies that matter, visit Cisco Services.

- To submit a service request, visit Cisco Support.

- To discover and browse secure, validated enterprise-class apps, products, solutions and services, visit Cisco Marketplace.

- To obtain general networking, training, and certification titles, visit Cisco Press.

- To find warranty information for a specific product or product family, access Cisco Warranty Finder.

Cisco Bug Search Tool

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

CONTENTS

Preface

This preface contains these sections:

- Obtaining Documentation and Submitting a Service Request, on page vii

Obtaining Documentation and Submitting a Service Request

For information on obtaining documentation, submitting a service request, and gathering additional information, see the monthly What's New in Cisco Product Documentation, which also lists all new and revised Cisco technical documentation, at:

http://www.cisco.com/en/US/docs/general/whatsnew/whatsnew.html

Subscribe to the What's New in Cisco Product Documentation as a Really Simple Syndication (RSS) feed and set content to be delivered directly to your desktop using a reader application. The RSS feeds are a free service and Cisco currently supports RSS version 2.0.

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 VLAN 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 QRangeinQ sub-interface where outer VLAN range of QRangeinQ overlaps with outer VLAN of QinQ. Attempting this configuration results in the splitting of the existing QinQ and QinQRange interfaces. However, the system can be recovered by deleting a recently configured QinQRange interface.

- In an interface which already has QinQRange configuration, you cannot configure the QRangeinQ sub-interface where outer VLAN range of QRangeinQ overlaps with inner VLAN of QinQRange. Attempting this configuration results in the splitting of the existing QinQ and QinQRange interfaces. However, the system can be recovered by deleting a recently configured QinQRange 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.

```
/* 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 10-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,
  ...
```

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.

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.

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 an additional four 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-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 is 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.

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
Router(config-if)# no shutdown
```

Running Configuration

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

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 10)

- 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
Double tagged frames	802.1Q (ethertype 0x8100) double tagged frames
	802.1ad (ethertype 0x88a8) 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
    - Rewrite outer tag and pop inner 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-1 tag: Translates the outermost two tags to a single tag

  • 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:

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
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
 !
!

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

/* 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 1: 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
QinQ	No rewrite
QinQ	Pop 1
QinQ	Push 1
QinQ	Translate 1 to 1
QinQ	Translate 1 to 2
QinQ	Translate 2 to 1
Untagged	No rewrite

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-1 tags: Translates the outermost two tags to a single tag.

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

Valid Ingress-Egress Rewrite Combinations

Table 2: 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
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 / 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

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

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

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

Note   The following rewrites are not supported for EoMPLS:

- Push 2

- Pop 2

- Translate 1-to-2

- Translate 2-to-1

- Translate 2-to-2

CHAPTER 3

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)

For more information, see References for Configuring Link Bundles, on page 23.

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 5000 Series Router supports 10G and 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.

- A combination of 10G and 100G links is not supported in the same ethernet link bundle.

- MAC accounting is not supported on Ethernet link bundles.

- The maximum number of supported links in each ethernet link bundle is 32 .

- The maximum number of supported ethernet link bundles is 64 .

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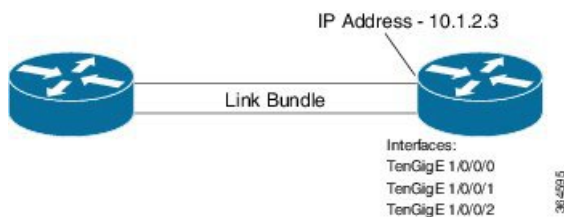
For an Ethernet bundle to be active, you must perform the same configuration on both connection endpoints of the bundle.

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

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.

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
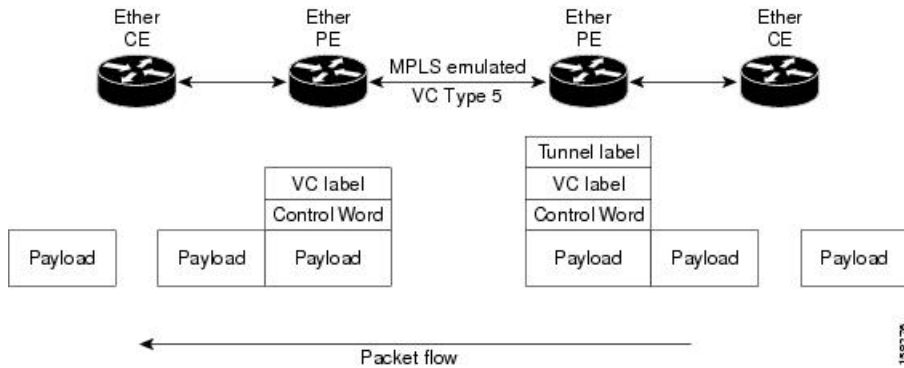
VLAN Mode

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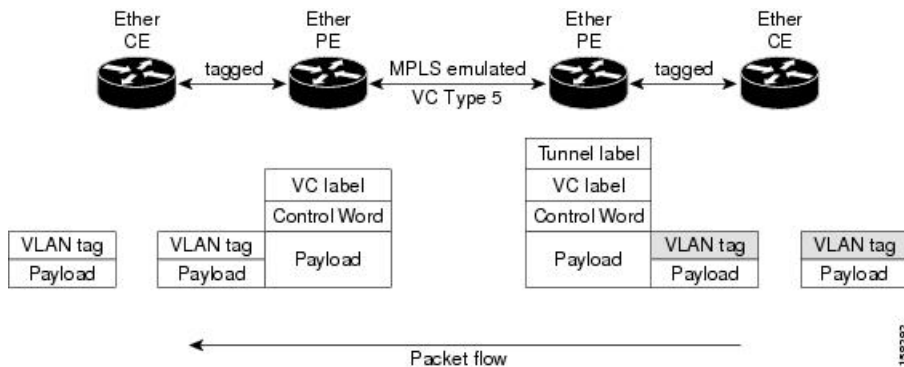
At the egress VLAN PE, the PE associates a VLAN tag to the frames coming off of the pseudowire and after switching the traffic internally, it sends out the traffic on an Ethernet trunk port.

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
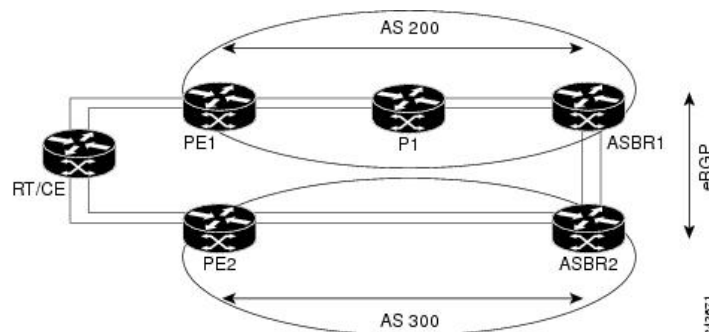
QinQ Mode

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 NCS500x Series Routers 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
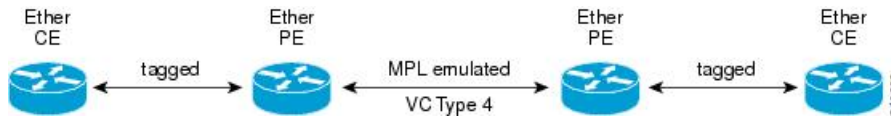
Note EoMPLS does not support pseudowire stitching or multi segments.

Limitations

The following are the limitations for EoMPLS:

- VLAN rewrite actions (Pop 2, Push 2, Translate 1-to-2, Translate 2-to-1, and Translate 2-to-2) are not supported on single or double-tagged attachment circuits. The following exceptions are allowed:

  - Egress Push 1 action is supported only if untagged layer 2 frames are received on the ingress of the pseudowire.

  - Ingress Push 1 and Translate 1-to-1 action is supported only if the attachment circuit TPID and the rewrite TPID are same.

  - Egress Pop 1 and Translate 1-to-1 action is supported only when the packets arriving on the pseudowire have the dot1q TPID set on the outer tag.

- Only one TPID is allowed for all sub-interfaces on a given physical port. Sub-interfaces with different outer TPID values in the encapsulation header are not allowed on the same physical port.

- VC-4(VLAN mode) and VC-11(IP interworking) type pseudowires are not supported.

- Hot-standby pseudowire redundancy is not supported.

- Pseudowire grouping is not supported.

- Pseudowire stitching or multi segments are not supported.

- Hardware load balancing on the ECMP path towards core is not supported.

- L2tpv3 is not supported.

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
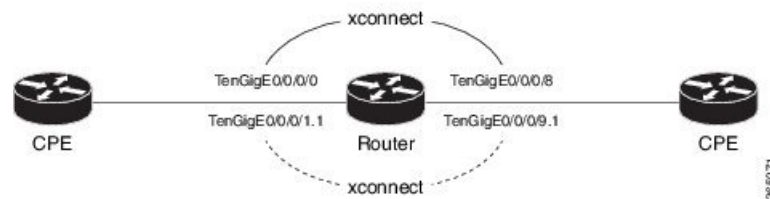
Configuration

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
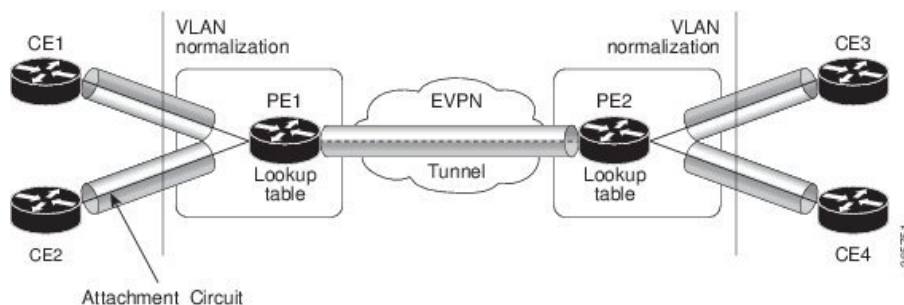
Flexible Cross-Connect Service

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
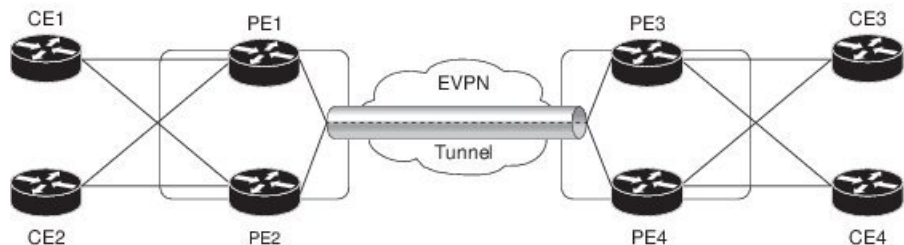
Consider the topology in which CE1 and CE2 are multi-homed to PE1 and PE2; CE3 and CE4 are multi-homed to PE3 and PE4. PE1 and PE2 advertise Ethernet A-D Ethernet Segment (ES-EAD) route to remote PEs that is PE3 and PE4. Similarly, PE3 and PE4 advertise ES-EAD route to remote PEs that is PE1 and PE2. 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)# 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)# 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)# 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)# interface GigabitEthernet 0/2/0/7.1
Router(config-l2vpn-fxs)# interface GigabitEthernet 0/2/0/7.2
Router(config-l2vpn-fxs)# 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)# interface GigabitEthernet 0/0/0/7.1
Router(config-l2vpn-fxs)# interface GigabitEthernet 0/0/0/7.2
Router(config-l2vpn-fxs)# 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)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs)# 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-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)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs)# 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-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)# interface Bundle-Ether4.1
Router(config-l2vpn-fxs)# interface Bundle-Ether5.1
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# 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)# interface Bundle-Ether4.1
Router(config-l2vpn-fxs)# interface Bundle-Ether5.1
Router(config-l2vpn-fxs)# commit
Router(config-l2vpn-fxs)# 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
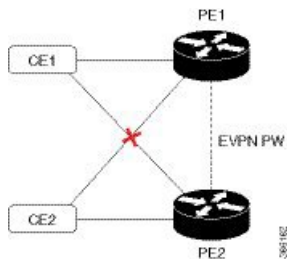
Configure Multi-Homed Flexible Cross-Connect Service using Local Switching

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)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs)# 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)# interface Bundle-Ether2.1
Router(config-l2vpn-fxs)# interface Bundle-Ether3.1
Router(config-l2vpn-fxs)# 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


!
```

References

This section provides additional information on understanding and implementing Layer 2 VPNs.

- Gigabit Ethernet Protocol Standards, on page 51
- Carrier Ethernet Model References, on page 51
- Default Configuration Values for Gigabit Ethernet and 10-Gigabit Ethernet, on page 53
- References for Configuring Link Bundles, on page 54

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 5000 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 51.

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. Technically, it also defines QinQ tagging, and MSTP. Cisco NCS 5000 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 5000 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 5000 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 5000 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 3: 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 .

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.