L2VPN and Ethernet Services Configuration Guide for Cisco NCS 5000 Series Routers, IOS XR Release 7.3.x

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Preface

This preface contains these sections:

Changes to This Document

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

Table 1: Changes to This Document

Date	Summary
October 2021	Initial release of this document.

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:

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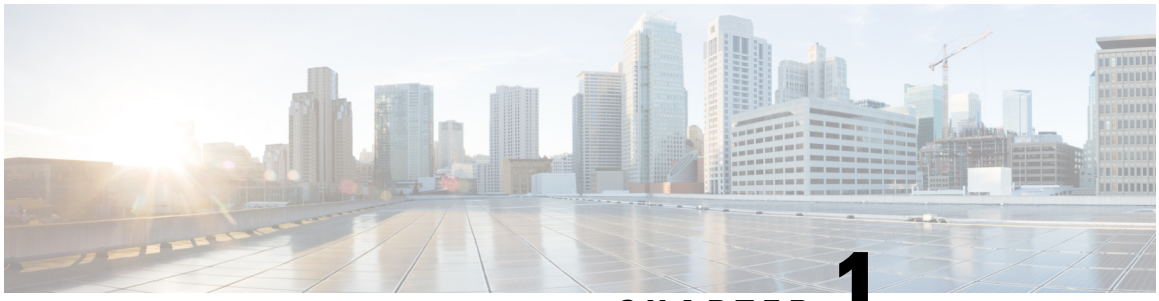


CHAPTER 1

New and Changed VPN Features

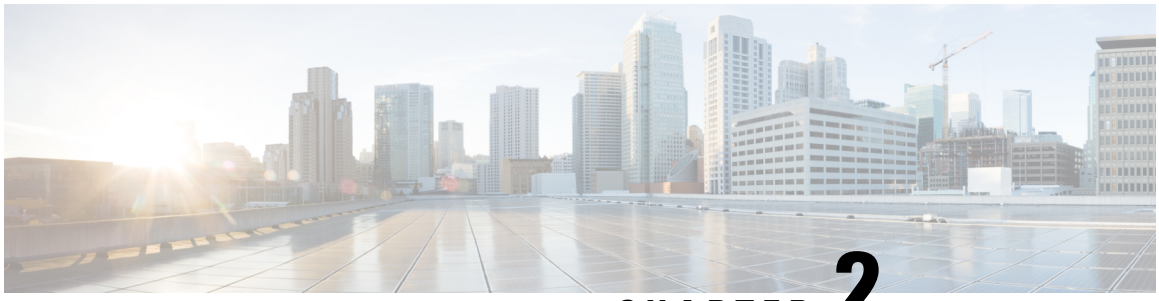
This table summarizes the new and changed feature information for the L2VPN and Ethernet Services Configuration Guide for Cisco NCS 5000 Series Routers, and tells you where they are documented.

New and Changed VPN Features

Table 2: VPN Features Added or Modified in IOS XR Release 7.3.x

Feature	Description	Changed in Release	Where Documented
GTP Load Balancing	This feature was introduced.	Release 7.3.2	GTP Load Balancing, on page 52

New and Changed VPN Features



CHAPTER 2

Configure Gigabit Ethernet for Layer 2 VPNs

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

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

Introduction to Layer 2 Virtual Private Networks

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

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

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

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

Introduction to Layer 2 VPNs on Gigabit Ethernet Interfaces

A L2VPN network enables service providers (SPs) to provide L2 services to geographically disparate customer sites. Typically, a SP uses an access network to connect the customer to the core network. This access network may use a mixture of L2 technologies, such as Ethernet and Frame Relay. The connection between the customer site and the nearby SP edge router is known as an attachment circuit (AC). Traffic from the customer travels

over this link to the edge of the SP core network. The traffic then tunnels through a pseudowire over the SP core network to another edge router. The edge router sends the traffic down another AC to the customer's remote site.

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

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

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

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

Switching can take place in the following ways:

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

Note

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

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

Configure Gigabit Ethernet Interfaces for Layer 2 Transport

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

```
/* 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
```

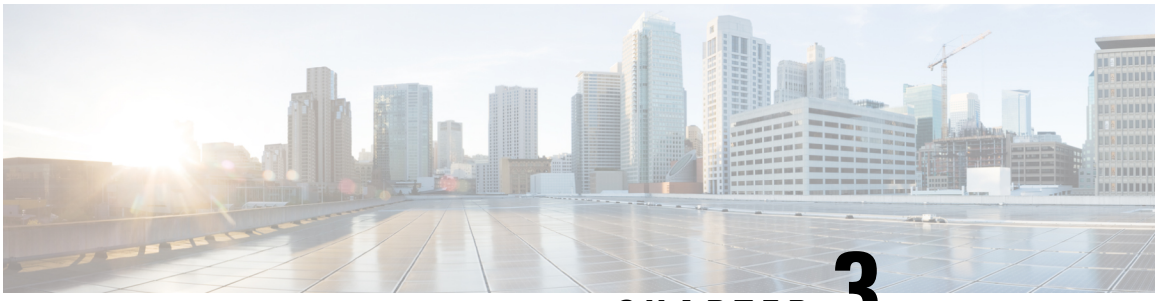
Running Configuration

```
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,
  ...
```



CHAPTER 3

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.

Encapsulation

Encapsulation defines the matching criteria that maps a VLAN, a range of VLANs. Different types of encapsulations are default, dot1q, dot1ad. The following are the supported encapsulation types:

- **encapsulation default**: Configures the default service instance on a port.
- **encapsulation dot1q vlan-id** : Defines the matching criteria to map 802.1Q frames ingress on an interface to the appropriate service instance.

- **encapsulation dot1ad vlan-id** : Defines the matching criteria to map 802.1ad frames ingress on an interface to the appropriate service instance.
- **encapsulation dot1q second-dot1q**: Defines the matching criteria to map Q-in-Q ingress frames on an interface to the appropriate service instance.
- **encapsulation dot1ad dot1q**: Defines the matching criteria to be used in order to map single-tagged 802.1ad frames ingress on an interface to the appropriate service instance.

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.
- When receiving single or double Dot1Q tagged traffic on an L2VPN pseudowire, the egress rewrite action Push 1 configured in an attachment circuit is not supported. The egress rewrite action Push 1 configured in an attachment circuit is supported only for untagged traffic received on an L2VPN pseudowire.

- Configure VLAN Subinterfaces, on page 8
- Introduction to Ethernet Flow Point, on page 11
- Configure VLAN Header Rewrite, on page 13
- VLAN Switch, on page 20

Configure VLAN Subinterfaces

Subinterfaces 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.

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

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

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

The following modes of VLAN subinterface configuration are supported:

- Basic dot1q Attachment Circuit
- Basic dot1ad Attachment Circuit
- Q-in-Q Attachment Circuit

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

encapsulation dot1q *vlan extra-id*

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

encapsulation dot1ad *vlan-id*

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

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

Restrictions and Limitations

To configure VLAN subinterface, the following restrictions are applicable.

- At least 64 VLAN-IDs in a VLAN list is required to overcome the limitation of only 9 VLAN ranges per NPU.
- For double-tagged packet, the VLAN range is supported only on the inner tag.
- VLANs separated by comma are called a VLAN list. VLAN list isn't supported on the router.
- If 0x9100/0x9200 is configured as tunneling ether-type, then dot1ad (0x88a8) encapsulation isn't supported.
- If any subinterface is already configured under a main interface, modifying the tunneling ether-type isn't supported.
- Following limitations are applicable to both outer and inner VLAN ranges:
  - 32 unique VLAN ranges are supported per NPU.
  - The overlap between outer VLAN ranges on subinterfaces of the same Network Processor Unit (NPU) isn't supported. A subinterface with a single VLAN tag that falls into a range configured on another subinterface of the same NPU is also considered an overlap.
  - The overlap between inner VLAN ranges on subinterfaces of the same NPU isn't supported.
  - Range 'any' doesn't result in explicit programming of a VLAN range in hardware and therefore doesn't count against the configured ranges.

Configuration Example

Configuring a VLAN subinterface involves:

- Creating a Ten Gigabit Ethernet subinterface
- 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 subinterface 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,
...
```

```
Router#show interfaces TenGigE 0/0/0/1.101
TenGigabitEthernet0/0/0/1.101 is down, line protocol is down
   Interface state transitions: 0
   Hardware is VLAN sub-interface(s), address is 008a.9678.0c04
   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 66-67,68-69,70-71,118-119,120-121,122-123,229,230,231
      Ethertype Any, MAC Match src any, dest any
   loopback not set,
   Last input never, output never
   Last clearing of "show interface" counters never
      0 packets input, 0 bytes
      0 input drops, 0 queue drops, 0 input errors
      0 packets output, 0 bytes
```

```
0 output drops, 0 queue drops, 0 output errors
```

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 13)
- 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 tags.

The frames can’t 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

Rewrite Encapsulation Combinations

The following table lists the supported and unsupported rewrite combinations:

Table 3: Rewrite Encapsulation Combinations

Rewrite Action	Supported Encapsulation Type	Unsupported Encapsulation
No rewrite	• untagged • default • dot1q range • dot1ad range • dot1q priority tagged • dot1ad priority tagged • dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag • custom 9100/9200 double tag	• dot1q any • dot1ad any

Rewrite Action	Supported Encapsulation Type	Unsupported Encapsulation
Pop 1	• dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag • custom 9100/9200 double tag	• untagged • default • dot1q range • dot1q any • dot1ad any • dot1ad range • dot1q priority tagged • dot1ad priority tagged
Pop 2	• dot1q double tag • dot1ad double tag • custom 9100/9200 double tag	• untagged • default • dot1q range • dot1q any • dot1ad any • dot1ad range • dot1q priority tagged • dot1ad priority tagged • dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any

Rewrite Action	Supported Encapsulation Type	Unsupported Encapsulation
Push 1	• untagged • default • dot1q range • dot1ad range • dot1q priority tagged • dot1ad priority tagged • dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag • custom 9100/9200 double tag	• dot1q any • dot1ad any
Push 2	• untagged • dot1q priority tagged • dot1ad priority tagged • dot1q • dot1ad	• default • dot1q range • dot1q any • dot1ad any • dot1ad range • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag • custom 9100/9200 double tag

Rewrite Action	Supported Encapsulation Type	Unsupported Encapsulation
Translate 1 to 1	• dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag	• untagged • default • dot1q range • dot1q any • dot1ad any • dot1ad range • dot1q priority tagged • dot1ad priority Tagged • custom 9100/9200 double tag
Translate 1 to 2	• dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any • dot1q double tag • dot1ad double tag	untagged Default dot1q range dot1q any dot1ad any dot1ad range dot1q priority tagged dot1ad priority Tagged Custom 9100/9200 double tag

Rewrite Action	Supported Encapsulation Type	Unsupported Encapsulation
Translate 2 to 2	• dot1q double tag • dot1ad double tag • custom 9100/9200 double tag	• untagged • default • dot1q range • dot1q any • dot1ad any • dot1ad range • dot1q priority tagged • dot1ad priority Tagged • dot1q • dot1ad • dot1q double inner tag range • dot1ad double inner tag range • dot1q double Inner tag any • dot1ad double inner tag any
translate 2-to-1	Not Supported	
dot1ad push 1	Not Supported	
dot1ad push 2	Not Supported	
dot1ad translate 1-to-1	Not Supported	
dot1ad translate 1-to-2	Not Supported	
dot1ad translate 2-to-2	Not Supported	
dot1ad translate 2-to-1	Not Supported	

VLAN Switch

The VLAN Switch feature enables L2 VLAN switching with minimal configuration. This feature allows you to configure L2 bridging without having to configure and manage separate bridge instances and sub-interfaces for each per VLAN L2 forwarding domain.

Prior to this feature, numerous sub-interfaces were required to configure and manage L2 bridging. Using separate sub-interfaces for each VLAN on a port overloads the system scalability and consumes hardware resources, slows down provisioning, and makes the device harder to manage.

Prior to Cisco IOS XR Software Release 6.5.1, an L2 VLAN sub-interface was required to be configured to either classify L2 traffic based on the VLAN tags included in the frame header, or to perform a rewrite on the frame header. This is achieved by adding, removing, or translating the VLAN tags in the frame header.

The Trunk level VLAN encapsulation provides a simpler configuration where you can directly configure a VLAN on a trunk interface, a physical interface, or LAG interface. You do not need a separate sub-interface to be configured.

A trunk is a point-to-point link between the device and another networking device. Trunks carry the traffic of multiple VLANs over a single link and allow you to extend VLANs across an entire network.

To deliver the traffic on a trunk port with several VLANs, the device uses the IEEE 802.1Q encapsulation (tagging) method that uses a tag that is inserted into the frame header. This tag carries information about the specific VLAN to which the frame and packet belong. This method allows packets that are encapsulated for several different VLANs to traverse the same port and maintain traffic separation between the VLANs. The encapsulated VLAN tag also allows the trunk to move traffic end-to-end through the network on the same VLAN.

Restrictions

The following restrctions are applicable on the Cisco NCS 5000 Router:

- dot1ad native VLAN is not supported.
- VLAN switched trunk cannot be configured on the same trunk (physical or LAG) as trunk l2 transport mode.
- To change the list of VLAN bridges, L2VPN vlan-switch instance must be deleted and recreated.
- A trunk interface (physical or LAG) cannot use a mix of 802.1Q outer tags 802.1ad outer tags.
- If dot1q native VLAN and VLAN switched trunk are both configured then the Native VLAN must be contained in the set of VLAN IDs matched by the **vlan-switched trunk** configuration.
- When VLAN switched trunk is configured, IP addresses must not be configured on a trunk.

Configure VLAN Switch

Perform this task to configure VLAN Switch.

Configuration Example

```
Router#configure
Router(config)#l2vpn
Router(config-l2vpn)#vlan-switch gl1
Router(config-l2vpn-vs)#vlan 1-200
Router(config-l2vpn-vs)#vni 501-700
Router(config-l2vpn-vs)#interface GigabitEthernet0/0/0/0
Router(config-l2vpn-vs)#interface GigabitEthernet0/0/0/1
Router(config-l2vpn-vs)#interface GigabitEthernet0/0/0/2
/* Binds the VLAN switch to three trunk interfaces GE/0/0/0-2 */
Router(config-l2vpn-vs)#commit


/* GE/0/0/0 accepts 802.1ad tagged VLAN traffic with VLAN IDs between 1 and 100.
Traffic is mapped (without outermost VLAN tag) to the per-VLAN bridge with the same VLAN
ID. */
```

```
Router#configure
Router(config)#interface GigabitEthernet0/0/0/0
Router(config)#vlan-switched trunk dot1ad 1-100
!

/* GE/0/0/1 accepts 802.1Q tagged VLAN traffic with VLAN IDs between 50 and 150.
Tagged traffic is mapped (without outermost VLAN tag) to the per-VLAN bridge with the same
 VLAN ID.
Also accepts untagged traffic that is assigned to per-VLAN bridge gl_vlan50. */

Router(config)#interface GigabitEthernet0/0/0/1
Router(config)#vlan-switched trunk dot1q 50-150 dot1q native vlan 50
!

/* GE/0/0/2 accepts all traffic and is statically assigned to the VLAN bridge gl_vlan100.
*/

Router(config)#interface GigabitEthernet0/0/0/2
Router(config)#vlan-switched access 100
!

Router(config-if)#commit
```

Running Configuration

```
l2vpn
 vlan-switch gl1
   vlan 1-200
   vni 501-700
   interface GigabitEthernet0/0/0/0
   interface GigabitEthernet0/0/0/1
   interface GigabitEthernet0/0/0/2
 !
!
interface GigabitEthernet0/0/0/0
 vlan-switched trunk dot1ad 1-100
!
interface GigabitEthernet0/0/0/1
 vlan-switched trunk dot1q 50-150 dot1q native vlan 50
!
interface GigabitEthernet0/0/0/2
 vlan-switched access 100
```

Verification

Verify the VLAN switch configuration. Reports the interface as being in VLAN switched trunk mode and gives the encapsulation and VLAN IDs that are matched.

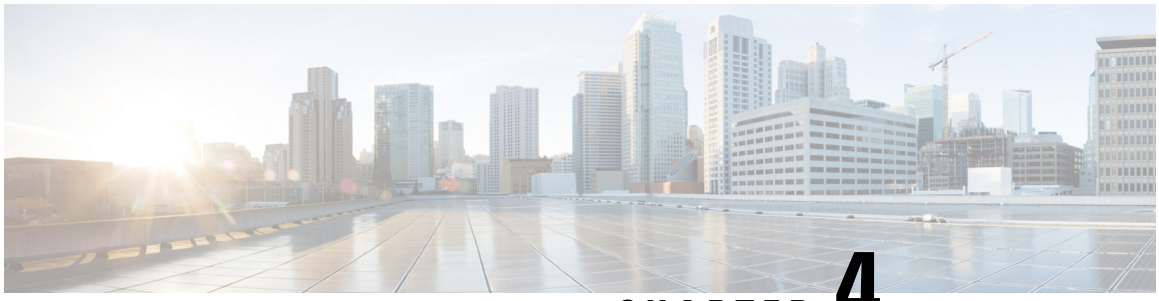
```
Router#show interfaces GigabitEthernet 0/0/0/0
Wed May 23
08:07:39.869 PDT
GigabitEthernet0/0/0/0 is up, line protocol is up
    Interface state transitions: 1
    Hardware is GigabitEthernet, address is 02fe.08cb.26c5 (bia
02fe.08cb.26c5)
    Internet address is Unknown
    MTU 1518 bytes, BW 1000000 Kbit (Max: 1000000 Kbit)
       reliability 255/255, txload 0/255, rxload 0/255
    Encapsulation 802.1Q Virtual LAN,
    vlan-switched trunk port: Dot1ad VLAN 1-100
```

```
    Full-duplex, 1000Mb/s, unknown, link type is force-up
    output flow control is off, input flow control is off
    Carrier delay (up) is 10 msec
    loopback not set,
    Last link flapped 00:05:32
    Last input never, 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
       0 packets input, 0 bytes, 0 total input drops
       0 drops for unrecognized upper-level protocol
       Received 0 broadcast packets, 0 multicast packets
                0 runts, 0 giants, 0 throttles, 0 parity
       0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
       0 packets output, 0 bytes, 0 total output drops
       Output 0 broadcast packets, 0 multicast packets
       0 output errors, 0 underruns, 0 applique, 0 resets
       0 output buffer failures, 0 output buffers swapped out
       1 carrier transitions


Router#show interfaces GigabitEthernet 0/0/0/1
Wed May 23
08:07:49.049 PDT
GigabitEthernet0/0/0/1 is up, line protocol is up
    Interface state transitions: 1
    Hardware is GigabitEthernet, address is 024f.88a0.8c9d (bia
024f.88a0.8c9d)
    Internet address is Unknown
    MTU 1518 bytes, BW 1000000 Kbit (Max: 1000000 Kbit)
       reliability 255/255, txload 0/255, rxload 0/255
    Encapsulation 802.1Q Virtual LAN, Native VLAN Id 50,
    vlan-switched trunk port: Dot1Q VLAN 50-150
    Full-duplex, 1000Mb/s, unknown, link type is force-up
    output flow control is off, input flow control is off
    Carrier delay (up) is 10 msec
    loopback not set,
    Last link flapped 00:05:08
    Last input never, 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
       0 packets input, 0 bytes, 0 total input drops
       0 drops for unrecognized upper-level protocol
       Received 0 broadcast packets, 0 multicast packets
                0 runts, 0 giants, 0 throttles, 0 parity
       0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
       0 packets output, 0 bytes, 0 total output drops
       Output 0 broadcast packets, 0 multicast packets
       0 output errors, 0 underruns, 0 applique, 0 resets
       0 output buffer failures, 0 output buffers swapped out
       1 carrier transitions

Router#show interfaces GigabitEthernet 0/0/0/2
Wed May 23
08:07:57.681 PDT
GigabitEthernet0/0/0/2 is up, line protocol is up
    Interface state transitions: 1
    Hardware is GigabitEthernet, address is 0246.c822.daae (bia
0246.c822.daae)
    Internet address is Unknown
    MTU 1514 bytes, BW 1000000 Kbit (Max: 1000000 Kbit)
       reliability 255/255, txload 0/255, rxload 0/255
    Encapsulation 802.1Q Virtual LAN,
```

```
vlan-switched access port: VLAN 100
Full-duplex, 1000Mb/s, unknown, link type is force-up
output flow control is off, input flow control is off
Carrier delay (up) is 10 msec
loopback not set,
Last link flapped 00:05:16
Last input never, 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
   0 packets input, 0 bytes, 0 total input drops
   0 drops for unrecognized upper-level protocol
   Received 0 broadcast packets, 0 multicast packets
            0 runts, 0 giants, 0 throttles, 0 parity
   0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
   0 packets output, 0 bytes, 0 total output drops
   Output 0 broadcast packets, 0 multicast packets
   0 output errors, 0 underruns, 0 applique, 0 resets
   0 output buffer failures, 0 output buffers swapped out
   1 carrier transitions
```

Associated Commands

- vlan-switched trunk
- vlan-switched access
- show interfaces



CHAPTER 4

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 29.

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 .

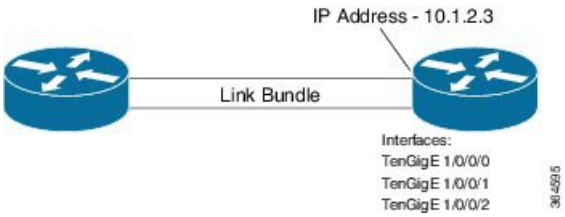
Configuration Example

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 Configure Link Bundles for Layer 2 VPNs, on page 25.

Characteristics of Link Bundles

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

Methods of Forming Bundles of Ethernet Interfaces

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

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

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

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

- The current aggregation status of the link

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

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

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

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

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

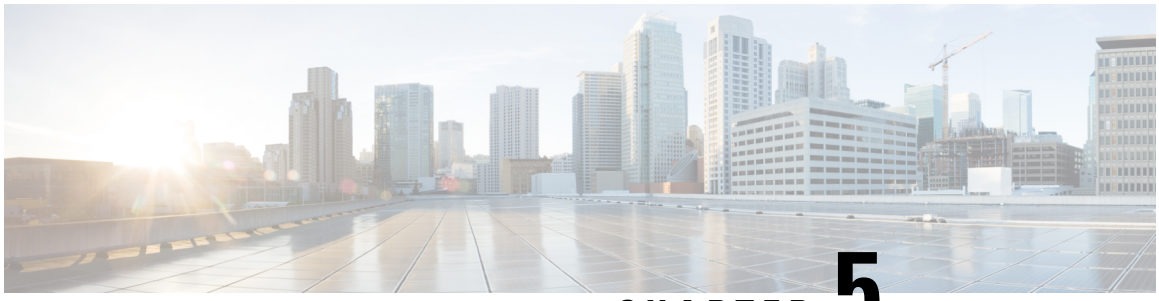
- EtherChannel—Cisco proprietary technology that allows the user to configure links to join a bundle, but has no mechanisms to check whether the links in a bundle are compatible.

Link Aggregation Through LACP

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

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

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



CHAPTER 5

Configure Multipoint Layer 2 Services

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

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

Prerequisites for Implementing Multipoint Layer 2 Services

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

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

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

- Configure IP routing in the core so that the provider edge (PE) routers can reach each other through IP.
- Configure a loopback interface to originate and terminate Layer 2 traffic. Make sure that the PE routers can access the other router's loopback interface.

Information About Implementing Multipoint Layer 2 Services

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

Multipoint Layer 2 Services Overview

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

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

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

Bridge Domain

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

When the number of bridge domains exceeds 200, to enable clean up and reprogramming, it takes about 120 seconds for unconfiguring L2VPN and rollback.

The following table details the minimum interval required between unconfiguring L2VPN and rollback:

Number of BDs	Minimum interval in seconds
250	180
500	300
750 or greater	600

Pseudowires

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

Access Pseudowire is not supported over VPLS Bridge Domain

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

Configuration Example

```
l2vpn
 bridge group bg1
```

```
  bridge-domain l2vpn
   interface TenGigE0/0/0/13.100
   !
  vfi 1
   neighbor 192.0.2.1 pw-id 12345
    pw-class mpls_csr
  !
 !
!
```

Virtual Forwarding Instance

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

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

VPLS for an MPLS-based Provider Core

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

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

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

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

VPLS for Layer 2 Switching

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

The storm control that is applied to multiple subinterfaces of the same physical port pertains to that physical port only. All subinterfaces with storm control configured are policed as aggregate under a single policer rate shared by all EFPs. None of the subinterfaces are configured with a dedicated policer rate. When a storm

occurs on several subinterfaces simultaneously, and because subinterfaces share the policer, you can slightly increase the policer rate to accommodate additional policing.

These features are supported:

- Bridging IOS XR Trunk Interfaces
- Bridging on EFPs

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

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

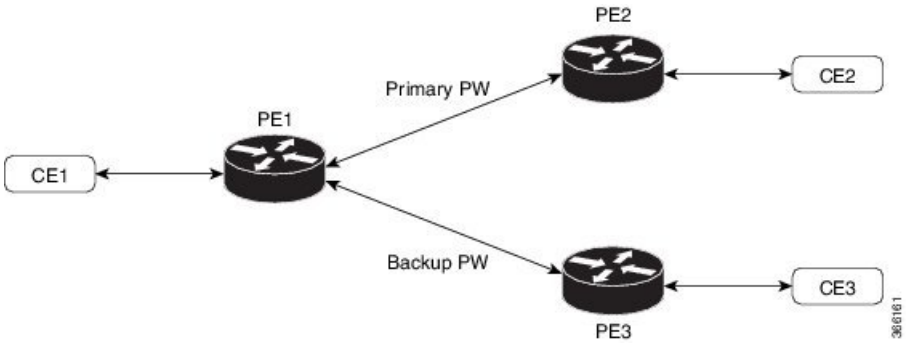
This is a sample IOS configuration with the **prefix-length-size 2** command:

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

Pseudowire Redundancy

Pseudowire redundancy allows you to configure a backup pseudowire in case the primary pseudowire fails. When the primary pseudowire fails, the PE router can switch to the backup pseudowire. You can elect to have the primary pseudowire resume operation after it becomes functional. The primary pseudowire fails when the PE router fail or due to any network related outage.

Figure 2: Pseudowire Redundancy



Forcing a Manual Switchover to the Backup Pseudowire

To force the router to switch over to the backup or switch back to the primary pseudowire, use the **l2vpn switchover** command in EXEC mode.

A manual switchover is made only if the peer specified in the command is actually available and the cross-connect moves to the fully active state when the command is entered.

Configuration

This section describes how you can configure pseudowire redundancy.

```
/* Configure PE1 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group XCON1
Router(config-l2vpn-xc)# p2p xc1
Router(config-l2vpn-xc-p2p)# interface GigabitEthernet 0/1/0/0.1
Router(config-l2vpn-xc-p2p)# neighbor ipv4 172.16.0.1 pw-id 1
Router(config-l2vpn-xc-p2p-pw)# backup neighbor 192.168.0.1 pw-id 1
Router(config-subif)# commit

/* Configure PE2 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group XCON1
Router(config-l2vpn-xc)# p2p xc1
Router(config-l2vpn-xc-p2p)# interface GigabitEthernet 0/1/0/0.1
Router(config-l2vpn-xc-p2p)# neighbor ipv4 10.0.0.1 pw-id 1
Router(config-subif)# commit

/* Configure PE3 */
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group XCON1
Router(config-l2vpn-xc)# p2p xc1
Router(config-l2vpn-xc-p2p)# interface GigabitEthernet 0/1/0/0.1
Router(config-l2vpn-xc-p2p)# neighbor ipv4 10.0.0.1 pw-id 1
Router(config-subif)# commit
```

Running Configuration

```
/* On PE1 */
!
l2vpn
 xconnect group XCON1
  p2p XCON1_P2P2
   interface GigabitEthernet 0/1/0/0.1
   neighbor ipv4 172.16.0.1 pw-id 1
    backup neighbor 192.168.0.1 pw-id 1
!

/* On PE2 */
!
l2vpn
 xconnect group XCON1
  p2p XCON1_P2P2
   interface GigabitEthernet 0/1/0/0.1
   neighbor ipv4 10.0.0.1 pw-id 1

!

/* On PE3 */
!
l2vpn
 xconnect group XCON1
  p2p XCON1_P2P2
   interface GigabitEthernet 0/1/0/0.1
   neighbor ipv4 10.0.0.1 pw-id 1

!
```

Verification

Verify that the configured pseudowire redundancy is up.

```
/* On PE1 */

Router#show l2vpn xconnect group XCON_1
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
------------------------   ----------------------------   ----------------------------
XCON_1     XCON1_P2P2 UP   Gi0/1/0/0.1            UP       172.16.0.1     1000   UP
                                                           Backup
                                                           192.168.0.1     1000   SB
------------------------------------------------------------------------------------

/* On PE2 */

Router#show l2vpn xconnect group XCON_1
Tue Jan 17 15:36:12.327 UTC
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
------------------------   ----------------------------   ----------------------------
XCON_1     XCON1_P2P2 UP   BE100.1                UP       10.0.0.1     1000   UP
------------------------------------------------------------------------------------

/* On PE3 */

Router#show l2vpn xconnect group XCON_1
Tue Jan 17 15:38:04.785 UTC
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
------------------------   ----------------------------   ----------------------------
XCON_1     XCON1_P2P2 DN   BE100.1                UP       10.0.0.1     1000   SB
------------------------------------------------------------------------------------

Router#show l2vpn xconnect summary
Number of groups: 3950
Number of xconnects: 3950
  Up: 3950  Down: 0  Unresolved: 0 Partially-programmed: 0
  AC-PW: 3950  AC-AC: 0  PW-PW: 0 Monitor-Session-PW: 0
Number of Admin Down segments: 0
Number of MP2MP xconnects: 0
  Up 0 Down 0
  Advertised: 0 Non-Advertised: 0
Number of CE Connections: 0
  Advertised: 0 Non-Advertised: 0
Backup PW:
  Configured   : 3950
  UP           : 0
  Down         : 0
  Admin Down   : 0
  Unresolved   : 0
  Standby      : 3950
  Standby Ready: 0
```

```
Backup Interface:
  Configured   : 0
  UP           : 0
  Down         : 0
  Admin Down   : 0
  Unresolved   : 0
  Standby      : 0
```

MAC Address-related Parameters

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

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

MAC Address Flooding

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

MAC Address-based Forwarding

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

MAC Address Source-based Learning

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

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

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

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

MAC Address Aging

A MAC address in the MAC table is considered valid only for the duration of the MAC address aging time. When the time expires, the relevant MAC entries are repopulated. When the MAC aging time is configured

only under a bridge domain, all the pseudowires and attachment circuits in the bridge domain use that configured MAC aging time.

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

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

MAC Address Limit

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

Configure MAC Address Limit

Configure the MAC address limit using the **maximum** command. The MAC address learning is restricted to the configured limit.

When the number of learned MAC addresses reaches the configured limit, you can configure the bridge behavior by using the **action** command. You can configure the action to perform one of the following:

- **flood**: All the unknown unicast packets, with unknown destinations addresses, are flooded over the bridge.
- **no-flood**: All the unknown unicast packets, with unknown destination addresses, are dropped.
- **shutdown** : All the packets are dropped.

When the MAC limit is exceeded, use the **notification {both | none | trap}** command to send notifications in one of the following forms:

- **trap**: Sends Simple Network Management Protocol (SNMP) trap notification.
- **both**: Sends both syslog and trap notifications.
- **none**: No notifications are sent.

By default, syslog message is sent.

Note Though you can modify the MAC address limit under the bridge domain, due to hardware limitation, the modification does not take effect.

Configuration Example

In this example, MAC address limit is configured as 5000 and MAC limit action is set to flood the packets. As notification is not configured, syslog entries are sent when the MAC limit is exceeded.

```
Router# configure
Router(config)# l2vpn
Router(config-l2vpn)# bridge group bg-0
Router(config-l2vpn-bg)# bridge-domain bd-0
Router(config-l2vpn-bg-bd)# mac
```

```
Router(config-l2vpn-bg-bd-mac)# limit
Router(config-l2vpn-bg-bd-mac-limit)# maximum 5000
Router(config-l2vpn-bg-bd-mac-limit)# action flood
```

Verification

Use the **show l2vpn bridge-domain** command to view the MAC address limit configuration.

```
Router# show l2vpn bridge-domain bd-name bd-0 detail
Legend: pp = Partially Programmed.
Bridge group: bg-0, bridge-domain: bd-0, id: 25, state: up, ShgId: 0, MSTi: 0
  Coupled state: disabled
  VINE state: EVPN Native
  MAC learning: enabled
  MAC withdraw: enabled
    MAC withdraw for Access PW: enabled
    MAC withdraw sent on: bridge port up
    MAC withdraw relaying (access to access): disabled
  Flooding:
    Broadcast & Multicast: enabled
    Unknown unicast: enabled
  MAC aging time: 300 s, Type: inactivity
  MAC limit: 5000, Action: flood, Notification: syslog
  MAC limit reached: no, threshold: 80%
  MAC port down flush: enabled
  MAC Secure: disabled, Logging: disabled
```

MAC Address Withdrawal

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

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

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

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

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

Configuration Examples for Multipoint Layer 2 Services

This section includes these configuration examples:

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

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

This configuration example shows how to configure PE 1:

```
configure
 l2vpn
  bridge group 1
   bridge-domain PE1-VPLS-A
    interface TenGigE0/0/0/0
    vfi 1
     neighbor 172.16.0.1 pw-id 1
     neighbor 192.168.0.1 pw-id 1
     !
   !
 interface loopback 0
  ipv4 address 10.0.0.1 255.0.0.0
```

This configuration example shows how to configure PE 2:

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

    vfi 1
     neighbor 10.0.0.1 pw-id 1
     neighbor 192.168.0.1 pw-id 1
     !
   !
 interface loopback 0
  ipv4 address 172.16.0.1 255.240.0.0
```

This configuration example shows how to configure PE 3:

```
configure
 l2vpn
  bridge group 1
   bridge-domain PE3-VPLS-A
    interface TenGigE0/0/0/2
    vfi 1
     neighbor 10.0.0.1 pw-id 1
     neighbor 172.16.0.1 pw-id 1
     !
   !
 interface loopback 0
  ipv4 address 192.168.0.1 255.255.0.0
```

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

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

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

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

Displaying MAC Address Withdrawal Fields: Example

This sample output shows the MAC address withdrawal fields:

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

Legend: pp = Partially Programmed.
Bridge group: 222, bridge-domain: 222, id: 0, state: up, ShgId: 0, MSTi: 0
  Coupled state: disabled
  MAC learning: enabled
  MAC withdraw: enabled
    MAC withdraw sent on: bridge port up
    MAC withdraw relaying (access to access): disabled
  Flooding:
    Broadcast & Multicast: enabled
    Unknown unicast: enabled
  MAC aging time: 300 s, Type: inactivity
  MAC limit: 4000, Action: none, Notification: syslog
  MAC limit reached: no
  MAC port down flush: enabled
  MAC Secure: disabled, Logging: disabled
  Split Horizon Group: none
  Dynamic ARP Inspection: disabled, Logging: disabled
  IP Source Guard: disabled, Logging: disabled
  DHCPv4 snooping: disabled
  IGMP Snooping: enabled
  IGMP Snooping profile: none
  MLD Snooping profile: none
  Storm Control: disabled
  Bridge MTU: 1500
  MIB cvplsConfigIndex: 1
  Filter MAC addresses:
  P2MP PW: disabled
  Create time: 01/03/2017 11:01:11 (00:21:33 ago)
  No status change since creation
  ACs: 1 (1 up), VFIs: 1, PWs: 1 (1 up), PBBs: 0 (0 up)
  List of ACs:
    AC: TenGigE0/2/0/1.7, state is up
      Type VLAN; Num Ranges: 1
      Outer Tag: 21
      VLAN ranges: [22, 22]
      MTU 1508; XC ID 0x208000b; interworking none
      MAC learning: enabled
      Flooding:
        Broadcast & Multicast: enabled
        Unknown unicast: enabled
      MAC aging time: 300 s, Type: inactivity
      MAC limit: 4000, Action: none, Notification: syslog
      MAC limit reached: no
      MAC port down flush: enabled
      MAC Secure: disabled, Logging: disabled
      Split Horizon Group: none
      Dynamic ARP Inspection: disabled, Logging: disabled
      IP Source Guard: disabled, Logging: disabled
      DHCPv4 snooping: disabled
      IGMP Snooping: enabled
```

```
      IGMP Snooping profile: none
      MLD Snooping profile: none
      Storm Control: bridge-domain policer
      Static MAC addresses:
      Statistics:
        packets: received 714472608 (multicast 0, broadcast 0, unknown unicast 0, unicast
0), sent 97708776
        bytes: received 88594603392 (multicast 0, broadcast 0, unknown unicast 0, unicast
0), sent 12115888224
        MAC move: 0
      Storm control drop counters:
        packets: broadcast 0, multicast 0, unknown unicast 0
        bytes: broadcast 0, multicast 0, unknown unicast 0
      Dynamic ARP inspection drop counters:
        packets: 0, bytes: 0
      IP source guard drop counters:
        packets: 0, bytes: 0
  List of VFIs:
    VFI 222 (up)
      PW: neighbor 10.0.0.1, PW ID 222, state is up ( established )
        PW class not set, XC ID 0xc000000a
        Encapsulation MPLS, protocol LDP
        Source address 21.21.21.21
        PW type Ethernet, control word disabled, interworking none
        Sequencing not set

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

Bridging on IOS XR Trunk Interfaces: Example

This example shows how to configure a Cisco NCS 5000 Series Routers as a simple L2 switch.

Important notes:

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

- This example assumes that the running config is empty, and that all the components are created.
- This example provides all the necessary steps to configure the Cisco NCS 5000 Series Routers to perform switching between the interfaces. However, the commands to prepare the interfaces such as no shut, negotiation auto, etc., have been excluded.
- The bridge domain is in a no shut state, immediately after being created.
- Only trunk (i.e. main) interfaces are used in this example.
- The trunk interfaces are capable of handling tagged (i.e. IEEE 802.1Q) or untagged (i.e. no VLAN header) frames.
- The bridge domain learns, floods, and forwards based on MAC address. This functionality works for frames regardless of tag configuration.
- The bridge domain entity spans the entire system. It is not necessary to place all the bridge domain ACs on a single LC. This applies to any bridge domain configuration.
- The show bundle and the show l2vpn bridge-domain commands are used to verify that the router was configured as expected, and that the commands show the status of the new configurations.
- The ACs in this example use interfaces that are in the admin down state.

Configuration Example

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

```
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)#end
RP/0/RSP0/CPU0:Jul 26 10:48:21.342 EDT: config[65751]: %MGBL-SYS-5-CONFIG_I : Configured
from console by lab
RP/0/RSP0/CPU0:router#show bundle Bundle-ether10

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

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

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

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

SUMMARY STEPS

1. **configure**
2. **interface Bundle-ether10**
3. **l2transport**
4. **interface GigabitEthernet0/2/0/5**
5. **bundle id 10 mode active**
6. **interface GigabitEthernet0/2/0/6**
7. **bundle id 10 mode active**
8. **interface GigabitEthernet0/2/0/0**
9. **l2transport**
10. **interface GigabitEthernet0/2/0/1**
11. **l2transport**
12. **interface TenGigE0/1/0/2**
13. **l2transport**
14. **l2vpn**

15. **bridge group examples**
16. **bridge-domain test-switch**
17. **interface Bundle-ether10**
18. **exit**
19. **interface GigabitEthernet0/2/0/0**
20. **exit**
21. **interface GigabitEthernet0/2/0/1**
22. **exit**
23. **interface TenGigE0/1/0/2**
24. Use the **commit** or **end** command.

DETAILED STEPS

Step 1 **configure**

Enters global configuration mode.

Step 2 **interface Bundle-ether10**

Creates a new bundle trunk interface.

Step 3 **l2transport**

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

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

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

Step 5 **bundle id 10 mode active**

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

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

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

Step 7 **bundle id 10 mode active**

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

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

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

Step 9 **l2transport**

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

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

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

Step 11 **l2transport**

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

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

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

Step 13 **l2transport**

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

Step 14 **l2vpn**

Enters L2VPN configuration mode.

Step 15 **bridge group examples**

Creates the bridge group **examples**.

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

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

Step 17 **interface Bundle-ether10**

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

Step 18 **exit**

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

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

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

Step 20 **exit**

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

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

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

Step 22 **exit**

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

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

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

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

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

end - Prompts user to take one of these actions:

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

Bridging on Ethernet Flow Points: Example

This example shows how to configure a Cisco NCS 5000 Series Router to perform Layer 2 switching on traffic that passes through Ethernet Flow Points (EFPs). EFP traffic typically has one or more VLAN headers. Although both IOS XR trunks and IOS XR EFPs can be combined as attachment circuits in bridge domains, this example uses EFPs exclusively.

Important notes:

- An EFP is a Layer 2 subinterface. It is always created under a trunk interface. The trunk interface must exist before the EFP is created.
- In an empty configuration, the bundle interface trunk does not exist, but the physical trunk interfaces are automatically configured. Therefore, only the bundle trunk is created.
- In this example the subinterface number and the VLAN IDs are identical, but this is out of convenience, and is not a necessity. They do not need to be the same values.
- The bridge domain test-efp has three attachment circuits (ACs). All the ACs are EFPs.
- Only frames with a VLAN ID of 999 enter the EFPs. This ensures that all the traffic in this bridge domain has the same VLAN encapsulation.
- The ACs in this example use interfaces that are in the admin down state (**unresolved** state). Bridge domains that use nonexistent interfaces as ACs are legal, and the commit for such configurations does not fail. In this case, the status of the bridge domain shows **unresolved** until you configure the missing interface.

Configuration Example

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

```
    BE10.999, state: down, Static MAC addresses: 0
    Gi0/6/0/7.999, state: unresolved, Static MAC addresses: 0
    Te0/1/0/2.999, state: down, Static MAC addresses: 0
  List of VFIs:
RP/0/RSP1/CPU0:router#
```

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

SUMMARY STEPS

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

DETAILED STEPS

Step 1 **configure**

Enters global configuration mode.

Step 2 **interface Bundle-ether10**

Creates a new bundle trunk interface.

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

Creates an EFP under the new bundle trunk.

Step 4 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

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

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

Step 6 **bundle id 10 mode active**

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

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

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

Step 8 **bundle id 10 mode active**

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

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

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

Step 10 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

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

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

Step 12 **encapsulation dot1q 999**

Assigns VLAN ID of 999 to this EFP.

Step 13 **l2vpn**

Enters L2VPN configuration mode.

Step 14 **bridge group examples**

Creates the bridge group named **examples**.

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

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

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

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

Step 17 **exit**

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

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

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

Step 19 **exit**

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

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

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

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

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

end - Prompts user to take one of these actions:

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

GTP Load Balancing

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
GTP Load Balancing	Release 7.3.2	In addition to the source IP address, destination IP address, and port number, this functionality enables using the unique tunnel endpoint identifier (TEID) to compute load balancing (or hashing) of traffic in tunnels between ports. Using the TEID ensures that load balancing occurs even if the other parameters don't have unique values, thus enabling efficient use of bandwidth and providing a reliable network. This functionality introduces the **hw-module loadbalancing gtp enable** command.

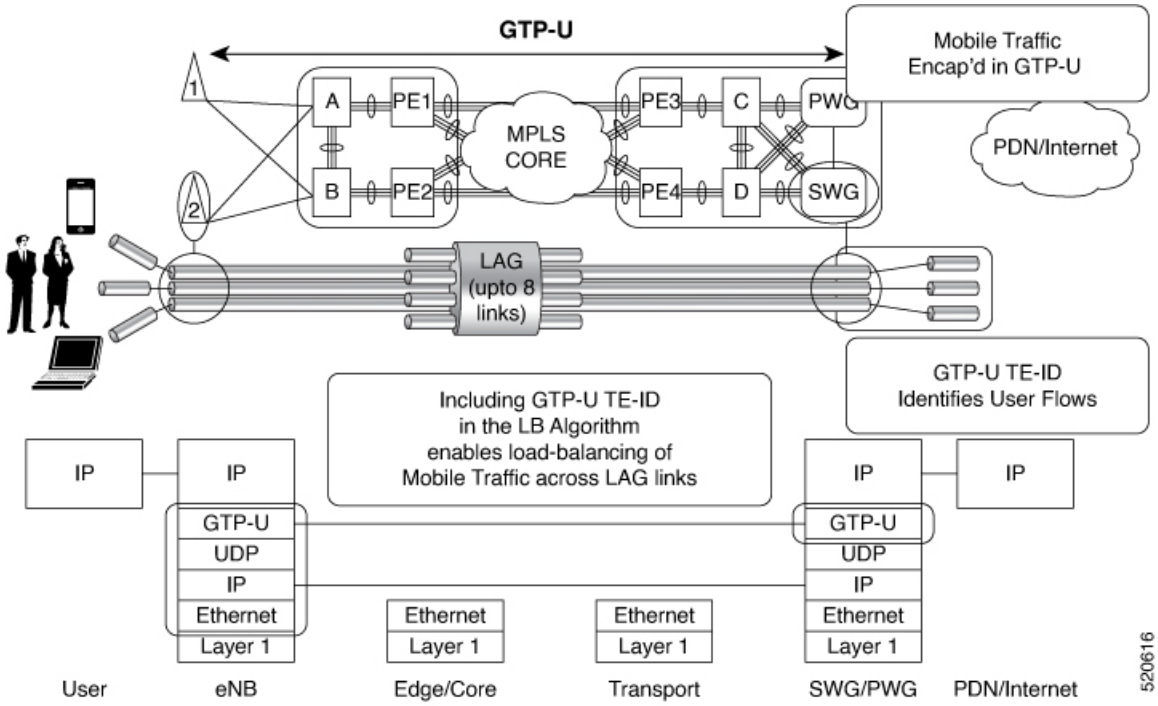
What is GTP?

GTP is a tunnel control and management protocol among General Packet Radio Service (GPRS) support nodes. Wireless networks use GTP tunnels to deliver mobile data. GTP includes GTP signaling (GTP-C) and data transfer (GTP-U) procedures. GTP-C specifies a tunnel control and management protocol, and is used to create, delete, and modify tunnels. GTP-U uses a tunneling mechanism to provide a service for carrying user data packets over the network.

What is GTP Load Balancing?

The following figure shows an illustration of the mobile transport GTP-U load balancing.

Figure 3: Mobile Transport GTP-U Load-Balancing



The global L3 flow-based load balancing considers the following fields:

- source address
- destination address
- router ID
- source port
- destination port

However, for GTP traffic, there are a limited number of unique values for these fields; this causes an uneven distribution of traffic. Sometimes, to facilitate redundancy and load balancing in a network, equal-cost paths exist to different destinations. Load balancing doesn't occur in such scenarios as the source and destination IP addresses and L4 ports are the same.

To achieve a greater distribution of traffic over equal-cost links, you can enable GTP TEID (Tunnel Endpoint ID) in the hash computation algorithm using the **hw-module loadbalancing gtp enable** command. Doing so ensures that the load balancing (hashing) computation algorithm includes the GTP TEID, unique for each traffic flow. The GTP load-balancing feature allows efficient distribution of traffic in mobile networks and provides increased reliability and availability for the network.

If the packet is UDP and the destination port is the GTP-U port (port number 2152), the GTP TEID is considered for loadbalancing.

The TEID in the GTP header of a GTP packet identifies individual tunnel endpoints, thus achieving better mobile traffic load balancing within any given GRE tunnel. Also, this helps in load-balancing GTP traffic over bundles at transit routers.

If TEID is present, load balancing based on tunnel endpoints is supported for Version 1 GTP packet and GTP version 2. For GTP version 0, load balancing occurs only if the fields described earlier have unique values, because there's no TEID in version 0.

Note GTP load balancing is performed only for GTP-U (user data) packets. The GTP-C (control data) packets use a different destination port number of 2123 and hence, are subject to only the global L3 flow-based load balancing.

GTP Load Balancing Guidelines and Limitations

- GTP load balancing is performed on IPv4 or IPv6 incoming packets with GTP payloads and on MPLS incoming labeled packets.
- This feature supports GTP hashing only when the GTP UDP port is 2152.
- The number of MPLS label stacks in the transport layer is limited to three for GTP hashing. GTP hashing isn't considered when the MPLS label stack exceeds three.
- You need not reboot the router after configuring or unconfiguring the **hw-module loadbalancing gtp enable** for GTP load balancing over MPLS to take effect.

Configuration

To enable GTP load balancing, configure the **hw-module loadbalancing gtp enable** command.

```
Router#config
Router(config)#hw-module loadbalancing gtp enable
Router(config)#commit
Router(config)#end
```

Verification

Run the following command to verify that GTP load balancing is enabled.

```
Router#show prm drv diagshell "getreg ING_GTP_CONTROL"
ING_GTP_CONTROL.ipipe0[1][0x3a004f00]=1: <GTP_HDR_FIRST_BYTE_MASK=0,
   GTP_HDR_FIRST_BYTE=0,GTP_ENABLE=1>
```

Associated Commands

hw-module loadbalancing gtp enable

Flow Aware Transport Pseudowire (FAT PW)

Routers typically loadbalance traffic based on the lower most label in the label stack which is the same label for all flows on a given pseudowire. This can lead to asymmetric loadbalancing. The flow, in this context, refers to a sequence of packets that have the same source and destination pair. The packets are transported from a source provider edge (PE) to a destination PE.

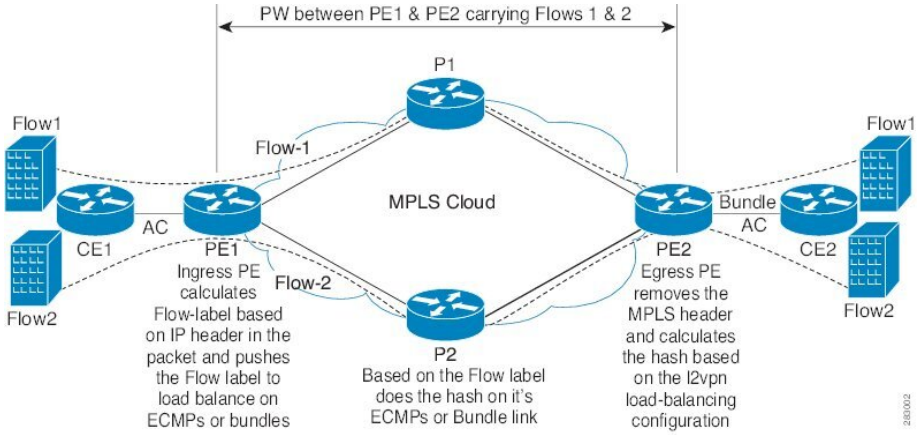
Flow-Aware Transport Pseudowires (FAT PW) provide the capability to identify individual flows within a pseudowire and provide routers the ability to use these flows to loadbalance traffic. FAT PWs are used to loadbalance traffic in the core when equal cost multipaths (ECMP) are used. A flow label is created based on

indivisible packet flows entering a pseudowire; and is inserted as the lower most label in the packet. Routers can use the flow label for loadbalancing which provides a better traffic distribution across ECMP paths or link-bundled paths in the core.

Note Based on the number of traffic flows, a SMAC based hashing tuple creates the same flow label or less number of flow labels.

The following figure shows a FAT PW with two flows distributing over ECMPs and bundle links.

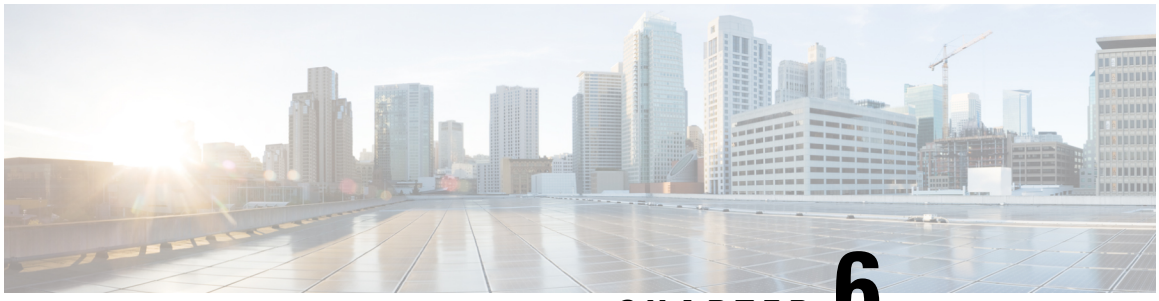
Figure 4: FAT PW with two flows distributing over ECMPs and Bundle-Links



An additional label is added to the stack, called the flow label, which contains the flow information of a virtual circuit (VC). A flow label is a unique identifier that distinguishes a flow within the PW, and is derived from source and destination MAC addresses, and source and destination IP addresses. The flow label contains the end of label stack (EOS) bit set and inserted after the VC label and before the control word (if any). The ingress PE calculates and forwards the flow label. The FAT PW configuration enables the flow label. The egress PE discards the flow label such that no decisions are made.

Core routers perform load balancing using the flow-label in the FAT PW with other information like MAC address and IP address. The flow-label adds greater entropy to improve traffic load balancing. Therefore, it's possible to distribute flows over ECMPs and link bundles.

You cannot send MPLS OAM ping traffic over a FAT PW, since there is no flow label support for MPLS OAM.



CHAPTER 6

Configure L2VPN Autodiscovery and Signaling

This chapter describes the L2VPN Autodiscovery and Signaling feature which enables the discovery of remote Provider Edge (PE) routers and the associated signaling in order to provision the pseudowires.

L2VPN Autodiscovery and Signaling

Autodiscovery refers to the process of finding the Provider Edge (PE) routers that participates in a given L2VPN instance. One of the protocols used for this is BGP.

Once the PE routers are discovered, pseudowires are signaled and established across each pair of PE routers. Signaling refers to the exchange of Virtual Circuit (VC) labels between the PE routers. The signaling protocol can be either LDP or BGP.

BGP-based VPLS Autodiscovery

VPLS is a multipoint Layer 2 bridging service for which BGP-based autodiscovery is well suited. BGP-based VPLS autodiscovery eliminates the need to manually provision the VPLS neighbors. VPLS autodiscovery enables each VPLS PE router to discover the other provider edge (PE) routers that are part of the same VPLS domain. VPLS Autodiscovery also tracks when PE routers are added to or removed from the VPLS domain. When the discovery process is complete, each PE router has the information required to setup VPLS pseudowires (PWs).

Even when BGP autodiscovery is enabled, pseudowires can be manually configured for VPLS PE routers that are not participating in the autodiscovery process.

BGP-based VPLS Autodiscovery with BGP Signaling

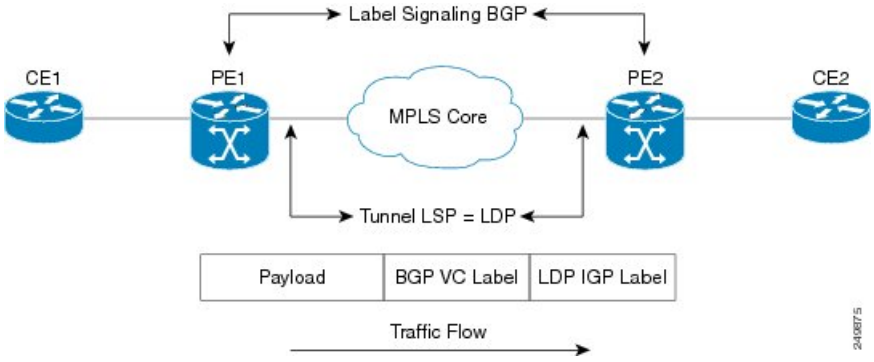
The BGP signaling and autodiscovery scheme have the following components:

- A means for a PE to learn which remote PEs are members of a given VPLS. This process is known as autodiscovery.

- A means for a PE to learn the pseudowire label expected by a given remote PE for a given VPLS. This process is known as signaling.

The BGP Network Layer Reachability Information (NLRI) takes care of the above two components simultaneously. The NLRI generated by a given PE contains the necessary information required by any other PE. These components enable the automatic setting up of a full mesh of pseudowires for each VPLS without having to manually configure those pseudowires on each PE.

Figure 5: Discovery and Signaling Attributes



Configuring BGP and LDP for BGP-based Autodiscovery

This is the basic BGP and LDP configuration that is required before proceeding to configure BGP-based autodiscovery.

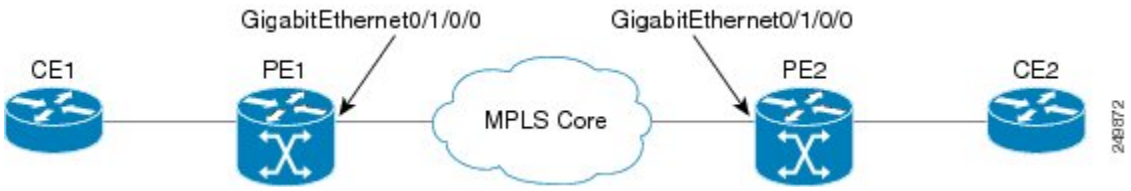
Configuration Example:

```
Router(config)# interface loopback-interface
Router(config-if)# ipv4 address ipv4-address subnet-mask
Router(config-if)# exit
Router(config)# mpls ldp
Router(config-ldp)# router-id ipv4-address
Router(config-ldp-if)# interface interface-name
Router(config-ldp-if)# exit
Router(config-ldp)# exit
Router(config)# router bgp as-number
Router(config-bgp)# address-family l2vpn vpls-vpws
Router(config-bgp-af)# exit
Router(config-bgp)# neighbor loopback ipv4 address of neighbor
Router(config-bgp-nbr)# remote-as remote-as-number
Router(config-bgp-nbr)# update-source loopback-interface
Router(config-bgp-nbr)# address-family l2vpn vpls-vpws
```

Running Configuration

The following figure illustrates an example of LDP and BGP network topology that is required for enabling BGP based autodiscovery.

Figure 6: LDP and BGP Configuration Example



Configuration at PE1:

```
interface Loopback1
 ipv4 address 10.0.0.10 255.255.255.255
!
mpls ldp
 router-id 10.0.0.10
 interface GigabitEthernet0/1/0/0
!
router bgp 120
 address-family l2vpn vpls-vpws
!
 neighbor 172.16.0.10
 remote-as 120
 update-source Loopback1
 address-family l2vpn vpls-vpws
```

Configuration at PE2:

```
interface Loopback1
 ipv4 address 172.16.0.10 255.240.0.0
!
mpls ldp
 router-id 172.16.0.1
 interface GigabitEthernt0/1/0/0
!
router bgp 120
 address-family l2vpn vpls-vpws
!
 neighbor 10.0.0.10
 remote-as 120
 update-source Loopback1
 address-family l2vpn vpls-vpws
```

Configuring BGP-based VPLS Autodiscovery with BGP Signaling

BGP and LDP need to be configured as indicated in the section Configuring BGP and LDP for BGP-based Autodiscovery, on page 58 before proceeding to the configurations in this section.

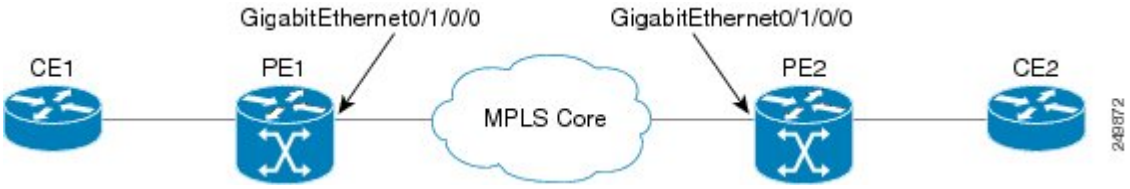
Configuration Example:

```
Router(config)# l2vpn
Router(config-l2vpn)# bridge group bridge-group-name
Router(config-l2vpn-bg)# bridge-domain bridge-domain-name
Router(config-l2vpn-bg-bd)# vfi vfi-name
Router(config-l2vpn-bg-bd-vfi)# autodiscovery bgp
Router(config-l2vpn-bg-bd-vfi-ad)# vpn-id vpn-id
Router(config-l2vpn-bg-bd-vfi-ad)# rd auto
```

```
Router(config-l2vpn-bg-bd-vfi-ad)# route-target 10.0.0.1:100
Router(config-l2vpn-bg-bd-vfi-ad-sig)# signaling-protocol bgp
Router(config-l2vpn-bg-bd-vfi-ad-sig)# ve-id 1
```

Running Configuration:

Figure 7: BGP-based VPLS Autodiscovery with BGP signaling



Configuration at PE1:

```
l2vpn
  bridge group gr1
   bridge-domain bd1
    interface GigabitEthernet0/1/0/1.1
    vfi vf1
    ! AD independent VFI attributes
    vpn-id 100
    ! Auto-discovery attributes
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol bgp
    ve-id 3
```

Configuration at PE2:

```
l2vpn
  bridge group gr1
   bridge-domain bd1
    interface GigabitEthernet0/1/0/2.1
    vfi vf1
    ! AD independent VFI attributes
    vpn-id 100
    ! Auto-discovery attributes
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol bgp
    ve-id 5
```

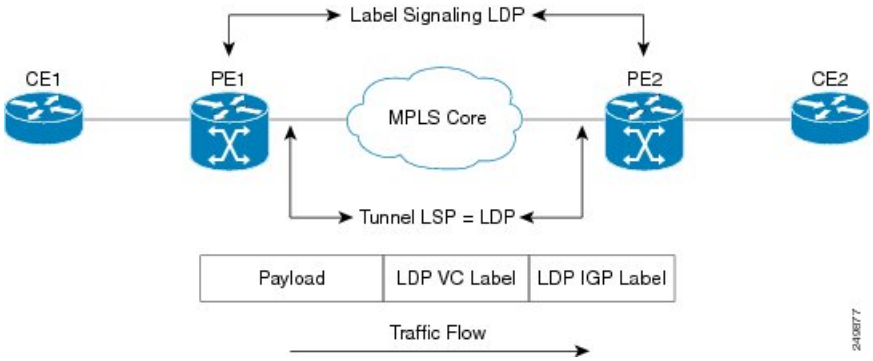
BGP-based VPLS Autodiscovery with LDP Signaling

A PE router advertises an identifier through BGP for each VPLS instance. This identifier is unique within the VPLS instance and acts like a VPLS ID. The identifier enables the PE router receiving the BGP advertisement to identify the VPLS associated with the advertisement and import it to the correct VPLS instance. In this manner, for each VPLS, a PE router learns the other PE routers that are members of the VPLS.

The signaling of pseudowires between provider edge devices, uses targeted LDP sessions to exchange label values and attributes. Forwarding Equivalence Class (FEC) 129 is used for the signaling. The information carried by FEC 129 includes the VPLS ID, the Target Attachment Individual Identifier (TAII) and the Source Attachment Individual Identifier (SAII).

The LDP advertisement also contains the inner label or VPLS label that is expected for the incoming traffic over the pseudowire. This enables the LDP peer to identify the VPLS instance with which the pseudowire is to be associated and the label value that it is expected to use when sending traffic on that pseudowire.

Figure 8: Discovery and Signaling Attributes



Configuring BGP-based VPLS Autodiscovery with LDP Signaling

BGP and LDP need to be configured as indicated in the section Configuring BGP and LDP for BGP-based Autodiscovery, on page 58 before proceeding to the configurations in this section.

Configuration Example:

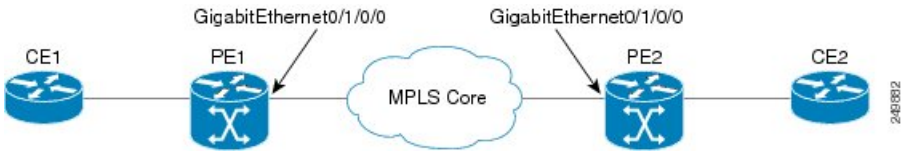
The below code block shows the basic configuration steps required for BGP-based VPLS autodiscovery with LDP Signaling.

```
Router(config)# l2vpn
Router(config-l2vpn)# bridge group {bridge group name}
Router(config-l2vpn-bg)# bridge-domain {bridge domain name}
Router(config-l2vpn-bg-bd)# vfi {vfi name}
Router(config-l2vpn-bg-bd-vfi)# autodiscovery bgp
Router(config-l2vpn-bg-bd-vfi-ad)# vpn-id 10
Router(config-l2vpn-bg-bd-vfi-ad)# rd auto
Router(config-l2vpn-bg-bd-vfi-ad)# route-target 10.0.0.1:100
Router(config-l2vpn-bg-bd-vfi-ad)# signaling-protocol ldp
Router(config-l2vpn-bg-bd-vfi-ad-sig)# vpls-id 120:200
Router(config-l2vpn-bg-bd-vfi-ad-sig)# commit
```

Running Configuration:

The following figure illustrates an example of configuring VPLS with BGP autodiscovery (AD) and LDP Signaling.

Figure 9: VPLS with BGP autodiscovery and LDP signaling



Configuration at PE1:

```
l2vpn
  router-id 10.0.0.10
  bridge group bg1
   bridge-domain bd1
    vfi vf1
    vpn-id 100
    autodiscovery bgp
    rd 1:100
    router-target 12:12
    signaling-protocol ldp
       vpls-id 120:200
```

Configuration at PE2:

```
l2vpn
  router-id 172.16.0.1
  bridge group bg1
   bridge-domain bd1
    vfi vf1
     vpn-id 100
     autodiscovery bgp
      rd 2:200
      router-target 12:12
      signaling-protocol ldp
       vpls-id 120:100
```

BGP-based VPWS Autodiscovery

BGP-based autodiscovery is possible even for point-to-point L2VPN services such as VPWS. However, true autodiscovery is not possible in VPWS as it is in VPLS. In VPWS, in order to connect the Customer Edge (CE) routers, an explicit configuration has to be done at each PE. Only the existence of other PEs can be indicated by autodiscovery.

BGP-based VPWS Autodiscovery with BGP Signaling

The two primary functions of the VPWS control plane are: auto-discovery and signaling. Both of these functions are accomplished with a single BGP Update advertisement.

When a VPWS cross-connect is configured with BGP autodiscovery and signaling enabled, BGP distributes NLRI for the cross-connect with the PE as the BGP next-hop and appropriate CE-ID. Additionally, the cross-connect is associated with one or more BGP export Route Targets (RTs) that are also distributed (along with NLRI).

Configuring BGP-based VPWS Autodiscovery with BGP Signaling

BGP and LDP need to be configured as indicated in the section Configuring BGP and LDP for BGP-based Autodiscovery, on page 58 before proceeding to the configurations in this section.

Configuration Example:

The below code block shows the basic configuration steps required for BGP-based VPWS autodiscovery with BGP Signaling.

```
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group {xconnect group name}
Router(config-l2vpn-xc)# mp2mp {instance name}
Router(config-l2vpn-xc-mp2mp)# vpn-id {vpn-id}
Router(config-l2vpn-xc-mp2mp)# l2-encapsulation vlan
Router(config-l2vpn-xc-mp2mp)# autodiscovery bgp
Router(config-l2vpn-xc-mp2mp-ad)# rd auto
Router(config-l2vpn-xc-mp2mp-ad)# route-target 172.16.0.1:100
Router(config-l2vpn-xc-mp2mp-ad)# signaling-protocol bgp
Router(config-l2vpn-xc-mp2mp-ad-sig)# ce-id 1
Router(config-l2vpn-xc-mp2mp-ad-sig-ce)# interface GigabitEthernet0/1/0/1.1 remote-ce-id 2
```

Running Configuration:

The following figure illustrates an example of configuring VPWS with BGP autodiscovery and BGP Signaling.

Figure 10: VPWS with BGP autodiscovery and BGP signaling

Configuration at PE1:

```
l2vpn
  xconnect group gr1
   mp2mp mp1
   vpn-id 100
   l2 encapsulation vlan
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol bgp
    ce-id 1
    interface GigabitEthernet0/1/0/1.1 remote-ce-id 2
```

Configuration at PE2:

```
l2vpn
  xconnect group gr1
   mp2mp mp1
   vpn-id 100
   l2 encapsulation vlan
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol bgp
    ce-id 2
    interface GigabitEthernet0/1/0/2.1 remote-ce-id 1
```

Verification:

PE1:

```
PE1# show l2vpn discovery xconnect
Service Type: VPWS, Connected
List of VPNs (1 VPNs):
XC Group: gr1, MP2MP mp1
   List of Local Edges (1 Edges):
     Local Edge ID: 1, Label Blocks (1 Blocks)
       Label base Offset   Size     Time Created
       ---------- ------   ----     -------------------
       16030     1         10       01/24/2009 21:23:04
        Status Vector: 9f ff
   List of Remote Edges (1 Edges):
     Remote Edge ID: 2, NLRIs (1 NLRIs)
       Label base Offset   Size     Peer ID         Time Created
       ---------- ------   ----     --------------- -------------------
      16045     1         10       10.0.0.1        01/24/2009 21:29:35
       Status Vector: 7f ff

PE1# show l2vpn xconnect mp2mp detail
Group gr1, MP2MP mp1, state: up
VPN ID: 100
VPN MTU: 1500
L2 Encapsulation: VLAN
Auto Discovery: BGP, state is Advertised (Service Connected)
     Route Distinguisher: (auto) 192.168.0.1:32770
   Import Route Targets:
       172.16.0.1:100
   Export Route Targets:
       172.16.0.1:100
   Signaling protocol:BGP
    CE Range:10
….
Group gr1, XC mp1.1:2, state is up; Interworking none
Local CE ID: 1, Remote CE ID: 2, Discovery State: Advertised
```

```
AC: GigabitEthernet0/1/0/1.1, state is up
   Type VLAN; Num Ranges: 1
   VLAN ranges: [1, 1]
   MTU 1500; XC ID 0x2000013; interworking none
PW: neighbor 10.0.0.1, PW ID 65538, state is up ( established )
   PW class not set, XC ID 0x2000013
   Encapsulation MPLS, Auto-discovered (BGP), protocol BGP
     MPLS         Local                          Remote
     ------------ ------------------------------ ------------------------------
     Label        16031                          16045
     MTU          1500                           1500
   Control word enabled                         enabled
     PW type      Ethernet VLAN                  Ethernet VLAN
     CE-ID        1                              2
     ------------ ------------------------------ ------------------------------


...
PE1# show bgp l2vpn vpws
BGP router identifier 192.168.0.1, local AS number 100
BGP generic scan interval 60 secs
BGP table state: Active
Table ID: 0x0
BGP main routing table version 913
BGP NSR converge version 3
BGP NSR converged
BGP scan interval 60 secs
Status codes: s suppressed, d damped, h history, * valid, > best
              i - internal, S stale
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network           Next Hop       Rcvd Label     Local Label
Route Distinguisher: 10.0.0.1:32775
*>i2:1/32             10.0.0.1         16045           nolabel
```

```
*>i3:1/32             110.0.0.1         16060           nolabel
Route Distinguisher: 192.168.0.1:32770 (default for vrf gr1:mp1)
*> 1:1/32             0.0.0.0         nolabel         16030
*>i2:1/32             10.0.0.1         16045           nolabel
*>i3:1/32             10.0.0.1         16060           nolabel

Processed 5 prefixes, 5 paths
```

PE2:

```
PE2# show l2vpn discovery xconnect
Service Type: VPWS, Connected
List of VPNs (1 VPNs):
XC Group: gr1, MP2MP mp1
   List of Local Edges (2 Edges):
     Local Edge ID: 2, Label Blocks (1 Blocks)
       Label base Offset   Size     Time Created
       ---------- ------   ----     -------------------
       16045     1         10       01/24/2009 21:09:14
       Status Vector: 7f ff
     Local Edge ID: 3, Label Blocks (1 Blocks)
       Label base Offset   Size     Time Created
       ---------- ------   ----     -------------------
       16060     1         10       01/24/2009 21:09:14
       Status Vector: 7f ff
   List of Remote Edges (1 Edges):
     Remote Edge ID: 1, NLRIs (1 NLRIs)
       Label base Offset   Size     Peer ID         Time Created
       ---------- ------   ----     --------------- -------------------
       16030     1         10       192.168.0.1       01/24/2009 21:09:16
     Status Vector: 9f ff

PE2# show l2vpn xconnect mp2mp detail
Group gr1, MP2MP mp1, state: up
```

```
VPN ID: 100
VPN MTU: 1500
L2 Encapsulation: VLAN
Auto Discovery: BGP, state is Advertised (Service Connected)
     Route Distinguisher: (auto) 10.0.0.1:32775
   Import Route Targets:
       172.16.0.1:100
   Export Route Targets:
       172.16.0.1:100
   Signaling protocol:BGP
     CE Range:10
...
Group gr1, XC mp1.2:1, state is up; Interworking none
Local CE ID: 2, Remote CE ID: 1, Discovery State: Advertised
AC: GigabitEthernet0/1/0/2.1, state is up
   Type VLAN; Num Ranges: 1
   VLAN ranges: [1, 1]
   MTU 1500; XC ID 0x2000008; interworking none
PW: neighbor 192.168.0.1, PW ID 131073, state is up ( established )
   PW class not set, XC ID 0x2000008
   Encapsulation MPLS, Auto-discovered (BGP), protocol BGP
     MPLS         Local                          Remote
     ------------ ------------------------------ ------------------------------
     Label        16045                          16031
     MTU          1500                           1500
     Control word enabled                        enabled
     PW type      Ethernet VLAN                  Ethernet VLAN
     CE-ID        2                              1
     ------------ ------------------------------ ------------------------------
...
```

```
PE2# show bgp l2vpn vpws
```

```
BGP router identifier 10.0.0.1, local AS number 100

BGP generic scan interval 60 secs

BGP table state: Active

Table ID: 0x0

BGP main routing table version 819

BGP NSR converge version 7

BGP NSR converged

BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best

              i - internal, S stale

Origin codes: i - IGP, e - EGP, ? - incomplete

   Network           Next Hop       Rcvd Label     Local Label

Route Distinguisher: 10.0.0.1:32775 (default for vrf gr1:mp1)

*>i1:1/32             192.168.0.1         16030           nolabel

*> 2:1/32             0.0.0.0          nolabel         16045

*> 3:1/32             0.0.0.0          nolabel         16060

Route Distinguisher: 192.168.0.1:32770

*>i1:1/32             192.168.0.1        16030           nolabel


Processed 4 prefixes, 4 paths
```

BGP-based VPWS Autodiscovery with LDP Signaling

Signaling of pseudowires requires exchange of information between two endpoints. LDP is better suited for point-to-point signaling.

A PE router advertises an identifier through BGP for the VPWS instance. The signaling of pseudowires between provider edge devices uses targeted LDP sessions to exchange label values and attributes and to configure the pseudowires. FEC 129 is used for the signaling. The information carried by FEC 129 includes the **xconnect** ID, the Target Attachment Individual Identifier (TAII) and the Source Attachment Individual Identifier (SAII).

Configuring BGP-basedased VPWS Autodiscovery with LDP Signaling

BGP and LDP need to be configured as indicated in the section Configuring BGP and LDP for BGP-based Autodiscovery, on page 58 before proceeding to the configurations in this section.

Configuration Example:

The below code block shows the basic configuration steps required for BGP based VPWS autodiscovery with LDP Signaling.

```
Router(config)# l2vpn
Router(config-l2vpn)# xconnect group {xconnect group name}
Router(config-l2vpn-xc)# mp2mp {instance name}
Router(config-l2vpn-xc-mp2mp)# vpn-id {vpn-id}
Router(config-l2vpn-xc-mp2mp)# l2-encapsulation vlan
Router(config-l2vpn-xc-mp2mp)# autodiscovery bgp
Router(config-l2vpn-xc-mp2mp-ad)# rd auto
Router(config-l2vpn-xc-mp2mp-ad)# route-target 172.16.0.1:100
Router(config-l2vpn-xc-mp2mp-ad)# signaling-protocol ldp
Router(config-l2vpn-xc-mp2mp-ad-sig)# ce-id 1
Router(config-l2vpn-xc-mp2mp-ad-sig-ce)# interface GigabitEthernet0/1/0/1.1 remote-ce-id 2
```

Running Configuration:

The following figure illustrates an example of configuring VPWS with BGP autodiscovery and LDP Signaling.

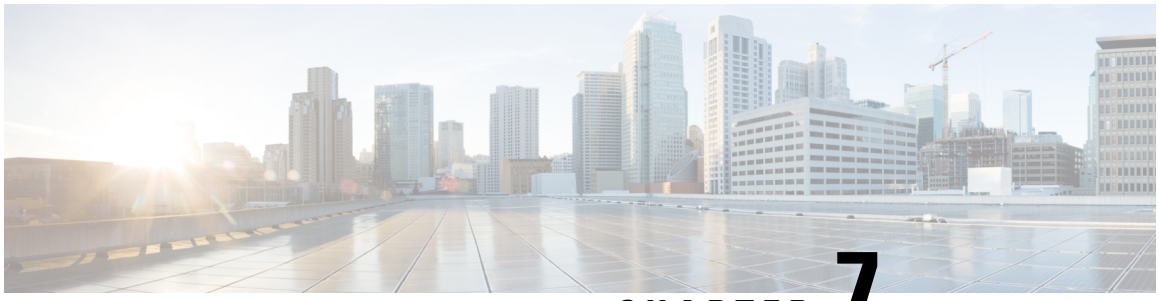
Figure 11: VPWS with BGP autodiscovery and LDP signaling

Configuration at PE1:

```
l2vpn
  xconnect group gr1
   mp2mp mp1
   vpn-id 100
   l2 encapsulation vlan
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol ldp
    ce-id 1
    interface GigabitEthernet0/1/0/1.1 remote-ce-id 2
```

Configuration at PE2:

```
l2vpn
  xconnect group gr1
   mp2mp mp1
   vpn-id 100
   l2 encapsulation vlan
    autodiscovery bgp
    rd auto
    route-target 172.16.0.1:100
    ! Signaling attributes
    signaling-protocol ldp
    ce-id 2
    interface GigabitEthernet0/1/0/2.1 remote-ce-id 1
```



CHAPTER 7

Storm Control

Storm Control provides Layer 2 port security under a Virtual Private LAN Services (VPLS) bridge by preventing excess traffic from disrupting the bridge. This module describes how to configure traffic storm control.

Storm Control

A traffic storm occurs when packets flood a VPLS bridge, creating excessive traffic and degrading network performance. Storm control prevents VPLS bridge disruption by suppressing traffic when the number of packets reaches configured threshold levels. You can configure separate threshold levels for different types of traffic on an access circuit (AC) under a VPLS bridge.

Storm control monitors incoming traffic levels on a port and drops traffic when the number of packets reaches the configured threshold level during any 1-second interval. The 1-second interval is set in the hardware and is not configurable. On Cisco NCS 5000 Series Router, the monitoring interval is always one second. The number of packets allowed to pass during this interval is configurable, per port, per traffic type. During this interval, it compares the traffic level with the storm control level that the customer configures. When the incoming traffic reaches the storm control level configured on the bridge port, storm control drops traffic until the end of storm control interval. At the beginning of a new interval, traffic of the specified type is allowed to pass on the port. The thresholds are configured using a packets-per-second (pps) and kilobit-per-second (kbps) rate.

Storm control has little impact on router performance. Packets passing through ports are counted regardless of whether the feature is enabled. Additional counting occurs only for the drop counters, which monitor dropped packets. Storm control counts the number of packets dropped per port. The drop counters are cumulative for all traffic types.

Supported Traffic Types for Storm Control

On each VPLS bridge port, you can configure up to three storm control thresholds—one for each of the supported traffic types. If you do not configure a threshold for a traffic type, then storm control is not enabled on that port or interface for that traffic type.

The supported traffic types are:

- Broadcast traffic—Packets with a packet destination MAC address equal to FFFF.FFFF.FFFF.
- Multicast traffic—Packets with a packet destination MAC address not equal to the broadcast address, but with the multicast bit set to 1. The multicast bit is bit 0 of the most significant byte of the MAC address.
- Unknown unicast traffic—Packets with a packet destination MAC address not yet learned.

Storm Control Thresholds

Storm control thresholds are configured at a packet-per-second and kilobit-per-second rate. A threshold is the number of packets of the specified traffic type that can pass on a port during a 1-second interval. Valid values for storm control thresholds are integers from 1 to 160000. Only kbps rate is supported by hardware. However, pps is supported; pps rate is converted to kbps. The pps rate is calculated as 1 pps = 8 kbps.

Restrictions for Storm Control

- Storm control parameters must be configured only at the interface or AC level under the bridge domain. Configuration under the bridge domain outside of the AC is not supported.
- Storm control rates are programmed in the hardware at the physical port level and not at the subinterface level. Hence, the storm control rates configured on a subinterface is applied to all the subinterfaces on the given physical port. Different storm control rates cannot be configured for different subinterfaces on the same physical port.
- Storm control is not supported for forwarding pseudowires (VFI PWs).
- No alarms are generated when packets are dropped.
- Only kbps rate is supported by hardware. Though the pps configuration is allowed, it is converted to kbps. The pps rate is calculated as 1 pps = 8 kbps.

Configure Storm Control

The storm control feature is disabled by default. It must be explicitly enabled on each port or bridge-domain for each traffic type. The thresholds are configured using a packets-per-second (pps) or kilobit-per-second (kbps) rate. Perform this task to configure storm control on an access circuit (AC).

Configuration Example

```
RP/0/RSP0/CPU0:router# configure
RP/0/RSP0/CPU0:router(config)# l2vpn
RP/0/RSP0/CPU0:router(config-l2vpn)# bridge group csco
RP/0/RSP0/CPU0:router(config-l2vpn-bg)# bridge-domain abc
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd)# interface GigabitEthernet0/1/0/0.100
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# storm-control broadcast kbps 4500
RP/0/RSP0/CPU0:router(config-l2vpn-bg-bd-ac)# commit
```

Running Configuration

```
configure
 l2vpn
  bridge group csco
   bridge-domain abc
    interface GigabitEthernet0/1/0/0.100
     storm-control broadcast kbps 4500
   !
```

Related Topics

- Storm Control, on page 71
- Supported Traffic Types for Storm Control, on page 72

Associated Commands

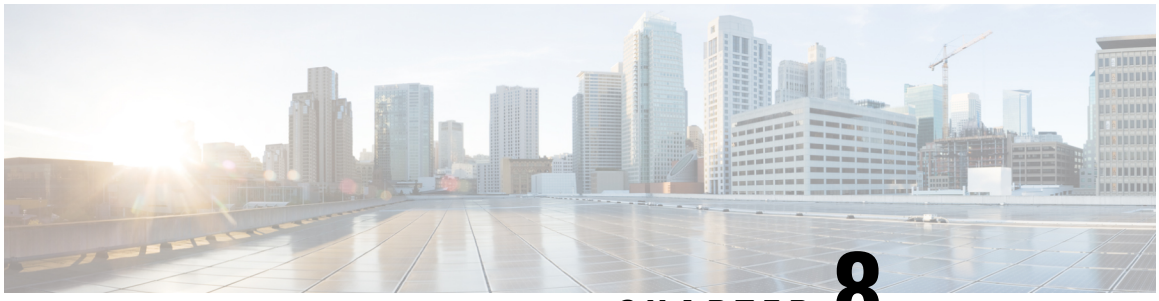
- storm-control

Related Topics

- Storm Control, on page 71
- Supported Traffic Types for Storm Control, on page 72

Associated Commands

- storm-control



CHAPTER 8

Configure Multiple Spanning Tree Protocol

This chapter introduces you to Multiple Spanning Tree Protocol (MSTP) which is one of the variants of Spanning Tree Protocol (STP) and describes how you can configure the MSTP feature.

Overview of Spanning Tree Protocol

Ethernet is no longer just a link-layer technology used to interconnect network vehicles and hosts. Its low cost and wide spectrum of bandwidth capabilities coupled with a simple plug and play provisioning philosophy have transformed Ethernet into a legitimate technique for building networks, particularly in the access and aggregation regions of service provider networks.

Ethernet networks lacking a TTL field in the Layer 2 (L2) header and, encouraging or requiring multicast traffic network-wide, are susceptible to broadcast storms if loops are introduced. However, loops are a desirable property as they provide redundant paths. Spanning tree protocols (STP) are used to provide a loop free topology within Ethernet networks, allowing redundancy within the network to deal with link failures.

There are many variants of STP; however, they work on the same basic principle. Within a network that may contain loops, a sufficient number of interfaces are disabled by STP so as to ensure that there is a loop-free spanning tree, that is, there is exactly one path between any two devices in the network. If there is a fault in the network that affects one of the active links, the protocol recalculates the spanning tree so as to ensure that all devices continue to be reachable. STP is transparent to end stations which cannot detect whether they are connected to a single LAN segment or to a switched LAN containing multiple segments and using STP to ensure there are no loops.

For more information, see References for Spanning Tree Protocol, on page 82

Restrictions for STP on Cisco NCS 5000 Series Routers

The following restrictions are applicable for STP on Cisco NCS 5000 Series Routers

- The only type of STP that is supported on Cisco NCS 5000 Series Routers is Multiple Spanning Tree Protocol (MSTP).
- Per vlan Spanning Tree(PVST/PVST+/PVRST) is not supported on Cisco NCS 5000 Series Routers.
- Access gateway feature is not supported.

Overview of MSTP

The Multiple Spanning Tree Protocol (MSTP) is an STP variant that allows multiple and independent spanning trees to be created over the same physical network. The parameters for each spanning tree can be configured separately, so as to cause a different network devices to be selected as the root bridge or different paths to be selected to form the loop-free topology. Consequently, a given physical interface can be blocked for some of the spanning trees and unblocked for others.

Having set up multiple spanning tree instances, the set of VLANs in use can be partitioned among them; for example, VLANs 1 - 100 can be assigned to spanning tree instance 1, VLANs 101 - 200 can be assigned to spanning tree instance 2, VLANs 201 - 300 can be assigned to spanning tree instance 3, and so on. Since each spanning tree has a different active topology with different active links, this has the effect of dividing the data traffic among the available redundant links based on the VLAN—a form of load balancing.

MSTP Support on Cisco NCS 5000 Series Routers

Cisco NCS 5000 Series Routers support MSTP, as defined in IEEE 802.1Q-2005, on physical Ethernet interfaces and Ethernet Bundle interfaces.

In addition, the below Cisco features are supported:

- BPDU Guard—This Cisco feature protects against misconfiguration of edge ports.
- Flush Containment—This Cisco feature helps prevent unnecessary MAC flushes that would otherwise occur following a topology change.
- Bringup Delay—This Cisco feature prevents an interface from being added to the active topology before it is ready to forward traffic.

MSTP BPDU Guard

The MSTP BPDU Guard feature protects against misconfiguration of edge ports.

Note In order to enable the MSTP BPDU Guard feature for an interface, the command **portfast bpduguard** must be configured on it.

Port Fast

The Port Fast feature manage the ports at the edge of the switched Ethernet network. For devices that only have one link to the switched network (typically host devices), there is no need to run MSTP, as there is only

one available path. Furthermore, it is undesirable to trigger topology changes (and resultant MAC flushes) when the single link fails or is restored, as there is no alternative path.

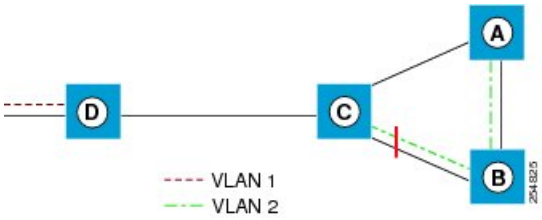
By default, MSTP monitors ports where no BPDUs are received, and after a timeout, places them into edge mode whereby they do not participate in MSTP. When **portfast** is explicitly configured on an interface, MSTP considers that interface to be an edge port and removes it from consideration when calculating the spanning tree. And hence the convergence time for the whole network is improved when **portfast** is configured.

Note MSTP BPDU Guard feature is supported by configuring interfaces in port fast mode. BPDU guard feature will error-disable the port on receiving BPDU packets.

Flush Containment

Flush containment is a Cisco feature that helps prevent unnecessary MAC flushes due to unrelated topology changes in other areas of a network. This is best illustrated by example. The following figure shows a network containing four devices. Two VLANs are in use: VLAN 1 is only used on device D, while VLAN 2 spans devices A, B and C. The two VLANs are in the same spanning tree instance, but do not share any links.

Figure 12: Flush Containment



If the link AB goes down, then in normal operation, as C brings up its blocked port, it sends out a topology change notification on all other interfaces, including towards D. This causes a MAC flush to occur for VLAN 1, even though the topology change which has taken place only affects VLAN 2.

Flush containment helps deal with this problem by preventing topology change notifications from being sent on interfaces on which no VLANs are configured for the MSTI in question. In the example network this would mean no topology change notifications would be sent from C to D, and the MAC flushes which take place would be confined to the right hand side of the network.

Note Flush containment is enabled by default, but can be disabled by configuration, thus restoring the behavior described in the IEEE 802.1Q standard.

Bringup Delay

Bringup delay is a Cisco feature that stops MSTP from considering an interface when calculating the spanning tree, if the interface is not yet ready to forward traffic. This is useful when a line card first boots up, as the system may declare that the interfaces on that card are *Up* before the dataplane is fully ready to forward traffic. According to the standard, MSTP considers the interfaces as soon as they are declared *Up*, and this may cause it to move other interfaces into the blocking state if the new interfaces are selected instead.

Bringup delay solves this problem by adding a configurable delay period which occurs as interfaces that are configured with MSTP first come into existence. Until this delay period ends, the interfaces remain in blocking state, and are not considered when calculating the spanning tree.

Bringup delay only takes place when interfaces which are already configured with MSTP are created, for example, on a card reload. No delay takes place if an interface which already exists is later configured with MSTP.

Configuring MSTP

The different steps involved in configuring MSTP are as follows:

1. Configure VLAN interfaces

```
Router# configure
Router(config)# interface TenGigE0/0/0/2.1001 l2transport
Router(config-subif)# encapsulation dot1q 1001
Router(config)# interface TenGigE0/0/0/3.1001 l2transport
Router(config-subif)# encapsulation dot1q 1001
Router(config)# interface TenGigE0/0/0/14.1001 l2transport
Router(config-subif)# encapsulation dot1q 1001
Router(config)# interface TenGigE0/0/0/2.1021 l2transport
Router(config-subif)# encapsulation dot1q 1021
Router(config)# interface TenGigE0/0/0/3.1021 l2transport
Router(config-subif)# encapsulation dot1q 1021
Router(config)# interface TenGigE0/0/0/14.1021 l2transport
Router(config-subif)# encapsulation dot1q 1021
Router(config-subif)# commit
```

2. Configure L2VPN bridge-domains with the VLAN interfaces configured in the previous step.

```
Router# configure
Router(config)# l2vpn bridge group mstp
Router(config-l2vpn-bg)# bridge-domain mstp1001
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/2.1001
Router(config-l2vpn-bg-bd-ac)# exit
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/3.1001
Router(config-l2vpn-bg-bd-ac)# exit
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/14.1001
Router(config-l2vpn-bg-bd-ac)# exit
Router(config-l2vpn-bg-bd)# exit
Router(config-l2vpn-bg)# exit
Router(config-l2vpn-bg)# bridge-domain mstp1021
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/2.1021
Router(config-l2vpn-bg-bd-ac)# exit
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/3.1021
Router(config-l2vpn-bg-bd-ac)# exit
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/14.1021
Router(config-l2vpn-bg-bd-ac)# commit
```

3. Configure MSTP.

```
Router# configure
Router(config)# spanning-tree mst abc
Router(config-mstp)# name mstp1
```

```
Router(config-mstp)# instance 1001
Router(config-mstp-inst)# vlan-ids 1001-1020
Router(config-mstp-inst)# exit
Router(config-mstp)# instance 1021
Router(config-mstp-inst)# vlan-ids 1021-1040
Router(config-mstp-inst)# exit
Router(config-mstp)# int tenGigE 0/0/0/2
Router(config-mstp-if)# exit
Router(config-mstp)# int tenGigE 0/0/0/3
Router(config-mstp-if)# exit
Router(config-mstp)# int tenGigE 0/0/0/14
Router(config-mstp-if)# commit
```

Running Configuration for MSTP

```
!
Configure
/* Configure VLAN interfaces */
interface TenGigE0/0/0/2.1001 l2transport
 encapsulation dot1q 1001
!
interface TenGigE0/0/0/3.1001 l2transport
 encapsulation dot1q 1001
!
interface TenGigE0/0/0/14.1001 l2transport
 encapsulation dot1q 1001

interface TenGigE0/0/0/2.1021 l2transport
 encapsulation dot1q 1021
!
interface TenGigE0/0/0/3.1021
 l2transport
 encapsulation dot1q 1021
!
interface TenGigE0/0/0/14.1021 l2transport
 encapsulation dot1q 1021
!
/* Configure L2VPN Bridge-domains */
l2vpn
 bridge group mstp
  bridge-domain mstp1001
   interface TenGigE0/0/0/2.1001
   !
   interface TenGigE0/0/0/3.1001
   !
   interface TenGigE0/0/0/14.1001
   !
bridge-domain mstp1021
   interface TenGigE0/0/0/2.1021
   !
   interface TenGigE0/0/0/3.1021
   !
   interface TenGigE0/0/0/14.1021
!
/* Configure MSTP */
spanning-tree mst abc
 name mstp1
 instance 1001
  vlan-ids 1001-1020
 !
```

```
instance 1021
  vlan-ids 1021-1040
 !
interface TenGigE0/0/0/2
 !
 interface TenGigE0/0/0/3
 !
 interface TenGigE0/0/0/14
```

Verification for MSTP

The MSTP configuration can be verified using the command **show spanning-tree mst**

```
/* Verify the MSTP configuration */
Router# show spanning-tree mst abc instance 121
Mon Jan 23 12:11:48.591 UTC
Role:  ROOT=Root, DSGN=Designated, ALT=Alternate, BKP=Backup, MSTR=Master
State: FWD=Forwarding, LRN=Learning, BLK=Blocked, DLY=Bringup Delayed

Operating in dot1q mode


MSTI 121:

  VLANS Mapped: 121-130

  Root ID    Priority    32768
             Address     dceb.9456.b9d4
             This bridge is the root
             Int Cost    0
             Max Age 20 sec, Forward Delay 15 sec


  Bridge ID  Priority    32768 (priority 32768 sys-id-ext 0)
             Address     dceb.9456.b9d4
             Max Age 20 sec, Forward Delay 15 sec
             Max Hops 20, Transmit Hold count  6


Interface    Port ID           Role State Designated           Port ID
             Pri.Nbr Cost                 Bridge ID             Pri.Nbr
------------ ------- --------- ---- ----- -------------------- -------
BE1          128.1   10000     DSGN FWD   32768 dceb.9456.b9d4 128.1
Te0/0/0/1    128.2   2000      DSGN FWD   32768 dceb.9456.b9d4 128.2
Te0/0/0/16   128.3   2000      DSGN FWD   32768 dceb.9456.b9d4 128.3
Te0/0/0/17   128.4   2000      DSGN FWD   32768 dceb.9456.b9d4 128.4
```

Configuring MSTP BPDU Guard

This section describes how you can configure MSTP BPDU Guard.

```
Router# configure
Router(config)# l2vpn bridge group bg1
Router(config-l2vpn-bg)# bridge-domain bd1
Router(config-l2vpn-bg-bd)# int TenGigE 0/0/0/7
Router(config-l2vpn-bg-bd-ac)# root
```

```
Router(config)# spanning-tree mst m0
Router(config-mstp)# interface tenGigE 0/0/0/7
Router(config-mstp-if)# portfast bpduguard
Router(config-mstp-if)# root
Router(config)# int tenGigE 0/0/0/7 l2transport
Router(config-if-l2)# commit
```

Running Configuration with MSTP BPDU Guard

```
!
Configure
l2vpn
 bridge group bg1
  bridge-domain bd1
   interface TenGigE0/0/0/7
   !
spanning-tree mst m0
 interface TenGigE0/0/0/7
  portfast bpduguard
!
interface TenGigE0/0/0/7
 l2transport
 !
```

Verification for MSTP BPDU Guard

Verify that you have configured MSTP BPDU Guard.

```
/* Verify the MSTP BPDU Guard configuration */
Router# show interfaces tenGigE 0/0/0/7
Wed Nov  9 09:23:56.268 UTC
TenGigE0/0/0/7 is error disabled, line protocol is administratively down
  Interface state transitions: 2
  Hardware is TenGigE, address is 7cad.7425.c8c8 (bia 7cad.7425.c8c8)
  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,
  Last link flapped 00:00:49
  Last input 00:00:40, output 00:00:40
  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
     38752 packets input, 4611429 bytes, 0 total input drops
     1 drops for unrecognized upper-level protocol
     Received 1 broadcast packets, 38751 multicast packets
              0 runts, 0 giants, 0 throttles, 0 parity
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
```

References for Spanning Tree Protocol

This section provides references for STP. For an overview of STP, see Overview of Spanning Tree Protocol, on page 75

STP Operation

All variants of STP operate in a similar fashion: STP frames (known as bridge protocol data units (BPDUs)) are exchanged at regular intervals over Layer 2 LAN segments, between network devices participating in STP. Such network devices do not forward these frames, but use the information to construct a loop free spanning tree.

The spanning tree is constructed by first selecting a device which is the *root* of the spanning tree (known as the root bridge), and then by determining a loop free path from the *root bridge* to every other device in the network. Redundant paths are disabled by setting the appropriate ports into a blocked state, where STP frames can still be exchanged but data traffic is never forwarded. If a network segment fails and a redundant path exists, the STP protocol recalculates the spanning tree topology and activates the redundant path, by unblocking the appropriate ports.

The selection of the root bridge within a STP network is determined by the lowest Bridge ID which is a combination of configured bridge priority and embedded mac address of each device. The device with the lowest priority, or with equal lowest priority but the lowest MAC address is selected as the root bridge.

The selection of the active path among a set of redundant paths is determined primarily by the port path cost. The port path cost represents the cost of transiting between that port and the root bridge - the further the port is from the root bridge, the higher the cost. The cost is incremented for each link in the path, by an amount that is (by default) dependent on the media speed. Where two paths from a given LAN segment have an equal cost, the selection is further determined by the lowest bridge ID of the attached devices, and in the case of two attachments to the same device, by the configured port priority and port ID of the neighboring attached ports.

Once the active paths have been selected, any ports that do not form part of the active topology are moved to the blocking state.

Topology Changes

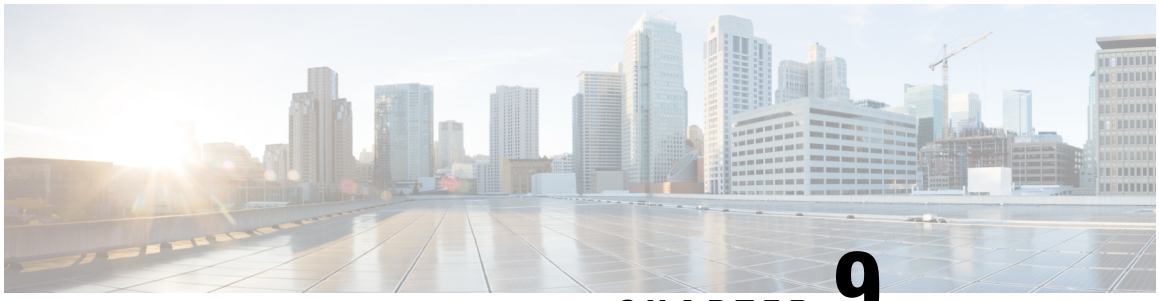
Network devices in a switched LAN perform MAC learning; that is, they use received data traffic to associate unicast MAC addresses with the interface out of which frames destined for that MAC address should be sent. If STP is used, then a recalculation of the spanning tree (for example, following a failure in the network) can invalidate this learned information. The protocol therefore includes a mechanism to notify topology changes around the network, so that the stale information can be removed (flushed) and new information can be learned based on the new topology.

A *Topology Change* notification is sent whenever STP moves a port from the blocking state to the forwarding state. When it is received, the receiving device flushes the MAC learning entries for all ports that are not blocked other than the one where the notification was received, and also sends its own topology change notification out of those ports. In this way, it is guaranteed that stale information is removed from all the devices in the network.

Variants of STP

There are many variants of the Spanning Tree Protocol:

- Legacy STP (STP)—The original STP protocol was defined in IEEE 802.1D-1998. This creates a single spanning tree which is used for all VLANs and most of the convergence is timer-based.
- Rapid STP (RSTP)—This is an enhancement defined in IEEE 802.1D-2004 to provide more event-based, and hence faster, convergence. However, it still creates a single spanning tree for all VLANs.
- Multiple STP (MSTP)—A further enhancement was defined in IEEE 802.1Q-2005. This allows multiple spanning tree instances to be created over the same physical topology. By assigning different VLANs to the different spanning tree instances, data traffic can be load-balanced over different physical links. The number of different spanning tree instances that can be created is restricted to a much smaller number than the number of possible VLANs; however, multiple VLANs can be assigned to the same spanning tree instance. The BPDUs used to exchange MSTP information are always sent untagged; the VLAN and spanning tree instance data is encoded inside the BPDU.
- Per-Vlan STP (PVST)—This is an alternative mechanism for creating multiple spanning trees; it was developed by Cisco before the standardization of MSTP. Using PVST, a separate spanning tree is created for each VLAN. There are two variants: PVST+ (based on legacy STP), and PVRST (based on RSTP). At a packet level, the separation of the spanning trees is achieved by sending standard STP or RSTP BPDUs, tagged with the appropriate VLAN tag.
- Per-Vlan Rapid Spanning Tree (PVRST)— This feature is the IEEE 802.1w (RSTP) standard implemented per VLAN, and is also known as Rapid PVST or PVST+. A single instance of STP runs on each configured VLAN (if you do not manually disable STP). Each Rapid PVST+ instance on a VLAN has a single root switch. You can enable and disable STP on a per-VLAN basis when you are running Rapid PVST+. PVRST uses point-to-point wiring to provide rapid convergence of the spanning tree. The spanning tree reconfiguration can occur in less than one second with PVRST (in contrast to 50 seconds with the default settings in the 802.1D STP).
- Resilient Ethernet Protocol (REP)— This is a Cisco-proprietary protocol for providing resiliency in rings. It is included for completeness, as it provides MSTP compatibility mode, using which, it interoperates with an MSTP peer.



CHAPTER 9

References

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

Gigabit Ethernet Protocol Standards

The 10-Gigabit Ethernet architecture and features deliver network scalability and performance, while enabling service providers to offer high-density, high-bandwidth networking solutions designed to interconnect the router with other systems in the point-of-presence (POP), including core and edge routers and L2 and Layer 3 (L3) switches.

The Gigabit Ethernet interfaces in Cisco NCS 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 85.

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 5: Gigabit Ethernet and 10-Gigabit Ethernet Modular Services Card Default Configuration Values

Parameter	Configuration File Entry	Default Value	Restrictions
Flow control	**flow-control**	egress on ingress off	none
MTU	**mtu**	1514 bytes for normal frames 1518 bytes for 802.1Q tagged frames 1522 bytes for QinQ frames	none
MAC address	**mac address**	Hardware burned-in address (BIA[2])	L3 only
L2 port	**l2transport**	off/L3	L2 subinterfaces must have L3 main parent interface
Egress filtering	**Ethernet egress-filter**	off	none
Link negotiation	**negotiation**	off	physical main interfaces only
Tunneling Ethertype	**tunneling ethertype**	0X8100	configured on main interface only; applied to subinterfaces only

Parameter	Configuration File Entry	Default Value	Restrictions
VLAN tag matching	**encapsulation**	all frames for main interface; only ones specified for subinterfaces	encapsulation command only subinterfaces

1. The restrictions are applicable to L2 main interface, L2 subinterface, L3 main interface, interflex L2 interface etc.
2. burned-in address

References for Configuring Link Bundles

This section provides references to configuring link bundles. For an overview of link bundles and configurations, see Configure Link Bundles for Layer 2 VPNs, on page 25.

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.